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Porangahau Estuary

Broad Scale Intertidal
Habitat Mapping



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Broad Scale Intertidal Habitat Mapping of Porangahau Estuary



Prepared for



February 2006

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Broad Scale Intertidal Habitat Mapping of Porangahau Estuary

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Cover photo: Porangahau Estuary

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Approved for release by:
Dr Barry Robertson, Manager – Coastal and Estuarine

1. INTRODUCTION

Estuarine intertidal areas play an important role in the nourishment of coastal ecosystems, linking terrestrial and marine environments and often encompassing high value ecological habitats and resources of cultural, recreational and/or commercial importance. Hawke's Bay Regional Council (HBRC) are monitoring a number of estuaries in their region and the Cawthron Institute (Cawthron) was contracted to undertake broad scale habitat mapping of Porangahau Estuary to assist in regional strategic planning, and in the management of specific issues associated with estuarine habitat (*e.g.* resource consents, pollution, and state of the environment monitoring).

This report summarises the results of a detailed point-in-time, spatial survey of major habitats in the intertidal regions of Porangahau Estuary. This report includes the following components:

- A CD-ROM containing the completed habitat maps (titled "*Broad Scale Intertidal Habitat Mapping: Porangahau Estuary*").
- A summary report (this document) which includes:
 - a methodology outline.
 - a map showing the broad scale habitats present (*e.g.* Rushland, Tussockland).
 - a map representing the pattern of dominant cover (*e.g.* *Leptocarpus similis*).
 - a summary table of major habitats and substrates within the estuary, providing the area and relative proportions of each grouping.
 - a brief summary of results for the Porangahau Estuary.

2. METHODS

2.1 Overview

The methodology used to collect data was based on the National Estuary Monitoring Protocol (Robertson *et al.* 2002) which uses field-verified broad scale mapping of habitat zones. This procedure involves the use of aerial photography together with detailed ground-truthing and digital mapping using Geographical Information System (GIS) technology. The broad scale habitat mapping approach provides a description of the intertidal environment according to dominant habitat types based on substrate characteristics (mud, sand, cobble, rock, shellfish beds, *etc*) and the vegetation present (*e.g.* rushes, tussocks, eelgrass, seaweed, *etc*), in order to develop a baseline map of the estuary. Once a baseline map has been constructed, changes in the position and/or size of

habitats (MfE Confirmed Indicators for the Marine Environment, ME6 2001) can be assessed by repeating the mapping exercise. This information can then be used to evaluate the implications of natural perturbations such as flood/climate events and human impacts such as land management practices (and related river water quantity and quality) on the structure and function of the intertidal ecosystem.

2.2 Aerial photography

Rectified 2.5 metre per pixel black and white aerial photographs of Porangahau Estuary were downloaded from the LINZ website. The quality and age of the photos available allowed shape files to be drawn to an accuracy of approximately ± 10 m with a scale of approximately 1:5000 needed on-screen to see the image clearly.

2.3 Ground-truthing of habitat features

Aerial photographs, through different textural and tonal patterns, indicate the presence of different substrate types and their spatial extents. To identify the dominant habitat present, and confirm the boundaries between substrates, experienced estuarine scientists from Cawthron walked over the whole estuary at low-mid tide during May 2005. Dominant habitat types, including various categories of bare and vegetated substrate were recorded directly onto laminated aerial photographs (scale 1:7,500) using the codes listed in Table 1. The upper boundary was set at MHWS (Mean High Water Spring), unless supra-littoral habitat was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS (Mean Low Water Spring). A 50 metre wide riparian strip was also mapped to indicate the type of habitat buffering the edge of the estuary from adjacent landuses.

2.4 Digitisation of habitat boundaries

Vegetation and substrate features were then digitally mapped on-screen from the rectified photographs using Arcmap 9.0 GIS software. This procedure involved copying, as precisely as possible, the habitat features recorded on aerial photographs during the field surveys onto rectified aerial photographs within the GIS. Each drawing was then saved to a shape file (or GIS layer) associated with each specific feature. The software was then used to produce maps and calculate the area cover for each habitat type.

3. CLASSIFICATION AND DEFINITIONS OF HABITAT TYPES

3.1 Classification of habitat features

The classification of substrate and habitat features has been based on the proposed estuarine national classification system (with adaptations), which was developed under a Ministry for the Environment SMF (Sustainable Management Fund) programme (Monitoring Changes in Wetland Extent: An Environmental Performance Indicator for Wetlands) by Lincoln Environmental, Lincoln. The classification system for wetland types is based on the Atkinson System (Atkinson 1985) and covers four levels, ranging from broad to fine scale. The broad scale mapping focuses on Levels III and IV (see Table 1). Substrate classification is based on surface layers only and does not consider underlying substrate; *e.g.* gravel fields covered by sand would be classed as sand. A list of all the classification types used in the study and their codes are given in Table 1, with definitions for classification of the Level III structural class provided in Section 3.3.

3.2 Habitat codes and terminology

Dominant biota with a spatial coverage of >2m in diameter has been classified using an interpretation of the Atkinson (1985) system. In this report biota and substratum are listed in order of dominance as described below:

- Individual plant species are coded using the two first letters of their Latin species and genus names *e.g.* Pldi = *Plagianthus divaricatus* (ribbonwood), Lesi = *Leptocarpus similis* (jointed wire rush).
- _ is used to indicate subdominant species *e.g.* Lesi_Pldi = Pldi is subdominant to Lesi. The classification is based on the subjective observation of which vegetation is the dominant or subdominant species within the patch, and not on percentage cover.
- Shape files in the GIS have been labelled in the same manner as that described above.

Table 1 Classification of estuarine habitat types (adapted UNEP-GRID classification).

Level I Hydrosystem	Level IA SubSystem	Level II Class	Level III Structural Class	Level IV Dominant Cover	Habitat Code
Estuary (alternating saline and freshwater)	Intertidal/supratidal	Saltmarsh	Shrub/Scrub/Forest	<i>Leptospermum scoparium</i> , "Manuka" <i>Ozothamnus leptophyllus</i> , "Cassinia, Tauhinu" <i>Pinus radiata</i> , "Pine tree" <i>Plagianthus divaricatus</i> , "Saltmarsh ribbonwood"	Lesc Ozle Pira Pldi
			Rushland	<i>Isolepis nodosa</i> , "Knobby clubrush" <i>Juncus kraussii</i> , "Searush" <i>Leptocarpus similis</i> , "Jointed wirerush"	Isno Jukr Lesi
			Grassland	<i>Ammophila arenaria</i> , "Marram grass" <i>Festuca arundinacea</i> , "Tall fescue" <i>Spinifex sericeus</i> , "Silvery grass" Unidentified grass	Amar Fear Spse Ungr
			Sedgeland	<i>Schoenoplectus pungens</i> , "Three square"	Isce
			Herbfield	<i>Samolus repens</i> , "Primrose" <i>Sarcocornia quinqueflora</i> , "Glasswort" <i>Selliera radicans</i> , "Remuremu"	Sare Saqu Sera
		Seagrass meadow	Seagrass meadow	<i>Zostera sp.</i> , "Eelgrass"	Zosp
		Macroalgal bed	Macroalgal bed	<i>Enteromorpha sp.</i> <i>Gracilaria chilensis</i> <i>Ulva sp.</i> , "Sea lettuce"	Ensp Grch Ulri
		Artificial Structure	Boulder Field man-made Rock Wall man-made Sand Field man-made Bridge Wharf		BFmm RFmm SFmm BRG WHF
		Mud/sandflat	Firm shell/sand Firm sand Soft sand Mobile sand Firm mud/sand Soft mud/sand Very soft mud/sand		FSS FS SS MS FMS SMS VSM
		Boulderfield Rockfield Stonefield Shell bank Shellfish field Worm field	Boulder field Rockfield Cobble field Gravel field Shell bank Cocklebed Musselreef Oysterreef Sabellid field		BF RF CF GF Shell Cockle Mussel Oyster Sabellid
	Subtidal	Water	Water		Water

3.3 Definitions of classification Level III Structural Class

- 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 dbh. Tree ferns ≥ 10 cm dbh are treated as trees.
- Treeland:** Cover of trees in canopy 20-80%. Trees are woody plants >10cm dbh.
- Scrub:** Woody vegetation in which the 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 diameter at breast height (dbh).
- Shrubland:** Cover of shrubs in canopy 20-80%. Shrubs are woody plants <10 cm diameter at breast height (dbh).
- 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.
- 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.
- Grassland:** Vegetation in which the cover of grass in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.
- Sedgeland:** Vegetation in which the cover of 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. Tussock-sedges and reed-forming sedges (c.f. REEDLAND) are excluded.
- Rushland:** Vegetation in which the cover of rushes in the canopy is 20-100% and in which the rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in the rush growth form are some species of Juncus and all species of, Leptocarpus. Tussock-rushes are excluded.
- 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. If the reed is broken the stem is both round and hollow – somewhat like a soda straw. The flowers will each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers, which look like that. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Examples include Typha, Bolboschoenus, Scirpus lacustris, 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 in which the 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 in which the lichen 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 chlorophyll, 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.
- Firm mud/sand:** A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate 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 walking on the substrate 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 on the substrate you'll sink greater than 5 cm.
- 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 less than 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 impossible.
- Soft sand:** Substrate containing greater than 99% sand. When walking on the substrate you'll sink greater than 2 cm.
- Stone field/Gravel field:** Land in which the area of unconsolidated gravel (2-20 mm diameter) and/or bare stones (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Stonefields and gravelfields are named based on which form has the greater ground cover. They are named from the leading plant species when plant cover of (1%.
- Cobble field:** Land in which the area of unconsolidated cobbles/stones (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 of $\geq 1\%$.
- Boulder field:** Land in which the area of unconsolidated bare boulders (> 200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover is $\geq 1\%$.
- Rock/Rock field:** Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover is $\geq 1\%$.
- 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.
- Cockle bed:** Area that is dominated by primarily dead cockle shells.
- Mussel reef:** Area that is dominated by one or more mussel species.
- Oyster reef:** Area that is dominated by one or more oysters species.
- Sabellid field:** Area that is dominated by raised beds of sabellid polychaete tubes.

4. RESULTS AND DISCUSSION

Overall, Porangahau is a relatively long and narrow estuary that is strongly river dominated in the upper reaches (southern extent) by the Porangahau River (Figure 1, A), becoming shallow and more open to the north where it spreads across broad tidal flats. A long sandy beach separates the estuary from the open coast, and with the estuary discharging through the beach to the open coast in the northeast (Figure 1, B&C). The estuary entrance is relatively mobile and moves along the beach in response to changes in coastal sand movement, wave action and river flow.



Figure 1 Porangahau Estuary showing the confined river-dominated upper reaches (A), and the open tidal flats near the discharge to the open coast (B&C).

The landward side of the estuary is dominated by extensive areas of grazed coastal duneland and pasture (Figure 2, A&B). To the south, a triangular peninsula of land is present between the river and the coast containing a dominant cover of grassland and residential development (including the golf course), and terrestrial forest (mainly pine trees) and rushland at the north end (Figure 2, C).



Figure 2 Terrestrial vegetation flanking Porangahau Estuary showing grazed tussock and pasture to the north (A&B), and pine trees and rushland on the triangular peninsula to the south (C).

The results of the broad scale survey of intertidal habitat within Porangahau Estuary are presented in Figure 3, and summarised in Figure 4 and Table 2. In total, 384 Ha of estuary was mapped, 342 Ha (89%) unvegetated, comprising 274 Ha (61%) of intertidal habitat and 110 Ha (29%) of subtidal habitat (represented as water). Vegetation was the dominant cover over 41 Ha (11%) of the estuary.

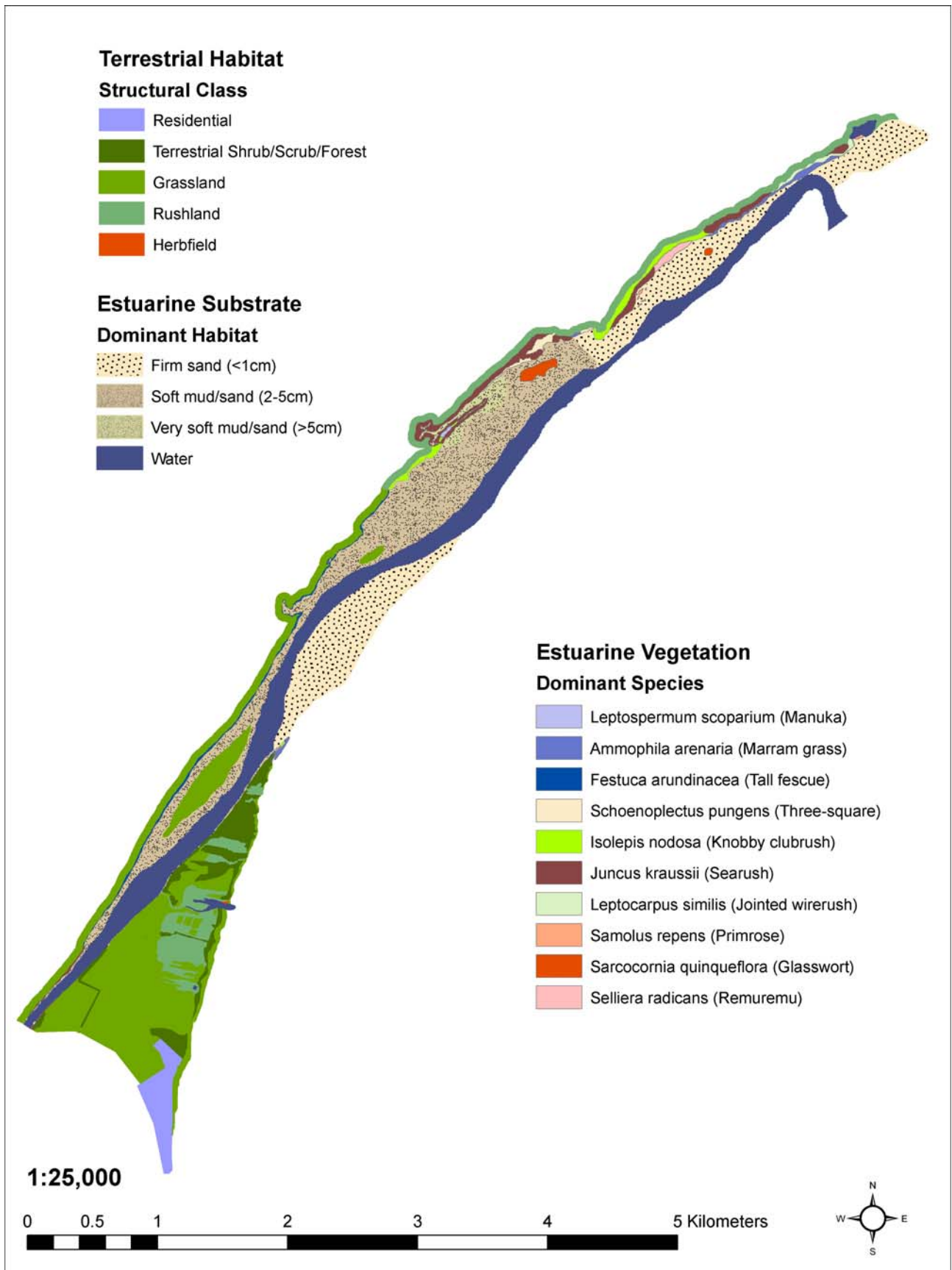
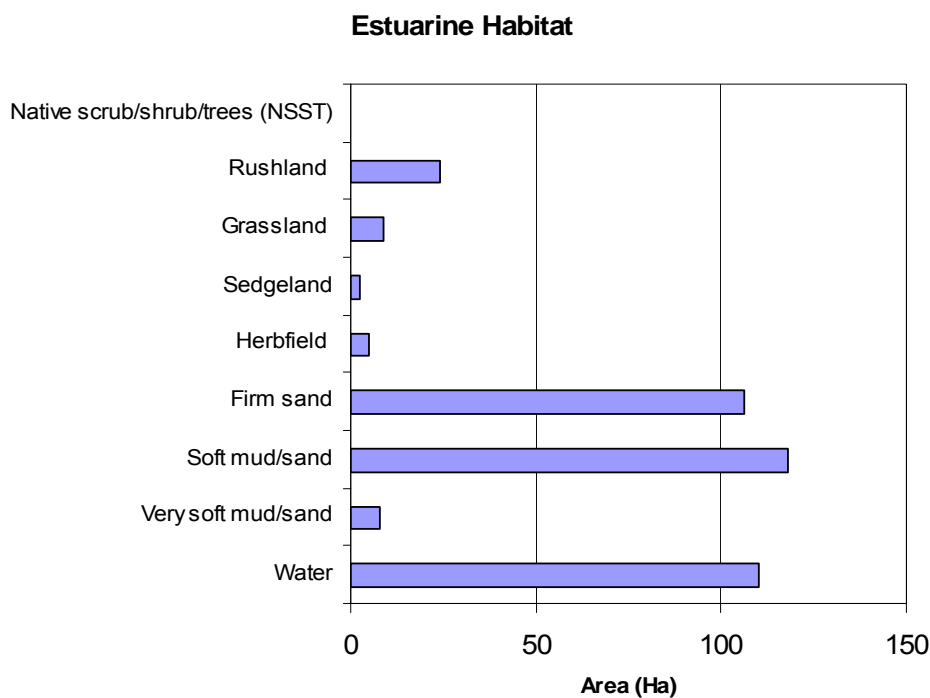


Figure 3 Broad structural habitat (vegetation and substrate) of Porangahau Estuary, May 2005.

Table 2 Area of dominant estuary habitats and substrata within Porangahau Estuary, May 2005.

PORANGAHAU: ESTUARY VEGETATION				
Class	Dominant cover	Primary subdominant	Area (Ha)	% of total
Native scrub/shrub/trees (NSST)			0.30	0.1
	<i>Leptospermum scoparium</i> (Manuka)	<i>Plagianthus divaricatus</i> (Saltmarsh ribbonwood)	0.30	0.1
Rushland			24.33	6.3
	<i>Isolepis nodosa</i> (Knobby clubrush)		0.40	0.1
		<i>Juncus kraussii</i> (Searush)	1.84	0.5
		Unidentified grass	4.58	1.2
	<i>Juncus kraussii</i> (Searush)		1.69	0.4
		<i>Leptocarpus similis</i> (Jointed wirerush)	14.03	3.7
	<i>Leptocarpus similis</i> (Jointed wirerush)		0.01	0.0
		<i>Isolepis nodosa</i> (Knobby clubrush)	1.78	0.5
Grassland			8.82	2.3
	<i>Ammophila arenaria</i> (Marram grass)		2.70	0.7
		<i>Spinifex sericeus</i> (Silvery grass)	0.43	0.1
	<i>Festuca arundinacea</i> (Tall fescue)		5.64	1.5
		<i>Isolepis nodosa</i> (Knobby clubrush)	0.06	0.0
Sedgeland			2.57	0.7
	<i>Schoenoplectus pungens</i> (Three-square)		2.57	0.7
Herbfield			5.12	1.3
	<i>Samolus repens</i> (Primrose)		0.18	0.0
		<i>Selliera radicans</i> (Remuremu)	0.12	0.0
	<i>Sarcocornia quinqueflora</i> (Glasswort)		3.08	0.8
	<i>Selliera radicans</i> (Remuremu)	<i>Samolus repens</i> (Primrose)	1.74	0.5
Unvegetated			342.43	89.3
	Firm sand		106.23	27.7
	Soft mud/sand		118.21	30.8
	Very soft mud/sand		7.79	2.0
	Water		110.20	28.7
Estuarine Total			383.6	100

**Figure 4** Dominant structural class habitats in Porangahau Estuary, May 2005.

Within the unvegetated estuary 51% (118 Ha) of the substrate was soft muddy sand, 46% (106 Ha) firm sand, and 3% (8 Ha) soft mud. Clean firm sands were dominant north of the estuary near the entrance and on the seaward (eastern) side of the Porangahau River, while upstream and on the landward (western) side of the river, soft mud/sand was the predominant substrate.

Where vegetation was the dominant estuarine cover, Rushland was most common (59%, 24 Ha), with *Juncus kraussii* (Searush) the dominant species. This was found mainly along the northwest landward margin of the estuary adjacent to the grazed duneland. Grassland was the next most dominant (24%, 9 Ha), with *Festuca arundinacea* (Tall fescue) dominant adjacent to grazed pasture in the southwest. Herbfields containing *Sarcocornia quinqueflora* (Glasswort), *Selliera radicans* (Remuremu), and *Samolus repens* (Primrose) were present in the northwest of the estuary (13%, 5 Ha).

The terrestrial margin of the estuary contained a variety of species forming a succession of estuarine plants through to terrestrial species (see Figure 5).

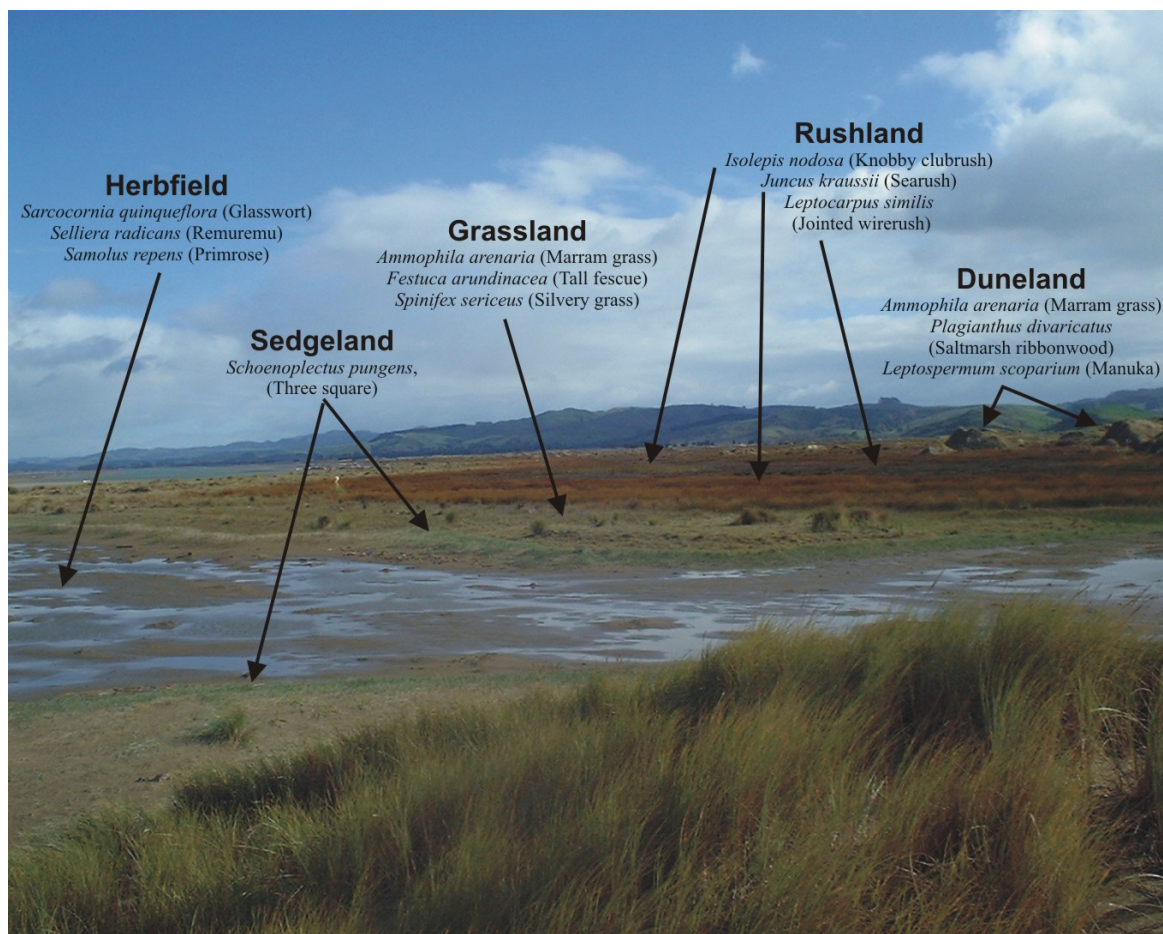


Figure 5 Example of estuarine to terrestrial succession of plants in Porangahau Estuary.

This succession was most intact in the northeast of the estuary where in the upper intertidal zone of the estuary unvegetated sands support herbfield species (*e.g.* Glasswort, Remuremu, Primrose) and, immediately above this, a relatively narrow band of sedgeland (*Schoenoplectus pungens*, “Three square”) was commonly present. A slight increase in elevation above that regularly inundated with saltwater corresponded to a change to grassland containing *Ammophila arenaria* “Marram grass” *Festuca arundinacea* “Tall fescue”, and *Spinifex sericeus* “Silvery grass”. Inland of this, rushland species began to dominate with often distinct bands of *Leptocarpus similis* “Jointed wirerush”, *Juncus kraussii* “Searush”, and *Isolepis nodosa* “Knobby clubrush” present. Ground elevation continued to increase and, inland of rushland, raised sand dunes were common supporting dense growths of marram grass as well as small stands of *Plagianthus divaricatus* “Saltmarsh ribbonwood”, *Leptospermum scoparium* “Manuka”, and occasionally *Ozothamnus leptophyllus* “Tauhinu”.

Dunelands continued inland for several hundred metres and, where unmodified and lightly grazed (*e.g.* Figure 6, A), provide a large and relatively stable vegetation buffer, particularly in areas north of the estuary. Development of duneland into pasture has previously occurred in the southwest, and is now occurring in terrestrial areas flanking the estuary to the north (*e.g.* Figure 6, B), while grazing among duneland is also common in this area. As a major part of the value of Porangahau Estuary relates to its largely undeveloped surrounding catchment, the significance of these activities is relatively high, even though the direct impact on the estuary currently appears quite low.



Figure 6 Example of duneland flanking Porangahau Estuary that is grazed but relatively unmodified (A) and being converted to pasture (B).

Table 3 and Figure 7 summarise the vegetation mapped around Porangahau. As there was no clear boundary along the terrestrial margin, a 50 metre wide buffer strip was applied from the upper edge of the estuary which was in close proximity to the fenced boundary to the estuary. At a broad

structural class, the vegetation bordering the estuary on the landward side was classified as either grassland, reflecting the developed pastureland in the southwest, or rushland reflecting the relatively intact but grazed margins in the northwest. The majority of the terrestrial area mapped was the triangular peninsula of land present between the river and the open coast. This area was dominated by grassland to the south, incorporating the golf course, the remainder being grazed pasture. To the north of the peninsula, pine plantations dominated with rushland present among the plantations. Although extensively modified in many areas, the area still retains a wide range of native plants and habitats that are relatively intact and therefore of ecological value.

Full details on the vegetation and substrates present, from which the broad scale figures and tables are derived, are included on the accompanying CD-ROM, “*Broad Scale Intertidal Habitat Mapping: Porangahau Estuary*”.

Table 3 Area of dominant terrestrial habitats surrounding Porangahau Estuary, May 2005.

PORANGAHAU: TERRESTRIAL VEGETATION				
Class	Dominant cover	Primary subdominant	Area (Ha)	% of total
Terrestrial			15.4	6.5
	Residential		15.4	6.5
Native scrub/shrub/trees (NSST)			29.7	12.6
	<i>Ozothamnus leptophyllus</i> (Cassinia, Tauhinu)		1.3	0.6
	<i>Pinus radiata</i> (Pine tree)		28.3	12.0
Rushland			54.2	23.0
	<i>Isolepis nodosa</i> (Knobby clubrush)		0.1	0.0
		<i>Festuca arundinacea</i> (Tall fescue)	0.9	0.4
		<i>Juncus kraussii</i> (Searush)	2.1	0.9
		Unidentified grass	28.4	12.0
	<i>Juncus kraussii</i> (Searush)		1.6	0.7
	<i>Leptocarpus similis</i> (Jointed wirerush)	<i>Festuca arundinacea</i> (Tall fescue)	3.3	1.4
		<i>Isolepis nodosa</i> (Knobby clubrush)	17.8	7.5
Grassland			133.6	56.6
	<i>Ammophila arenaria</i> (Marram grass)		2.9	1.2
		<i>Isolepis nodosa</i> (Knobby clubrush)	5.7	2.4
	<i>Festuca arundinacea</i> (Tall fescue)		0.8	0.3
	<i>Spinifex sericeus</i> (Silvery grass)	<i>Lagurus ovatus</i> (Harestail)	4.0	1.7
	Unidentified grass		89.6	38.0
		<i>Isolepis nodosa</i> (Knobby clubrush)	30.7	13.0
Herbfield			0.1	0.0
	<i>Samolus repens</i> (Primrose)	<i>Selliera radicans</i> (Remuremu)	0.1	0.0
Unvegetated			3.1	1.3
	Water		3.1	1.3
Terrestrial Total			236.0	100

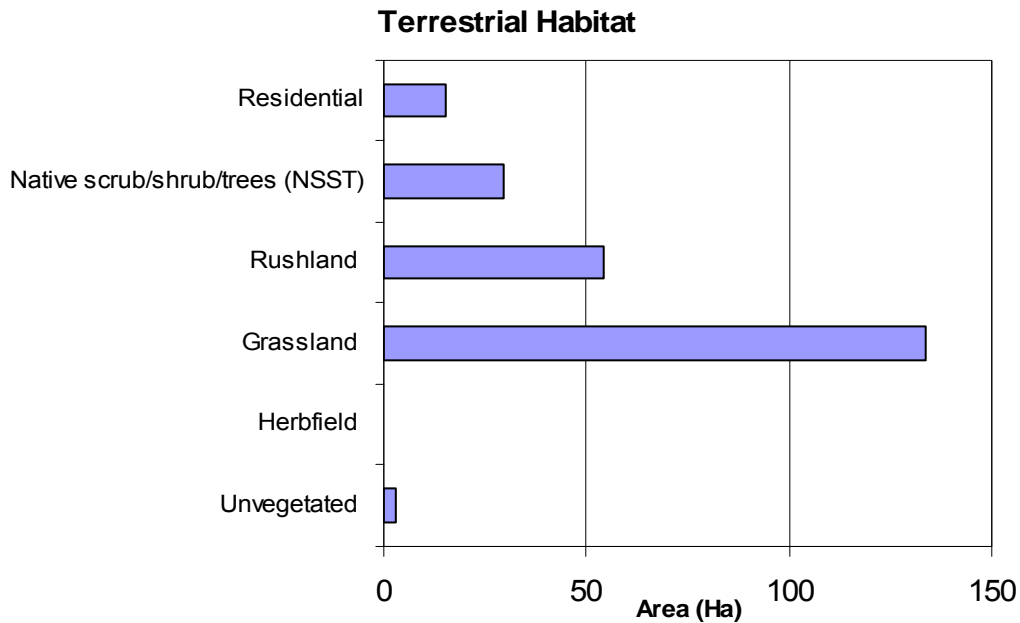


Figure 7 The area of structural class habitats of Porangahau Estuary, May 2005.

5. OVERVIEW

The broad scale habitat characterisation of the Porangahau Estuary identified the following features:

- The upper portion of the estuary is river dominated, becoming shallow and more open in lower reaches to the north where it spreads across broad tidal flats.
- Unvegetated habitat dominated the estuary (89%), made up of soft mud/sand sand (31%), water (subtidal) (29%), and firm sand (28%).
- Estuarine vegetation (11%) was generally confined to narrow bands along the edge of the river margins and was dominated by rushland and grassland.
- Surrounding land cover was dominated by grassland and duneland, with small areas of plantation forestry.

Overall this estuary has no obvious indications of high nutrient loadings (*e.g.* nuisance macroalgal blooms or sulphide-rich, muddy sediments), although sediment deposition is obvious in the upper reaches. The northwest of the estuary had the most intact buffering vegetation, although this is currently being grazed and/or developed into pasture. Protection of vegetation surrounding the estuary, and minimising sediment input from upstream sources are considered the most important aspects for maintaining estuary health.

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7. REFERENCES

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