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# Jacobs River Estuary

## Broad Scale Habitat Mapping 2012/13

Prepared for

**Environment Southland**

**December 2013**

**Cover Photo: Jacobs River Estuary, smothering macroalgae covering very soft muds, Aparima Arm, February 2013.**

Jacobs River Estuary, February 2013

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## Broad Scale Habitat Mapping 2012/13

Prepared for
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By

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All photos by Wriggle except where noted otherwise.

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# EXECUTIVE SUMMARY


This report summarises the results of the 2013 broad scale intertidal habitat mapping of Jacobs River Estuary, a medium-sized (720ha) "tidal lagoon" type estuary that discharges to the sea at Riverton. It is one of the key estuaries in Environment Southland'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 central basin of the estuary (55%, 307ha), but extensive areas of soft mud (30%, 167ha) were present in the sheltered upper reaches of both arms. There had been a small (2ha) increase in soft mud since 2003, but no significant change in dominant substrate cover from 2003-2013.
- High density nuisance macroalgae (>50%) covered 30% (149ha) of the intertidal area, with highest densities in the sheltered upper reaches of both arms. Remaining intertidal areas supported a moderate cover of non-nuisance low density growths. High density nuisance macroalgae increased significantly from 2003-2013 (from <5% to 30%), with low density growths increasing steadily since 2003.
- Gross eutrophic conditions covered 30% (141ha) of the estuary and had increased significantly from 2008 (4%, 20ha) and 2003 (<4%).
- Dense seagrass cover (>50%) was present (10.3ha, 2.5%), but had significantly reduced from 2008 (16.7ha, 3.9%) and 2003 (17.4, 4.2%) primarily due to smothering by macroalgae and fine sediments in the upper reaches of both arms since 2003.
- Saltmarsh covered 76ha (10%), of which 71% was dominated by rushland (jointed wire rush) and 17% by the weed-grass tall fescue. Localised drainage and conversion to grassland at the edges of the estuary contributed to a small decrease in tussock and rushland.
- Densely vegetated 200m terrestrial margin (scrub and forest) cover was low (11%), with pasture (primarily dairy grazing) dominating the margin (72%), along with the urban features of Riverton (14%). There had been no significant change from 2008-2013.

| RATINGS | | | CONDITION RATINGS | | | CHANGE RATINGS |
|---|---|---|---|---|---|---|
| Major Issue | Overall Rating | Indicator | 2003 | 2008 | 2013 | Change from 2003 Baseline |
| Muddiness | POOR | Soft mud area | Very Poor | Very Poor | Very Poor | Small Increase |
| Eutrophication | POOR | Low density macroalgal cover | Low | Moderate | Moderate | Early Warning Trigger - trend of increase |
| | | High density macroalgal cover | Low | Very High | Very High | Very Large Increase |
| | | Gross eutrophic condition area | Fair | Poor | Very Poor | Very Large Increase |
| Habitat Modification | MODERATE | Seagrass Coefficient/area | Fair | Fair | Fair | Very Large Decrease |
| | | Saltmarsh area | Moderate | Moderate | Moderate | Small Decrease |
| | | Densely vegetated margin area | Poor | Poor | Poor | Small Decrease |

## 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 results indicate that although large sections of the lower estuary remain in good condition, there has been a significant decline in estuary quality since 2003, and especially over the past five years. In particular, the poorly flushed parts of the Aparima and Pourakino arms were excessively muddy, had high nuisance macroalgal growths, and contained poorly oxygenated sediments with toxic sulphides. These gross eutrophic areas are displacing high value seagrass beds and stressing saltmarsh habitat. The macroinvertebrate community in these areas is severely degraded (little animal life is able to establish in the anoxic sediments, and surface feeding species are few in number and limited to those tolerant of poor conditions). Such conditions limit food availability for fish and birdlife, and show the capacity of the estuary to assimilate nutrient and sediment loads from the catchment is currently exceeded. Aesthetic and amenity values in these parts of the estuary are now also severely compromised.

Other key issues not addressed by this broad scale mapping include; disease risk associated with shellfish consumption and bathing, toxicity near urban stormwater drains, and excessive nutrient inputs. The latter is expected to be the primary driver of the eutrophication symptoms being expressed, with >80% of the nutrient load to Jacobs River Estuary likely to be entering from the heavily developed Aparima arm.

## RECOMMENDED MONITORING AND MANAGEMENT

Eutrophication and sedimentation have previously been identified as major issues in Jacobs River Estuary (Robertson and Stevens 2008), with worsening eutrophication symptoms reported annually since 2008 (e.g. Stevens and Robertson 2012, Robertson and Stevens 2012, 2013). To assess these issues, annual monitoring of sedimentation rates and macroalgal cover is recommended, and broad scale habitat mapping every 5 years (next due in 2018). Fine scale monitoring of eutrophic sites should be repeated in Feb. 2014, and again in 2016 when the 5 yearly fine scale trend monitoring at the existing central basin sites falls due. Fine scale saltmarsh and seagrass health assessments are also recommended.

Previous recommendations (e.g. Stevens and Robertson 2011, 2012) are reiterated for the prioritised development of catchment nutrient and sediment guideline criteria for each estuary type in Southland to derive thresholds protecting against adverse sediment and nutrient impacts. Assessment of the extent to which catchment loads meet guideline criteria will enable ES to sustainably manage the estuary and its surroundings. If catchment inputs can be assimilated by the estuary, it will flourish and provide sustainable human use and ecological values in the long term. If catchment loads exceed the estuary's assimilative capacity, it will continue to degrade. Jacobs River Estuary is recommended as a high priority for this work because of its current condition and rate of degradation.

# 1. INTRODUCTION

Environment Southland (ES) has an established long-term coastal monitoring programme that contributes to the information necessary to make effective management decisions. An outline of the monitoring and management process used for Jacobs River Estuary is summarised in the margin flow diagram, and 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 identify major issues (Table 1) and appropriate monitoring design. A preliminary EVA has been completed for Jacobs River Estuary and is reported on in Robertson and Stevens (2008).
2. **Broad Scale Habitat Mapping** (NEMP approach). This component, which documents the key habitats within the estuary (Table 2), and changes to these habitats over time, was undertaken in 2003 (Robertson et al. 2003), and repeated in 2008 (Stevens and Robertson 2008). The third broad scale survey is the focus of the current report.
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators (Table 2) including sedimentation rate monitoring (established in 2011). This component, which provides detailed information on the condition of the Jacobs River Estuary, has been undertaken in 2003, 2004, 2005, 2006 (Robertson and Stevens 2006), and 2011 (Robertson and Stevens 2011). Monitoring of gross eutrophic sites has been undertaken in 2012 and 2013 (Robertson and Stevens 2012, 2013).

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

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

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

In pre-European times, Jacobs River Estuary was bounded by bush clad hills and low lying bush, and the sheltered waters at the confluence of the Aparima and Pourakino Rivers provided a safe harbour and ample seafood to support a substantial Maori Pa at Aparima. In the early nineteenth century, whalers and sealers came to the south coast and a whaling station was established at Riverton. By the end of the 1830s whaling was declining and pastoral farming of the rich alluvial soils of the river valleys resulted in the mass clearance of native forest far into the interior. By 1905 most of the agriculturally viable land around Jacob's River had been cleared of bush.

At the turn of the 20th Century the Pourakino River was navigable 10-15kms upstream allowing timber to be shipped to Riverton which had become an important port shipping timber, wool, grain and other produce. A branch railway from Invercargill was opened in 1879, along with a railway bridge across the lower estuary, giving access to virgin podocarp and beech forest to the west of Riverton. In 1904 a new railway bridge and causeway was built through the estuary which remained open until 1978 when the Tuatapere Branch Line was closed, with the truss bridge and causeway removed in 2001. Today Riverton remains a fishing port with the surrounding district supporting dairy, sheep and mixed farming.

Jacobs River Estuary itself is a moderate sized (729ha) "tidal lagoon" type estuary discharging to the sea at Riverton. The estuary is shallow (mean depth ~2m) and has a mixture of poorly flushed and well flushed areas. It drains a primarily agricultural catchment bordered by a mix of vegetation and landuses (predominantly grazed pasture and urban). Human use of the estuary is high and is used for walking, shellfish collecting, boating, fishing, duck shooting, bird watching, and bathing.

The estuary has extensive sand and mudflats, and seagrass and saltmarsh areas. Habitat diversity is moderate with tidal flats and saltmarsh providing important habitat for native fish, birdlife and tidal flat organisms. However, as a consequence of historical drainage, extensive weed growth, intensive farming in the catchment, and grazing of margins, poorly flushed parts of the estuary are relatively vulnerable to eutrophication and sedimentation.

Catchment development is evident with moderately degraded water quality entering the estuary, common nuisance blooms of macroalgae (*Ulva* and *Gracilaria*), and accumulations of deep soft muds. As a consequence, the estuary has several very eutrophic areas.

**JACOBS RIVER ESTUARY**

**Vulnerability Assessment**
Identifies issues and recommends monitoring and management. Preliminary assessment completed in 2008 (Robertson and Stevens 2008)

**Jacobs River Estuary Issues**
Extensive and increasing eutrophication and sedimentation
Moderate habitat loss (saltmarsh, terrestrial margin)

**Monitoring**

**Broad Scale Mapping**
Sediment type
Saltmarsh
Seagrass
Macroalgae
Land margin
**5 -10 yearly**
First undertaken in 2003.
Repeated in 2008, 2013.

**Fine Scale Monitoring**
Grain size, RPD
Organic Content
Nutrients, Metals
Invertebrates
Macroalgae
Sedimentation
**4yr Baseline then 5 yearly**
Baseline in 2003-06.
Eutrophic sites monitored 2012, 2013.

**Condition Ratings**
Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Benthic Community, Organic content, N and P, Toxicity, Sedimentation rate
**Other Information**
Previous reports, Observations, Expert opinion

**ESTUARY CONDITION**
Eutrophication
Sedimentation
Toxic Contaminants
Habitat Loss (saltmarsh, seagrass, terrestrial margin)

**Recommended Management**
- Limit intensive landuse.
- Set nutrient and sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Manage weeds and pests.

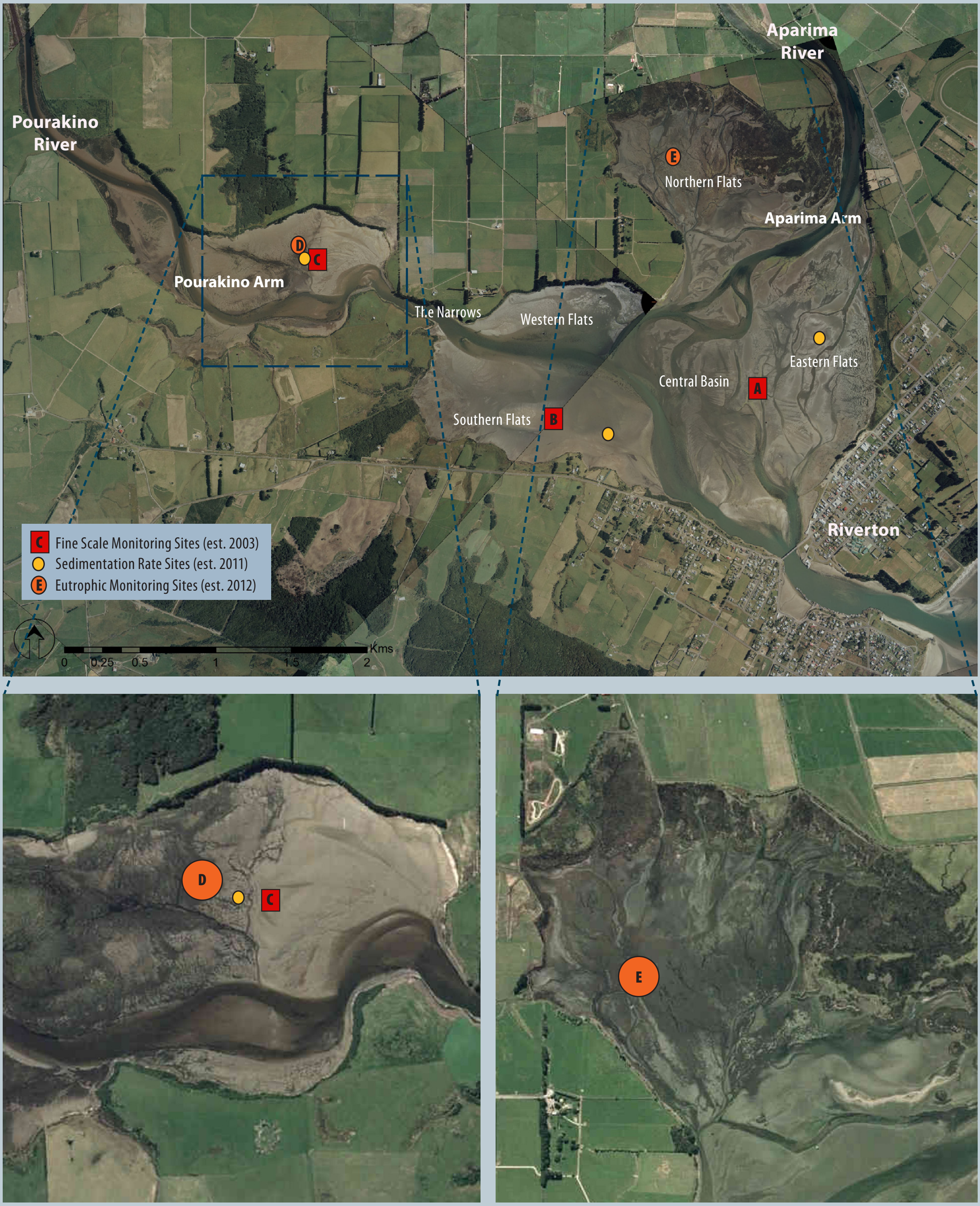
# 1. INTRODUCTION (CONTINUED)

**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 are the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there. |
| **Disease Risk** | Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses. |
| **Toxic Contamination** | In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life. |
| **Habitat Loss** | Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is 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. |




1. Pourakino Arm - eutrophic Site D and fine scale Site C.

2. Aparima Arm - eutrophic Site E.

**Figure 1. Jacobs River Estuary - location of fine scale and sedimentation rate monitoring sites.**

# 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).

Rectified ~10cm/pixel resolution colour aerial photos flown in early 2013 were supplied by ES. Photos at a scale of 1:3,500 were laminated, and experienced scientists ground-truthed the spatial extent of dominant habitat and substrate types on 10, 11 and 26 February 2013 by walking the area and recording features directly on the laminated aerial photos. Previously mapped features were re-checked in the field using an iPad (iGIS app) which showed live positioning in relation to 2008 shapefiles of estuary features.

Field notes and photographs were subsequently combined 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.

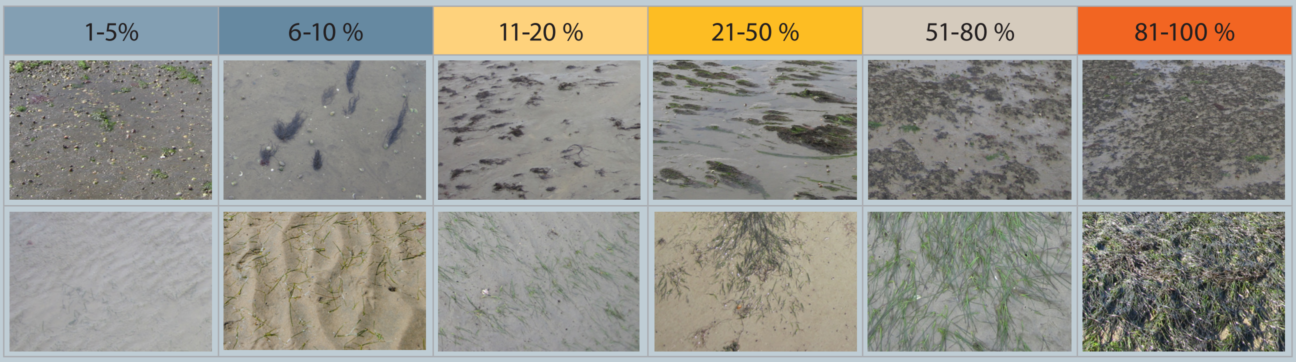
Appendix 1 lists the definitions used to classify substrate and vegetation. The composition of vegetation was classified using an interpretation of the Atkinson (1985) system, where the dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram 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 2 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 2003 and 2008 surveys (Robertson et al. 2003, Stevens and Robertson 2008).

**Figure 2. Visual rating scale for percentage cover estimates of macroalgae (top) and seagrass (bottom).**



# 2. METHODS (CONTINUED)

## CONDITION AND CHANGE RATINGS

A series of broad scale estuary "condition and change ratings" (below) have been proposed for Jacobs River Estuary 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, condition 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 | 16-25% of estuary substrate is soft mud | Post baseline, monitor 5 yearly. Initiate ERP |
| Very Poor | >25% 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) |

## 2. METHODS (CONTINUED)

### 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 and excessive nutrients 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%)+(1 x %cover 1-5%)+(3 x %cover 5-10%)+(6x %cover 10-20%)+(9x %cover 20-50%)+(12 x %cover 50-80%)+(15 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. Decrease 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, unless it is naturally limited by physical characteristics.

**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 densely 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

Firm sands in the central basin of the estuary.

Very soft muds in the northern flats of the Aparima arm.

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

In 2013, 729ha of estuary was mapped, comprising 478ha unvegetated intertidal flats, 76ha tidal saltmarsh, and 10ha dense (>50%) seagrass (Table 3). A further 165ha was classified as subtidal. The mapping extent mirrored as much as possible that presented in Stevens and Robertson (2008) and Robertson et al. (2003) to facilitate the comparison of results for key condition ratings (Table 3). The minor changes between surveys evident in Table 3 predominantly reflect the availability of high resolution aerial photos in 2013 enabling more accurate mapping of key features.

**Table 3. Summary of broad scale features, Jacobs River Estuary, 2003, 2008 and 2013.**

| Dominant Estuary Features | 2003 | | 2008 | | 2013 | |
|---|---|---|---|---|---|---|
| | Ha | % | Ha | % | Ha | % |
| Saltmarsh | 75.8 | 10.5 | 74 | 10.2 | 76.1 | 10.4 |
| Seagrass (>50% cover) | 17.4 | 2.4 | 16.7 | 2.3 | 10.3 | 1.4 |
| Unvegetated intertidal flats | 476.4 | 66.0 | 482.3 | 66.5 | 477.2 | 65.5 |
| Subtidal | 152.2 | 21.1 | 152 | 21.0 | 165.2 | 22.7 |
| **TOTAL** | **722** | **100** | **725** | **100** | **729** | **100** |

### 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.

Figure 3 and Table 4 summarise the intertidal substrate of Jacobs River Estuary. Sand (307ha, 55%) was the dominant substrate, most located in the relatively well flushed central basin of the estuary. Firm mud was prominent among rushland (57ha, 10%), while soft and very soft muds were very extensive (167ha, 30%) - the vast majority located in the sheltered upper estuary arms. The dominance of extensive mud areas have a condition rating of "very poor".

**Table 4. Summary of dominant intertidal substrate, Jacobs River Estuary, February 2013.**

| Dominant Substrate | Area Ha | Percentage | Comments |
|---|---|---|---|
| Artificial structures | 0.3 | 0.0 | Wharfs and bridges near the estuary entrance. |
| Rock field | 1.1 | 0.2 | Near the estuary entrance and in the Narrows. |
| Rock field man-made | 0.0 | 0.0 | Predominantly along terrestrial margins in the lower reaches of the estuary. |
| Boulder field man-made | 0.7 | 0.1 | Predominantly along terrestrial margins in the lower reaches of the estuary. |
| Cobble field | 6.0 | 1.1 | Mostly upstream of the Riverton road bridge, and in narrow bands along the upper intertidal flats and in river channels. |
| Gravel field | 23.5 | 4.2 | |
| Mobile sand | 2.0 | 0.4 | In the Pourakino Arm near the Narrows. |
| Firm sand | 168.6 | 30.0 | Widespread in the southeast of the estuary by Riverton. |
| Firm mud/sand | 136.3 | 24.2 | In the upper reaches of the central estuary basin. |
| Firm Mud | 56.9 | 10.1 | Underlying saltmarsh in both arms in the upper estuary. |
| Soft mud | 26.9 | 4.8 | Predominantly in the north Aparima arm embayment, the Pourakino arm, and on the southern flats of the central basin. |
| Very soft mud/sand | 140.3 | 24.9 | |
| **Total** | **563** | **100** | |

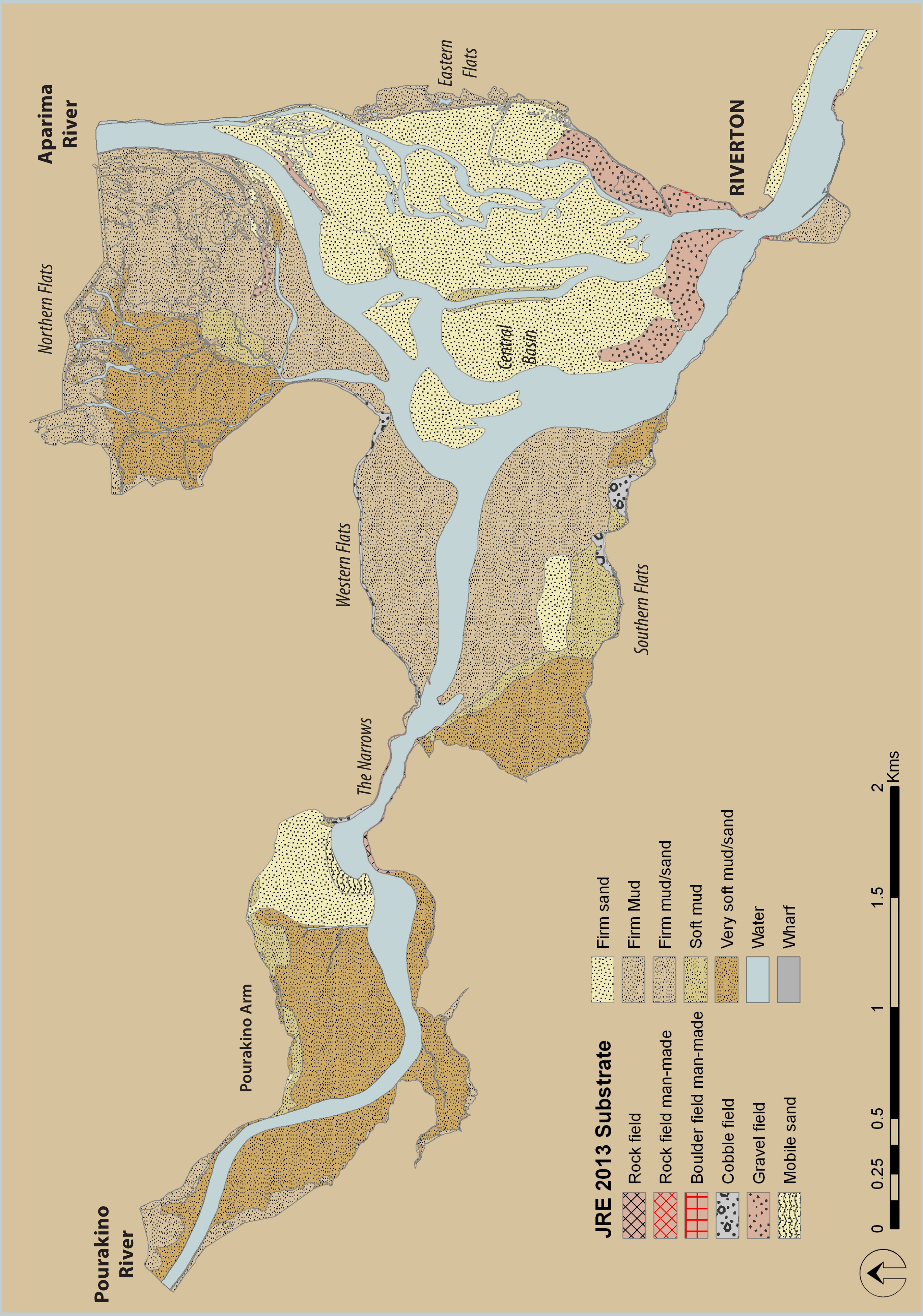



Figure 3. Map of dominant intertidal substrate types - Jacobs River Estuary, February 2013.

## BROAD SCALE MAPPING (CONT.)

| SOFT MUD % COVER CONDITION RATING |
|---|
| 2003 VERY POOR |
| 2008 VERY POOR |
| 2013 VERY POOR |

| SOFT MUD AREA CHANGE RATING |
|---|
| 2003-2008 SMALL INCREASE |
| 2003-2013 SMALL INCREASE |

### CHANGES IN ESTUARY SOFT MUD 2003-2013

The primary indicator of sediment impacts is the area of the estuary dominated by soft muds. Changes in the area of soft mud from broad scale mapping in the estuary since 2003 are summarised in Table 5. Compared to the 2003 baseline, there has been a slight increase (2.2ha) in the area of soft mud, mostly on the southern flats immediately south of the Narrows, and the percent cover condition rating has shown a corresponding increase. It remains in the "very poor" category (>25%) first recorded in 2003.

**Table 5. Broad substrate categories, Jacobs River Estuary, 2003, 2008 and 2013.**

| Substrate Class | 2003 | | 2008 | | 2013 | |
|---|---|---|---|---|---|---|
| | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent |
| Other | 11.5 | 2.0 | 34.3 | 6.0 | 31.5 | 5.6 |
| Sand | 330.1 | 58.4 | 315.3 | 55.0 | 306.9 | 54.6 |
| Firm Mud | 58.9 | 10.4 | 56.9 | 9.9 | 56.9 | 10.1 |
| Soft mud | 165.0 | 29.2 | 166.3 | 29.0 | 167.2 | 29.7 |
| TOTAL | 565 | 100 | 573 | 100 | 564 | 100 |

The increased mud cover has occurred among dense *Gracilaria* beds where gross nuisance conditions exist and have expanded since 2003. Elsewhere in the estuary, little broad scale change was evident although it is notable that several of the low tide flow channels running through the central basin have moved since 2008, although the underlying substrate has not changed. These changes in the low tide drainage channels are considered most likely to have resulted from Aparima River flood flows crossing the eastern flats of the estuary. Consequently in 2013 more of the Aparima River was discharging directly across the central basin flats at low tide than evident in previous years. Because the Aparima River contributes the largest input of nutrients to the estuary (>80% - based on NIWAs CLUES model), an increase in macroalgal cover in the central basin is possible if these flow patterns continue.

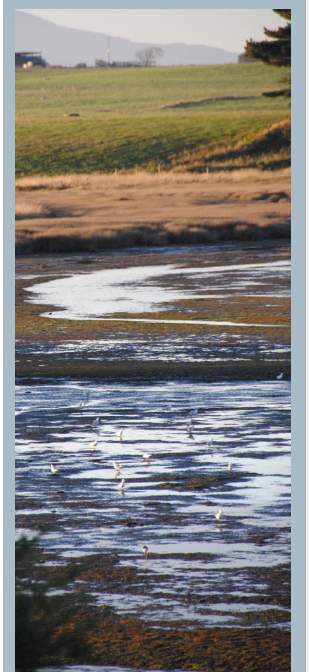
### INTERTIDAL MACROALGAL COVER

Nuisance 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, Figure 4) showed:

- There was a significant percentage of high to very high nuisance macroalgal cover (30.4%, 149ha).
- Low density macroalgal percentage cover was rated as moderate.
- The dominant macroalgae were the red alga *Gracilaria chilensis* and the green alga *Ulva intestinalis*.
- The most extensive growths were present in the sheltered upper estuary reaches of the Pourakino and Aparima Arms, and on the southern flats of the central basin.

Condition ratings have been developed to 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 in estuaries.

The Macroalgal Coefficient (MC) for low density cover within the estuary in 2013 was 3.8 (Table 6), a condition rating of "moderate", reflecting widespread low growth across much of the estuary. The high density macroalgal cover was rated as "very high" with 30% of the estuary experiencing dense (>50%) macroalgal growths. The areas of highest macroalgal percentage cover were on the soft muds of the Pourakino Arm, and on the southern and northern flats of the estuary (Figure 4).



High density *Gracilaria* beds in the Aparima arm).

# 3. RESULTS AND DISCUSSION (CONTINUED)

## BROAD SCALE MAPPING (CONT.)

**LOW DENSITY MACROALGAL CONDITION RATING**

**2013 MODERATE**

**HIGH DENSITY MACROALGAL CONDITION RATING**

**2013 VERY HIGH**

Black, anoxic, sulphide-rich sediments among *Gracilaria* in the Pourakino Arm.

**HIGH DENSITY MACROALGAL COVER CHANGE RATING**

**2003 to 2013 VERY LARGE INCREASE**

**Table 6. Summary of intertidal macroalgal cover, Jacobs River Estuary, Feb. 2013.**

| MACROALGAE | Jacobs River Estuary | | |
|---|---|---|---|
| Percentage Cover | Ha | % | Dominant species |
| <1% | 60 | 12.2 | - |
| 1-5% | 79 | 16.1 | *Ulva intestinalis, Gracilaria, Ulva lactuca* |
| 5-10% | 27 | 5.5 | *Ulva intestinalis, Gracilaria* |
| 10-20% | 39 | 7.9 | *Ulva intestinalis, Gracilaria* |
| 20-50% | 137 | 27.9 | *Ulva intestinalis, Gracilaria, Ulva lactuca* |
| 50-80% | 7.5 | 1.5 | *Gracilaria, Ulva intestinalis, Ulva lactuca* |
| >80% | 141.1 | 28.8 | *Gracilaria, Ulva intestinalis* |
| **TOTAL** | **490** | **100** | |

These areas are characterised by an extensive and often smothering cover of growing and decaying macroalgae, and represent a continuation of the decline in estuary condition monitored annually since 2007. The most affected upper estuary parts of the estuary act as settling areas for algae and sediment carried in by the tide and prevailing wind, and also receive the most obvious inputs of drainage from agricultural lands in the catchment via the Pourakino and Aparima Rivers.

The excessive growths of macroalgae have reduced sediment dissolved oxygen, increased sulphide in the sediments, caused nuisance odours, and promoted extensive sediment trapping. These are all contributing to a significant decline in the quality of habitat areas otherwise favoured by high value species such as seagrass. In the Pourakino Arm, the most adversely affected, the highly eutrophic, anoxic and sulphide-rich sediment conditions appear so severe that macroalgae is starting to die off in localised patches (see sidebar photo).

### CHANGES IN INTERTIDAL MACROALGAL COVER 2003-2013

The Condition Rating (revised in 2011 following a review of data compiled for Southland since 2007), and Macroalgal Coefficient results for the 2003-2013 period, are presented in Table 7. Since 2003 both the low density (MC) and high density (% cover) ratings have increased, indicating worsening conditions in the estuary. The deteriorating ratings primarily reflect the dramatic expansion of macroalgae in soft sediment areas in the sheltered reaches of the upper Aparima and Pourakino Arms.

**Table 7. Summary of intertidal macroalgal cover, Jacobs River Estuary, 2003, 2007-2013.**

| Year | Low Density (MC) Rating | High Density (%) Rating | Result |
|---|---|---|---|
| 2003 | LOW | LOW (<5%) | Less than 5% of the estuary with high density (>50%) cover (based on both personal observation and Robertson et al. 2002). |
| 2007 | MODERATE 1.9 | MODERATE (7%) | Low-Moderate cover across most of estuary. Isolated patches of high cover in sheltered arms and by Aparima River. No cover >80%. |
| 2008 | MODERATE 2.4 | VERY HIGH (35%) | Large increase in areas of high cover in sheltered arms (Aparima River, and in lower Central Basin). 90ha with cover >80%. |
| 2009 | MODERATE 2.4 | VERY HIGH (32%) | Relatively extensive areas of high cover in sheltered arms and by Aparima River. Predominantly low cover in Central Basin. |
| 2010 | MODERATE 2.5 | VERY HIGH (33%) | Increase in extensive areas of high cover in sheltered arms and by Aparima River. Predominantly low cover in Central Basin. |
| 2011 | MODERATE 1.9 | VERY HIGH (30%) | Continued high cover in sheltered upper Pourakino and Aparima Arms. Reduced cover in Central Basin and lower Southern Flats. |
| 2012 | MODERATE 2.3 | VERY HIGH (31%) | High nuisance cover in sheltered upper Pourakino and Aparima Arms and Southern Flats. Low cover in Central Basin. |
| 2013 | MODERATE 3.8 | VERY HIGH (30%) | High nuisance cover in sheltered upper Pourakino and Aparima Arms and Southern Flats. Moderate cover in Central Basin. |

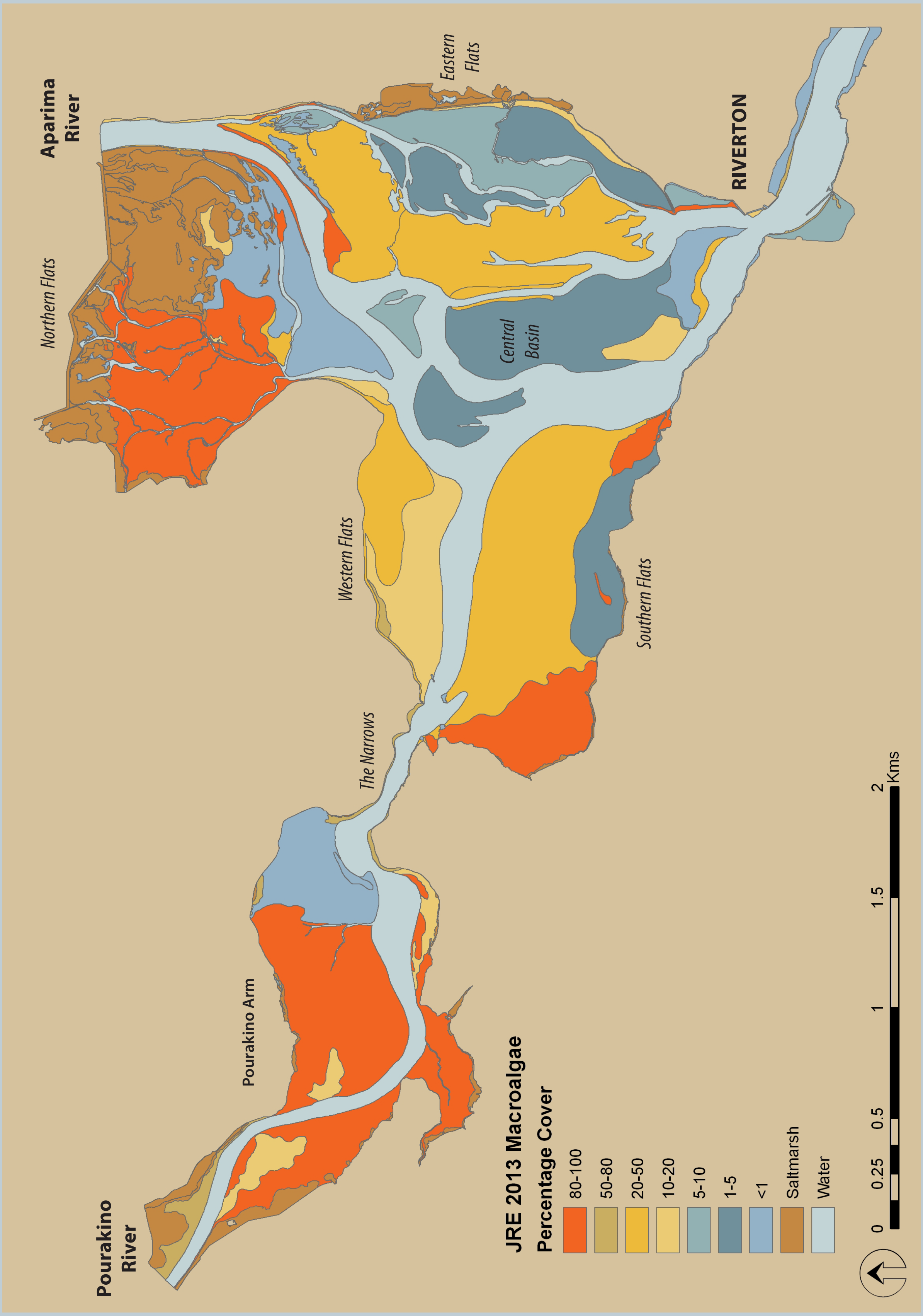



**Figure 4. Map of intertidal macroalgal cover - Jacobs River Estuary, February 2013.**

## BROAD SCALE MAPPING (CONT.)

| GROSS EUTROPHIC AREA CONDITION RATING |
|---|
| 2003 FAIR |
| 2008 POOR |
| 2013 VERY POOR |

| GROSS EUTROPHIC AREA CHANGE RATING |
|---|
| 2003-2013 VERY LARGE INCREASE |

Gross eutrophic areas in the Aparima Arm.

### GROSS EUTROPHIC CONDITIONS

When sediments exhibit combined symptoms of a high mud content, a shallow RPD, elevated nutrient and organic concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover), they represent gross eutrophic conditions. These conditions will kill or displace most estuarine animals and shellfish, and also release nutrients previously bound in the sediments. As these nutrients will predominantly be released in the form of ammonia, which is much more readily available to fuel macroalgal growth, a cycle of increasing habitat deterioration will establish that is likely to be difficult to reverse. These conditions are most likely to be present in the relatively rare sheltered tidal flats of an estuary which are also those most favourable for the growth of high value seagrass habitat.

### CHANGES IN GROSS EUTROPHIC CONDITIONS 2003-2013

A condition rating has been developed that recognises that gross eutrophic conditions should not be present in short residence time estuaries (like Jacobs River), with their presence providing a clear signal that the assimilative capacity of the estuary is being exceeded. The rating for 2013 places the estuary in the "very poor" category with 141ha (30%) of the estuary in a severely degraded state (Table 8, Figure 5). A trend of worsening conditions evident since 2003 (Table 8) highlights the rapid expansion of gross conditions, and declining sediment quality, in Jacobs River Estuary over the past 10 years.

**Table 8. Gross eutrophic intertidal zones, Jacobs River Estuary, 2003, 2008 and 2013.**

| | 2003 | | 2008 | | 2013 | |
|---|---|---|---|---|---|---|
| | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent |
| Gross eutrophic area | <20 | <4% | 20 | 4% | 141 | 30% |

The most degraded sites are concentrated in natural deposition zones within the estuary (Figure 5) where the combined influence of flocculation at the saltwater/freshwater interface, widening of river channels entering the estuary (reducing flow velocities), and limited tidal flushing all serve to concentrate catchment inputs of sediments and nutrients, and provide good conditions for the growth of macroalgae.

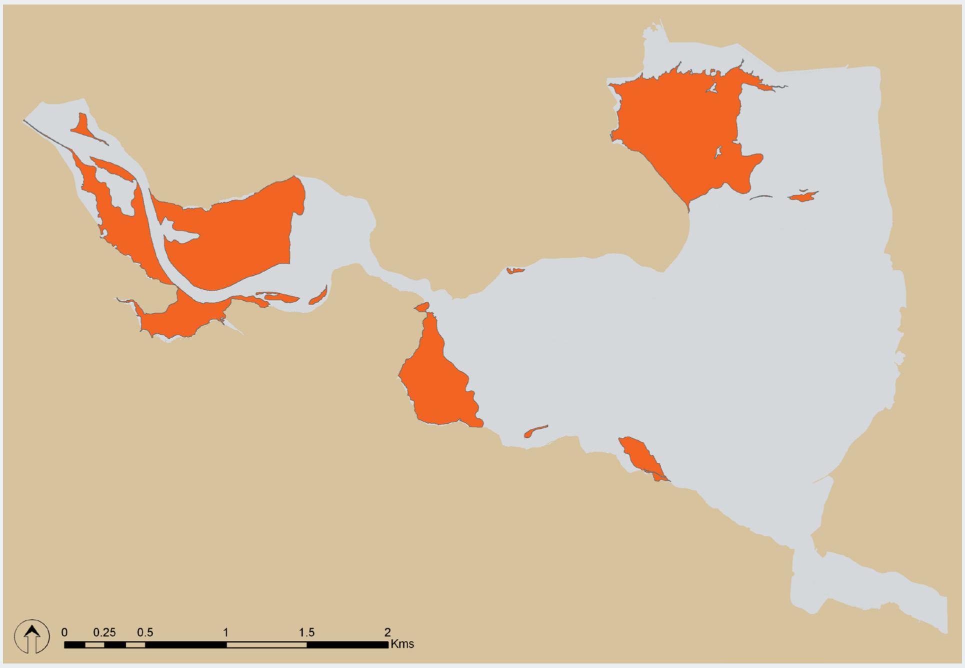



**Figure 5. Location of gross eutrophic zones - Jacobs River Estuary, February 2013.**

## BROAD SCALE MAPPING (CONT.)

| SEAGRASS COEFFICIENT CONDITION RATING |
|---|
| 2003 FAIR (1.2) |
| 2008 FAIR (0.96) |
| 2013 FAIR (0.91) |

Seagrass growing along the upper tidal fringes of the Pourakino River.

| SEAGRASS AREA CHANGE RATING |
|---|
| 2003-2013 VERY LARGE 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. Seagrass meadows are also a major source of detrital material, and the bacteria and fungi that decompose this material contribute significantly to the sediment nitrogen pool supporting macroalgal growth and provide a food source for zooplankton, worms, etc., which are the base of the predatory food web. Though tolerant of a wide range of conditions, seagrass is vulnerable to stressors, in particular 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 9 and Figure 6) showed:

- Most of the intertidal area (90%) was rated as having a "low" or "very low" (<5%) percentage cover.
- High density (>50%) cover was restricted to two areas in the well flushed central basin, and covered only a small part of the estuary (2.5%).
- 7% of the estuary had seagrass with a moderate (5-50%) cover - predominantly growing adjacent to dense beds in the central basin, and in smaller patches on intertidal flats in the Pourakino Arm.

**Table 9. Summary of seagrass cover, Jacobs River Estuary, February 2013.**

| Percentage Cover | Area (ha) | Percentage |
|---|---|---|
| <1% | 373 | 90.2 |
| 1-5% | 0.0 | 0.0 |
| 5-10% | 5.0 | 1.2 |
| 10-20% | 7.2 | 1.7 |
| 20-50% | 18.0 | 4.4 |
| 50-80% | 0.0 | 0.0 |
| >80% | 10.3 | 2.5 |
| **Total** | **414** | **100** |

The 2013 Seagrass Coefficient (SC) was "low" (0.91), a condition rating of "fair". The dense seagrass beds in the relatively well flushed central basin appeared in relatively good condition with little fine mud, relatively well oxygenated sediments, and no significant macroalgal smothering. In contrast, seagrass condition in the more sheltered parts of the estuary was clearly being compromised by extensive mud, excessive macroalgal growth, and shallow sediment oxygenation.

### CHANGES IN INTERTIDAL SEAGRASS COVER 2003-2013

A comparison of dense (>50%) seagrass cover in 2003, 2008 and 2013 (Table 10, Figure 7) shows a 7.1ha (59%) reduction of dense seagrass in the estuary since 2003, a seagrass area change rating of "very large decrease". This is also reflected in a declining seagrass coefficient (presented in sidebar). The losses have occurred predominantly in the Pourakino Arm (Figure 7) and, to a lesser extent, in the Aparima Arm where seagrass beds were already displaced by extensive macroalgal growths when broad scale mapped in 2003.

In the Pourakino Arm, patches of seagrass remain (Figure 6), but the previously intact beds of dense seagrass have become much more fragmented and with a reduced density due primarily to smothering by macroalgae and inundation with fine sediments since 2003. Positively, where smothering macroalgal growth had been flushed from the intertidal flats, seagrass beds were starting to regrow and spread back over the unvegetated intertidal sediments in a few places indicating that the primary stressor on seagrass beds was from physical smothering by dense macroalgal growths.

**Table 10. Summary of dense (>50%) seagrass cover, Jacobs River Estuary, 2003, 2008 and 2013.**

| Seagrass Area | 2003 | | 2008 | | 2013 | |
|---|---|---|---|---|---|---|
| | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent |
| (>50% cover) | 17.4 | 4.2 | 16.7 | 3.9 | 10.3 | 2.5 |

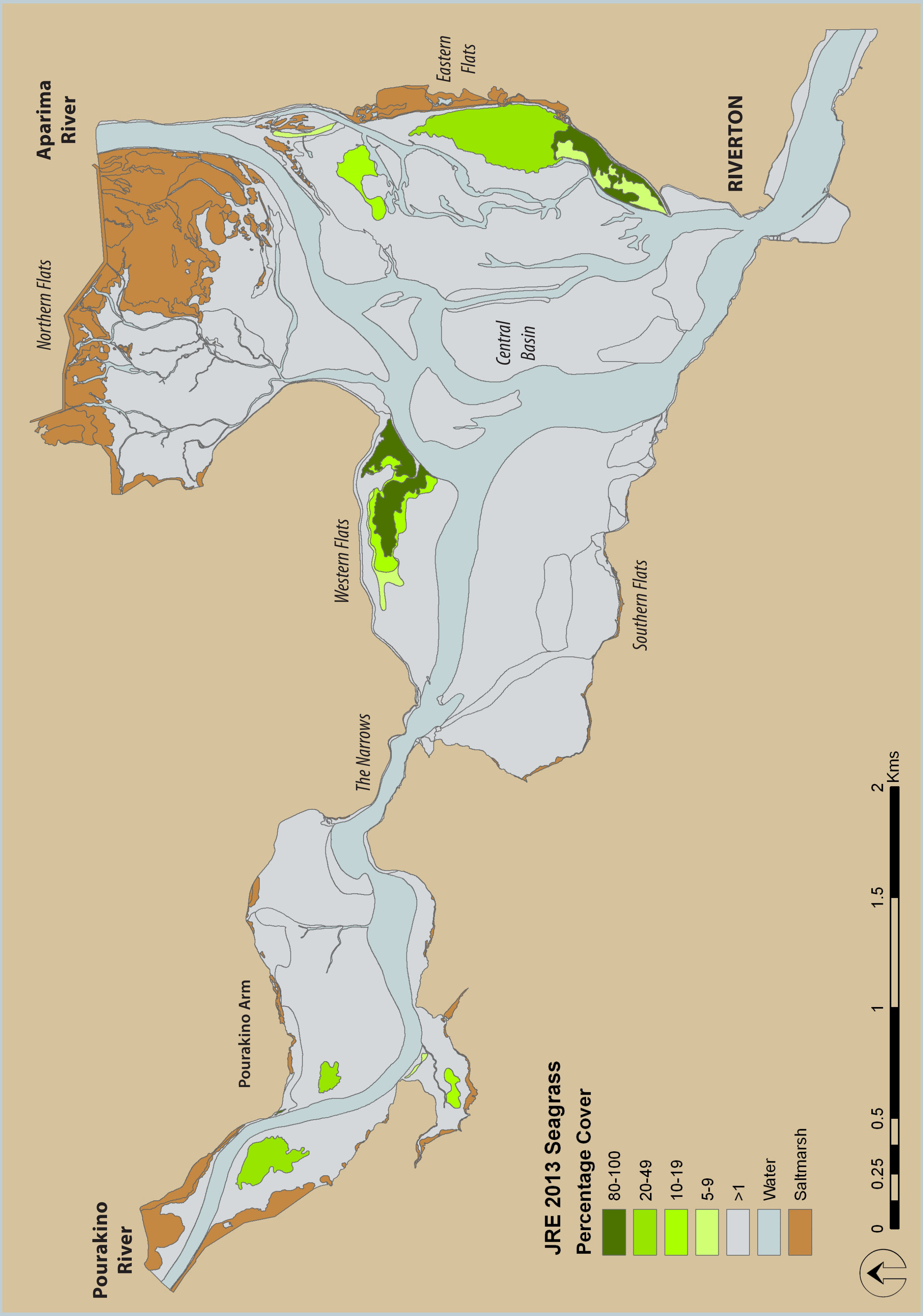



Figure 6. Map of intertidal seagrass cover - Jacobs River Estuary, February 2013.

## BROAD SCALE MAPPING (CONT.)

Dense seagrass beds on the western flats of the central basin.

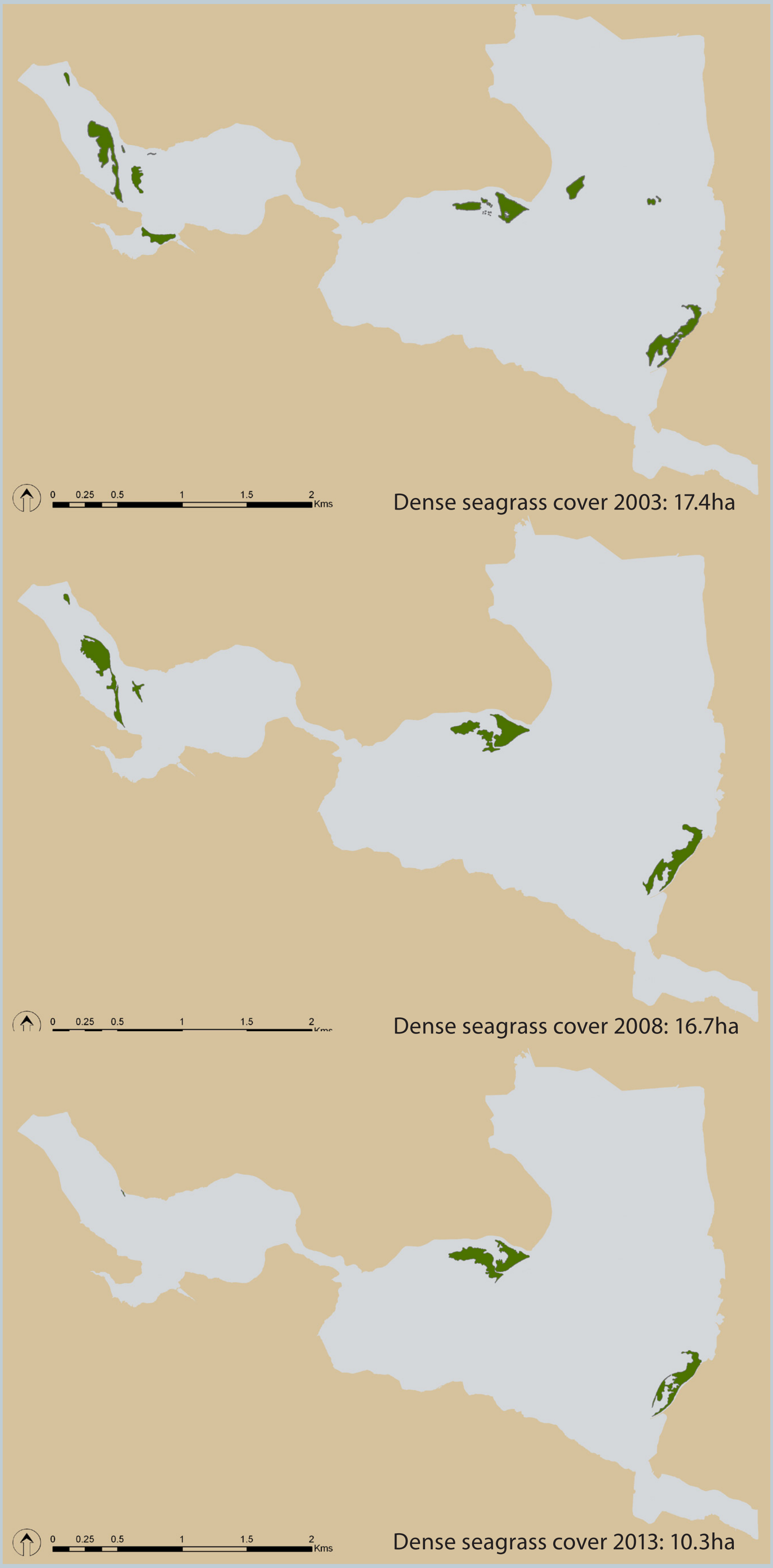



**Figure 7. Location of dense (>50%) seagrass cover in Jacobs River Estuary, 2003, 2008 and 2013.**

## BROAD SCALE MAPPING (CONT.)

| SALTMARSH % COVER CONDITION RATING |
|---|
| 2003 MODERATE |
| 2008 MODERATE |
| 2013 MODERATE |

Dominant cover of tall fescue near a shore-parallel drainage channel on the eastern side of the central basin (above), and among saltmarsh ribbonwood in the west (below).

### 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 important habitat for a variety of species including fish and birds. Table 11 and Figure 9 summarise the 2013 saltmarsh mapping results. Overall, 10% of the estuary (76ha) is saltmarsh, a condition rating of "moderate".

Key findings were:

- The dominant saltmarsh cover (71%) was jointed wire rush, predominantly in exclusive stands near the upper intertidal margins, and the introduced grass weed- tall fescue (17%).
- The vegetated sequence commonly comprised a narrow band of subdominant flax and tall fescue, landward of often wide beds of jointed wire rush, with small sedgefields (three square) or herbfields occasionally present at the seaward edge of rushes.
- The most extensive areas of saltmarsh were located in the upper tidal reaches of the Aparima and Pourakino Arms, and along the eastern edge of the central basin.
- In many areas saltmarsh was largely cut off from direct tidal inundation by drainage ditches running parallel to the shore (see top sidebar photo), and the vegetation reflected this, being dominated by freshwater tolerant species e.g. flax, tall fescue, and three square.
- Elsewhere in the estuary, saltmarsh was often restricted to narrow strips because of habitat limitations caused by seawalls and reclamations, or by natural rockfields or low cliffs.

Historical land clearance and margin development, particularly drainage, reclamation and channelisation of the many small freshwater inflows and inlets around the estuary edge, has greatly diminished the extent and cohesiveness of the saltmarsh remaining in the estuary. Such changes have significantly reduced the capacity of the estuary to assimilate sediment and nutrient inputs, and almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary. Because much of the estuary is now surrounded by pasture, weeds (e.g. tall fescue) have infiltrated previously native-dominated saltmarsh areas and become well established (see sidebar photos). Ongoing development of estuary margins, as evident in Figure 8 below, is continuing to place pressure on remaining saltmarsh areas, and particularly will restrict any natural migration in response to predicted sea level rise.

**Figure 8. 2013 aerial photo showing recent land clearance, stream channelisation, and bunding of saltmarsh margins - Jacobs River Estuary, February 2013.**

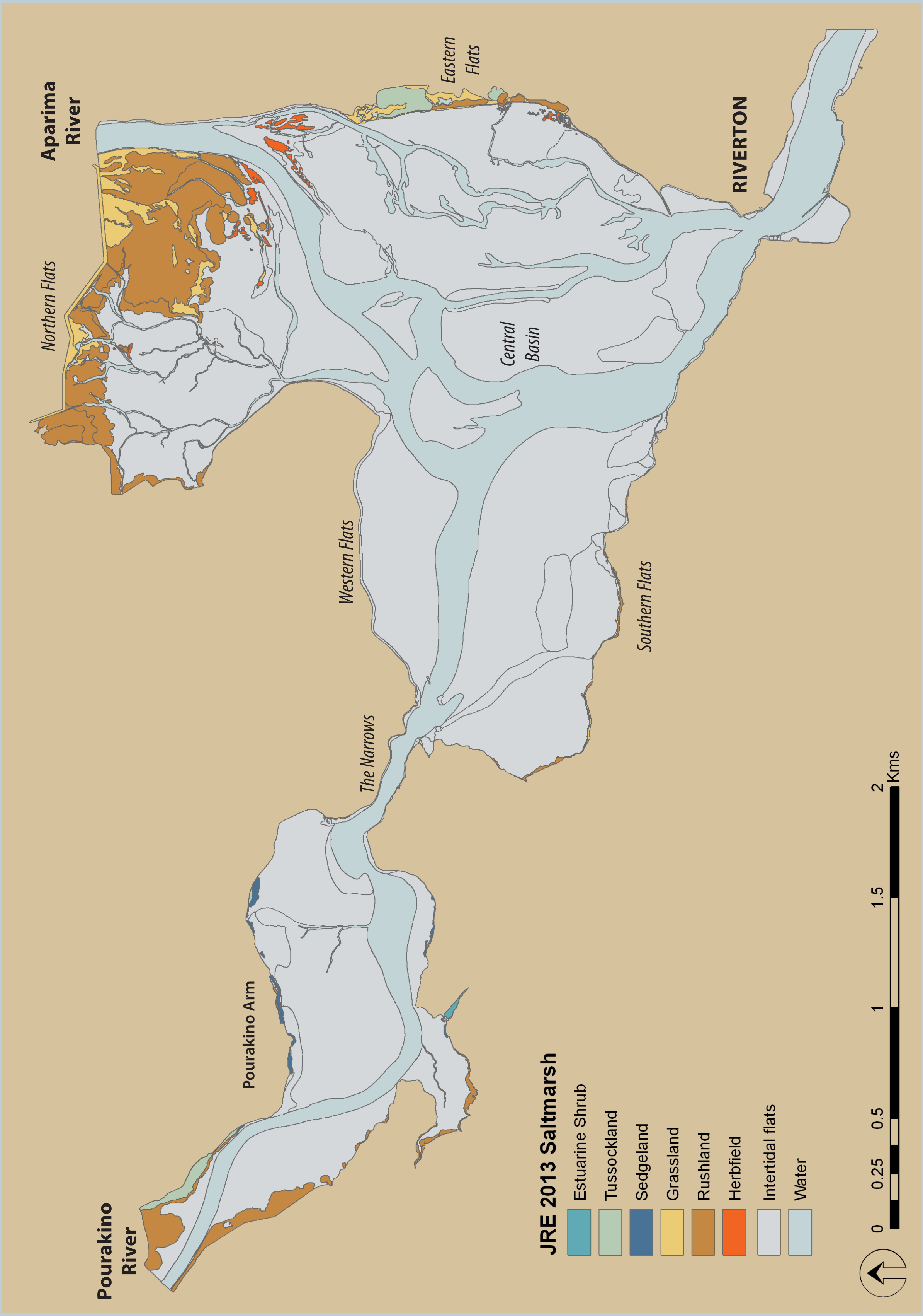



**Figure 9. Map of saltmarsh vegetation - Jacobs River Estuary, February 2013.**

# 3. RESULTS AND DISCUSSION (CONTINUED)

## BROAD SCALE MAPPING (CONT.)

*Tall fescue is a densely tufted, long-lived, perennial native European grass that has been widely planted in New Zealand as a turf and forage grass. It can tolerate saline, sandy soils and being waterlogged for up to a month at a time, meaning it is able to establish in saltmarsh areas where other terrestrial weeds cannot survive. Once established, it is known to produce chemical compounds that hinder plant growth by preventing or slowing down the growth of both seedlings and much older shrubs and trees, while its clumped roots and foliage can overgrow smaller native herbfield species. As such, it has the capacity to adversely affect the regenerative capability of saltmarsh vegetation.*

| SALTMARSH AREA CHANGE RATING |
|---|
| 2003-2013 SMALL DECREASE |

**Table 11. Summary of saltmarsh cover, Jacobs River Estuary, February 2013.**

| Class | Dominant Species | Primary subdominant species | Ha | % |
|---|---|---|---|---|
| Estuarine Shrub | | | 0.3 | 0.4 |
| | *Plagianthus divaricatus (Saltmarsh ribbonwood)* | *Apodasmia similis (Jointed wirerush)* | *0.3* | *0.4* |
| Tussockland | | | 4.4 | 5.8 |
| | *Phormium tenax (New Zealand flax)* | | *0.3* | *0.4* |
| | | *Apodasmia similis (Jointed wirerush)* | *2.4* | *3.1* |
| | | *Festuca arundinacea (Tall fescue)* | *1.7* | *2.2* |
| | | *Native scrub* | *0.1* | *0.1* |
| Sedgeland | | | 1.4 | 1.8 |
| | *Schoenoplectus pungens (Three-square)* | | *0.8* | *1.1* |
| | | *Selliera radicans (Remuremu)* | *0.5* | *0.7* |
| Grassland | | | 13.2 | 17.4 |
| | *Festuca arundinacea (Tall fescue)* | | *0.1* | *0.2* |
| | | *Plagianthus divaricatus (Saltmarsh ribbonwood)* | *4.4* | *5.8* |
| | | *Apodasmia similis (Jointed wirerush)* | *4.1* | *5.4* |
| | | *Phormium tenax (New Zealand flax)* | *2.5* | *3.3* |
| | | *Ulex europaeus (Gorse)* | *1.4* | *1.9* |
| | | *Ammophila arenaria (Marram grass)* | *0.3* | *0.4* |
| | | *Samolus repens (Primrose)* | *0.3* | *0.3* |
| | | *Unidentified introduced weeds* | *0.1* | *0.1* |
| Rushland | | | 54.1 | 71.1 |
| | *Apodasmia similis (Jointed wirerush)* | | *18.7* | *24.6* |
| | | *Festuca arundinacea (Tall fescue)* | *21.0* | *27.6* |
| | | *Plagianthus divaricatus (Saltmarsh ribbonwood)* | *10.5* | *13.7* |
| | | *Schoenoplectus pungens (Three-square)* | *3.7* | *4.8* |
| | | *Phormium tenax (New Zealand flax)* | *0.2* | *0.2* |
| | | *Selliera radicans (Remuremu)* | *0.1* | *0.1* |
| Herbfield | | | 2.8 | 3.6 |
| | *Samolus repens (Primrose)* | *Selliera radicans (Remuremu)* | *2.0* | *2.7* |
| | *Selliera radicans (Remuremu)* | *Samolus repens (Primrose)* | *0.7* | *1.0* |
| **TOTAL** | | | **76** | **100** |

### CHANGES IN SALTMARSH COVER 2003-2013

The condition rating for saltmarsh measures a percentage change from an established baseline. Based on the summary information in Table 12, and using 2003 data as a baseline, the 2013 saltmarsh condition rating is rated as "small decrease". This reflects small ongoing drainage and conversion of tussock and rushland to grassland at the edges of the estuary. There has also been a notable increase in the cover of tall fescue within saltmarsh areas since 2003.

**Table 12. Comparison of 2003, 2008 and 2013 saltmarsh area.**

| Vegetation Class | 2003 | | 2008 | | 2013 | |
|---|---|---|---|---|---|---|
| | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent |
| Scrub | 1.0 | 1.3 | 0 | 0 | 0.3 | 0.4 |
| Tussockland | 8.2 | 10.9 | 4.3 | 5.8 | 4.4 | 5.8 |
| Sedgeland | 1.5 | 2.0 | 0.9 | 1.3 | 1.4 | 1.8 |
| Grassland | 7.9 | 10.4 | 12.4 | 16.9 | 13.2 | 17.4 |
| Rushland | 57.3 | 75.5 | 55.0 | 74.6 | 54.1 | 71.1 |
| Herbfield | 0 | 0 | 1.1 | 1.5 | 2.8 | 3.6 |
| TOTAL | 76 | 100 | 74 | 100 | 76 | 100 |

## BROAD SCALE MAPPING (CONT.)

**VEGETATED MARGIN % COVER CONDITION RATING**

**2003 POOR**

**2008 POOR**

**2013 POOR**

### 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 13 and Figure 10) showed:

- The 200m terrestrial margin was dominated by grassland (72%) primarily used for dairy farming.
- Residential and smaller commercial and industrial uses around Riverton accounted for 14%.
- Only a small percentage (11%) had scrub/forest cover, a condition rating of "poor".
- Scrub/forest cover was dominated by exotic species e.g. gorse, pine, macrocarpa, and common weeds e.g. blackberry, broom and was commonly restricted to a narrow band between surrounding pasture and the estuary.

The remaining scrub/forest buffer appears not to have been cleared simply because the steep margins of the estuary are unsuitable for farming (see top sidebar photo, Figure 10). This largely introduced scrub offers some capacity to buffer the estuary against sediment, nutrient and weed inputs to the estuary, however it would be greatly enhanced by being extended in area, and with an increased presence of native plants.

Around Riverton itself, the estuary margin has been extensively modified, with artificial seawalls and reclamations present along much of the estuary edge. Various industries have established along the foreshore in the south east with very limited natural buffering capacity remaining (see middle sidebar photo). Elsewhere, grassland is a dominant feature to the estuary edge (lower photos).

**Table 13. Summary of the 200m terrestrial margin, Jacobs River Estuary, February 2013.**

| Dominant 200m terrestrial margin cover | 2008 % | 2013 % |
|---|---|---|
| Forest | 0.2 | 0.2 |
| Scrub/Forest | 4.2 | 3.6 |
| Scrub | 6.1 | 6.8 |
| Tussockland | 1.0 | 0.0 |
| Grassland | 68.8 | 71.8 |
| Duneland | 0.2 | 0.3 |
| Residential | 11.1 | 2.9 |
| Commercial | 1.7 | 1.8 |
| Industrial | 1.1 | 1.1 |
| Artificial structure (Road) | 2.9 | 2.9 |

### CHANGES IN 200m TERRESTRIAL MARGIN COVER 2008-2013

When compared to the 2008 results, the 2013 margin mapping identified the conversion of small areas of densely vegetated scrub/forest and tussockland (flax) to pasture. These losses of dense vegetated terrestrial margin (2-3%) fit the condition rating of a "small decrease".

**VEGETATED 200m MARGIN CHANGE RATING**

**2008-2013 SMALL DECREASE**


Figure 10. Map of 200m terrestrial margin vegetation - Jacobs River Estuary, February 2013.

# 4. SUMMARY AND CONCLUSIONS

Table 10 summarises condition ratings and overall ratings in relation to the key issues addressed by the broad scale monitoring (i.e. sediment, eutrophication and habitat modification).

**Table 14. Summary of broad scale condition ratings for Jacobs River Estuary 2003, 2008 and 2013.**

| RATINGS | | | CONDITION RATINGS | | | CHANGE RATINGS |
|---|---|---|---|---|---|---|
| Major Issue | Overall Rating | Indicator | 2003 | 2008 | 2013 | Change from 2003 Baseline |
| Muddiness | POOR | Soft mud area | Very Poor | Very Poor | Very Poor | Small Increase |
| Eutrophication | POOR | Low density macroalgal cover | Low | Moderate | Moderate | Early Warning Trigger - trend of increase |
| | | High density macroalgal cover | Low | Very High | Very High | Very Large Increase |
| | | Gross eutrophic condition area | Fair | Poor | Very Poor | Very Large Increase |
| Habitat Modification | MODERATE | Seagrass Coefficient/area | Fair | Fair | Fair | Very Large Decrease |
| | | Saltmarsh area | Moderate | Moderate | Moderate | Small Decrease |
| | | Densely vegetated margin area | Poor | Poor | Poor | Small Decrease |

In summary, Jacobs River Estuary was dominated by firm sand and firm mud/sand substrate (55%) located primarily in the central basin and lower estuary. Very extensive areas of soft and very soft mud (30%) were prominent in the more sheltered upper reaches of both arms, while firm muds (10%) dominated within saltmarsh. High density (>50% cover) macroalgal growth was very extensive (30% of the estuary) located predominantly in the upper estuary deposition zones. *Gracilaria* covered much of the surface in these areas, and gross eutrophic conditions were present (e.g. very soft muds, and anaerobic, and sulphide rich sediments, nuisance macroalgal cover). Seagrass (*Zostera*) was present over 8% of the estuary but high density beds were restricted to the well flushed central basin and covered only 2% of the estuary. Saltmarsh (10% of the estuary) was confined to a narrow strip around much of the estuary, with expansive beds present in the upper Aparima Arm, and to a lesser extent in the upper Pourakino Arm. The 200m terrestrial margin was dominated by grassland (72%), primarily dairy grazing, the urban features of Riverton (14%), and gorse-dominated scrub and forest (11%). Much of the estuary edge around Riverton featured reclaimed shorelines and artificial structures (e.g. rockwalls, wharfs).

Based on the key broad scale indicators of sediment, eutrophication and habitat loss, it is clear that Jacobs River Estuary is in a degraded condition, with the health of the estuary declining significantly since 2003. Much of the degradation related to habitat modification can be attributed to historical changes (e.g. forest clearance, reclamation, shoreline armouring, drainage), although relatively small losses of saltmarsh and densely vegetated margin continue. The historical changes, particularly forest clearance and drainage, have certainly contributed directly to the excessive input of soft mud in the estuary through increased erosion and reduced filtering. While sediment inputs are still an ongoing issue, the primary issue in the estuary is eutrophication, as previously identified in the results from broad scale habitat mapping, fine scale monitoring, sedimentation rate monitoring, and annual macroalgal monitoring (e.g. Robertson et al. 2002, Robertson and Stevens 2006, 2008, 2010, 2011, Stevens and Robertson 2007, 2008, 2009, 2010, 2011, 2012).

The rapid increase in nuisance macroalgal growth since 2003, combined with the presence of soft muds, have seen widespread gross eutrophic conditions develop in the sheltered upper reaches of both arms (gross nuisance conditions now cover 30% of the estuary, compared with 4% in 2008 and <4% in 2003). These conditions have caused the displacement of seagrass beds, are stressing saltmarsh habitat, are causing significant adverse ecological impacts to sediment dwelling organisms, and creating conditions unfavourable for birds and fish. Aesthetic and amenity values in these parts of the estuary are now also severely compromised.

The primary driver of the eutrophication symptoms being expressed is considered to be excessive catchment nutrient loads. In Jacobs River, >80% of the nutrient load is likely to be entering from the more heavily developed Aparima Arm, with many of the impacts evident in the Pourakino Arm also likely to be driven by inputs from this source. Previous reports triggered recommendations for nutrient source identification (Stevens and Robertson 2008), and an immediate (~60%) reduction in nutrient and sediment loads from the catchment (Stevens and Robertson 2007, 2008, 2009, 2010). The importance of these actions, yet to be instigated, were reiterated in Robertson and Stevens (2011), and Stevens and Robertson (2011, 2012) and are again emphasised. Recommendations for ongoing monitoring and management are put forward in Sections 5 and 6.

# 5. MONITORING

Jacobs River Estuary has been identified by Environment Southland as a high priority for monitoring, and is a key part of their coastal monitoring programme being undertaken in a staged manner throughout the Southland region. The future monitoring recommendations are outlined as follows:

**Macroalgal and Seagrass Monitoring**

- Continue with the programme of annual broad scale mapping of macroalgae. Next monitoring due in February/March 2014.

**Broad Scale Habitat Mapping**

- Continue with the programme of 5 yearly broad scale habitat mapping. Next monitoring due in February/March 2018.

**Fine Scale Monitoring**

- Monitor fine scale sites established in 2012 (Robertson and Stevens 2012) in representative poorly flushed vulnerable areas in the Pourakino and Aparima Arms in February 2014, and again in February 2016 when the 5 yearly fine scale trend monitoring at three existing sites falls due.
- Extend the fine scale monitoring programme to include assessment of seagrass and saltmarsh health (e.g. biomass, density, root mass and depth, invasive species presence) at representative locations.

**Sedimentation Rate Monitoring**

- Because sedimentation is a priority issue in the estuary it is recommended that all sediment plate depths be measured annually and that additional sediment plates be deployed at representative locations so that the sedimentation rate over much larger parts of the estuary can be determined (see Robertson and Stevens 2011). These plates will also be used to gauge the success of actions taken to reduce sediment inputs.

# 6. MANAGEMENT

Eutrophication and sedimentation have been identified as a major issue in Jacobs River Estuary since at least 2007-8 (Robertson and Stevens 2008, Stevens and Robertson 2007, 2008), as has been the case for several other Southland estuaries (e.g. New River, Waimatuku and Waituna Lagoon).

To address these issues, it is recommended that appropriate catchment nutrient and sediment guideline criteria be developed for each estuary type in Southland and that these guideline criteria are then used to assess the extent to which catchment loads meet these guidelines. Estuaries where guidelines are exceeded are prioritised for more extensive investigations, monitoring and management. The key steps in such an approach are as follows:

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

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

# 7. ACKNOWLEDGEMENTS

Many thanks to Ben Robertson (Wriggle) for assistance with fieldwork, and to Nick Ward (Coastal Scientist, Environment Southland) for his review of this report.

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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.