

## **Broad Scale Intertidal Habitat Mapping of Haldane Estuary**



Prepared for



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Prepared for



by

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Cover photo: Haldane Estuary (Environment Southland)

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Approved for release by:  
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## 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. Environment Southland (ES) are monitoring a number of estuaries in their region and the Cawthron Institute (Cawthron) has previously undertaken both broad and fine scale habitat mapping and assessment of estuaries in the Southland region (*e.g.* Jacobs River, New River, Mataura, Awarua Bay, Bluff Harbour, Waikawa) 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).

To further extend the spatial coverage of the estuaries being monitored, ES and Cawthron recently undertook broad scale mapping of the intertidal substrate and habitat complexes present in Haldane Estuary. This report summarises the results of a detailed point-in-time, spatial survey of major habitats in the intertidal regions of Haldane Estuary. This report includes the following components:

- A CD-ROM containing the completed habitat maps (titled “*Broad Scale Intertidal Habitat Mapping: Haldane 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 Haldane 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 Colour aerial photography**

Aerial photographs of Haldane Estuary were taken on 28 November 2004 by Les McGraw (ES) and provided to Cawthron as rectified “tiff” files at scales of 1:10,000.

## **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, an experienced estuarine scientist (Cawthron) walked over the whole estuary at low-mid tide during November 2004. Dominant habitat types, including various categories of bare and vegetated substrate were recorded directly onto laminated aerial photographs (scale 1:5,000 to 1:10,000) 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 10 metre wide riparian strip was also mapped to indicate the type of habitat surrounding the edge of the estuary.

## **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).

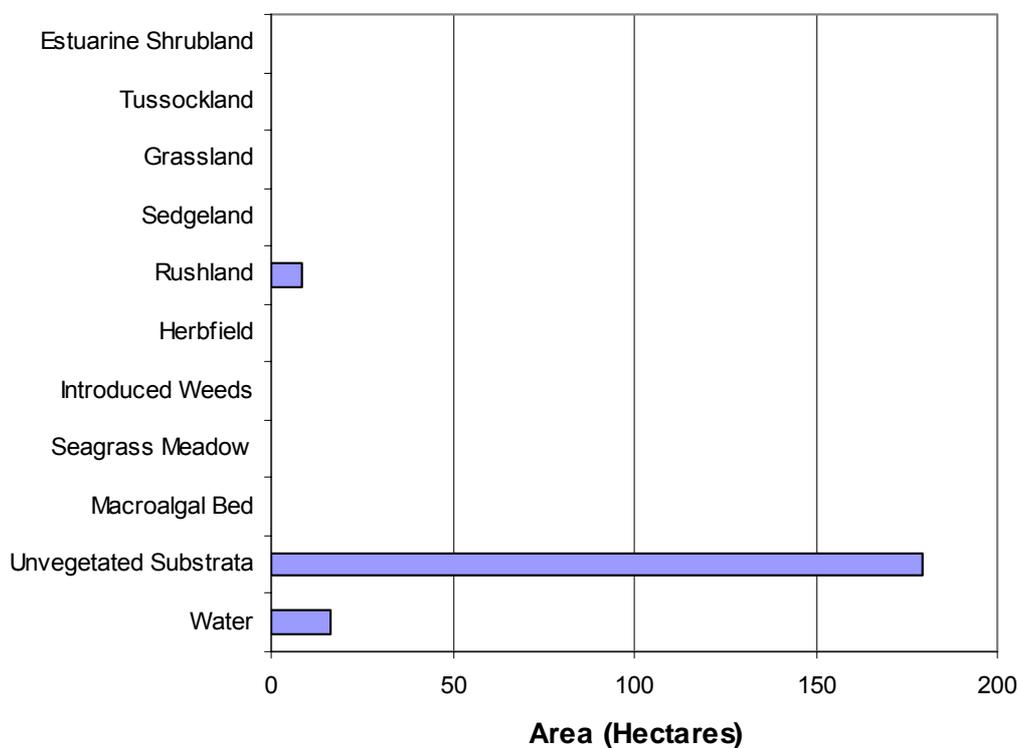
Level I Hydrosystem	Level IA SubSystem	Level II Class	Level III Structural Class	Level IV Dominant Cover	Habitat Code	
Estuary (alternating saline and freshwater)	Intertidal/ supratidal	Saltmarsh	Shrub/Scrub/Forest	<i>Cordyline australis</i> "Cabbage tree" <i>Coprosma repens</i> "Taupata" <i>Cypressus macrocarpa</i> <i>Hebe</i> spp., "Hebe species" <i>Leptospermum scoparium</i> , "Manuka" <i>Lupinus arboreus</i> , "Tree lupin" Native trees <i>Pinus radiata</i> , "Pine tree" <i>Plagianthus divaricatus</i> , "Saltmarsh ribbonwood" <i>Podocarpus totara</i> , "Totara" <i>Ulex europaeus</i> , "Gorse"	Coau Core Cuma Hesp Lesc Luar Natr Pira Pldi Poto Uleu	
			Estuarine Shrubland Tussockland	<i>Plagianthus divaricatus</i> , "Saltmarsh ribbonwood" <i>Carex</i> spp. "Sedge" <i>Phormium tenax</i> , "New Zealand flax" <i>Puccinella stricta</i> , "Salt grass"	Pldi Casp Phte Pust	
			Grassland	<i>Ammophila arenaria</i> , "Marram grass" <i>Festuca arundinacea</i> , "Tall fescue" Unidentified grass	Amar Fear Ungr	
			Sedgeland Rushland	<i>Isolepis cernua</i> , "Slender clubrush" <i>Isolepis nodosa</i> , "Knobby clubrush" <i>Juncus kraussii</i> , "Searush" <i>Leptocarpus similis</i> , "Jointed wirerush"	Isce Isno Jukr Lesi	
			Herbfield	<i>Leptinella dioica</i> <i>Samolus repens</i> , "Primrose" <i>Sarcocornia quinqueflora</i> , "Glasswort" <i>Selliera radicans</i> , "Remuremu"	Ledi Sare Saqu Sera	
			Introduced weeds	Unidentified Introduced Weeds	Inwe	
			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 SM VSM
Boulderfield Rockfield Stonefield	Boulder field Rockfield Cobble field Gravel field		BF RF CF GF			
Shell bank Shellfish field	Shell bank Cocklebed Musselreef Oysterreef		Shell Cockle Mussel Oyster			
Worm field	Sabellid field		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  $\geq 10$  cm dbh. Tree ferns  $\geq 10$  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, groyne, 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

The results of the broad scale survey of intertidal habitat within Haldane Estuary are summarised in Figure 1 and Table 2, and presented graphically in Figure 2. In total, 206 Ha of estuary was mapped (Table 2), comprising 189 Ha of intertidal habitat and 17 Ha of subtidal habitat (represented as water). The intertidal habitat was dominated by unvegetated substrata (179 Ha, 95%), with only 5% (9.8 Ha) of the estuary having vegetation as the dominant cover.



**Figure 1** The area of structural class habitats (based on dominant cover) in Haldane Estuary.

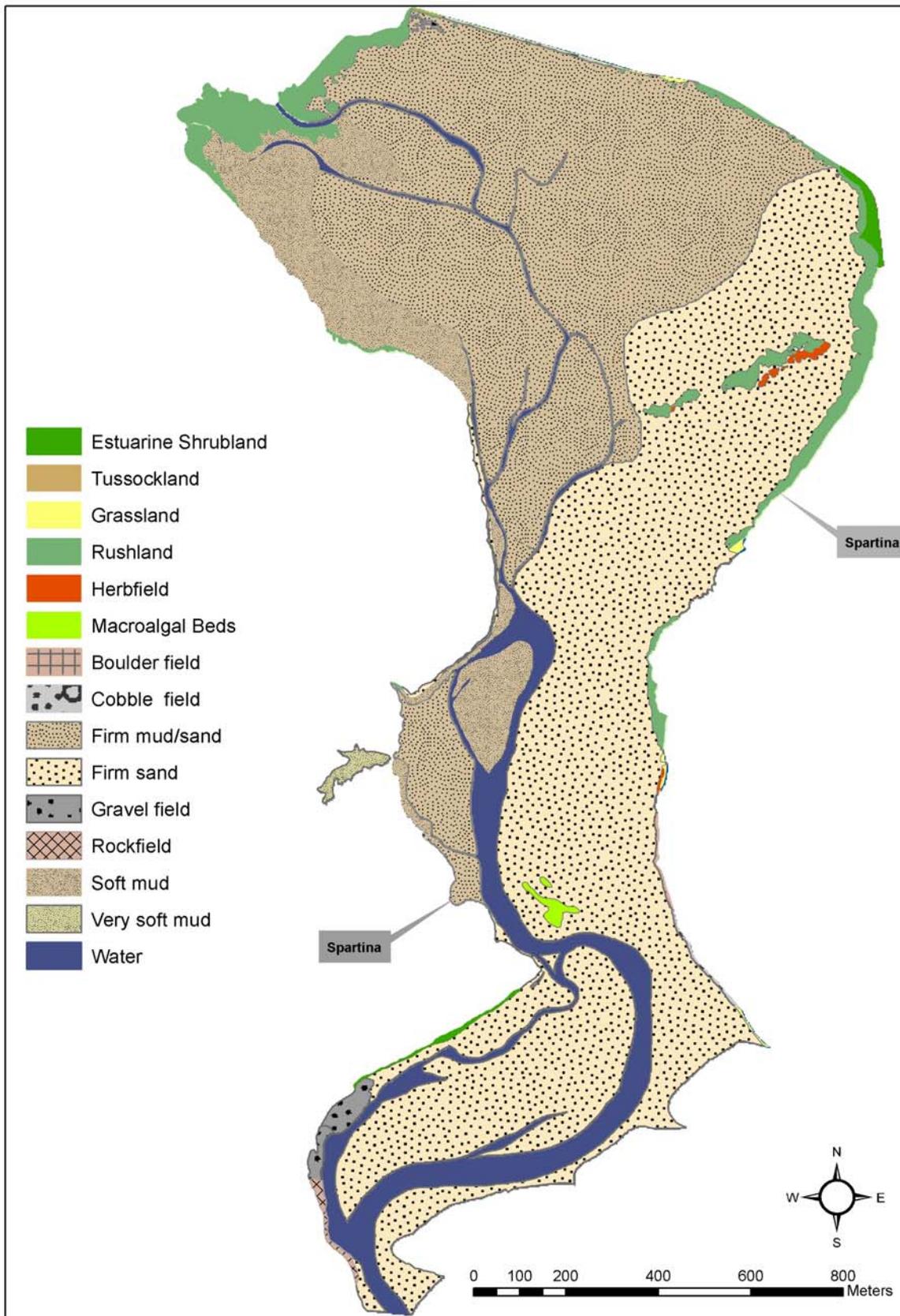
Within the unvegetated substrata 46% (82.2 Ha) was made up of firm sand, 44% (78.4 Ha) firm muddy sand, 9% (16.6 Ha) was classified as soft mud, with the remaining 1% (2.25 Ha) consisting of mixture of very soft mud, gravel, cobble, boulder, and rock. Overall, there was a marked transition in sediment type across the estuary, with the eastern side being predominantly clean firm sands, with the west and northwest being predominantly soft mud. Gravel, cobble, boulder, and rock were found mainly in the true right of the estuary near the entrance.

**Table 2** Area of dominant habitats and substrata within Haldane Estuary, November 2004.

<b>ESTUARINE VEGETATION</b>			<b>Area</b>	<b>% of</b>
<b>Class</b>	<b>Dominant species</b>	<b>Primary Sub-dominant</b>	<b>(Ha)</b>	<b>Total</b>
<b>Estuarine Shrubland</b>			<b>0.62</b>	<b>6.3</b>
	Lupinus arboreus (Tree lupin)	Ammophila arenaria (Marram grass)	0.20	2.1
	Plagianthus divaricatus (Saltmarsh ribbonwood)	Phormium tenax (New Zealand flax)	0.42	4.3
<b>Tussockland</b>			<b>0.02</b>	<b>0.2</b>
	Phormium tenax (New Zealand flax)	Plagianthus divaricatus (Saltmarsh ribbonwood)	0.02	0.2
<b>Grassland</b>			<b>0.24</b>	<b>2.4</b>
	Festuca arundinacea (Tall fescue)		0.23	2.3
	Festuca arundinacea (Tall fescue)	Lupinus arboreus (Tree lupin)	0.01	0.1
<b>Rushland</b>			<b>8.40</b>	<b>85.6</b>
	Leptocarpus similis (Jointed wirerush)		7.51	76.5
		Plagianthus divaricatus (Saltmarsh ribbonwood)	0.74	7.5
		Samolus repens (Primrose)	0.11	1.2
		Selliera radicans (Remuremu)	0.04	0.5
<b>Herbfield</b>			<b>0.23</b>	<b>2.3</b>
	Samolus repens (Primrose)	Selliera radicans (Remuremu)	0.23	2.3
<b>Macroalgal Bed</b>			<b>0.31</b>	<b>3.2</b>
	Gracilaria chilensis		0.31	3.2
<b>Grand Total</b>			<b>9.8</b>	<b>100</b>

<b>UNVEGETATED SUBSTRATA</b>			<b>Area</b>	<b>% of</b>
<b>Class</b>	<b>Dominant substrata</b>	<b>Primary Sub-dominant</b>	<b>(Ha)</b>	<b>Total</b>
<b>Rock field</b>			<b>0.26</b>	<b>0.1</b>
	Rockfield	Boulder field	0.26	0.1
<b>Boulder field</b>			<b>0.09</b>	<b>0.1</b>
	Boulder field	Cobble field	0.05	0.0
		Firm sand (<1cm)	0.04	0.0
<b>Cobble field</b>			<b>0.27</b>	<b>0.1</b>
	Cobble field		0.09	0.1
		Boulder Field man-made	0.15	0.1
		Rockfield	0.03	0.0
<b>Gravel field</b>			<b>1.07</b>	<b>0.6</b>
	Gravel field		0.70	0.4
		Boulder field	0.37	0.2
<b>Firm sand</b>			<b>82.22</b>	<b>45.8</b>
	Firm sand (<1cm)		81.74	45.6
		Boulder field	0.08	0.0
		Cobble field	0.40	0.2
<b>Firm mud/sand</b>			<b>78.38</b>	<b>43.7</b>
	Firm mud/sand (0-2cm)		78.38	43.7
<b>Soft mud/sand</b>			<b>16.58</b>	<b>9.2</b>
	Soft mud/sand (2-5cm)		16.58	9.2
<b>Very soft mud/sand</b>			<b>0.56</b>	<b>0.3</b>
	Very soft mud/sand (>5cm)		0.56	0.3
<b>Grand Total</b>			<b>179.4</b>	<b>100</b>

<b>OVERALL SUMMARY - Haldane Estuary</b>		<b>Area (Ha)</b>	<b>% of Total</b>
Water (subtidal)		16.6	8.1
Unvegetated Substratum		179.4	87.2
Estuarine Vegetation		9.8	4.8
<b>Grand Total</b>		<b>205.8</b>	<b>100</b>



**Figure 2** Broad structural habitat (vegetation and substrates) of Haldane Estuary, November 2004.

Where vegetation was the dominant cover, Rushland was most common (86%, 8.4 Ha), with *Leptocarpus similis* (Jointed wirerush) the dominant species. This was found mainly towards the northwest where the main river flows enter the estuary, as well as along the eastern margins, and extended beyond the estuary margins to stands dominated by *Leptocarpus*, ribbonwood, and flax. Two small islands located in the northeast of the estuary were characterised by a cover of *Leptocarpus* and herbfields containing *Selliera radicans*, “Remuremu” and *Samolus repens*, “Primrose”. Two very small patches of the introduced invasive cord grass *Spartina* were found and are marked on Figure 2. These patches were not large enough to be mapped (<2m coverage) but have been included as it may be possible to remove them before they become widely established.

On the eastern margin near the middle of the estuary, an excellent example was present of an intact sequence of estuarine species through to mature forest (Figure 3).



**Figure 3** Photo of a sequence of estuarine species through to mature forest within the Haldane Estuary, November 2004.

Overall, Haldane Estuary was somewhat unusual in that much of the vegetation surrounding the estuary was separated from the estuary itself by a sharp change in ground level. Figure 4 illustrates several examples from around the estuary including eroded banks, small cliffs or the road reclamation. These features are the primary reason that the overall vegetation cover for the estuary was relatively low with most of the surrounding vegetation considered terrestrial, rather than estuarine.

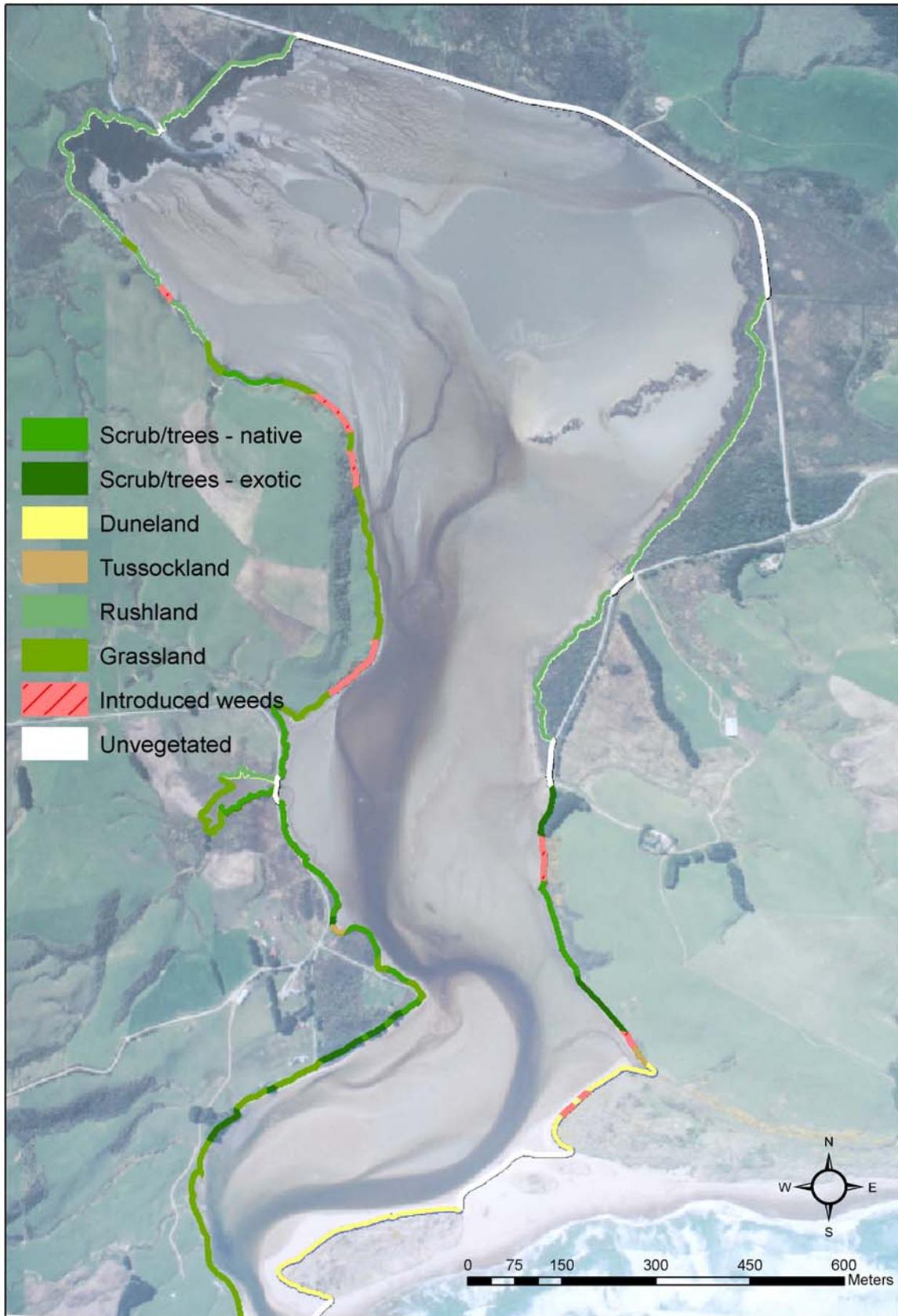


**Figure 4** Examples of vegetation separated from the estuary by changes in ground level.

The type of habitat immediately bordering the estuary is summarised in Table 3 and presented in Figure 5. Extensive modification of the land surrounding the estuary is evident through agricultural development – including drainage and bush clearance activities. Probably the most significant impact on the estuary has been the road around the estuary. The road has formed a barrier between the estuary itself and much of the low-lying surrounding land, particularly in the north and northeast of the estuary, and also the small arm of the estuary in the west. Where previously these areas would have been predominantly intertidal rushland, water flows are now very much reduced and the vegetation is dominated by freshwater tolerant plants, or has been drained and reclaimed as pasture.

**Table 3** Riparian habitat surrounding Haldane Estuary, November 2004.

<b>HABITAT BORDER</b>		
<b>Class</b>	<b>Dominant species</b>	<b>%</b>
<b>Scrub/trees - native</b>		<b>13.2</b>
	Native trees	11.7
	Leptospermum scoparium (Manuka)	1.5
<b>Scrub/trees - exotic</b>		<b>6.3</b>
	Cupressus macrocarpa	1.0
	Lupinus arboreus (Tree lupin)	1.7
	Pinus radiata (Pine tree)	3.5
<b>Duneland</b>		<b>6.1</b>
	Ammophila arenaria (Marram grass)	6.1
<b>Tussockland</b>		<b>0.9</b>
	Phormium tenax (New Zealand flax)	0.9
<b>Grassland</b>		<b>18.9</b>
	Unidentified grass	18.9
<b>Rushland</b>		<b>26.5</b>
	Leptocarpus similis (Jointed wirerush)	24.9
	Isolepis nodosa (Knobby clubrush)	1.6
<b>Introduced weeds</b>		<b>6.6</b>
	Ulex europaeus (Gorse)	6.6
<b>Unvegetated</b>		<b>21.5</b>
	Firm sand (<1cm)	4.9
	Road	15.9
	Water	0.7
<b>Grand Total</b>		<b>100</b>



**Figure 5** Habitat features surrounding Haldane Estuary, November 2004.

Despite the impact of the road, rushland was still the dominant habitat border, followed by grassland (farm pasture), and unvegetated areas (predominantly the road around the northeast of the estuary). Native and exotic scrub and trees were found mainly around the central margins of the estuary, while duneland was present only at the mouth of the estuary. Introduced weeds were predominantly gorse.

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: Haldane Estuary*”.

## 5. OVERVIEW

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

- Unvegetated habitat was dominated by firm sand (46%) and firm muddy sand (44%), with few areas of very soft mud.
- Estuarine vegetation was dominated by rushland, but much of the vegetation surrounding the estuary was separated from the estuary itself by a sharp change in ground level.
- Extensive modification of the estuary margin was evident through agricultural development – including drainage and bush clearance activities.

Overall this estuary appears to receive a relatively low level of sediment input, and there are no obvious indications of high nutrient loadings. The northwest of the estuary had the muddiest sediments and little vegetation buffering farmland from the estuary.

## 6. ACKNOWLEDGEMENTS

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## 7. REFERENCES

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