coastalmanagement

Porirua Harbour

Broad Scale Habitat Mapping 2012/13

Prepared for

Greater Wellington Regional Council

November 2013

Cover Photo: Onepoto Arm, Porirua Harbour, January 2013.


Te Onepoto Bay showing the constructed causeway restricting tidal flows.

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by

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All photos by Wriggle except where noted otherwise.

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PORIRUA HARBOUR - EXECUTIVE SUMMARY

This report summarises the results of the 2013 broad scale intertidal habitat mapping of Porirua Harbour, a large (809ha), well flushed "tidal lagoon" type estuary fed by a number of small streams. It comprises two arms, each a relatively simple shape, Onepoto (285ha) and Pauatahanui (524ha). Compared to the majority of NZ's tidal lagoon estuaries which tend to drain almost completely at low tide, the harbour has a large subtidal component (65%). It is one of the key estuaries in Wellington Regional Council's long-term coastal monitoring programme. The following sections summarise broad scale monitoring results (from the current report and previous studies), condition ratings, overall estuary condition, and monitoring and management recommendations.

BROAD SCALE RESULTS

- Sandy substrate dominated the intertidal area (72%, 169ha), with the sandiest areas primarily located towards the estuary entrances.
- Intertidal soft and very soft mud cover had increased significantly since 2008 (from 3ha to 20ha), mostly on flats between Kakaho and Horokiri, and was a dominant feature over 8% of the intertidal zone. Very soft muds were also a dominant feature in subtidal areas (not mapped).
- High density nuisance macroalgae (>50%) covered 8% (23ha) of the intertidal area, with highest densities on the Porirua and Horokiri Stream deltas. Remaining intertidal areas supported widespread low density growths that have shown a trend of increase since 2008.
- Gross eutrophic conditions were not a prominent intertidal feature within the estuary.
- Dense intertidal seagrass cover (>50%) was present in both arms (15%, 46ha), but had declined significantly from historical cover (23% reduction in Pauatahanui since 1980, and 38% decline since 1962 in Onepoto). Since 2008, dense intertidal seagrass cover had declined a further 9% (4ha). Losses since 2008 are attributed primarily to the combined stress of macroalgal smothering and increased sediment muddiness.
- Estimated historical saltmarsh cover in the estuary was >200ha, but current cover is 50ha (6% of the estuary), 49.6ha located in the Pauatahanui Arm, and just 0.3ha in the Onepoto Arm. Losses have been primarily from displacement by reclamation and margin development (road and rail). There has been no significant change in saltmarsh cover since 2008, although several restoration initiatives have improved saltmarsh quality.
- The densely vegetated margin (scrub and forest) cover was low (17%). Margins were dominated by grassland (36%), residential development (31%), artificial structures (10%) and commercial development (4%). No significant change was apparent since 2008.

RATINGS		CONDITION RATINGS		CHANGE RATINGS
Major Issue	Indicator	2008	2013	Change from 2008 Baseline
Sediment	Soft mud area	VERY GOOD	FAIR	VERY LARGE INCREASE
Eutrophication	Low density macroalgal cover	MODERATE	MODERATE	TRENDING UP = WARNING
	High density macroalgal cover	MODERATE	MODERATE	VARIABLE = WARNING
	Gross eutrophic condition area	VERY GOOD	VERY GOOD	NO SIGNIFICANT CHANGE
Habitat Modification	Seagrass Coefficient/area	GOOD	GOOD	MODERATE DECREASE
	Saltmarsh area	MODERATE	MODERATE	NO SIGNIFICANT CHANGE
	Densely vegetated margin area	POOR	POOR	NO SIGNIFICANT CHANGE

ESTUARY CONDITION AND ISSUES

In relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication, and habitat modification), the 2013 broad scale mapping results show that both sediment and eutrophication are ongoing issues within the harbour. Although large sections of the estuary remain in good condition, the decline in estuary quality evident since 2008 (i.e. increased muddiness, decreased seagrass cover, and increased macroalgal growth) indicate that current inputs of fine sediment and nutrients to the estuary are too high. Consequently, inputs need to be reduced to levels the estuary can assimilate without exhibiting a decline in quality.

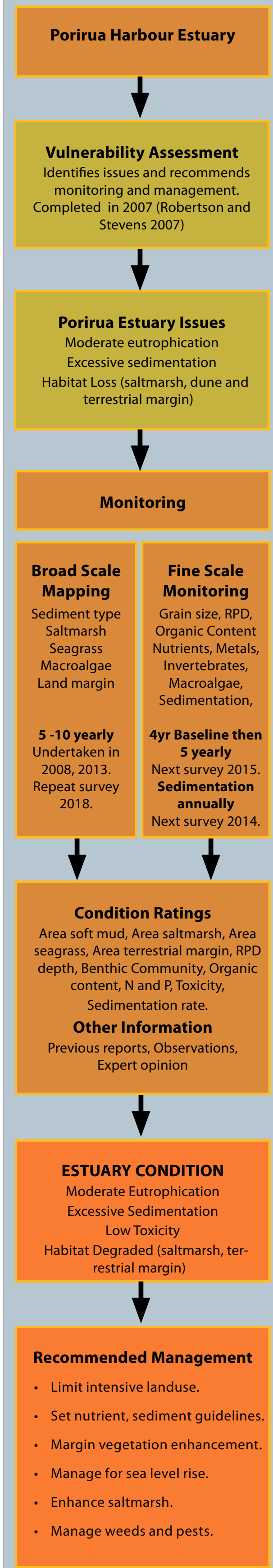
RECOMMENDED MONITORING AND MANAGEMENT

Sediment muddiness and infilling, and nutrient enrichment, have been identified as key issues in Porirua Harbour. To monitor these issues it is recommended that broad scale habitat mapping be repeated every 5 years (next due in 2018). In addition broad scale mapping of subtidal habitat is scheduled for 2014 to characterise dominant substrate type, sediment condition (RPD), and vegetative cover, particularly seagrass. Fine scale intertidal monitoring is recommended on a 5 yearly cycle (next due in 2015), but should be reviewed and integrated with the existing fine scale subtidal monitoring. It is recommended that sediment (grain size, oxygenation and sedimentation rate) and macroalgal monitoring continue annually.

For management, it is recommended that catchment nutrient guideline criteria be developed for the estuary, and the current catchment nutrient loads be estimated (note this has already been done for sediment). If catchment loads exceed the estuary's guidelines then it is recommended that sources of elevated loads in the catchment be identified, and management undertaken to minimise their adverse effects on estuary uses and values.

Opportunities to increase the cover of saltmarsh and the vegetated terrestrial margin should be encouraged, and plans developed to facilitate the expansion of estuary margins in response to predicted sea level rise.

1. INTRODUCTION



Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. In 2007, Greater Wellington Regional Council (GWRC) identified a number of estuaries in its region as immediate priorities for long term monitoring and initiated monitoring of key estuaries in a staged manner. The estuaries currently monitored include; Porirua Harbour, Lake Onoke, and Whareama, Hutt and Waikanae estuaries. Risk assessments have also been undertaken to establish management priorities for a number of other estuaries.

The monitoring and management process used for Porirua Harbour is summarised in the margin flow diagram, and is described below. It consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002):

1. **Ecological Vulnerability Assessment** (EVA) of the estuary to major issues (see Table 1) and appropriate monitoring design. This component has been completed for Porirua Harbour and is reported on in Robertson and Stevens (2007b).
2. **Broad Scale Habitat Mapping** (NEMP approach). This component (see Table 2) documents the key habitats within the estuary, and changes to these habitats over time. Broad scale intertidal mapping of Porirua Harbour was undertaken in 2008 (Stevens and Robertson 2008). Since then, annual mapping of macroalgal cover has been undertaken (see Stevens and Robertson 2012). The current report focuses on detailed broad scale habitat mapping undertaken in the summer of 2012/13 to assess the current state of the estuary, and changes since 2008.
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (see Table 2). This component, comprising an initial 3 year baseline of detailed information on the condition of Porirua Harbour, commenced in 2008 and is reported on in Robertson and Stevens 2008, 2009, 2010. Sedimentation rates in the estuary have been monitored annually in the Harbour since 2008 (see Stevens and Robertson 2013, Figure 1).

To help evaluate overall estuary condition and decide on appropriate monitoring and management actions, a series of condition ratings have also been developed and are described in Section 2.

The current report describes the following work undertaken in January 2013:

- Broad scale mapping of intertidal estuary sediment types.
- Broad scale mapping of intertidal macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria*).
- Broad scale mapping of intertidal seagrass (*Zostera muelleri*) beds.
- Broad scale mapping of saltmarsh vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.

Porirua Harbour, is a large (807ha), well flushed "tidal lagoon" type estuary fed by a number of small streams. It comprises two arms, each a relatively simple shape, Onepoto (283ha) and Pauatahanui (524ha). The arms are connected by a narrow channel at Paremata, and the estuary discharges to the sea via a narrow entrance west of Plimmerton. Residence time in the estuary is less than 3 days however, compared to the majority of NZ's tidal lagoon estuaries which tend to drain almost completely at low tide, the harbour has a large subtidal component (65%).

The estuary is relatively shallow (mean depth ~1m), and the large intertidal area (287ha, 35% of the estuary) supports extensive areas (59ha) of seagrass growing in firm mud/sand and shellfish. The estuary has high ecological values and high human use, and provides a natural focal point for the thousands of people that live near or visit its shores.

The harbour has been extensively modified over the years (see following page), particularly the Onepoto Inlet where almost all of the historical shoreline and saltmarsh have been reclaimed and most of the inlet is now lined with steep straight rockwalls flanked by road and rail corridors. The Pauatahanui Inlet is less modified (although most of the inlet's margins are also encircled by roads), with extensive areas of saltmarsh remaining in the north and east, a large percentage of which have been improved through local community efforts.

Catchment land use in the Onepoto Inlet is dominated by urban (residential and commercial) cover. In the steeper Pauatahanui Inlet catchment, grazing dominates although urban (residential) development is significant in some areas. A recent report (Gibb and Cox 2009) identifies sedimentation as a major problem in the estuary and indicates that both estuary arms are highly likely to rapidly infill and change from tidal estuaries to brackish swamps within 145-195 years. The dominant sources contributing to increasing sedimentation rates in the estuary were identified as discharges of both bedload and suspended load from the various input streams. Elevated nutrient inputs are also causing moderate eutrophication symptoms (i.e. poor sediment oxygenation and moderate nuisance macroalgal cover) in the estuary.

Historically, Porirua Harbour was surrounded by a tall dense podocarp/broad leaf forest, including wetlands in low lying areas, and saltmarsh around the gently sloping estuary margins. The estuary itself would have been largely sandy with clear waters, supporting extensive seagrass and shellfish beds, abundant fish (including whitebait), and birdlife.

Following human arrival, particularly European settlement from the early 1850's, clearance of protective forests and drainage of filtering wetlands greatly increased sedimentation to the estuary, causing a gradual shift from clear waters and clean sands, to muddier substrate and more turbid waters in the estuary.

More permanent impacts to the estuary also occurred with the development of road and rail corridors, flood control measures, and reclamation of estuary flats. This was particularly severe in Onepoto Inlet from the late 1950's, where large parts of the estuary were reclaimed and developed (see photos below). As a consequence, there have been significant losses of intertidal flats in the estuary (~100ha), steep armouring of shorelines with rock, and extensive displacement of saltmarsh and terrestrial margin vegetation. Saltmarsh loss is estimated at 50% in Pauatahanui Inlet, and 99% in Onepoto Inlet.

Figure 1 indicates the likely extent of historical estuary and saltmarsh habitat in relation to the existing harbour, and shows >200ha of combined losses in both arms. Combined with degradation of remaining habitat through elevated inputs of sediment, toxins and pathogens, plus habitat modification and disturbance, it is clear that the estuary has been significantly impacted. Despite this, it retains many of the features that make it highly valued, and its ecological integrity, although compromised, remains intact and able to be improved.

Improvement requires effective management of the key drivers of change in the estuary (see Table 1), and a unified vision for the estuary. This is being established through the Porirua Harbour and Catchment Strategy and Action Plan, jointly supported by Porirua and Wellington City Councils, GWRC, Ngati Toa, and many community interest groups (e.g. PCC 2012).

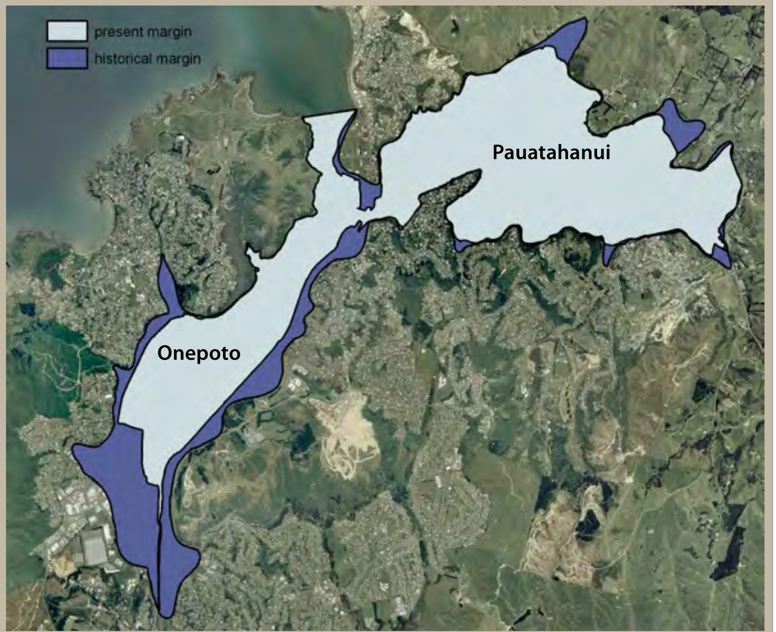


Figure 1. Likely extent of historical estuary and saltmarsh habitat in relation to Porirua Harbour today.

Porirua Harbour circa 1845.
Brees, Samuel Charles 1810-1865: Plan showing the several points of view of the sketches illustrative of the West Coast. [1844 or 1845]. Ref: B-031-036. Alexander Turnbull Library, Wellington, New Zealand. http://natlibgovt.nz/records/23150330.

Reclamation within Onepoto Arm of Porirua Harbour, 1962.
Pataka Museum Collection, Porirua Library. Copied from PCC website.

Road and rail corridor reclamation in the Onepoto arm of Porirua Harbour, 1958.

Work site and beginnings of reclamation across Porirua Harbour.
Negatives of the Evening Post newspaper. Ref: EP/1958/1446-F. Alexander Turnbull Library, Wellington, New Zealand. http://natlib.govt.nz/records/22890574

Land reclamation at Paremata for railway (Main Trunk Line) including machinery, workmen, and boats on Porirua Harbour, Wellington Region.
Negatives of the Evening Post newspaper. Ref: EP/1958/4247-F. Alexander Turnbull Library, Wellington, New Zealand. http://natlib.govt.nz/records/22307317

Aerial view of the reclamation works for the railway at Porirua, Wellington district.
Negatives of the Evening Post newspaper. Ref: EP/1958/3000-F. Alexander Turnbull Library, Wellington, New Zealand. http://natlib.govt.nz/records/23257389

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 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 *Cladophora, Ulva (Enteromorpha),* 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 commonplace 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 broad and fine scale NEMP indicators (shading signifies indicators used in the broad scale monitoring assessments)**.**

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	Grain Size	Fine scale measurement of sediment type.
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.

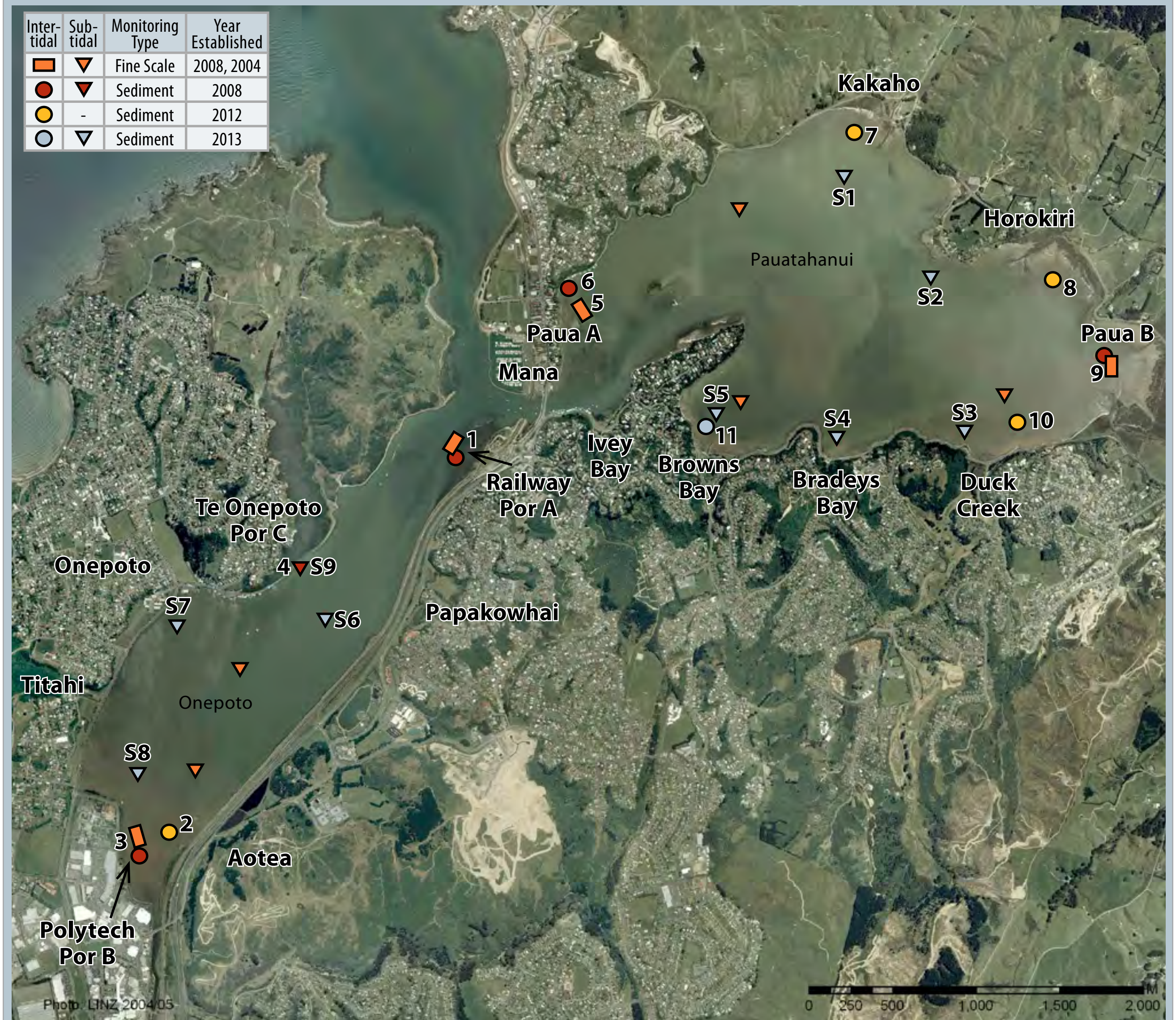


Figure 2. Porirua Harbour showing the location of fine scale sites and buried sediment plates established in 2007/8, 2012, and 2013.

Pauatahanui Inlet - View across Mana intertidal flats to Ivey Bay.

2. METHODS

BROAD SCALE HABITAT MAPPING

Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the NEMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of aerial photography, detailed ground-truthing, and GIS-based digital mapping used to record the primary habitat features present. Very simply, the method involves three key steps:

- Obtaining laminated aerial photos for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing).
- Digitising the field data into GIS layers (e.g. ArcMap).

Existing 2010 aerial photos of the estuary at a scale of 1:3,000 were laminated, and experienced scientists ground-truthed the spatial extent of dominant habitat and substrate types between 11-16 January 2013 by walking the area and recording features directly on the laminated aerial photos.

In August 2013, LINZ supplied rectified ~0.3m/pixel resolution colour aerial photos flown between 10 December 2012 and 30 January 2013. Field notes and photographs were subsequently combined with the 2013 aerials to produce GIS-based habitat maps showing dominant cover of: substrate, macroalgae (e.g. *Ulva, Gracilaria*), gross eutrophic conditions, seagrass (*Zostera*), saltmarsh vegetation, and the 200m wide terrestrial margin vegetation/land use.

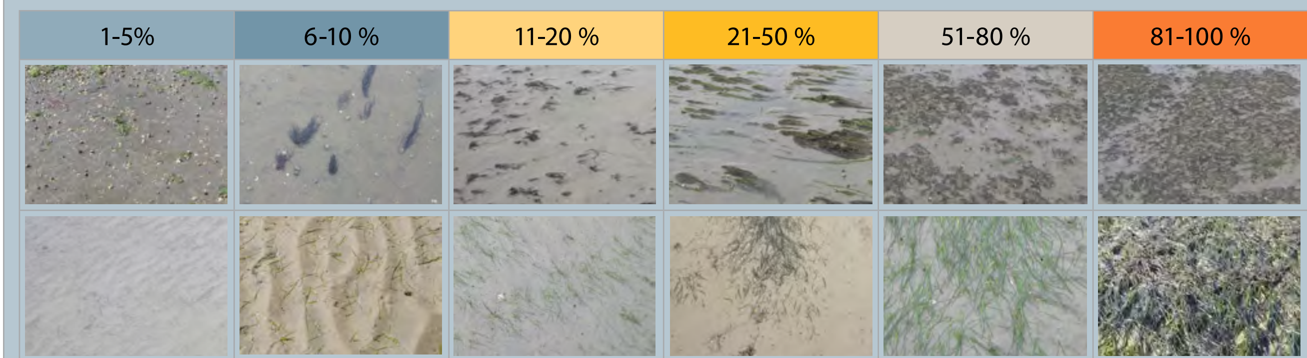
Appendix 1 lists the definitions used to classify substrate and vegetation. The composition of vegetation was classified using an interpretation of the Atkinson (1985) system, where the dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. Dominance was indicated by the order of codes and the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

When present, macroalgae and seagrass were mapped using a 6 category percent cover rating scale (see Figure 3 below) to describe density.

Broad scale habitat features were subsequently digitised from aerial photos into ArcMap 9.3 shapefiles using a Wacom Cintiq21UX drawing tablet. The broad scale results are summarised in Section 3, with the supporting GIS files (supplied on a separate CD) providing a much more detailed data set designed for easy interrogation to address specific monitoring and management questions.

The georeferenced spatial habitat maps allow the 2013 results to be compared to changes from the 2008 survey (Stevens and Robertson 2008). However, as photography was undertaken without regard to tidal height, features in some parts of the intertidal area have been interpolated where direct mapping has not been possible.

Figure 3. Visual rating scale for percentage cover estimates of macroalgae (top) and seagrass (bottom).



CONDITION AND CHANGE RATINGS

A series of broad scale estuary "condition and change ratings" (below) have been proposed for Porirua Harbour based on ratings developed for NZ's estuaries - e.g. Robertson & Stevens 2006, 2007, 2008, 2012 and a recent review of NZ monitoring data (Robertson and Stevens, in prep). As more NZ data become available, and the understanding of estuary condition improves, conditions ratings will continue to be revised and updated.

The ratings are designed to be used in combination with each other, along with other important condition indices, and expert input, when evaluating overall estuary condition and deciding on appropriate management. Some condition ratings 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).

SOFT MUD (PERCENT COVER)

Estuaries are a sink for sediments. Where large areas of soft mud are present, they are likely to lead to major and detrimental ecological changes that could be very difficult to reverse, and indicate where changes in land management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Good	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Fair	6%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Poor	>15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	>5% of estuary substrate is soft mud	Initiate ERP (Evaluation and Response Plan)

SOFT MUD (CHANGE IN AREA)

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 10 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP

LOW DENSITY MACROALGAL COVER

A two part macroalgae condition rating has been developed: 1. for low density (<50%) macroalgal cover throughout the estuary, and 2. a warning indicator for hotspots of high density (>50%) cover (see following rating). Low density macroalgal condition is rated using a continuous index (the macroalgae coefficient - MC) based on the percentage cover of macroalgae in defined categories in the estuary where cover is <50%. The equation used is: ***MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1.5 x %cover 5-10%)+(4.5 x %cover 10-20%)+(7.5 x %cover 20-50%))/100.***

LOW DENSITY MACROALGAL COVER CONDITION RATING

CONDITION RATING	DEFINITION	MC	RECOMMENDED RESPONSE
Very Low	Very Low	0.0 - 0.2	Monitor at 5 year intervals after baseline established
Low	Low	>0.2 - 0.8	Monitor at 5 year intervals after baseline established
	Low Low-Moderate	>0.8 - 1.5	Monitor at 5 year intervals after baseline established
Moderate	Low-Moderate	>1.5 - 2.2	Monitor yearly. Initiate ERP
	Moderate	>2.2 - 4.5	Monitor yearly. Initiate ERP
High	High	>4.5 - 7.0	Monitor yearly. Initiate ERP
	Very High	>7.0	Monitor yearly. Initiate ERP
Early Warning Trigger	Trend of increasing Macroalgae Coefficient		Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

HIGH DENSITY MACROALGAL COVER

The high density macroalgae condition rating targets areas of high density growth and is applied to the percentage of the estuary where the cover of intertidal macroalgae exceeds 50%. While this may not necessarily be combined with the presence of nuisance conditions, dense growths are an early warning of the estuary potentially exceeding its assimilative capacity and developing gross eutrophic conditions. A trend of an increasing dense macroalgal cover, or an increasing Macroalgal Coefficient for low density cover, provides an "early warning trigger" for initiating management action.

HIGH DENSITY MACROALGAL COVER CONDITION RATING

CONDITION RATING	>50% MACROALGAL COVER OVER:	RECOMMENDED RESPONSE
Very Low	<1% of estuary	Monitor at 5 year intervals after baseline established
Low	1-5% of estuary	Post baseline, monitor 5 yearly. Initiate ERP
Moderate	6-10% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
High	11-30% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>30% of estuary	Monitor yearly. Initiate Evaluation & Response Plan

HIGH DENSITY MACROALGAL COVER (CHANGE IN AREA)

Increases in the area of dense macroalgal cover indicate changes in catchment land use management are likely to be needed. Because extensive cover of dense macroalgae is commonly associated with gross eutrophic conditions that can be very difficult to reverse, even relatively small changes from baseline conditions should be evaluated as a priority.

HIGH DENSITY MACROALGAL COVER, AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 5 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor annually. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

GROSS EUTROPHIC CONDITIONS (AREA)

Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow Redox Potential Discontinuity (RPD) depth, elevated nutrient and total organic carbon concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover).

Persistent and extensive areas of gross nuisance conditions should not be present in short residence time estuaries, and their presence provides a clear signal that the assimilative capacity of the estuary is being exceeded. Consequently, the actual area exhibiting nuisance conditions, rather than the % of an estuary affected, is the primary condition indicator. Natural deposition and settlement areas, often in the upper estuary where flocculation at the freshwater/saltwater interface occurs, are commonly first affected. The gross eutrophic condition rating is based on the area affected by the combined presence of poorly oxygenated and muddy sediments, and a dense (>50%) macroalgal cover, as follows:

GROSS EUTROPHIC CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	No nuisance conditions	Monitor at 5 year intervals after baseline established
Low	Area of nuisance conditions <0.5ha	Monitor at 5 year intervals after baseline established
Fair	Area of nuisance conditions 0.5-5ha	Post baseline, monitor 5 yearly. Initiate ERP
Poor	Area of nuisance conditions 6-20ha	Post baseline, monitor annually. Initiate ERP
Very Poor	Area of nuisance conditions >20ha	Post baseline, monitor annually. Initiate ERP
Early Warning Trigger	Area of nuisance conditions >0.5ha or increasing	Initiate ERP (Evaluation and Response Plan)

GROSS EUTROPHIC CONDITIONS (CHANGE IN AREA)

Increases in the area of gross eutrophic conditions indicate changes in catchment land use management are likely to be needed. Because of the highly undesirable and often rapidly escalating decline in estuary quality associated with gross eutrophic conditions, even relatively small changes from baseline conditions should be evaluated as a priority.

GROSS EUTROPHIC AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No increase	Area of cover (ha) not increasing, or is decreasing	Monitor at 5 year intervals after baseline established
Small Increase	Increase in area of cover (ha) <5% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Moderate Increase	Increase in area of cover (ha) 5-15% from baseline	Post baseline, monitor annually. Initiate ERP
Large Increase	Increase in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Increase	Increase in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

SEAGRASS INDEX

Seagrass (*Zostera muelleri*) grows in soft sediments in NZ estuaries where its presence enhances estuary biodiversity. Though tolerant of a wide range of conditions, it is vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide).

A continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(0.5 x %cover 1-5%)+(2 x %cover 5-10%)+(3.5 x %cover 10-20%)+(6 x %cover 20-50%)+(9 x %cover 50-80%)+(12 x %cover >80%))/100.***

The "early warning trigger" for initiating management action is a trend of a decreasing Seagrass Coefficient.

SEAGRASS CONDITION RATING

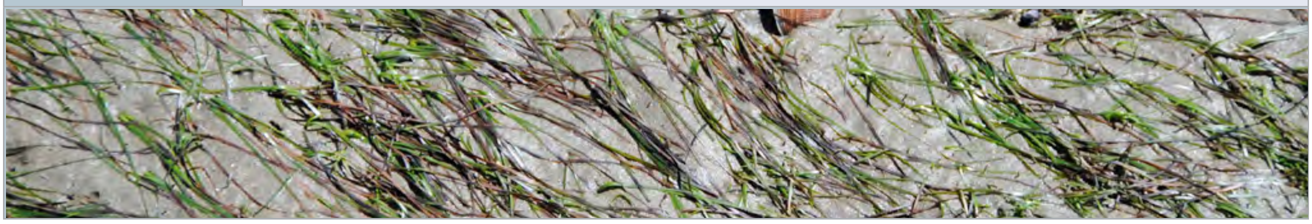
CONDITION RATING	DEFINITION	SC	RECOMMENDED RESPONSE
Poor	Very Low	0.0 - 0.2	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low	>0.2 - 0.8	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate	>0.8 - 1.5	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate	>1.5 - 2.2	Monitor at 5 year intervals after baseline established
	Moderate	>2.2 - 4.5	Monitor at 5 year intervals after baseline established
Very Good	High	>4.5 - 7.0	Monitor at 5 year intervals after baseline established
	Very High	>7.0	Monitor at 5 year intervals after baseline established
Early Warning Trigger	Trend of decreasing Seagrass Coefficient		Initiate ERP (Evaluation and Response Plan)

SEAGRASS (CHANGE IN AREA)

Seagrass is vulnerable to fine sediments in the water column, rapid sediment deposition, poor sediment quality (particularly reduced oxygen or production of sulphide), excessive macroalgal growth, high nutrient concentrations, and reclamation. Decreases in seagrass extent is likely to indicate an increase in these types of pressures.

SEAGRASS AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Area of cover (ha) not decreasing, or is increasing	Monitor at 5 year intervals after baseline established
Small Decrease	Decrease in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decrease in area of cover (ha) 5-15% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decrease in area of cover (ha) 16-50% from baseline	Post baseline, monitor annually. Initiate ERP
Very Large Decrease	Decrease in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP



2. METHODS (CONTINUED)

SALTMARSH (PERCENT COVER)

A variety of saltmarsh species (commonly dominated by rushland but including scrub, sedge, tussock, grass, reed, and herb fields) grow in the upper margins of most NZ estuaries where vegetation stabilises fine sediment transported by tidal flows. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth and have strong aesthetic appeal. Where saltmarsh cover is limited, these values are decreased. The "early warning trigger" for initiating management action is <5% of the estuary as saltmarsh.

SALTMARSH PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 10 year intervals after baseline established
High	11%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	6%-10% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Very Low	<2% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<5% of estuary area is saltmarsh	Initiate ERP (Evaluation and Response Plan)

SALTMARSH (CHANGE IN AREA)

Saltmarshes are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Decrease in saltmarsh extent is likely to indicate an increase in these types of pressures.

SALTMARSH AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Area of cover (ha) not decreasing, or is increasing	Monitor at 10 year intervals after baseline established
Small Decrease	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decline in area of cover (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decline in area of cover (ha) 11-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Decrease	Decline in area of cover (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

TERRESTRIAL VEGETATED BUFFER (PERCENT COVER)

The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer protects against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat. The "early warning trigger" for initiating management action is <50% of the estuary with a densely vegetated margin.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING

CONDITION RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	81%-100% cover of terrestrial vegetated buffer	Monitor at 10 year intervals after baseline established
High	51%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	26%-50% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Poor	5%-25% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<50% cover of terrestrial vegetated buffer	Initiate ERP (Evaluation and Response Plan)

TERRESTRIAL VEGETATED BUFFER (CHANGE IN AREA)

Estuaries are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion. Reduction in the vegetated buffer around the estuary is likely to result in a decline in estuary quality.

TERRESTRIAL VEGETATED BUFFER AREA CHANGE RATING

CHANGE RATING	DEFINITION	RECOMMENDED RESPONSE
No Decrease	Vegetated buffer not decreasing, or is increasing	Monitor at 10 year intervals after baseline established
Small Decrease	Decline in vegetated buffer (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Moderate Decrease	Decline in vegetated buffer (ha) 5-10% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Large Decrease	Decline in vegetated buffer (ha) 11-50% from baseline	Post baseline, monitor 5 yearly. Initiate ERP
Very Large Decrease	Decline in vegetated buffer (ha) >50% from baseline	Post baseline, monitor annually. Initiate ERP

3. RESULTS AND DISCUSSION

BROAD SCALE MAPPING

Top to bottom - soft mud near Horokiri and Porirua streams, and armoured shorelines in the Onepoto arm, Jan 2013.

Broad scale habitat mapping uses measures of the area of soft mud, macroalgal cover, gross eutrophic zones, seagrass, saltmarsh, and densely vegetated 200m terrestrial margin to apply condition ratings to assess key estuary issues of sedimentation, eutrophication, and habitat modification. The results of the January 2013 broad scale assessment are presented in the following sections.

A total of 284ha of estuary was mapped in 2013, 188ha unvegetated intertidal flats, 51ha tidal saltmarsh, and 46ha intertidal seagrass (Table 3). As noted previously by Stevens and Robertson (2008), the large subtidal component of the estuary (525ha, 65% is submerged at low tide) means Porirua Harbour is unlike the majority of New Zealand's tidal lagoon estuaries which tend to empty almost completely at low tide. This is a consequence of the physical structure of the estuary, combined with extensive historical losses (estimated to be ~200ha) of intertidal estuary flats and saltmarsh through reclamation and drainage. Because the subtidal area is large in relation to remaining intertidal areas, and is a dominant sink for sediment deposition, subtidal influences clearly need to be included in any assessment of key estuary issues of sedimentation and eutrophication. GWRC currently are undertaking further work to better characterise subtidal conditions in the harbour in relation to these aspects.

Table 3. Summary of dominant broad scale features, Porirua Harbour, Jan. 2013.

Estuary Location	Pauatahanui Arm		Onepoto Arm		Entire Estuary	
2013 Area	Ha	%	Ha	%	Ha	%
Saltmarsh	49.7	9.5%	0.7	0.3%	50.4	6.2%
Seagrass (>50% cover)	27.7	5.3%	18.0	6.3%	45.7	5.7%
Unvegetated	139.7	26.7%	48.0	16.8%	187.7	23.2%
Water	306.9	58.6%	217.9	76.6%	524.8	64.9%
TOTAL	524	100%	285	100%	809	100%

INTERTIDAL SUBSTRATE MAPPING

Where soil erosion from catchment development exceeds the assimilative capacity of an estuary, impacts such as increased muddiness and turbidity, shallowing, increased nutrients, changes in saltmarsh and seagrass habitats, reduced sediment oxygenation, increased organic matter degradation by anoxic processes (e.g. sulphide production), and alterations to fish and invertebrate communities can result. Also, because contaminants are most commonly associated with finer sediment particles, extensive areas of fine soft muds provide a sink which concentrate catchment contaminants. The primary indicator of sediment impacts is the area of the estuary dominated by soft and very soft muds, with estuaries with an area >5% mud exceeding the early warning trigger for management action.

Figure 4 and Table 4 summarise the unvegetated intertidal substrate of Porirua Harbour. Soft mud was a dominant feature over 8% of the estuary (10% of the Pauatahanui Arm and 5% of the Onepoto Arm), an overall condition rating of 'fair'. Outside of these muddy areas the estuary was dominated by firm mud/sand (58%) located mostly in the lower intertidal flats of both arms, and cobble, gravel and rock (17%) located primarily around the upper shores. Firm sand (8%) and mobile sand (8%) were also prominent around intertidal sand bars and in areas with high current flows near the entrance to each arm. All of these non-muddy habitats appeared to be in good (healthy) ecological condition.

The two arms of the estuary were relatively similar in their substrate mix, the main differences being the Pauatahanui Arm had less cobble (2% vs 23%) and more firm sand (10% vs 1%) than the Onepoto Arm.

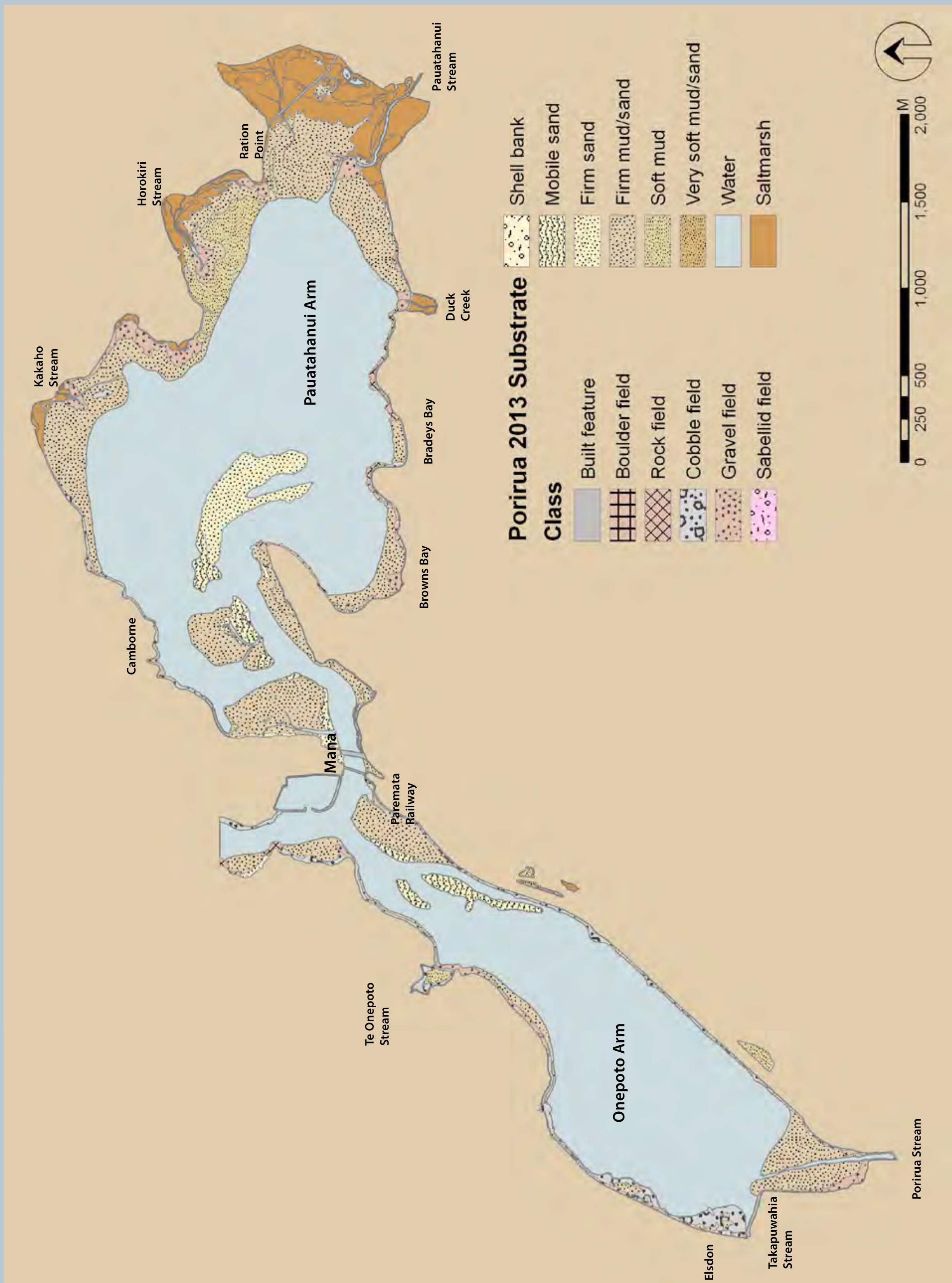


Figure 4. Map of Intertidal Substrate Types - Porirua Harbour, Jan. 2013.

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

Other small but notable features of the estuary were artificial structures (1.7%) and residential boathouses (0.6%). In particular, the presence of extensive areas protected by seawalls reflect where past reclamation has changed the character of the upper shore from predominantly gently sloping saltmarsh, to steep rocky edges that rise abruptly from the intertidal zone (see photos at bottom of page). The steep slopes, along with associated increases in wave energy and tidal inundation, combine to create conditions generally unfavourable for saltmarsh - most strongly evident in the Onepoto Arm and along the southern shoreline of the Pauatahanui Arm.

Further, the seawalls greatly reduce the capacity for the estuary to respond to changes in sediment and water levels that are likely to result from predicted sea level rise, one of the major stressors identified in the recent vulnerability assessment of the estuary (see Robertson and Stevens 2007b). Seawalls also reduce the diversity of available habitat for key ecological uses such as bird feeding and roosting and whitebait spawning, and create a physical barrier discouraging human access to the estuary.

Table 4. Summary of dominant intertidal substrate, Porirua Harbour, **January 2013.**

Estuary Location	Pauatahanui Arm		Onepoto Arm		Entire Estuary	
Area	Ha	%	Ha	%	Ha	%
Artificial structure	2.0	1%	2.0	3%	4.1	2%
Residential	0.8	1%	0.6	1%	1.4	1%
Rock field	3.4	2%	0.7	1%	4.1	2%
Boulder field	0.0	0%	0.1	0%	0.1	0%
Cobble field	2.8	2%	14.9	23%	17.6	8%
Gravel field	13.1	8%	4.1	6%	17.2	7%
Sabellid (tube worm) field	0.1	0%	0.2	0%	0.3	0%
Shell bank	1.1	1%	0.0	0%	1.1	0%
Mobile sand	7.4	4%	6.5	10%	14.0	6%
Firm sand	17.0	10%	0.6	1%	17.7	8%
Firm mud/sand	103.2	62%	32.8	50%	136.0	58%
Soft mud	16.5	10%	3.0	5%	19.5	8%
Very soft mud	0.0	0%	0.3	0%	0.3	0%
Grand Total	167.4	100%	66.0	100%	233.4	100%




Examples of artificial barriers along the estuary margin.

BROAD SCALE MAPPING (CONT.)

SOFT MUD % COVER CONDITION RATING
2008 VERY GOOD (1%)
2013 FAIR (8%)

SOFT MUD AREA CHANGE RATING
2008-2013 VERY LARGE INCREASE

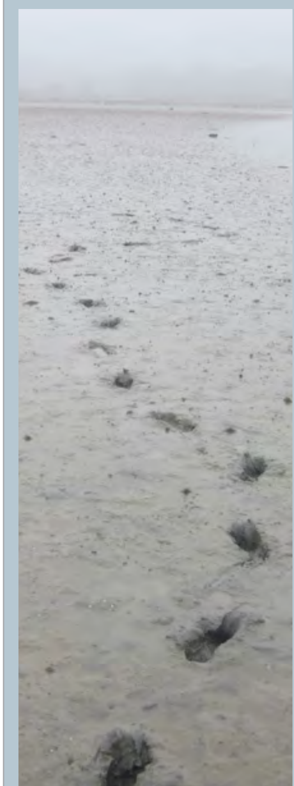
CHANGES IN INTERTIDAL ESTUARY SOFT MUD 2008-2013

The percent cover of major substrate classes in the Porirua Harbour in 2008 and 2013 are summarised in Table 5. There was no appreciable change in the artificial sub-strates or hard (rock/boulder/gravel) habitat types. However, the area dominated by soft mud increased very significantly (16.1ha), from 2008 to 2013 (Figure 5), matched by a reduction in the area of firm muddy sand. Most of this change occurred in the Pauatahanui Arm (Figure 5), with the largest increases in mud evident on the flats between Horokiri and Kakaho.

Table 5. Broad intertidal substrate categories, Porirua Harbour, 2008 and 2013.

Substrate Class	2008		2013	
	Area (ha)	Percent	Area (ha)	Percent
Built features/Residential	5.4	2%	5.5	2%
Rock/Boulder/Cobble/Gravel/Tubeworm field	37.1	16%	39.3	17%
Shell bank/Mobile sand	14.1	6%	15.1	6%
Firm sand	19.3	8%	17.7	8%
Firm muddy sand	155.0	66%	136.0	58%
Soft mud	3.4	1%	19.5	8%
Very soft mud	0.0	0%	0.3	0.1%
TOTAL	234	100%	233	100%

The condition rating for soft mud has changed from "good" in 2008, to "fair" in 2013, with the overall soft mud change condition rating a "very large increase" (>50% from the 2008 baseline).



Soft muds on previously sandy tidal flats near the Horokiri Stream mouth.

The increased mud coverage identified in the broad scale mapping is consistent with intertidal sedimentation rate measurements that show a 5.6mm increase from Jan. 2012 - Jan. 2013 at the Horokiri and Kakaho sediment plate sites, compared to mean annual aver-age deposition of <1mm/year over the upper tidal reaches of the Pauatahanui Arm since 2008 (see Stevens and Robert-son 2013).

As any large increase in mud within the estuary is a cause of significant concern, potential sources of sediment inputs to the estuary between 2008 and 2013 should be investigated to determine whether the increase is a response to direct inputs from development of the surrounding catchment, from flood deposition, or from reworking of sediment within the estuary.

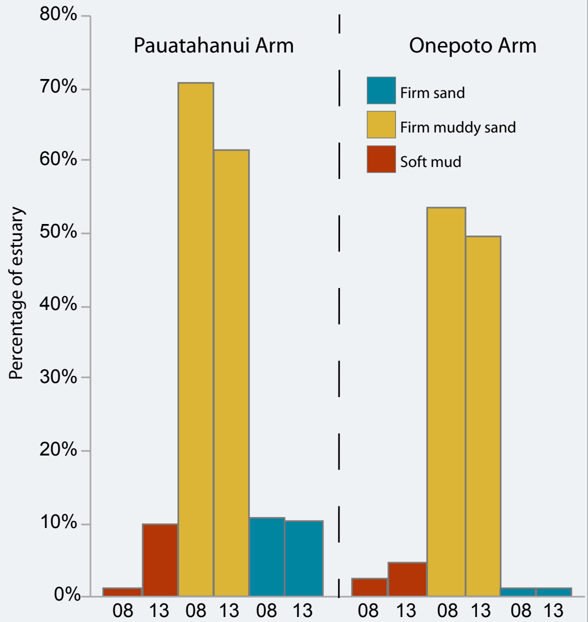


Figure 5. Change in the percentage of mud and sand as a dominant substrate class in Porirua Harbour, 2008-2013.

BROAD SCALE MAPPING (CONT.)

LOW DENSITY MACROALGAL CONDITION RATING

2013 MODERATE

HIGH DENSITY MACROALGAL CONDITION RATING

2013 MODERATE

GROSS EUTROPHIC AREA CONDITION RATING

2013 VERY GOOD

Gracilaria growing on sand-flats at Mana.

INTERTIDAL MACROALGAL COVER

Macroalgal blooms are a symptom of estuary eutrophication. These can deprive seagrass beds of light causing their decline, while decaying macroalgae can accumulate subtidally and on shorelines causing oxygen depletion and nuisance odours. The results of the 2013 intertidal macroalgal survey (Table 6 and Figure 6) showed:

- A large portion of the intertidal area (33%) had a low/very low percentage cover.
- High-very high (>50%) dense nuisance macroalgal cover was present - 15.7ha (7.1%) in the Pauatahanui Arm, and 7.4ha (11.9%) in the Onepoto Arm.
- Dense macroalgal cover commonly coincided with the presence of soft, poorly oxygenated, muds however significant gross nuisance conditions were not evident.
- The dominant macroalgae were the red alga *Gracilaria chilensis* (growing throughout the intertidal area but most commonly near stream deposition zones), and the green alga *Ulva lactuca* (which grows rapidly throughout the estuary and in channel areas wherever it can attach to the substrate).
- For the first time since 2008, macroalgal cover near the Porirua Stream mouth did not exceed 50% cover. However, the presence of nearby subtidal deposits suggests this is attributable to recent flushing of the intertidal flats, rather than improved conditions.

The condition ratings for macroalgal cover were revised in 2013 following a review of the extensive NZ estuary data set compiled by Wriggle since 2007. The revised ratings better characterise the distribution of low density macroalgal growths in the estuary (which generally do not cause significant nuisance conditions), and distinguish these from areas of high density macroalgal growths that are commonly associated with nuisance conditions and sediment deterioration, particularly when they combine with excessive soft muds.

The Macroalgal Coefficient (MC) for low density cover within the estuary in 2013 was 3.2 (Table 6). This fits a condition rating of "moderate", reflecting widespread low growth across much of the Pauatahanui (60% with low growth) and Onepoto (33%) arms. The lower value for Onepoto reflects the scarcity of wide, sheltered intertidal flats where low density macroalgal growth is commonly found.

The high density macroalgal cover was rated as "moderate" with 8% of the estuary experiencing dense (>50%) macroalgal growths. This was lower than the 11% cover ("high" rating) recorded in 2012, the change attributed primarily to reduced cover on the Porirua Stream delta associated with recent flushing of macroalgae from the tidal flats into subtidal areas.

While not reflected in a significant overall change in cover, a spatial shift was evident in macroalgae in the Pauatahanui arm over the previous 12 months. Cover had increased near the Horokiri Stream mouth (from 20-50% up to 50-80%), which coincided with increased sediment deposition in this area, while macroalgal cover decreased around the Pauatahanui Stream mouth (50-80% down to 20-50%).

Table 6. Summary of intertidal macroalgal cover, Porirua Harbour, January 2013.

Percentage Cover	Pauatahanui Arm			Onepoto Arm			Entire Estuary	
	Ha	%	Dominant species	Ha	%	Dominant species	Ha	%
Unvegetated	61.8	27.6	-	20.1	32.6	-	81.9	28.7
1-5%	8.8	3.9	*Gracilaria, Ulva* sp.	5.5	8.9	*Gracilaria, Ulva* sp.	14.3	5.0
5-10%	32.9	14.7	*Ulva* sp., *Gracilaria*	9.5	15.4	*Gracilaria, Ulva* sp.	42.2	14.9
10-20%	49.7	22.2	*Gracilaria, Ulva* sp.	7.3	11.8	*Gracilaria, Ulva* sp.	57.0	20.0
20-50%	54.6	24.4	*Gracilaria, Ulva* sp.,	11.9	19.4	*Gracilaria, Ulva* sp.	66.5	23.3
50-80%	15.6	7.0	*Gracilaria, Ulva* sp.	5.4	8.7	*Gracilaria, Ulva* sp.	21.0	7.4
>80%	0.1	0.1	*Ulva* sp., *Gracilaria*	2.0	3.2	*Gracilaria, Ulva* sp.	2.1	0.7
TOTAL	**224**	**100**		**62**	**100**		**286**	**100**

3. RESULTS AND DISCUSSION (CONTINUED)

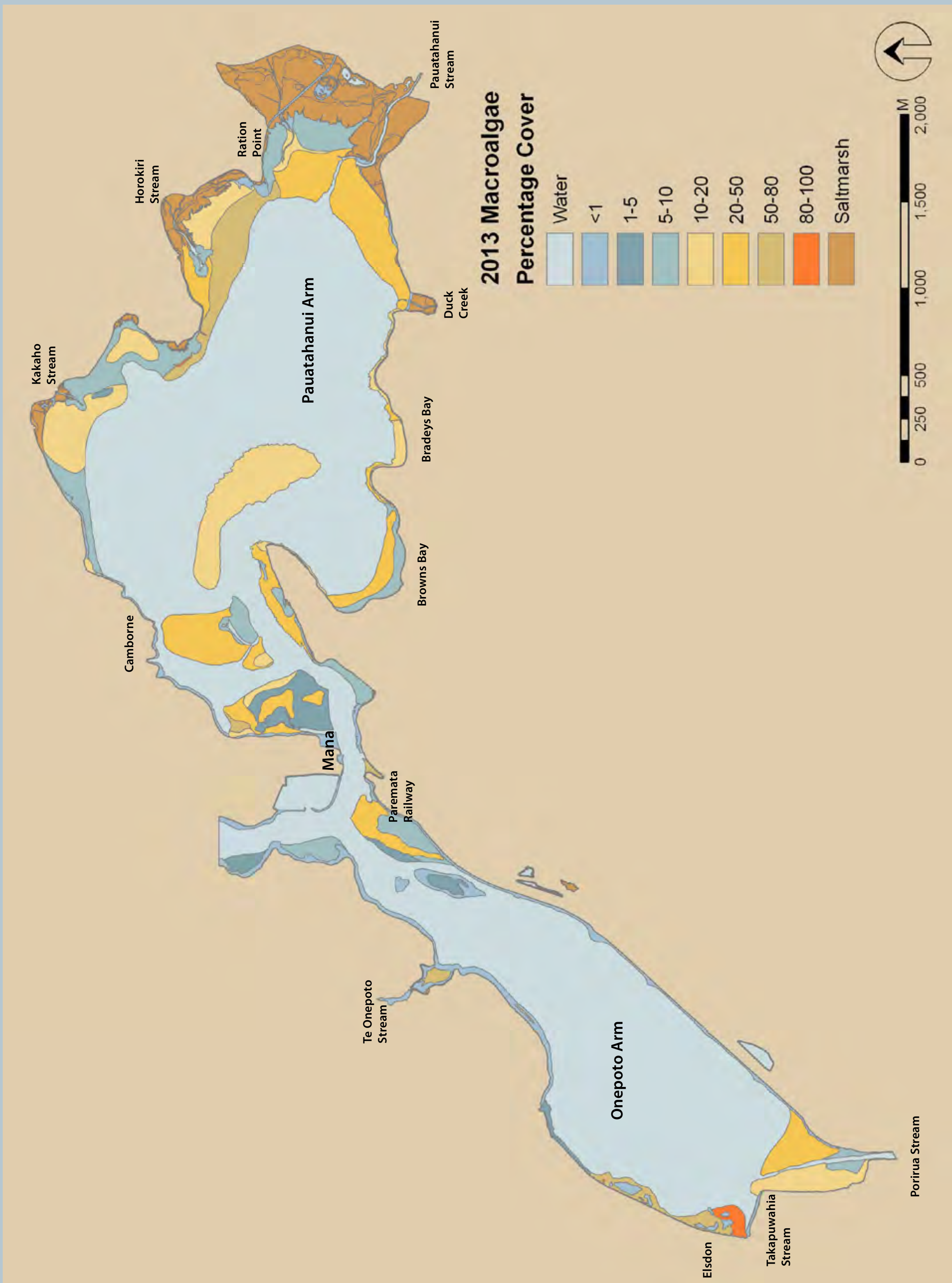


Figure 6. Map of Intertidal Macroalgal Cover - Porirua Harbour, January 2013.

BROAD SCALE MAPPING (CONT.)

LOW DENSITY MACROALGAL COVER CHANGE RATING
2013 WARNING TRIGGER (TREND OF INCREASE)

HIGH DENSITY MACROALGAL COVER CHANGE RATING
2008-2013 VARIABLE

CHANGES IN INTERTIDAL MACROALGAL COVER 2008 - 2013

Table 7 summarises both low and high density macroalgal growth from 2008-2013 and presents recalculated values using the condition ratings as revised in 2013.

Since 2008, high density intertidal macroalgal growth has been consistently at the upper end of the "moderate" category, or within the "high" category. The variable 8-15% cover most likely reflects fluctuations in observed cover as a consequence of river flows and wave action redepositing macroalgae from the intertidal flats into subtidal areas under flood or storm conditions. Although there is no clear trend to indicate significantly worsening conditions, the stable presence of high density intertidal macroalgal growths (that are on the verge of causing nuisance conditions) shows nutrient inputs to the estuary are sufficient to maintain elevated growths of macroalgae. This is further supported by the relatively steady increase of low density "moderate" non-nuisance macroalgae cover from 2008 to 2013. This trend of increase throughout the estuary activates the "warning trigger" and highlights care needs to be taken to ensure the assimilative capacity of the estuary is not exceeded.

It is therefore recommended that annual macroalgal monitoring be continued, that appropriate catchment nutrient guideline criteria be developed, and that the extent to which catchment loads meet these guidelines be assessed. The key steps in such an approach are as follows:

- Assign catchment nutrient load guideline criteria to the estuary based on available catchment load/estuary response information from other relevant estuaries.
- Estimate catchment nutrient loads to each estuary using available catchment models and stream monitoring data.
- Determine the extent to which each estuary meets guideline catchment load criteria.
- Assess the potential for requiring more detailed assessments of priority catchments (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling).
- Develop plans for targeted management or restoration of priority catchments.

Overall, the approach is intended to ensure that the assimilative capacity of the estuary is not exceeded so that the estuary can flourish and provide sustainable human use and ecological values in the long term.

Table 7. Summary of intertidal macroalgal cover, Porirua Harbour, 2008-2013.

Year	Low Density (MC) Rating	High Density (%) Rating	Result
2008	MOD 2.6	MOD (9%)	High cover (50-80%) near Porirua Stream mouth in Onepoto Arm dominated by *Ulva*. 10-20% cover across most of Pauatahanui Arm, dominated by *Gracilaria*.
2009	MOD 2.0	HIGH (15%)	High *Ulva* cover (50-80%) near Porirua Stream mouth. Large increase near Pauatahanui Stream mouth (50-80% cover dominated by *U. intestinalis*). Increased growth by Paremata boathouses (20-50% cover).
2010	MOD 3.1	MOD (10%)	High *Ulva* cover (50-80%) near Porirua Stream mouth. Dominant cover near Pauatahanui Stream mouth changed from *U. intestinalis* to *Ulva* sp. Increased cover in northeast Pauatahanui Arm (1-5% to 20-50%).
2011	MOD 3.0	MOD (10%)	High cover (50-100%) near Porirua Stream mouth dominated by *Ulva* sp. High cover (50-80%) near Pauatahanui Stream mouth dominated by *Gracilaria*.
2012	MOD 2.9	HIGH (11%)	High cover (50-100%) near Porirua Stream mouth dominated by *Ulva* sp. High cover (50-80%) near Pauatahanui Stream mouth dominated by *Gracilaria*.
2013	MOD 3.2	MOD (8%)	High cover (50-80%) near Porirua Stream mouth dominated by *Gracilaria*. High cover (50-80%) near Horokiri Stream mouth dominated by *Gracilaria*.

BROAD SCALE MAPPING (CONT.)

SEAGRASS COEFFICIENT CONDITION RATING
2008 GOOD
2013 GOOD
2013 WARNING TRIGGER (TREND OF DECREASE)

SEAGRASS AREA CHANGE RATING
1962-80 to 2008 VERY LARGE DECREASE
2008 to 2013 MODERATE DECREASE

INTERTIDAL SEAGRASS COVER

Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Though tolerant of a wide range of conditions, seagrass is vulnerable to excessive nutrients, fine sediments in the water column, and sediment quality (particularly if there is a lack of oxygen and the production of toxic sulphide).

The results of the 2013 intertidal seagrass survey (Table 8 and Figure 7) showed:

- Dense (>50%) seagrass cover was present in both arms but overall, most of the intertidal area (80%) had no seagrass cover.
- The intertidal seagrass percentage cover rating is relatively high primarily because the intertidal area is relatively small. Seagrass extent across the entire estuary would be in the "low" category.
- Intertidal seagrass beds were predominantly located high in the tidal range, with the largest beds near well flushed low tide channels toward the estuary entrance.

The 2013 Seagrass Coefficient (SC) was "low-moderate" (2.0), a condition rating of "good", with higher dense cover (>50%) present in the Onepoto Arm (27%, SC=2.7) compared to the Pauatahanui Arm (13%, SC=1.7).

Table 8. Summary of intertidal seagrass cover, Porirua Harbour, January 2013.

SEAGRASS	Pauatahanui Arm		Onepoto Arm		Entire Estuary	
Percentage Cover	Ha	%	Ha	%	Ha	%
<1%	179.8	83%	48.4	73%	228.2	80%
1-5%	0	0%	0	0%	0	0.0%
5-10%	0	0%	0	0%	0	0%
10-20%	2.1	1%	0	0%	2.1	1%
20-50%	7.6	3%	0.3	1%	7.9	3%
50-80%	3.7	2%	12.5	19%	16.2	6%
>80%	24.1	11%	5.5	8%	29.5	10%
TOTAL	**217**	**100%**	**68**	**100%**	**284**	**100%**

CHANGES IN INTERTIDAL SEAGRASS COVER

Aerial photographs from the early 1900's show intertidal seagrass was historically abundant in both the Onepoto and Pauatahanui Arms. Since at least that time, seagrass cover has substantially reduced, primarily as a consequence of reclamation, but with increasing fine sediment muddiness (and related effects e.g. reduced water clarity, smothering, reduced sediment oxygenation), and excessive nutrient loads also likely to have played a significant role in seagrass decline.

The best historical baselines currently available of seagrass cover are mapping of the Pauatahanui Arm presented in Healy (1980), and estimates from the Onepoto Arm undertaken by Matheson and Wadwha (2012) based on 1962 aerial photos. Table 9 presents these historical estimates, alongside those derived from more recent ground-truthed broad scale assessments of the entire estuary in 2008 (Figure 7, Stevens and Robertson 2008) and 2013 (Figure 8).

The estimates in Table 9 have been spatially segregated to indicate where the greatest changes in the estuary have occurred. The results show very large decreases in seagrass since 1980 in the Pauatahanui Arm (23% reduction), and since 1962 in the Onepoto Arm (38% reduction). The Pauatahanui Arm losses have been primarily from intertidal flats at the mouth of Pauatahanui Stream, and at Ration Point, Kakaho, Duck Creek, and Camborne, attributable to physical changes rather than reclamation. Losses have been offset by small increases near Mana, and a large increase in the central basin of the arm which has become much shallower over the past 30 years. Largest losses in the Onepoto Arm were caused by reclamations at Mana and Elsdon.

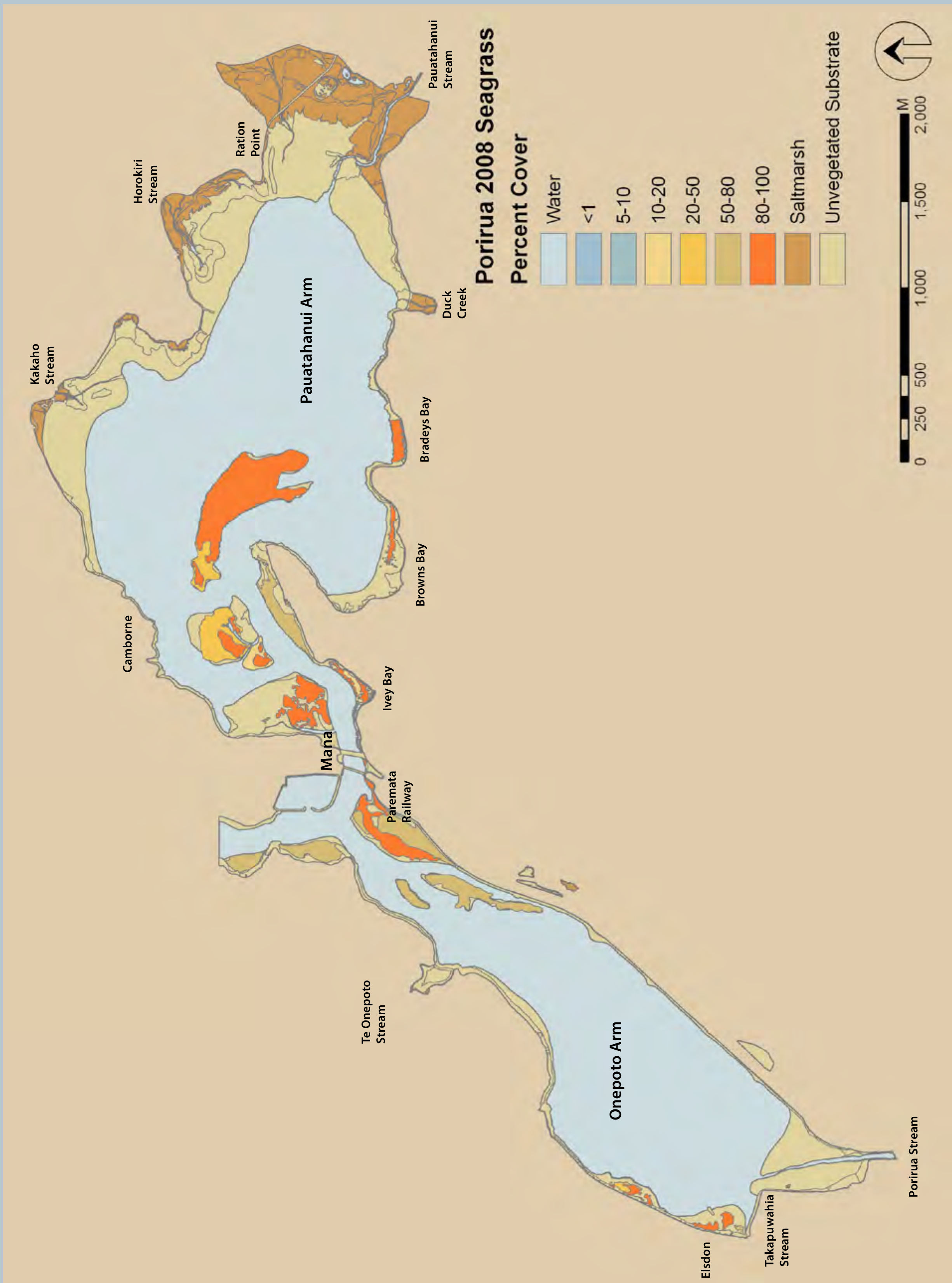


Figure 7. Map of Intertidal Seagrass Cover - Porirua Harbour, January 2008.

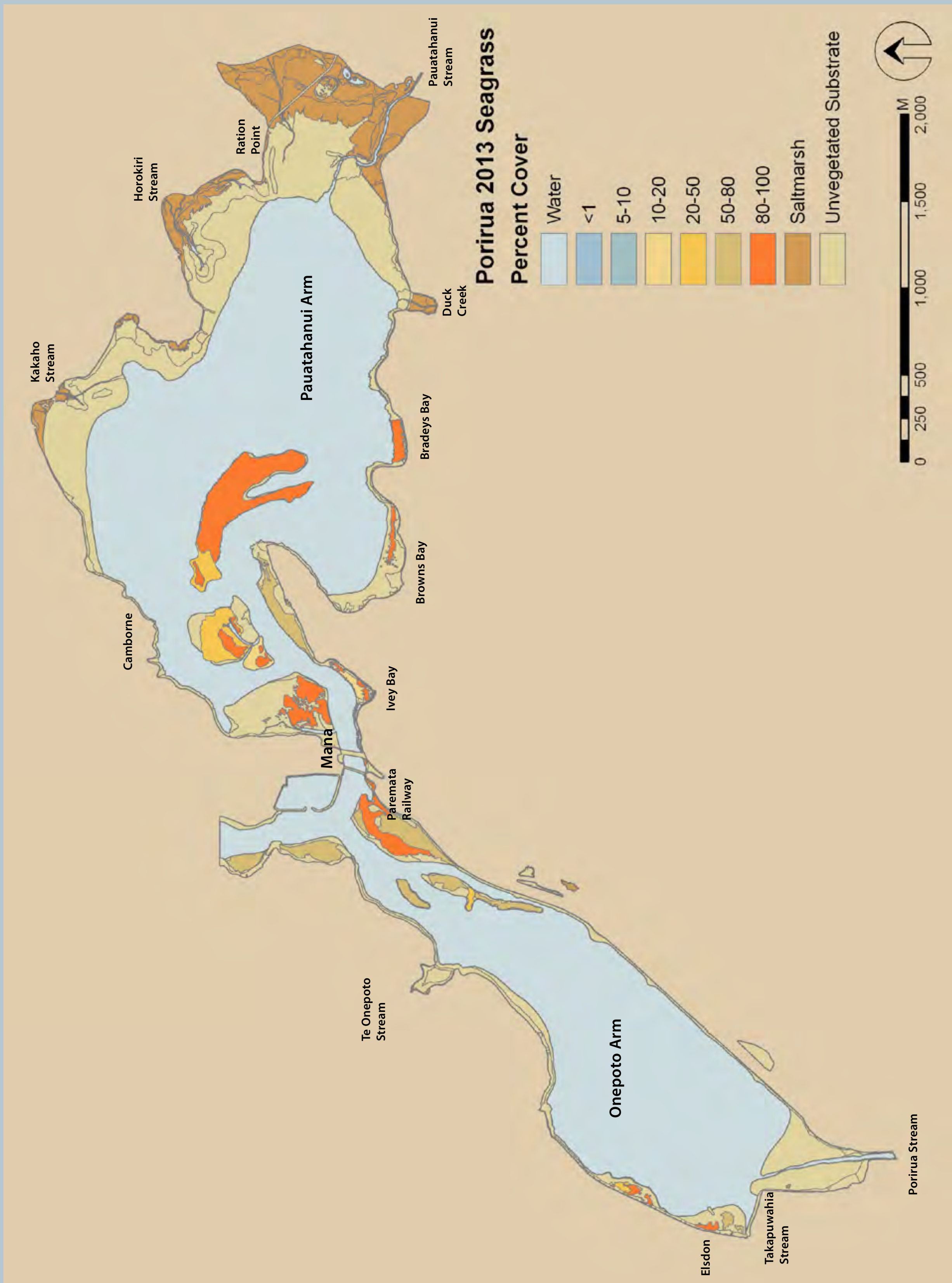


Figure 8. Map of Intertidal Seagrass Cover - Porirua Harbour, January 2013.

BROAD SCALE MAPPING (CONT.)

Remnant seagrass bed near Porirua Stream mouth.

Table 9. Summary of dense (>50%) intertidal seagrass cover (ha), Porirua Harbour, 1942, 1962, 1980, 2008, 2013.

	Location	1942[1]	1962[1]	1980[2]	2008[3]	2013
Pauatahanui Arm	Mana	2.0	not assessed	1.2	4.3	4.3
	Camborne	indet.	not assessed	0.2	0	0
	Kakaho	indet.	not assessed	6.2	0	0
	Ration Point (Paua. Stream)	19.5	not assessed	26.0	0	0
	Duck Creek	indet.	not assessed	0.2	0	0
	Bradey's Bay	indet.	not assessed	0.2	1.4	1.4
	Browns Bay	0.7	not assessed	0	0.9	0.9
	Ivey Bay-Morehouse Point	1.4#	not assessed	2.7	4.4	4.2
	Mid harbour	indet.	not assessed	0	19.1	17.3
Pauatahanui Total (ha)		**-**	**-**	**36.7**	**30**	**28**
Onepoto Arm	Western entrance	0.5	1.8#	not assessed	4.2	4.2
	Mana marina	indet.	3.2	not assessed	0	0
	Railway	indet.	14.8	not assessed	14.1	11.9
	Elsdon	indet.	8.5##	not assessed	1.6	1.5
Onepoto Total (ha)		**-**	**28**	**-**	**20**	**18**
Porirua Harbour Total (ha)		**-**	**65** (combined baseline)		**50**	**46**

[1] source Matheson and Wadwha (2012). Indet. indicates photo resolution insufficient to determine presence/absence.
[2] source Healy (1980).
[3] 2008 values are modified from those in Stevens and Robertson (2008) which were based on 2005 aerial photos flown at high tide. Current estimates have been derived from 2008 aerials with much improved resolution and low tide coverage.
#value modified from Matheson and Wadwha (2012) in which seagrass was truncated at the edge of the aerial photos.
##value modified from Matheson and Wadwha (2012) to include seagrass on the western shores of Onepoto Arm.

The 9% decline in intertidal seagrass detected from 2008 to 2013 (7% in the Pauatahanui Arm and 12% in the Onepoto Arm) reflects a small but significant reduction in Ivey Bay, and a larger decrease in the Onepoto Arm on the lower tidal reaches of the flats opposite the Paremata railway station. This decrease, a condition rating of "moderate", is correlated with elevated macroalgal growths (20-50% cover) which were commonly present on and within the seagrass beds in both areas. It is considered most likely that the observed declines in seagrass are being driven by the combined stress of macroalgal smothering, and the impact of increased muddiness contributing to reduced sediment oxygenation and poor water clarity. The latter is particularly evident with wind generated waves readily resuspending soft muds deposited in shallow subtidal areas in both arms, greatly reducing clarity. However, Matheson and Wadwha (2012) link seagrass loss primarily to nutrient levels in the harbour that (at times) reach levels known to cause toxicity symptoms. Consequently it is recommended that catchment nutrient inputs to the harbour be assessed and compared to appropriate nutrient load criteria.

A broad scale subtidal assessment of the Harbour is scheduled for 2013/14 to more fully characterise seagrass coverage and substrate conditions in the Harbour.

Seagrass bed adjacent to the Paremata railway reclamation.

BROAD SCALE MAPPING (CONT.)

SALTMARSH % COVER CONDITION RATING
2008 MODERATE
2013 MODERATE

Extensive beds of rushland, eastern Pauatahanui Arm.

SALTMARSH MAPPING

Saltmarsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds, and provides an important habitat for a variety of species including fish and birds. Porirua Harbour is notable for the virtual absence of saltmarsh around the estuary margins developed for residential, or commercial/industrial/transportation uses and where the steep, armoured shoreline prevents saltmarsh establishment. Tables 10, 11 and Figure 9 summarise the results of the 2013 saltmarsh mapping. Overall, 50ha (6.3%) of saltmarsh remains in the estuary, an overall condition rating of "moderate" but with a "very low" rating in the Onepoto Arm. Key findings were:

- Artificial barriers (primarily seawalls flanking road and rail corridors and reclaimed areas) surround 2/3rds of the estuary and have displaced most of the historical saltmarsh cover.
- The most extensive areas of remaining saltmarsh were located in the largely undeveloped eastern and northern side of the Pauatahanui Arm.
- The dominant saltmarsh was rushland (58%), and estuarine shrubs (22%).
- Introduced grass and weeds were a common subdominant cover near the terrestrial margin.

Table 10. Summary of saltmarsh cover, Porirua Harbour, 2008 and 2013.

Estuary Location	Pauatahanui Arm		Onepoto Arm		Entire Estuary	
Year	2008	2013	2008	2013	2008	2013
Area	Ha (%)	Ha (%)	Ha (%)	Ha (%)	Ha (%)	Ha (%)
Saltmarsh	50.6 (9.7)	49.7 (9.5)	0.8 (0.3)	0.7 (0.3)	51.4 (6.4)	50.4 (6.2)
Estuarine Shrub	11.3 (2.1)	11.0 (2.1)	-	-	11.3 (1.4)	11.0 (1.4)
Tussockland	0.7 (0.1)	0.7 (0.1)	0.5 (0.2)	-	1.2 (0.1)	0.7 (0.1)
Grassland	7.9 (1.5)	7.7 (1.5)	-	-	7.9 (1.0)	7.7 (1.0)
Rushland	29.2 (5.6)	28.5 (5.5)	0.2 (0.1)	0.5 (0.2)	29.4 (3.6)	29.0 (3.6)
Reedland	0.6 (0.1)	0.5 (0.1)	0.01 (0)	0.01 (0)	0.6 (0.1)	0.5 (0.1)
Herbfield	1.1 (0.2)	1.1 (0.2)	0.01 (0)	0.2 (0.1)	1.1 (0.1)	1.3 (0.2)
Unvegetated	473 (90.3)	474 (90.5)	282 (99.7)	284 (99.7)	755 (93.6)	758 (93.8)
Intertidal flats	173.0 (33.0)	167.4 (31.9)	61.5 (21.7)	66.0 (23.2)	234.4 (29.1)	233.4 (28.9)
Water	300.2 (57.3)	306.9 (58.6)	220.7 (78.0)	217.9 (76.6)	520.9 (64.5)	524.8 (64.9)
Total	524 (100)	524 (100)	283 (100)	285 (100)	807 (100)	809 (100)

Figure 9 highlights that the east of the Pauatahanui Arm (where more natural estuary profiles remain) was dominated by wide beds of rushland (mostly searush and jointed wire rush) which, as the terrestrial influence increased, transitioned through areas dominated by saltmarsh ribbonwood (*Plagianthus divaricatus*) and grassland (mostly tall fescue - *Festuca arundinacea*). Within the dominant rushland and grassland vegetation classes a wide variety of common estuarine plants were present (Table 11), with introduced weeds a common subdominant cover, particularly among the grassland. *Sarcocornia* dominated herbfields were also common on raised shell banks at the upper tidal zone in the north and east.

Within the Onepoto Arm, the largest vegetated area was located in the small Te Onepoto embayment which is dominated by rushland (searush *Juncus kraussii* and jointed wire rush (*Apodasmia similis*) - Figure 9. Elsewhere the vegetation consisted mostly of small patches of *Sarcocornia* (glasswort) dominated herbfields at the edges of the main body of the estuary where it is restricted to a narrow range of suitable habitat mostly among the steep faced riprap seawalls bordering the upper tidal reaches.

3. RESULTS AND DISCUSSION (CONTINUED)

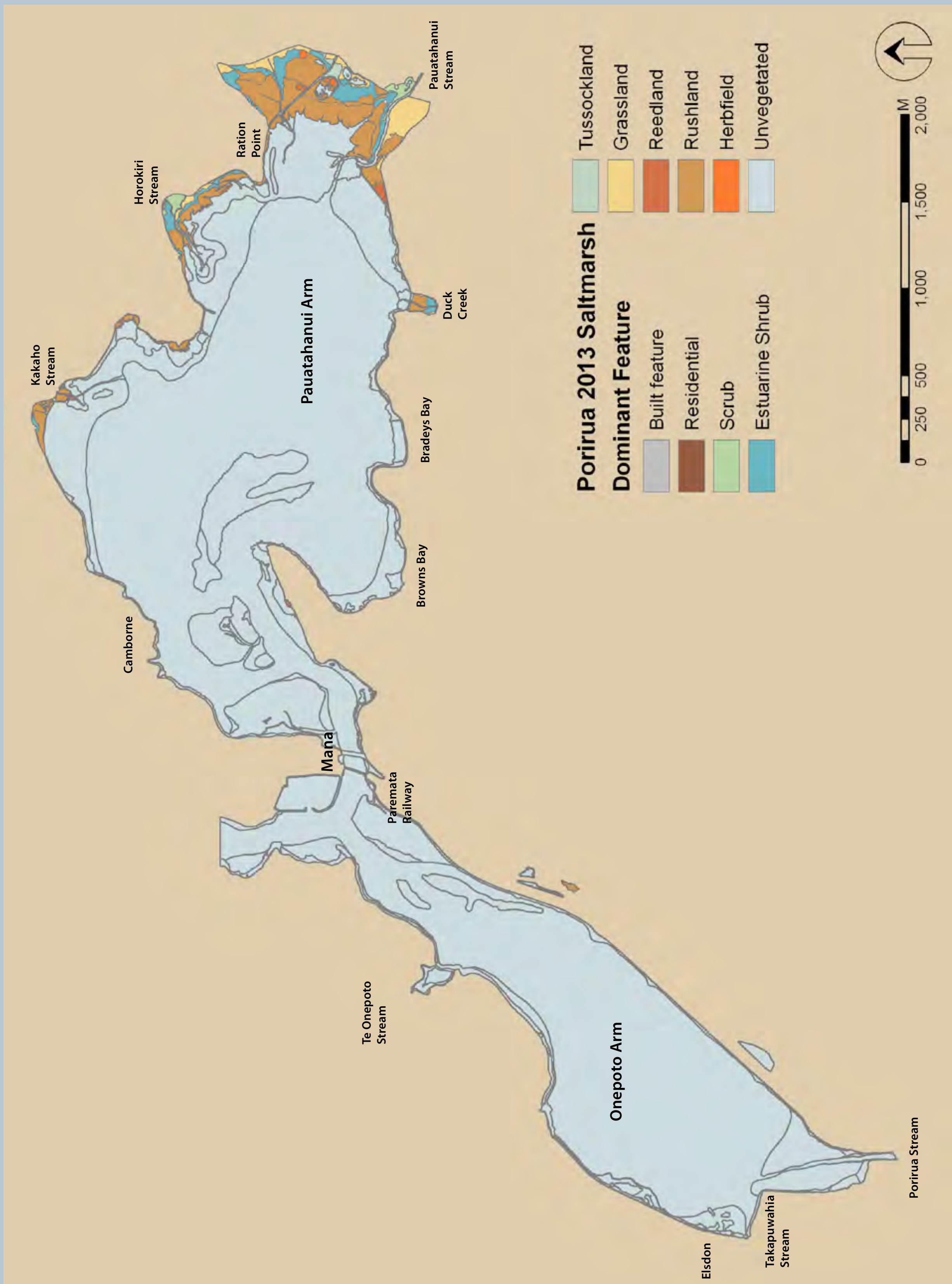


Figure 9. Map of Saltmarsh Vegetation - Porirua Harbour, January 2013.

Table 11. Summary of broad scale vegetation of Porirua Harbour, January 2013.

Class	Dominant Species	Primary subdominant species	Pauatahanui		Onepoto		Entire Estuary	
			Ha	%	Ha	%	Ha	%
Scrub			1.9	0.4%			1.9	0.2%
	Coprosma propinqua (Mingimingi)	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	0.06	0.01			0.06	0.01
	Native scrub/forest	-	0.83	0.16			0.83	0.10
		Festuca arundinacea (Tall fescue)	0.99	0.19			0.99	0.12
Estuarine Shrub			9.2	1.8%			9.2	1.1%
	Plagianthus divaricatus (Saltmarsh ribbonwood)	-	0.12	0.02			0.12	0.02
	Plagianthus divaricatus (Saltmarsh ribbonwood)	*Festuca arundinacea (Tall fescue)*	3.51	0.67			3.51	0.44
		Juncus kraussii (Searush)	0.43	0.08			0.43	0.05
		Apodasmia similis (Jointed wirerush)	5.08	0.97			5.08	0.63
Tussockland			0.7	0.1%			0.7	0.1%
	Phormium tenax (New Zealand flax)	*Plagianthus divaricatus (Saltmarsh ribbonwood)*	0.73	0.14			0.73	0.09
Grassland			7.7	1.5%			7.7	1.0%
	Festuca arundinacea (Tall fescue)	*Ficinia (Isolepis) nodosa (Knobby clubrush)*	1.38	0.26			1.38	0.17
		Apodasmia similis (Jointed wirerush)	3.87	0.74			3.87	0.48
		Phormium tenax (New Zealand flax)	0.61	0.12			0.61	0.08
		Plagianthus divaricatus (Saltmarsh ribbonwood)	0.53	0.10			0.53	0.07
		Samolus repens (Primrose)	0.03	0.01			0.03	0.00
		Unidentified introduced weeds	0.94	0.18			0.94	0.12
	Unidentified grass	*Unidentified introduced weeds*	0.40	0.08			0.40	0.05
Rushland			28.5	5.5%	0.5	0.2%	29.0	3.6%
	Juncus kraussii (Searush)	-	10.88	2.08			10.88	1.35
		Festuca arundinacea (Tall fescue)	0.86	0.17			0.86	0.11
		Apodasmia similis (Jointed wirerush)	4.45	0.85	0.42	0.15	4.87	0.60
		Plagianthus divaricatus (Saltmarsh ribbonwood)	5.76	1.10			5.76	0.72
		Samolus repens (Primrose)	2.92	0.56			2.92	0.36
		Sarcocornia quinqueflora (Glasswort)			0.07	0.03	0.07	0.01
		Schoenoplectus pungens (Three-square)	0.02	0.00			0.02	0.00
	Apodasmia similis (Jointed wirerush)	-	0.93	0.18			0.93	0.12
		Juncus kraussii (Searush)	0.83	0.16	0.05	0.02	0.88	0.11
		Phormium tenax (New Zealand flax)	0.17	0.03			0.17	0.02
		Plagianthus divaricatus (Saltmarsh ribbonwood)	1.67	0.32			1.67	0.21
Reedland			0.5	0.1%	0.0	0.0%	0.5	0.1%
	Typha orientalis (Raupo)		0.50	0.10	0.01	0.00	0.51	0.06
Herbfield			1.1	0.2%	0.2	0.1%	1.3	0.2%
	Samolus repens (Primrose)	-	0.02	0.00			0.02	0.00
		Selliera radicans (Remuremu)	0.31	0.06			0.31	0.04
	Sarcocornia quinqueflora (Glasswort)	-	0.01	0.00	0.04	0.01	0.05	0.01
		Samolus repens (Primrose)	0.14	0.03			0.14	0.02
		Selliera radicans (Remuremu)	0.25	0.05	0.13	0.05	0.38	0.05
	Selliera radicans (Remuremu)	-	0.18	0.04			0.18	0.02
		Juncus kraussii (Searush)	0.04	0.01			0.04	0.00
		Samolus repens (Primrose)	0.17	0.03			0.17	0.02
		Sarcocornia quinqueflora (Glasswort)			0.01	0.00	0.01	0.00
Total saltmarsh vegetation			49.7	9.5	0.7	0.3	50.4	6.2
Unvegetated substrate			167.4	31.9	66.0	23.2	233.4	28.9
Water			306.9	58.6	217.9	76.6	524.8	64.9
Grand Total			**524**	**100**	**285**	**100**	**809**	**100**

3. RESULTS AND DISCUSSION (CONTINUED)

BROAD SCALE MAPPING (CONT.)

SALTMARSH AREA CHANGE RATING
2008-2013 NO DECREASE

CHANGES IN SALTMARSH COVER 2008-2013

The condition rating for saltmarsh measures a percentage change from an established baseline. Based on the summary information in Table 10, and using 2008 data as a baseline, the 2013 saltmarsh condition rating is rated as a "no decrease". Although small changes can be seen in 2008 and 2013 results, these relate to changes in the extent and interpretation of mapped features rather than changes in the area of saltmarsh.

One of the very visible and positive changes occurring in the estuary is the effort being put into saltmarsh restoration by the community, DOC, PCC, and GWRC. This includes the ongoing development of a boardwalk around the Pauatahanui Arm which is re-establishing public access to the estuary margin previously cut off in many places by roads that flank much of the estuary (photo below).

Elsewhere margin plantings are evident in many locations. Because of the greatly reduced cover of saltmarsh, even small areas of restoration have the potential to greatly increase the extent and quality of saltmarsh in the estuary (photos below).


Mana


Ration Point


Kakaho

This is particularly so in the Onepoto Arm where recent planning initiatives led by PCC and GWRC have sought to identify priority areas for restoration. These include margins near the Porirua Stream mouth (below left), and Motukaraka Point (below right). These are some of the few remaining shoreline areas in the estuary without seawalls, which therefore provide a relatively simple opportunity to re-establish gently sloping saltmarsh habitat in areas where migration of saltmarsh in response to sea level rise (SLR) is still possible.


Porirua Stream mouth


Motukaraka Point

BROAD SCALE MAPPING (CONT.)

VEGETATED MARGIN % COVER CONDITION RATING
2008 POOR
2013 POOR

VEGETATED MARGIN CHANGE RATING
2008-2013 NO SIGNIFICANT CHANGE

TERRESTRIAL MARGIN COVER

Like saltmarsh, a densely vegetated terrestrial margin filters and assimilates sediment and nutrients, acts as an important buffer that protects against introduced grasses and weeds, is an important habitat for a variety of species, provides shade to help moderate stream temperature fluctuations, and improves estuary biodiversity. The results of the 200m terrestrial margin survey (Table 12 and Figure 10) showed:

- Most of the immediate estuary margin had been modified by roading, causeways, seawalls, or reclamations.
- The mapped 200m wide terrestrial margin buffer was dominated by grassland (36%), residential development (31%) artificial structures (10%) and commercial development (4%).
- Scrub and forest (17%) was primarily located within Whitireia Park in the northwest of the Onepoto Arm, and in pockets among residential areas in Pauatahanui Arm.

The extent of densely vegetated terrestrial buffer (17%) fits the condition rating of "poor", with no significant change from 2008.

Table 12. Summary of the 200m terrestrial margin, Porirua Harbour, January 2013.

Class	Dominant Feature	Pauatahanui	Onepoto	Entire Estuary
Forest	Mixed native and exotic forest	-	1%	1%
Scrub/Forest	Mixed native and exotic scrub/forest	12%	3%	8%
Scrub	Mixed native and exotic scrub	0.2%	18%	8%
Estuarine Shrub	Saltmarsh ribbonwood	0.1%	0%	0.03%
Tussockland	Carex spp. (Sedge)	-	0.2%	0.1%
Grassland	Grassed pasture and amenity areas	39%	33%	36%
Water		-	4%	2%
Artificial structure	Railway	-	3%	1%
	Road	6%	11%	9%
Residential		43%	17%	31%
Commercial		-	8%	4%
TOTAL		**100**	**100**	**100**

The extensive presence of road and rail corridors directly bordering ~2/3rds of each arm of the estuary (see Figure 10) greatly impinges upon the high aesthetic and natural values of the estuary, and breaks the natural sequence of estuarine to terrestrial vegetation. This is most pronounced in the Onepoto Arm where small, remnant, poorly flushed estuary embayments are cut off from the main body of the estuary e.g. Aotea Lagoon. The reclaimed areas of railway and motorway are dominated by introduced weeds and grass. Accumulations of rubbish from Porirua continue to be a feature of the Onepoto Arm (photo lower left). Whitireia Park continues to recover well from the fire that destroyed much of the scrub cover in 2010.

Residential areas in the north west and south of Pauatahanui Arm are notable for the scrub/forest corridors remaining among the housing and bordering the estuary. Public access tracks are well utilised in these areas, but roading still presents a significant barrier to public access to the estuary.

The northern and eastern margin of Pauatahanui remains relatively undeveloped grassland (grazed pasture), with a few pockets of scrub/forest and residential development. Grassland adjacent to the estuary generally contained a range of introduced weeds.

Overall, the terrestrial margin is dominated by artificial structures, residential, and commercial/industrial developments, and grazed pasture. As a consequence of this significant past development, it retains very few habitat features that are unmodified and in their natural state.

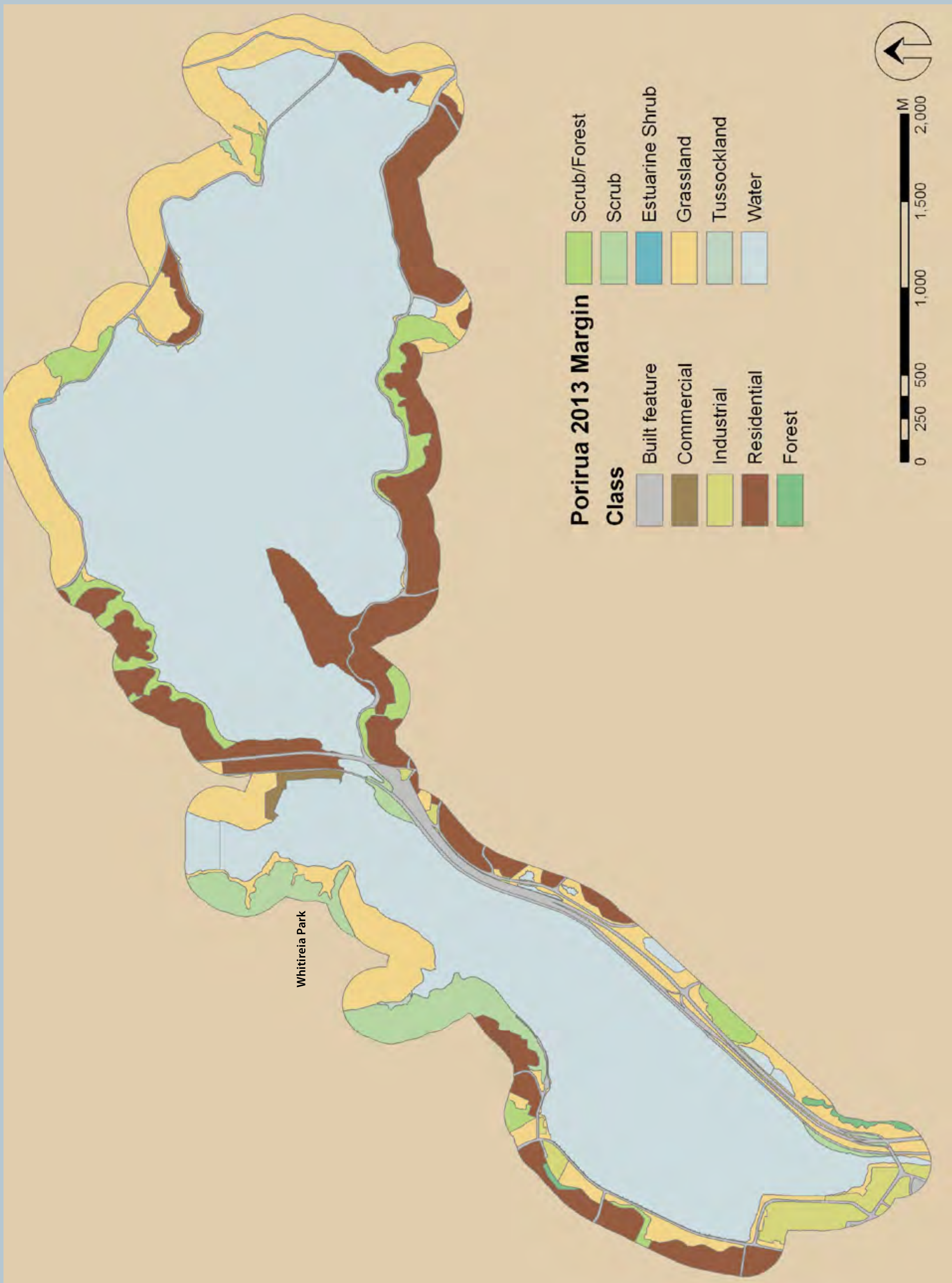


Figure 10. Map of 200m Terrestrial Margin Vegetation - Porirua Harbour, January 2013.

4. SUMMARY AND CONCLUSIONS

Table 13 summarises condition ratings in relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication and habitat modification).

Table 13. Summary of broad scale condition ratings for Porirua Harbour 2008, 2013.

Major Issue	Indicator	2008	2013	Change from 2008 Baseline
Sediment	Soft mud area	VERY GOOD	FAIR	VERY LARGE INCREASE
Eutrophication	Low density macroalgal cover	MODERATE	MODERATE	TRENDING UP = WARNING
	High density macroalgal cover	MODERATE	MODERATE	VARIABLE = WARNING
	Gross eutrophic condition area	VERY GOOD	VERY GOOD	NO SIGNIFICANT CHANGE
Habitat Modification	Seagrass area	GOOD	GOOD	MODERATE DECREASE
	Saltmarsh area	MODERATE	MODERATE	NO SIGNIFICANT CHANGE
	Densely vegetated margin area	POOR	POOR	NO SIGNIFICANT CHANGE

Overall, the majority of the intertidal area in both arms was characterised by unvegetated, poorly sorted firm muddy sands, with only small areas dominated by soft mud. Intertidal seagrass beds were present in both arms. Most of the estuary margin has been extensively modified and is bounded by artificial structures (e.g. riprap seawalls, road and rail networks), with the terrestrial land cover dominated by grassland, residential/commercial developments. Consequently, saltmarsh is virtually non-existent in the Onepoto Arm, and although much diminished from historical cover, relatively large areas remain in the eastern and northern parts of the Pauatahanui Arm.

While the estuary remains predominantly sandy (~70% firm sand and firm mud/sand), soft and very soft mud now cover 8% of the surface sediments in the estuary. This reflects a very large increase in the area of soft mud (from 3ha to 20ha) between 2008 and 2013. Most of this change has occurred on the intertidal flats between Horokiri and Kakaho in the Pauatahanui Arm, where it appears that resent subtidal mud deposits sourced from catchment sources (Gibb and Cox 2009), are being re-mobilised and re-deposited to intertidal areas by waves generated by the prevailing wind. The subtidal deposits are extensive with a large portion dominated by muddy sediments (e.g. Healy 1980, Milne et al. 2008).

Macroalgal growth (dominated by *Gracilaria* and *U. lactuca*) remained at moderate levels, with a widespread low density cover in both arms. High density growths remained evident near Porirua Stream, and had increased near the Horokiri Stream mouth where mud deposition had also occurred. No large zones of gross eutrophic conditions were present in the estuary.

Intertidal seagrass (*Zostera*) beds were present in both arms, primarily near well flushed low tide channels and by the harbour entrance. The beds appeared relatively resilient (many of the remaining beds were evident in historical aerial photos), but have clearly declined from their past coverage. In particular, large intertidal beds at the mouth of Pauatahanui Stream, and at Ration Point, Kakaho, Duck Creek, and Camborne have all been lost since 1980, attributable to physical changes rather than reclamation. From 2008 to 2013 there have been losses of 7% in the Pauatahanui Arm (a small but significant reduction in Ivey Bay) and 12% in the Onepoto Arm (on the lower tidal reaches of the flats opposite the Paremata railway station). Declines are considered most likely being driven by the combined stress of macroalgal smothering, and the impact of increased muddiness contributing to reduced sediment oxygenation and poor water clarity.

Around the estuary edges, saltmarsh vegetation has not changed significantly since 2008. 50ha (6.3%) of saltmarsh remains in the estuary (49.6ha in Pauatahanui, and 0.3ha in Onepoto), of which 58% was dominated by rushland and 22% estuarine shrubs. Several areas around the estuary are benefiting greatly from community and Council saltmarsh restoration initiatives.

The estuary's 200m terrestrial margin remained unchanged from 2008 and was dominated by grassland (36%), residential development (31%), artificial structures (10%) and commercial development (4%). Artificial shoreline structures (e.g. rockwalls, floodbanks, causeways) were a dominant feature around 2/3rds of the estuary, and severely restrict the area available for saltmarsh growth and access to the estuary. In many areas, saltmarsh was either absent or restricted to very narrow bands which greatly limits its role in natural buffering of the estuary from sediment and nutrient inputs.

5. MONITORING

Porirua Harbour has been identified by GWRC as a priority for monitoring, and is a key part of GWRC's coastal monitoring programme being undertaken in a staged manner throughout the region. This arises because the estuary is large, has high ecological and human use values, and is very vulnerable to excessive sediment muddiness, eutrophication and disease risk. Based on the 2013 monitoring results and condition ratings, and changes since 2008, it is recommended that monitoring continue as follows:

Broad Scale Habitat Mapping

Repeat broad scale intertidal habitat mapping on a 5 yearly basis. Next monitoring due in January 2018. In addition, it is recommended that broad scale mapping of subtidal habitat be undertaken to characterise dominant substrate type, sediment condition (RPD), and vegetative cover, particularly seagrass. As part of this work, additional sediment plates should be established in the deeper subtidal basins near the existing fine scale subtidal sites.

Sediment Monitoring

To address problems associated with increasing muddiness and a "poor-fair" sediment oxygenation rating (Stevens and Robertson 2013), monitor sedimentation rate, redox potential discontinuity depth, and grain size at the existing intertidal and subtidal sites annually until the situation improves (next scheduled for January 2014).

Macroalgal Monitoring

Based on the widespread cover of macroalgae and the presence of nuisance conditions, annual monitoring of macroalgal cover is recommended (next scheduled for January 2014).

Fine Scale Monitoring

Following completion of baseline monitoring in 2010, repeat fine scale intertidal monitoring at 5 yearly intervals (next scheduled for January 2015). In addition, the subtidal fine scale monitoring programme, currently undertaken independently of the intertidal programme, should be reviewed and integrated within a 'whole of estuary' monitoring approach.

Catchment Landuse

Track and map key changes in catchment landuse, particularly where activities have the potential to release sediments or nutrients to the harbour (5 yearly).

Catchment Sediment and Nutrient Inputs

In order to develop sediment and nutrient budgets, nutrient and suspended sediment inputs from major sources during both base-flow and flood conditions should be monitored and used in the validation of modelled load estimates that have been produced for the harbour.

6. MANAGEMENT

Increasing and elevated muddiness and nutrient enrichment have been identified as significant issues in Porirua Harbour. Catchment sediment input load assessments have been undertaken (Oliver et al. in press) and initiatives are underway to reduce sediment inputs to the estuary through a variety of targeted catchment landuse restoration initiatives.

To compliment this work it is recommended that nutrient guideline criteria be established for the estuary, and the current catchment nutrient loads be estimated. If catchment loads exceed the estuary's guidelines then it is recommended that sources of elevated loads in the catchment be identified. To prevent avoidable inputs, best management practices (BMPs) should be identified and implemented to reduce sediment, nutrient, and pathogen runoff from any identified catchment "hotspots".

In addition, because estuary condition has been degraded by extensive past modifications (particularly saltmarsh reclamation and the loss of vegetated terrestrial margin), there is a high potential for estuary restoration to be undertaken. This is formally recognised through the Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012) which identifies a range of strategies and priorities for improving estuary quality. Proposed initiatives to improve and expand saltmarsh and vegetated terrestrial margin habitat in particular, are strongly supported for these greatly under-represented habitats.

7. ACKNOWLEDGEMENTS

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APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS.

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia*.

Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.

Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.

Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.

Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrate type when unvegetated or the leading plant species when plant cover is ≥1%.

Rock field: Land in which the area of residual rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulder fields are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover is ≥1%.

Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.

Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.

Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 cm.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.