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Broad Scale Mapping of Motueka River Intertidal Delta Habitats using Historical Aerial Photographs

Prepared for

Tasman District Council

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by

Ben Tuckey, Barry Robertson and Rowan Strickland

Cawthron Institute
98 Halifax Street East
Private Bag 2
NELSON
NEW ZEALAND

Phone: +64.3.548.2319
Fax: +64.3.546.9464
Email: info@cawthron.org.nz

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This document is an accompanying report to the two CDs entitled 'Broad Scale Mapping of Motueka River Intertidal Delta Habitats using Historical Aerial Photographs'.

Report reviewed by:

Stephanie Thompson
Coastal Scientist

Approved for release by:

Dr Barry Robertson
Coastal and Estuarine Group Manager

1. INTRODUCTION

Estuaries are highly productive areas that play an important role as a boundary between land and sea. An estuary provides a link between terrestrial and marine ecosystems and nourishes the marine food web (Gillespie 1983). They can encompass high-value ecological habitat and resources of cultural, recreational and commercial importance.

In 2003, a detailed point-in-time, spatial description of major habitats of the Motueka River intertidal delta region was undertaken using a methodology known as broad scale mapping. The results of this investigation (Robertson *et al.* 2003) were reported as an output of the coastal component of the Motueka Integrated Catchment Management (Motueka ICM) Programme (FRST 2000-2002 Contract No. C09X0014).

The aim of broad scale habitat mapping is to describe the intertidal environment according to different dominant habitat types based on surface features of substrate characteristics (mud, sand, cobble, *etc*) and vegetation type (mangrove, eelgrass, salt marsh species, *etc*), in order to develop a baseline map (Robertson *et al.* 2002). 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. This procedure involves the use of aerial photography together with detailed ground-truthing and digital mapping using Geographical Information System (GIS) technology. An outline of the approach is provided in detail in Robertson *et al*. (2002) and in summary below.

Cawthron was commissioned by the Tasman District Council in 2004 to undertake historical broad scale mapping of the Motueka River intertidal delta. The purpose of the project was to use the recent broad scale maps produced as part of the Motueka Integrated Catchment Management (Motueka ICM) Programme as a guide, to produce broad scale maps using historical black and white aerial photos of the Motueka River intertidal delta region. Aerial photographs of the Motueka River intertidal delta region were obtained for the years 1947, 1977 and 1986. This report presents a brief outline of the methodologies, a summary of the dominant habitat types for each of the study years and two CD-ROMs containing the detailed habitat maps.

2. METHODS

2.1 Construction of recent broad scale maps

The methodologies used to construct recent broad scale maps for the estuary monitoring protocol are detailed in Robertson *et al.* (2002) and summarised below.

2.1.1 Aerial photography

The recent colour photograph used for the original Motueka estuary study (Robertson *et al.* 2003) was taken in June 2001 by New Zealand Aerial Mapping Ltd. and provided to us as a rectified tiff file at a scale of 1:10,000.

2.1.2 Classification of habitat features

The classification of the features followed the proposed national classification system (with adaptations), which was developed under a Ministry of 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;

- Level I: Hydrosystem (*e.g.* intertidal river delta)
- Level II: Wetland Class (*e.g.* saltmarsh, mud/sand flat, macroalgal bed)
- Level III: Structural Class (*e.g.* marshland, mobile sand, cobble)
- Level IV: Dominant Cover (*e.g. Leptocarpus similis*)

Substrate classification was based on surface layers only and did not consider underlying substrate; *e.g.* cobble or gravel fields covered by sand would be classed as sand flat. The classification of habitats in the current study was based on Level III and Level IV. A list of all the classification types used in the study and their codes are given in Table 1, followed by the definitions for classification of the Level III structural class. Further detail is provided in Section 3.

Table 1. Adapted estuarine components of UNEP-GRID classification

Level I Hydrosystem	**Level IA Sub-System**	**Level II Wetland Class**	**Level III Structural Class**	**Level IV Dominant Cover**	**Habitat Code**
River delta (alternating saline and freshwater)	Intertidal/ supratidal	Saltmarsh	Grassland	*Ammophila arenaria*, "Marram grass' *Elytrigia pycnanph*,, "Sea couch" *Festuca arundinacea*, "Tall fescue" *Paspalum distichum*, "Mercer grass"	Amar Elpy Fear Padi
			Herbfield	*Apium prostratum*, "Native celery" *Cotula coronopifolia* , "Bachelor's button" *Leptinella dioica* *Plantago coronopus*, "Buck's-horn plantain" *Samolus repens*, "Primrose" *Sarcocornia quinqueflora*, "Glasswort" *Selliera radicans*, "Remuremu" *Suaeda novae – zelandiae*, "Sea blite" *Triglochin striata*, "Arrow-grass"	Appr Coco Ledi Plco Sare Saqu Sera Suno Trst
			Reedland	*Glyceria maxima*, "Reed sweetgrass" *Spartina anglica*, "Cord grass" *Spartina alterniflora*, "Smooth cord grass" *Typha orientalis*, "Raupo"	Glma Span Spal Tyor
			Rushland	*Baumea juncea*, " Bare twig rush" *Isolepis nodosa*, "Knobby clubrush" *Juncus artoiculatus*, "Jointed rush" *Juncus effuses*, "Softrush" *Juncus kraussii*, "Searush" *Juncus pallidus*, " Pale rush" *Leptocarpus similis*, "Jointed wirerush" *Wilsonia backhousei*	Baju Isno Juar Juef Jukr Jupa Lesi Wiba
			Sedgeland	*Cyperus eragrostis*, "Umbrella sedge" *Cyperus ustulatus*, "Giant umbrella sedge *Eleocharis sphacelata*, "Bamboo spike-sedge" *Isolepis cernua*, "Slender clubrush" *Schoenoplectus pungens*, "Three-square"	Cyer Cyus Elsp Isce Scpu
			Scrub	*Avicennia marina var. resinfera*, "Mangrove" *Cordyline australis*, "Cabbage tree" *Cytisus scoparius*, "Broom" *Leptospermum scoparium*, "Manuka" *Plagianthus divaricatus*, "Saltmarsh ribbonwood" *Ulex europaeus*, "Gorse"	Avre Coau Cysc Lesc Pldi Uleu
			Tussockland	*Cortaderia* sp., "Toetoe" *Phormium tenax*, "New Zealand flax" *Poa cita*, "Silver tussock" *Puccinella stricta*, "Salt grass" *Stipa stipoides*, "Needle tussock"	Co sp Phte Poa Pust Stst
		Seagrass meadows	Seagrass meadow	*Zostera* sp., "Eelgrass"	Zo sp
		Macroalgal bed	Macroalgal bed	*Enteromorpha* sp. *Gracilaria chilensis* *Ulva* sp., "Sea lettuce"	En sp Grch Ulri

Table 1 continued.

Level I Hydrosystem	Level IA Sub-System	Level II Wetland Class	Level III Structural Class	Level IV Dominant Cover	Habitat Code
		Mud/sandflat	Firm shell/sand (<1cm)		FSS
			Firm sand (<1cm)		FS
			Soft sand		SS
			Mobile sand (<1cm)		MS
			Firm mud/sand (0-2cm)		FMS
			Soft mud/sand (2-5cm)		SM
			Very soft mud/sand (>5cm)		VSM
		Stonefield	Gravel field		GF
			Cobble field		CF
		Boulderfield	Boulder field		BF
		Rockland	Rockland		RF
		Shell bank	Shell bank		Shell
		Shellfish field	Cocklebed		Cockle
			Musselreef		Mussel
			Oysterreef		Oyster
		Worm field	Sabellid field		Sabellid
	Subtidal	Water	Water		Water

2.1.3 Ground-truthing of habitat features

Field surveys were undertaken at the estuary to verify photography, and identify dominant habitat and map boundaries. The approach involved an experienced estuarine scientist plus a technician walking over the whole estuary at low-mid tide, identifying the dominant habitats and their boundaries and recording these as codes on aerial images at a scale of approximately 1:5,000 or 1:10,000. The upper boundary was set at MHWS (Mean High Water Spring); however in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal. The lower boundary was set at MLWS (Mean Low Water Spring). The substrate types and their spatial extents were confirmed by field verification of the textural and tonal patterns identified on the aerial photographs. The codes and list of dominant habitat types, including various categories of bare and vegetated substrate, are shown in Table 1.

2.1.4 Digitisation of habitat boundaries

Vegetation and substrate features were then digitally mapped on-screen from the rectified photographs using the Arcview™ 3.2 software package 'image analysis' extension. This procedure required using the mouse to draw habitat boundaries overlaid on rectified aerial photographs on the computer screen, as precisely as possible, around the features identified from the field surveys. Each drawing was then saved to a shape file or GIS layer associated with each specific feature. To calculate the area cover for a chosen habitat type, the Arcview™ 'X-tools' extension was used. This provided the area of any selected features in hectares.

2.2 Construction of historical broad scale map

All of the historical Motueka broad scale mapping study was performed on the latest update of the Arcview™ 3.2 software package, Arcview™ 8, for the remainder of the report referred to as ArcMap™.

2.2.1 Black and white aerial photography

The 1940s historical photograph used for the Motueka study was taken on March 27 1947, supplied by New Zealand Aerial Mapping Ltd., and was provided as a black and white tiff file at a scale of 1:18,000. The tiff file had been rectified. The 1970-80s historical photographs used for the Motueka study were supplied by GeoSmart as black and white tiff files, one taken on July 2 1986 at a scale of 1:18,000 and one taken on July 12 1977 at a scale of 1:25,000. A combination of different scale photographs was required as the higher resolution photos did not include the whole area of the intertidal delta required. The resolution of the 1977 photograph was not adequate to justify performing a historical survey for 1977 instead of 1986. The tiff files from GeoSmart had not been rectified.

2.2.2 Rectification of tiff files

The tiff files were rectified within ArcMap™ using a geo-referencing tool. Several features common to both the historical photographs (tiff files) and the rectified images used to generate the recent broad scale maps were located (*i.e.* the corner of a house or intersection of roads). These locations became control points. Using geo-referencing tool within ArcMap™, the locations within the historical photographs (tiff files) corresponding to the control points created from the rectified images were matched. Once the images were matched, the tiff files were saved as rectified tiffs.

2.2.3 Digitisation of habitat boundaries

As previously described in Section 2.1.4, vegetation and substrate features were then digitally mapped on-screen from the rectified photos. The shape files produced by the recent broad scale survey in ArcView™ 3.2 are directly compatible with ArcMap™. Wherever possible, these shape files generated from the recent broad scale maps were manipulated so that they corresponded to the habitat boundaries of the historical photograph. To calculate the area cover for a chosen habitat type, a macros developed by Paul Barter (Cawthron Institute) was used. This gave the area of any selected features in hectares.

2.2.4 Limitations of methodology

Historical photographs, particularly the earlier ones, were of a poor quality (the photographs were black and white and the resolution was low) and consequently the definition of the boundaries in the mapping process was unclear. In particular, it was difficult to distinguish categories within the unvegetated habitat from historical photographs without ground-truthing. Consequently, the extent of soft muds, cobbles, sands *etc.* in the estuary in earlier years was not mapped but the overall boundary of these habitats were easily apparent.

The limitation in accurately identifying and mapping vegetated cover species from historical photographs was the justification for only presenting the structural habitats on the broad scale habitat maps in this report. Although dominant cover species could be estimated in many instances, the inability to ground-truth these habitats meant that the limit of resolution was more appropriately set to structural habitats (*e.g.* rushland, reedland) rather than including probable dominant cover (*e.g. Leptocarpus similis*). However, the estimated dominant cover habitat maps were included on the CD-ROMs, as this detail may be relevant for specific areas of the estuary.

In addition, there was evidence from the earliest photographs of the Motueka intertidal delta region, that reclamation of a portion of the tidal flats had occurred, but because the vegetation buffer between estuary and agricultural land was larger and identification of vegetation difficult, the boundary between land and estuary was blurred. This made locating habitat boundaries difficult as there was less range in tone and texture compared with the colour photographs used for the recent broad scale maps. In vegetation patches where more than one type of vegetation was dominant, it was often difficult to distinguish between the different types of vegetation. When this problem could not be resolved, as a last resort instead of having two shape files relating to two different dominant habitats (*i.e. Leptocarpus similis* and *Juncus krausii*), one shape file was created encompassing both of the habitats. It is inevitable that in situations where judgement calls are required, there is the possibility of introducing errors.

3. CLASSIFICATION AND DEFINITIONS OF HABITAT TYPES

3.1 Habitat codes and terminology

The identified vegetation patches were classified using an interpretation of the Atkinson (1985) system (Table 1), described below:

- The individual plant species have been coded by using the two first letters of their Latin species and genus names *e.g.* Pldi = ribbonwood, *Plagianthus divaricatus*.
- / separates canopy vegetation *e.g.* Pldi/Lesi (ribbonwood is taller than jointed wire rush).
- \- separates vegetation with approximately the same height *e.g.* Lesi-Jukr (jointed wire rush is the same height as searush).
- ( ) are used for subdominant species *e.g.* (Pldi)/Lesi = dominant cover is jointed wire rush and subdominant cover is ribbonwood. The use of ( ) is not based on percentage cover but the subjective observation of which vegetation is the dominant or subdominant species within the patch.
- The classification always starts with the tallest vegetation type and works down *e.g.* (Pldi/Baju)/Lesi-Jukr = a patch with a dominant cover of jointed wire rush and searush (which are of the same height) with a subdominant cover of ribbonwood and *Baumea juncea* (which are taller than the dominant cover).

3.2 Definitions of Classification Level III Structural Class

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.

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 lacutris, Eleocharis sphacelata,* and *Baumea articulata.*

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.

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. Included in the sedge growth form are many species of *Carex, Uncinia,* and *Scirpus.* Tussock-sedges and reed-forming sedges (c.f. REEDLAND) are excluded.

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).

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 > 10 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.*

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 ≥ 10cm dbh are treated as trees.

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 occassionally 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 that can be seen without the use of 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.

Stonefield/gravelfield: 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. The appropriate name is given depending on whether stones or gravel form the greater area of ground surface. Stonefields and gravelfields are named from the leading plant species when plant cover of ≥ 1%.

Boulderfield: 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 ≥ 1%.

Rockland: 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 ≥1%

Cocklebed: Area that is dominated by primarily dead cockle shells.

Musselreef: Area that is dominated by one or more mussel species.

Oysterreef: 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

4.1 1947 Habitat Map

Refer to Figure 1, Figure 2, Figure 3 and Figure 4 and Table 2. The 1947 broad-scale habitat map featured a total estuary area of 797 ha, of which unvegetated substrate and water were dominant (86.3% of total estuary area, covering 687 ha). Rushland was the most abundant vegetation (7.1% of the total estuary area, covering 57 ha), of which *Leptocarpus similis* (6.1% of the total estuary area) was likely to be dominant, with smaller areas of *Juncus kraussii* and *Isolepis nodosa*. Subdominant species in mixed rushland likely included the herbfield species *Sarcocornia quinqueflora, Selliera radicans* and *Samolus repens*, the sedge *Isolepis cernua* and *Schoenoplectus pungens*. Scrubland (*Plagianthus divaricatus,* ribbonwood) accounted for 3.5% of the total vegetated area, and was likely mixed with the grass *Festuca arundinacea*, rushland *Juncus*, *Leptocarpus* and herbfield species *Sarcocornia* and *Samolus.* Areas where herbfield dominated (predominantly *Sarcocornia* with some *Samolus*) accounted for 3.1% of the total vegetated area. There was also a small area of macroalgae, likely in the form of mixed beds of *Ulva* and *Gracilaria*.

4.2 1986 Habitat Map

Refer to Figure 1, Figure 2, Figure 5 and Figure 6 and Table 2. The 1986 broad-scale survey featured a total estuary area of 756 ha of which unvegetated substrate and water were dominant (91.0% of estuary area, covering 687 ha). Again rushland was the most abundant vegetation (3.8% of the total estuary area, covering 29 ha) of which *Leptocarpus similis* (2.5% of the total estuary area) was dominant, with *Juncus kraussii* and *Isolepis nodosa* forming smaller patches. Rushland habitat (namely *Leptocarpus*) had decreased substantially, as there was approximately half the 1947 extent of rushland in the estuary in 1986. Subdominant species within the rushland likely included the herbfield species *Sarcocornia quinqueflora, Selliera radicans* and *Samolus repens*, the sedge *Isolepis cernua* and *Schoenoplectus pungens*, and the “sea couch” grass *Elytrigia pycnamph*. Herbfields were very similar to 1947, covering 3.4% of the total estuary area (26 ha), with *Sarcocornia quinqueflora* still the dominant species (3.1% of the total estuary area). The extent of *Plagianthus divaricatus* scrubland had decreased compared to 1947. Scrubland was still often mixed with smaller areas of *Leptocarpus, Juncus, Festuca* and herbfield species). There was a minor area containing a macroalgal bed (likely a combination of *Ulva* and *Gracilaria*).

4.3 2001 Habitat Map

Refer to Figure 1, Figure 2 and Table 2. The most recent broad-scale habitat map produced by Robertson *et al.* (2003) estimated the total estuary area to be 756 ha, of which unvegetated substrate and water were dominant (91.7% of estuary area, covering 704 ha). Herbfield had changed very little in extent over the three habitat maps, and was now the most abundant vegetation (3.52% of the total estuary area, covering 27 ha) of which *Sarcocornia quinqueflora* (3.1% of the total estuary) was dominant. Rushlands accounted for 3.0% of the total estuary area which *Leptocarpus similis* was the dominant species, along with smaller areas of *Juncus kraussii*. There were also minor areas containing scrubland (*Plagianthus divaricatus,* ribbonwood) and macroalgal beds. Further detail can be found in Robertson *et al.* (2003).

Table 2. The broad-scale details of the habitat mapping of the Motueka intertidal delta.

	1947		**1986**		**2001**	
	Area (ha)	**% Total Area**	**Area (ha)**	**% Total Area)**	**Area (ha)**	**% Total Area**
Scrubland	**27.62**	**3.47**	**7.62**	**1.01**	**9.93**	**1.31**
Plagianthus divaricatus	27.62	3.47	7.62	1.01	9.93	1.31
Rushland	**56.99**	**7.14**	**28.64**	**3.79**	**22.38**	**2.96**
Juncus kraussii	6.00	0.75	8.40	1.11	5.95	0.79
Leptocarpus similis	48.40	6.07	18.76	2.48	16.37	2.16
Isolepis nodosa	0.01	0.00	0.29	0.04	0.06	0.01
Juncus kraussii – Leptocarpus similis	2.58	0.32	1.19	0.16	0	0
Reedland	**0.43**	**0.05**	**0.39**	**0.05**	**0.33**	**0.04**
Typha orientalis	0.43	0.05	0.39	0.05	0.33	0.04
Grassland	**0**	**0**	**0**	**0**	**0.23**	**0.03**
Festuca arundinacea	0	0	0	0	0.23	0.03
Herbfield	**24.35**	**3.06**	**25.52**	**3.38**	**26.60**	**3.52**
Sarcocornia quinqueflora	24.20	3.04	23.27	3.08	23.29	3.08
Samolus repens	0.15	0.02	2.25	0.30	3.19	0.42
Selliera radicans	0	0	0	0	0.10	0.01
Macroalgal Bed	**3.64**	**0.46**	**6.24**	**0.83**	**3.47**	**0.46**
Entermorpha sp	0	0	0	0	0.04	0.01
Ulva rigida - Gracilaria chilensis	3.64	0.46	6.24	0.83	3.43	0.45
Unvegetated + Water	**687.50**	**86.27**	**687.21**	**90.95**	**703.50**	**91.68**
Total Area of Estuary	**796.90**		**755.62**		**756**	

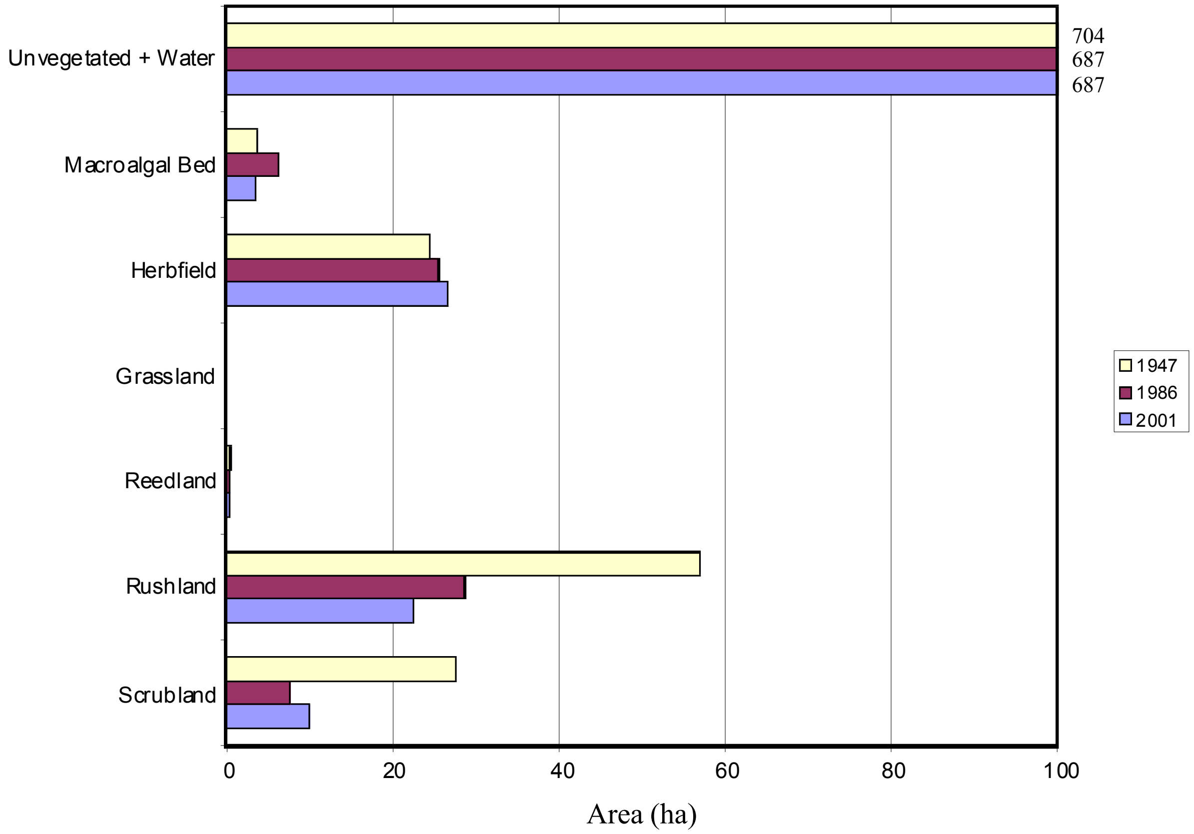

Figure 1. The areas of selected structural class habitats of the Motueka intertidal delta across the surveys.

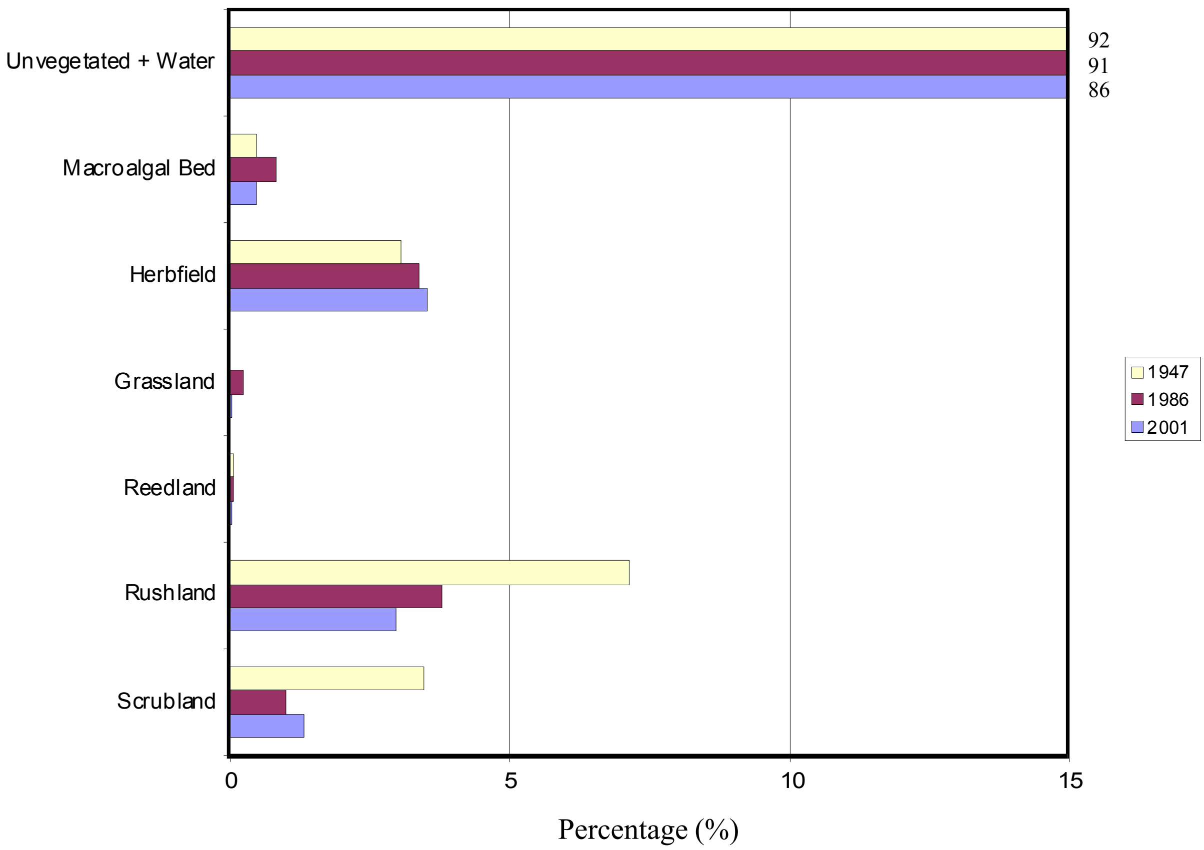

Figure 2. The percentage of selected structural class habitats of the Motueka intertidal delta across the surveys.

Figure 3. Estuary boundary (red line) for Motueka intertidal delta – 1947.

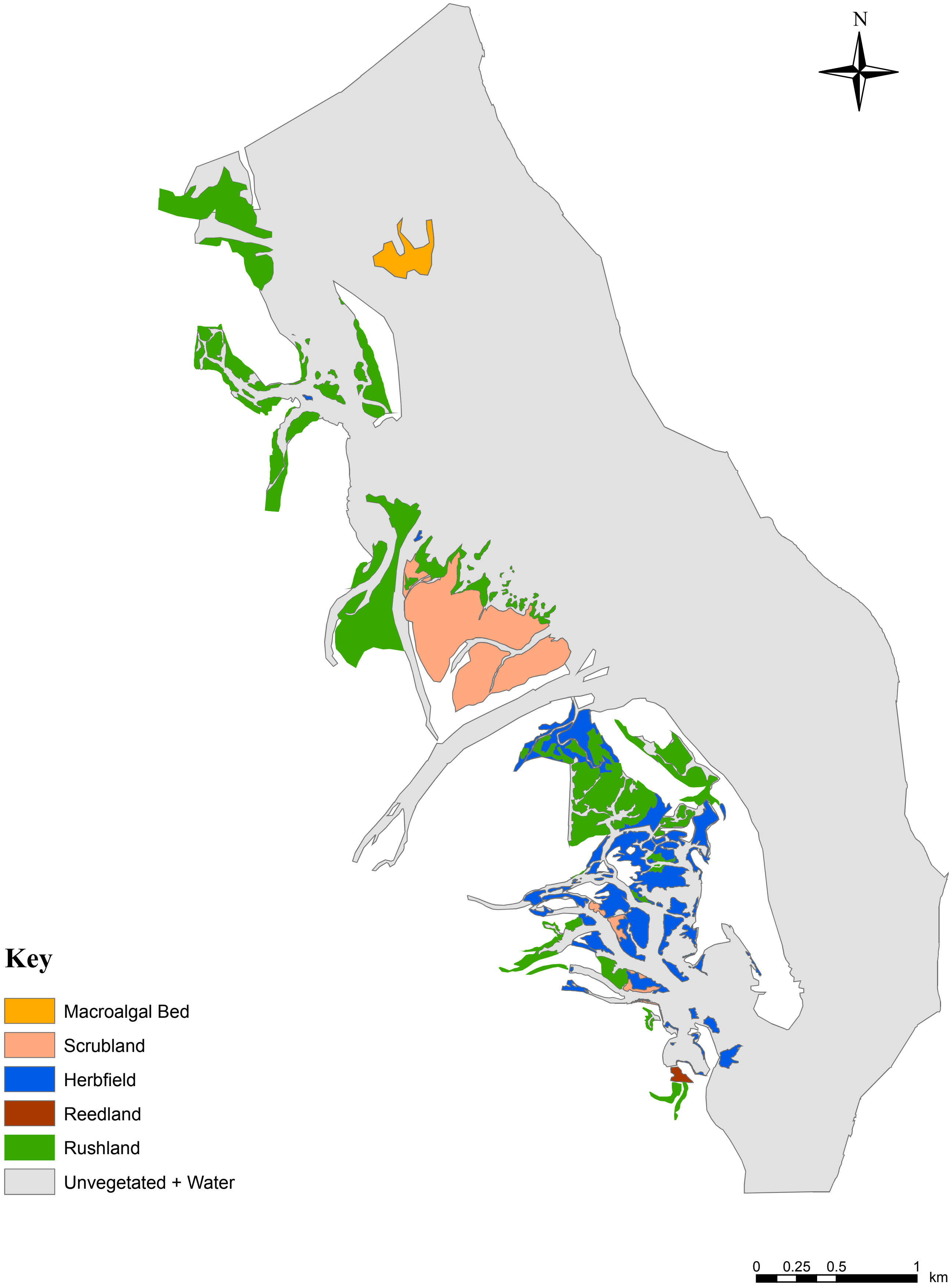

Figure 4. Estimated structural habitat of the Motueka intertidal delta – 1947.

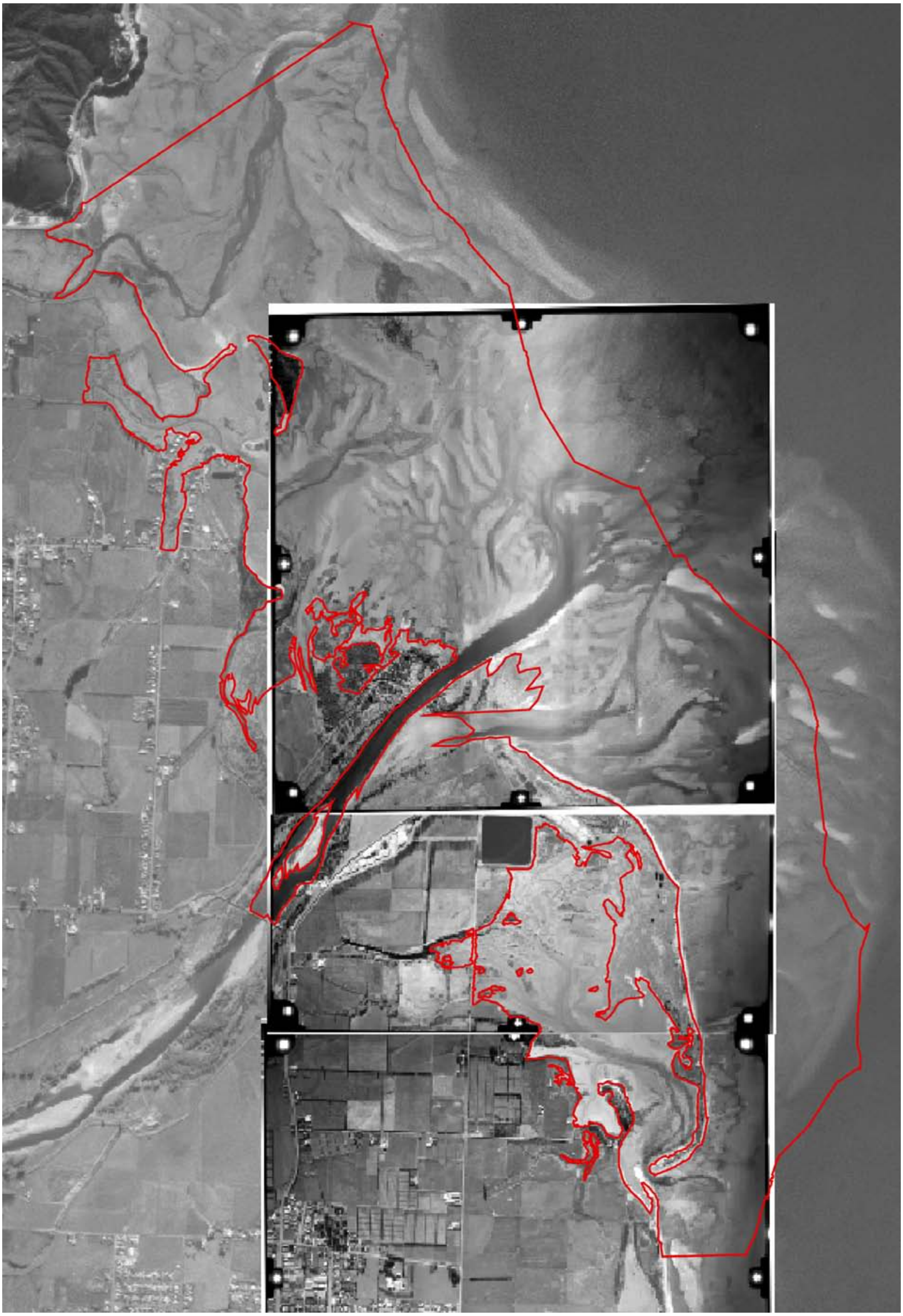

Figure 5. Estuary boundary (red line) for Motueka intertidal delta – 1986.

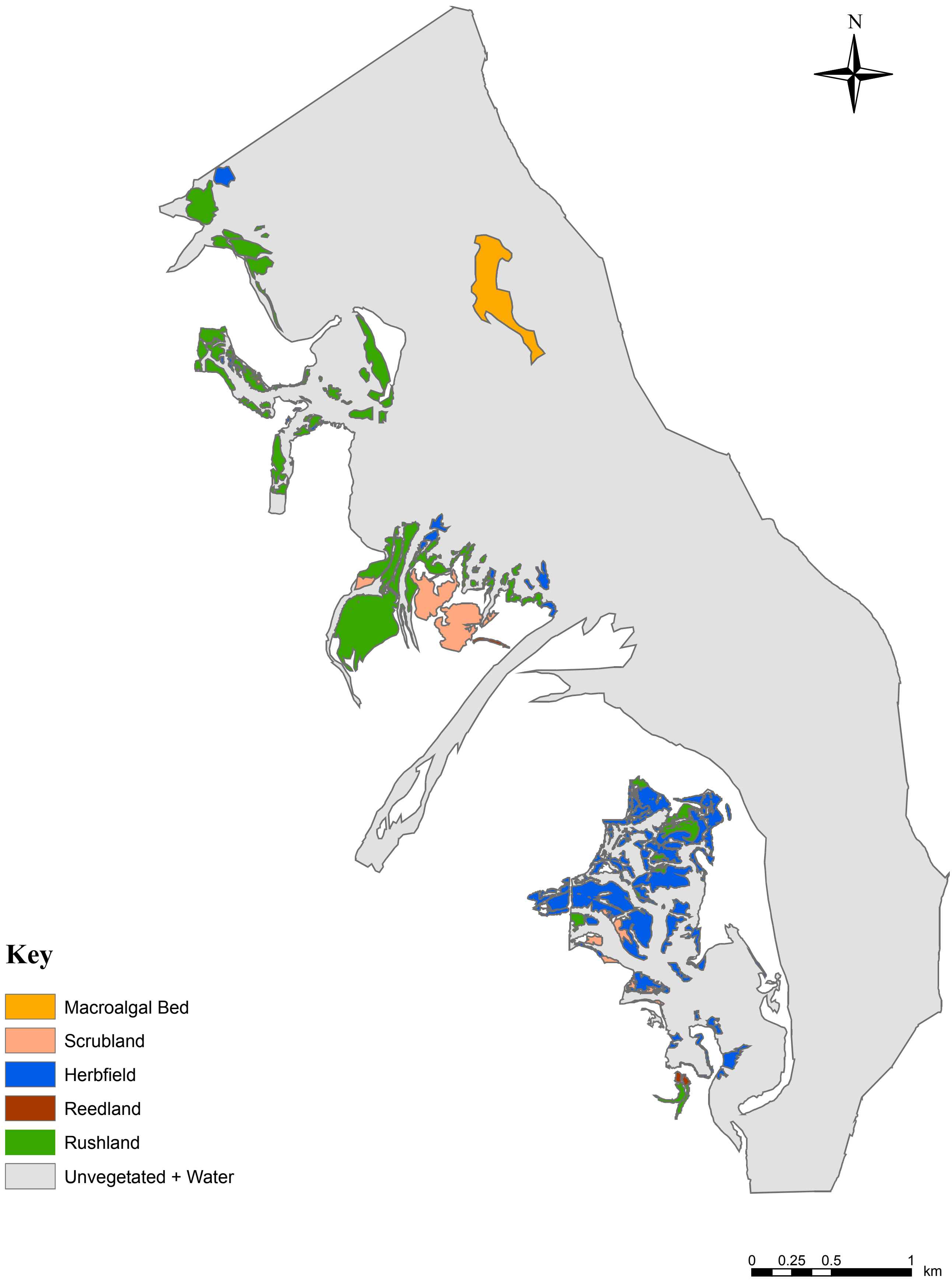

Figure 6. Estimated structural habitat of the Motueka intertidal delta – 1986.

5. DISCUSSION

In overview, the results of the historical broad scale mapping of the Motueka delta/estuary show that there have been significant broad scale changes to habitat over the period 1947 to present. The main changes are as follows:

- The total area of the estuary decreased by approximately 50 ha in the period 1947 to 1986. Since 1986, the area has altered very little. It is also noted that the 1947 aerial photograph suggested that prior to 1947 there had already been significant alteration of delta habitat, possibly in the order of 200-300 ha.
- The reduction in area has occurred primarily in the vegetated upper intertidal to supra-tidal margin around the estuary (rushland 28 ha loss and scrubland 20 ha loss). Alteration to other vegetated habitat (*e.g.* herbfields and grassland) has likely been at a much smaller scale.

The key habitat types included in this loss are as follows:

- Unvegetated tidal channels
    - Cobble/gravel channels
    - Mud/sand channels
- Vegetated tidal flats
    - Salt marsh herbfields (e.g. glasswort),
    - Rushland (jointed wire rush) and
    - Scrubland (saltmarsh ribbonwood) vegetation.
- Unvegetated tidal flats
- Freshwater inputs

The changes are almost certainly the direct result of drainage, flood control and reclamation works for agricultural purposes. In particular, the combined action of stopbanks, drainage works, realignment and floodgates on almost all the small streams entering the original delta area has resulted in the reduction and obstruction of tidal flows and a consequent loss of estuarine habitat.

Such habitat is widely acknowledged to have high value in terms of both marketable and non-marketable goods and services. For example, an ecosystem services valuation of all the ecosystem types in the world (Costanza *et al.* 1997) found that estuaries had the highest value and salt marshes contributed significantly to this value. High on the list of ecosystem services provided by estuaries is nutrient recycling, disturbance regulation, breeding and nursery grounds for biota (including fish), sediment retention, habitat for resident and transient populations, point and non-point source waste treatment, water regulation, food production, recreation and cultural.

The sediment retention (and its associated nutrient retention) service is particularly important in relation to the Motueka delta/estuary. The most recent estuary habitat map (Robertson *et al*. 2003) shows the Motueka to have a very low percentage of muddy sediments (< 8% of estuary area) compared to typical NZ estuaries (Robertson *et al.* 2002). Such a characteristic signifies an estuary with a low capacity to retain the fine river-borne sediments.

The efficiency of sediment trapping within the estuary depends on the capacity of an estuary in relation to the rate of sedimentation and energy available for transport. If these are not in balance, either trapping or by-passing occurs. Given that the trapping ability of the estuary has been significantly reduced through past drainage activities and consequent wetland habitat loss, the majority of fine sediments now bypasses the estuary and settles offshore in Tasman Bay. A recent subtidal sediment survey offshore of the Motueka delta confirms this deposition pattern (Gillespie *et al*. 2004 in press). An obvious consequence of this reduction in nutrient retention is a lowered productivity within the estuary (including fish) and an enhancement offshore.

The extent to which the estuary fisheries have been affected by the loss in estuary habitat is explored in the following section.

6. IMPACTS ON FISH AND FISH HABITAT

6.1 Purpose

The purpose of this discussion is to provide a preliminary indication of the likely impacts of the historical habitat changes to fish life in the Motueka estuary. This has been achieved by identifying the fish species likely to utilise the Motueka estuary (based on species records both from within and outside the catchment), and the likely impact to these species through the recorded habitat changes.

6.2 Fish and fish habitat utilisation

Fish likely to utilise the various habitats found through the estuarine reach of the Motueka River are divided into two groups: freshwater fish and marine wanderers.

Freshwater fish: Of the 35 freshwater fish in New Zealand (McDowall 2000) 21 have been recorded in the Motueka catchment (New Zealand Freshwater Fish Database - NZFFD). Thirteen of these fish have a marine phase in their life cycle, thus requiring them to migrate up or down rivers and in and out of the sea. On the basis of their recorded presence in either the Motueka catchment or other Tasman Bay rivers, 15 species have been included in the list of freshwater fish predicted to utilise the Motueka estuary (Table 3) as well as the likely habitats they occupy. It is emphasized however that only a few of these freshwater species are likely to utilise the estuary as more than just a migratory pathway.

Marine wanderers

A number of marine fish species utilise estuaries to feed, spawn and rear their juveniles however how many and for what reasons is not well known. A study of the nearby Waimea Inlet recorded 31 marine species (Davidson & Moffat 1990). Given the comparative extent of the Waimea Inlet it is perhaps not appropriate to suggest that the same species richness could be expected in the Motueka estuary. Nevertheless they are included in Table 3 as an indication of the Motueka estuary's likely past species richness as well as the likely habitats they occupy. Again however it is emphasized that many of the marine wanderers only likely to visit the estuary occasionally.

Table 3. Fish species that utilise the Motueka estuary and habitat utilisation (Bold = common in estuary; P = present).

Freshwater Fish*	Scientific Name	FW Inputs	Cobble/gravel tide channels	Mud/sand tide channels	Vegetated flats	Exposed flats
FRESHWATER FISH*						
Common smelt	***Retropinna retropinna***	***P***	***P***	***P***		
Inanga	***Galaxias maculatus***	***P***	***P***	***P***		
Common bully	***Gobiomorphus cotidianus***	***P***	***P***	***P***		
Giant bully	***Gobiomorphus gobioides***	***P***	***P***	***P***		
Black flounder	***Rhombosolea retiaria***	***P***	***P***	***P***	***P***	***P***
Shortfin eel	***Anguilla australis***	***P***	***P***	***P***	***P***	***P***
Lamprey	*Geotria australis*	*P*	*P*	*P*		
Longfin eel	*Anguilla dieffenbachii*	*P*	*P*	*P*		
Giant kokopu	*Galaxias argenteus*	*P*	*P*	*P*		
Banded kokopu	*Galaxias fasciatus*	*P*	*P*	*P*		
Shortjaw kokopu	*Galaxias postvectis*	*P*	*P*	*P*		
Koaro	*Galaxias brevipinnis*	*P*	*P*	*P*		
Torrentfish	*Cheimarrichthys fosteri*	*P*	*P*	*P*		
Redfin bully	*Gobiomorphus huttoni*	*P*	*P*	*P*		
Bluegill bully	*Gobiomorphus hubbsi*	*P*	*P*	*P*		
MARINE WANDERERS**						
Yellowbelly flounder	***Rhombosolea leporina***			***P***	***P***	***P***
Sand flounder	***Rhombosolea plebeia***			***P***	***P***	***P***
Common sole	***Peltorhamhus novaezealandiae***			***P***	***P***	***P***
Witch	***Arnnoglossus scapha***			***P***	***P***	***P***
Yelloweye mullet	***Aldrichetta fosteri***	***P***	***P***	***P***	***P***	***P***
Grey mullet	***Mugil cephalus***	***P***	***P***	***P***	***P***	***P***
Stargazer	***Leptoscopus macropygus***			***P***	***P***	***P***
Cockabully	***Grahamina nigripenne***		***P***	***P***	***P***	***P***
Kahawai	***Arripis trutta***		***P***	***P***		***P***
Garfish	***Reporhamphus ihi***		***P***	***P***	***P***	***P***
Seahorse	***Hippocampus abdominalis***		***P***	***P***	***P***	***P***
Spotty	***Pseudolabrus celidotus***		***P***	***P***		***P***
Jack mackerel	***Trachurus novaezelandiae***		***P***	***P***	***P***	***P***
Blue shark	*Prionace glauca*		*P*	*P*		*P*
Bronze whaler	*Carcharinus brachyurus*		*P*	*P*		*P*
Hammerhead shark	*Sphyrna*		*P*	*P*		*P*
Spiny dogfish	*Squalus spp.*		*P*	*P*		*P*
Rig	*Mustelus lenticulatus*		*P*	*P*		*P*
Eagle ray	*Myliobatis tenuicaudatis*		*P*	*P*		*P*
Pilchard	*Sardinops neopilchardus*		*P*	*P*		*P*
Anchovy	*Engraulis australis*		*P*	*P*		*P*
Red cod	*Pseudophycis bacchus*		*P*	*P*		*P*
Gurnard	*Chelidonichthys kumu*		*P*	*P*		*P*
Rockfish	*Acanthoclinus fuscus*		*P*			*P*
Trevally	*Caranx lutescens*		*P*	*P*		*P*
Kingfish	*Seriola grandis*		*P*	*P*		*P*
Snapper	*Chrysophrys auratus*		*P*	*P*		*P*
Tarakihi	*Nemadactylus macropterus*		*P*	*P*		*P*
Barracouta	*Thyrsites atun*		*P*	*P*		*P*
Blue mackerel	*Scomber australasicus*		*P*	*P*		*P*
Pufferfish	*Contusus richei*		*P*	*P*		*P*

* All recorded upstream of the Motueka estuary in the NZFFD except short-jawed kokopu and black flounder (the latter 2 species presence based on ** below.

** Predicted to utilise the Motueka estuary based on habitat availability and fish distribution elsewhere in Tasman Bay.

6.3 Impacts of habitat modification

6.3.1 Freshwater inputs up to spring high tide influence

Other than the main channel of the Motueka River, all freshwater inputs are controlled by some form of floodgate and other forms of flood control (stopbanks and chanelisation). There appears to be no tidal influence in the reaches immediately above the more effective floodgates. At least 15 freshwater fish species require passage past these structures. Tidal flap-gates are designed to open only when there is sufficient head of water behind them to open the gate as the tide drops. Once the head is lowered the gates close. This means that for a migratory fish wanting to get past this structure there is only a small opportunity in which to make a break through the opening. In many cases the velocities generated at these outlets are more than most of the migratory species can cope with. It is therefore not difficult to imagine the adverse impact that such structures have on freshwater fish species richness and abundance upstream, though the extent of this impact is not well understood. Other species that do not have such an upstream migratory urge, but would normally wander to and from all habitats in the estuary at each tide change, are segregated from upstream habitats by flap-gates. Apart from the issue of fish passage, flap-gates alter tidal dynamics and effectively shorten one habitat type (below the flap-gate) and alter the other from a brackish to a freshwater habitat (above the flap-gate).

Figure 7. Flap-gates such as these effectively exclude migratory freshwater fish from reaching habitat above these structures.

Flap-gates are usually installed where stopbanking is carried out to assist drainage and development of land for agriculture, horticulture or urban development. In many circumstances estuarine margins are reclaimed for such development. Another process that takes place along with stopbanking is draining of associated wetlands and confinement of flows to drainage canals.

Figure 8. Stopbanking and drains – both confine estuarine and freshwater input habitats.

Freshwater input habitats are better known for their importance as inanga spawning habitats. During late summer months inanga spawn in vegetation flooded at spring high tides where such habitats coincide with a zone at the upstream limit of the saltwater wedge. On successive spring tides the eggs hatch and larvae migrate downstream and out to sea with the receding tide to return approximately five months later as whitebait.

Modification of this habitat severely impacts inanga since it is an annual fish and successful reproduction is governed not only by its short life span but also by the limited and vulnerable area available for it to spawn. As mentioned, tidal floodgates modify the natural tidal process that is critical as a cue for adult spawners and as a mechanism to facilitate spawning, egg hatching, the passive out-migration of larvae and the upstream migration of whitebait. Another impact is the modification and disturbance of the vegetation at inanga spawning sites and the loss of adult rearing in these habitats and upstream.

Other fish are also found in this habitat but the reason for their choice of this habitat is not well known. Without understanding the full impact of habitat modification on these species, it would be safe to say that any limitation on access and reduction in area will deplete their number. Such species are: shortfin eel, common bully, black flounder and common smelt. In addition to the resident species in this habitat, all other freshwater species listed in Table 3 require migratory access through this habitat, either on their way to or from the sea. While it is reasonable to postulate that floodgates have an impact on these fish, the degree of this impact is not understood.

Figure 9. Examples of flap-gate controlling freshwater inputs. The grass margins along the stream at left have potential for inanga spawning but the flap-gates are likely to severely limit spawning success. The picture at right is a less modified example but still limited as fish habitat because of the flap-gate immediately downstream of it.

6.3.2 Cobble and gravel armoured tidal channels

These channels are an extension of the freshwater input habitats. What makes them different is that they are subject to tidal influence. This habitat type is more clearly separated at its upstream limit by tidal flood-gates. In a channel without tidal control such as the mainstem of the Motueka River this separation is not so obvious. Fish found utilising these habitats are generally freshwater species such as: inanga, shortfin eel, common bully, black flounder and common smelt. At high tide, any of the marine wanderers listed in Table 3 also could be found in these habitats, though most commonly these would be yelloweye mullet.

At the upstream limit of some of these habitats it is possible that inanga find areas to spawn where the right mix of freshwater spring tidal influence occurs in conjunction with suitable riparian vegetation. More often than not these are the very locations that tidal flap-gates have been placed.

Figure 10. Cobble and gravel armoured tidal channels seen here at low tide. The upstream limits of these habitats are separated by flap-gates as shown on right.

6.3.3 Mud/sand tidal channels

Most of these habitats are also extensions of freshwater inputs and in such cases are separated by tidal flood-gates. Freshwater fish occupying these habitats are likely to be confined to giant bully, shortfin eel and shoaling species such as inanga and smelt. Marine wanderers such as flounder and yelloweye mullet are likely to persist at all tides, but could be joined by any number of those listed in Table 3 at high tide.

In the same way that the cobble and gravel tidal channels provide some inanga spawning opportunity at their upstream limits, so do these mud/sand channels. An area of suitable grasses for inanga to spawn is depicted in Figure 11.

Figure 11. Mud/sand tidal channels. Grasses suitable for inanga to spawn are seen in the centre of the photo at right – this vegetation would only be inundated at spring tide.

6.3.4 *Vegetated tidal flats*

These habitats are the marshland flats that are bisected by numerous tidal channels and characterised by vegetation that is inundated at high tide and often left exposed at low tide. Fish occupying these habitats are mostly the marine wanderers, but how they utilise these habitats is not well understood.

Figure 12. Vegetated tidal flats – dominated by saltmarsh ribbonwood, sea-rush and jointed wire rush.

6.3.5 *Exposed tidal flats*

Exposed tidal flats in the Motueka estuary can be mud, sand, cobble/gravel or a mixture of all three. These habitats are utilised by fish listed in Table 3 as marine wanderers. At full tide, it is not uncommon to see yelloweye mullet and kahawai feeding in these habitats, but the extent and purpose for which these habitats are used by these and other fish species is not well known.

Figure 13. Exposed tidal flats at the entrance to the Kumeras.

The scope for restoration

Modifications such as drainage, stopbanking and flapgates that have taken place in and around the Motueka estuary have altered, reduced and confined the estuary from a wild and dynamic delta to a very modified and tamed outflow with some estuarine components that are unlikely to represent the original estuary. The effect of these modifications on fish is that their available habitat has been reduced and the occurrence of many of the natural processes that may have once supported a diverse and different ecosystem and fish community have been removed or altered. For example, rather than an extensive floodplain with wetlands and varying successions of flora and fauna communities, the estuary now has very defined limits and flow channels and stable vegetated areas.

Given the development that has taken place around the Motueka estuary, attempting to restore it to its former landscape would be difficult if not impossible and would possibly be at conflict with community aspirations. However, some of the lower Motueka River's former values could be restored or enhanced with some imaginative and adaptive management. An example of this would be the installation of control structures that both protect productive land from flooding but also allow better fish access.

7. REFERENCES

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8. BROAD SCALE MAPPING OF MOTUEKA RIVER DELTA USING HISTORICAL PHOTOGRAPHS COMPACT DISKS (CDS) AND FILE INSTALLATION PROCEDURES

Details on setting up, viewing and contents of the two accompanying CDs are as follows:

8.1 Contents

CD 1 of 2

- **Motueka_1986 pt1.zip** – contains part of 1986 aerial photograph (tiff file), 1977 aerial photograph (tiff file) and habitat layer files.
- **Winzip.exe** – file extraction utility

CD 2 of 2

- **Motueka_1986 pt2.zip** – contains parts of 1986 aerial photograph (two tiff files).
- **Motueka_1947.zip** – contains 1947 aerial photograph (tiff file) and habitat layer files.

8.2 Setting up

It is important to note that the files are very large, and will take up a good deal of space on your computer's hard disk. To prevent any problems be sure that installation is performed on a machine with at least 1.2 GB MB of free space.

Before viewing any of the intertidal delta habitat data you will need to unzip the appropriate zip file. The data files on the CDs have been compressed using WinZip. To extract the files for a chosen year, simply double click the left mouse button on the appropriate zip file. Winzip will provide further instructions on file extraction. Extract the folder within the zipped file to an appropriate place on your computer.

Important Notes:

- The contents of **Motueka_1986 pt2.zip** (two tiff files) needs to be extracted and placed within the folder, **Motueka_1986**.
- It is important to retain the folder names **Motueka_1947** and **Motueka_1986**.

The Motueka_1947 and Motueka_1986 maps are now ready to be viewed.

8.3 Help with data

If problems arise when loading or using these data, please contact:

Paul Barter

Scientist – Coastal and Estuarine Group

Cawthron Institute

Private Bag 2

NELSON

Phone: (03) 548 2319

Facsimile: (03) 546 9464

E-mail : paul.barter@cawthron.org.nz