CAWTHRON INSTITUTE

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BASELINE MAPPING OF SELECTED INTERTIDAL HABITATS WITHIN GROVE ARM, QUEEN CHARLOTTE SOUND

BASELINE MAPPING OF SELECTED INTERTIDAL HABITATS WITHIN GROVE ARM, QUEEN CHARLOTTE SOUND

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Prepared for Marlborough District Council (MDC)

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EXECUTIVE SUMMARY

OVERVIEW

Cawthron Institute was commissioned by the Marlborough District Council (MDC), through Envirolink MLDC67, to prepare a baseline vegetation and structural class habitat map for two intertidal regions (Okiwa Bay and Ngakuta Bay) within the Grove Arm branch of the inner Queen Charlotte Sound (QCS). MDC is currently developing a long-term State of Environment (SOE) monitoring strategy for Pelorus and Queen Charlotte Sounds' coastal environments, and this work follows the recommended approach (as outlined in Envirolink MLDC59) to identify and carry out baseline assessments of key '*at risk*' intertidal habitats within one of the Sounds. Both the intertidal and subtidal regions of Okiwa and Ngakuta Bays have been recognised as significant sites within the Marlborough Sounds based on their unique ecological values.

The present report summarises the results of point-in-time spatial surveys of major intertidal habitats in both Okiwa and Ngakuta estuaries based on December 2011 aerial photographs. Implications for overall estuary ecological health are discussed and recommendations are made regarding possible management responses and ongoing Queen Charlotte Sound SOE monitoring.

MAPPING RESULTS

- The areal extent of the Okiwa and Ngakuta estuaries was estimated to be ~75 ha and ~10 ha, respectively.
- Mud habitats in Okiwa Bay comprised a larger proportion of the intertidal zone than typical of many other New Zealand estuaries. Non-vegetated structural habitats (*i.e.* mud, sand, gravel/cobble) in Ngakuta Bay were within the percent coverage ranges typical of other estuaries in the Nelson/Marlborough region.
- Vegetated habitats covered 12% and 26% of Okiwa and Ngakuta intertidal zones, respectively, and were dominated by rushland and seagrass (eelgrass – *Zostera* sp.) meadows. Both estuaries had a relatively low percent coverage of other fringing salt marsh habitats, such as sedgelands and/or reedlands.
- Supra-littoral habitats (*i.e.* ~10 m wide strip above the high-tide line) in both bays were substantially modified, consisting mainly of terrestrial shrub/scrub (a mixture of both exotic and native species), and grasslands dominated by *Festuca arundinacea* and unidentified grasses.

ESTUARY CONDITION

- A comparison of the existing percent coverage of the key structural and vegetative habitats of the Grove Arm intertidal regions with other nearby estuaries reflects a high general diversity, with some indications of a comparatively well-functioning estuarine system, *e.g.* relatively high seagrass presence in comparison to other nearby estuaries.
- Despite suspected reductions in the extent of estuary margins and more recent changes in catchment land-use activities (*e.g.* forestry and agriculture) that may have resulted in a

loss of intertidal and supra-littoral habitats, most of the essential estuarine habitats are still present in both Okiwa and Ngakuta Bays.

- The areal extent of seagrass meadows in the bays is small relative to some estuaries in Tasman Bay, but still is considered regionally important in terms of ecosystem services provided given their relative percent coverage to other Grove Arm intertidal vegetation and substrate habitats.
- A potential issue was identified regarding the health of the seagrass habitat in both Okiwa and Ngakuta estuaries. Blackening of seagrass leaves typical of a "*fungal wasting disease"* caused by infestation by the slime mould *Labrynthula* sp. was observed within patches of seagrass habitat.
- Various reclamations, roading and boat ramp areas have resulted in a general '*hardening*' of intertidal margins and the related deterioration of estuary function in terms of land/sea connectivity.

RECOMMENDATIONS

The estuaries within Grove Arm are an integral element of the coastal ecosystem of Queen Charlotte Sound,as they provide significant contributions to important ecosystem processes (*e.g.* maintenance of biodiversity and nourishment of the coastal food web). Consequently, monitoring the health of Grove Arm estuaries should be considered a high priority in the context of the values attached to the surrounding Sounds and coastal regions (*e.g.* commercial and recreational fish resources).

We recommend reassessment of baseline estuary characteristics at approximately five-year intervals. We also suggest that Council consider complementary completion of a fine-scale assessment of individual reference sites as indicators of estuary condition/health as described in the Estuary Monitoring Protocol (EMP). This will enable evaluation of both broad- and fine-scale changes in estuary condition over time and further comparisons with the performance of other similar habitats in the Marlborough Sounds would provide an important step towards achieving integrated coastal management for the Sounds. It will also provide context for ongoing consent and water quality monitoring in the region.

We also acknowledge the potential two-way benefits (and additional insights) that could be gained by coordinating the estuary monitoring with community and/or iwi monitoring initiatives wherever possible. A multi-stakeholders approach, as undertaken for Delaware Inlet in Nelson, is gaining recognition as an improved management model of coastal habitats in New Zealand.

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INTRODUCTION

1.1. Background

Estuarine intertidal and associated supra-littoral (~10 m wide strip above the high-tide line) habitats play an important role in linking terrestrial and marine environments. As such, they are conduits for a two-way land/sea exchange of materials and function as nutrient processing zones that are critical for the sustainability of coastal ecosystems. Estuary intertidal areas often encompass habitats of high ecological and biodiversity value, and contain resources of cultural, recreational and/or commercial importance. Broad-scale mapping of these habitats can be used to assist in regional strategic planning and in the management of specific issues associated with estuarine habitats; *e.g.* resource consents, pollution monitoring and State of the Environment (SOE) monitoring.

The nationally important Marlborough Sounds coastal marine ecosystem presently faces rapidly increasing environmental pressures from agricultural and residential development of adjacent catchments, recreational usage and expanding aquaculture. Because of the morphological, hydrodynamic and ecological complexity and length of shoreline involved, it has been challenging to implement a long-term strategy to investigate and monitor potential impacts of these pressures on ecosystem integrity.

To begin meeting this challenge, Marlborough District Council (MDC) plans to develop a long-term State of Environment (SOE) monitoring strategy for Pelorus and Queen Charlotte Sounds' coastal environments. Recent advancements in our understanding of the hydrodynamics within the Sounds (Knight & Beamsley 2012; updated by B. Knight, Cawthron Institute, pers. comm.) provides suitable context for integrating monitoring sites in a way that may enable interpretation of cause and effect relationships with regard to any observed impacts. A general approach was outlined by Cawthron Institute (Cawthron) through a previous Envirolink advice grant (MLDC59). The strategy requires identification and baseline assessment of key "*at risk*" intertidal habitats within both Sounds for step-wise incorporation into a standardised monitoring framework. Progressing seaward from the Havelock estuary, MDC proposes to survey inner Sound locations in order to prioritise a network of sites suitable for incorporation into an evolving, long-term monitoring programme.

Cawthron was requested by MDC to prepare baseline vegetation and structural class habitat maps for two intertidal regions within Grove Arm, inner Queen Charlotte Sound (QCS). These regions were selected in recognition of (1) their high value at both a regional and local community level, and (2) the perceived risks associated with adjacent land-based stressors and high recreational usage. The mapping output will be used by Council to engage and encourage involvement of local community and iwi interests in future management of the ecological health of Grove Arm shoreline habitats. Over the longer term, this project will also contribute to management of the greater Marlborough Sounds region by providing an initial step towards an integrated SOE monitoring site network. This future network will enable MDC to better manage ecologically sensitive habitats. The proposed initiative will also benefit the region by expanding a joint Tasman District Council/Nelson City Council estuary monitoring strategy for the Nelson Bays to include the adjacent Marlborough region. Such continuity in monitoring protocols will enable a more extensive cross-referencing of estuarine habitats and their relative coverage across the top of the South Island.

The present report summarises the results of a detailed, point-in-time spatial survey of major habitats in the intertidal regions of Okiwa and Ngakuta Bays in Grove Arm, QCS. The following features are included:

- Baseline broad-scale maps of key intertidal habitats in Grove Arm, QCS,
- Calculation of intertidal habitat areas and interpretation with regard to ecological importance within the greater Sounds region,
- Recommendations for incorporation into a long-term SOE monitoring strategy, and
- A CD-ROM with a working version of the completed habitat maps.

1.2. Study area

1.2.1. Grove Arm

Grove Arm is situated to the west of Picton at the extreme south-western (landward) end of QCS (Figure 1). Although it receives no major freshwater inflows, there are several small streams draining the surrounding catchments where a number of dairy farms are located. These inflows are important influences on the existing intertidal habitat structure and may at times have a localised effect on water quality.

Grove Arm has a history of frequent toxic micro-algal blooms (MacKenzie *et al.* 1998, 2004). The area may function as an incubator where blooms develop and are dispersed to other parts of QCS. High oceanic salinities of surface waters within inland reaches of Grove Arm are common and the embayment usually supports a relatively high phytoplankton biomass (MDC unpublished data, Figure 2). Inorganic nutrient concentrations generally follow a predictable seasonal pattern, although bottom waters usually contain high levels of nitrate throughout the year and nutrient enrichment episodes associated with intrusions of oceanic water have been identified (MacKenzie, pers.comm. - Figure 3). The mechanism of these intrusions is not completely understood, however it may involve the onset of estuarine-like circulation during heavy rainfall periods and tidally driven jets of deep bottom water flowing into QCS from Tory Channel.

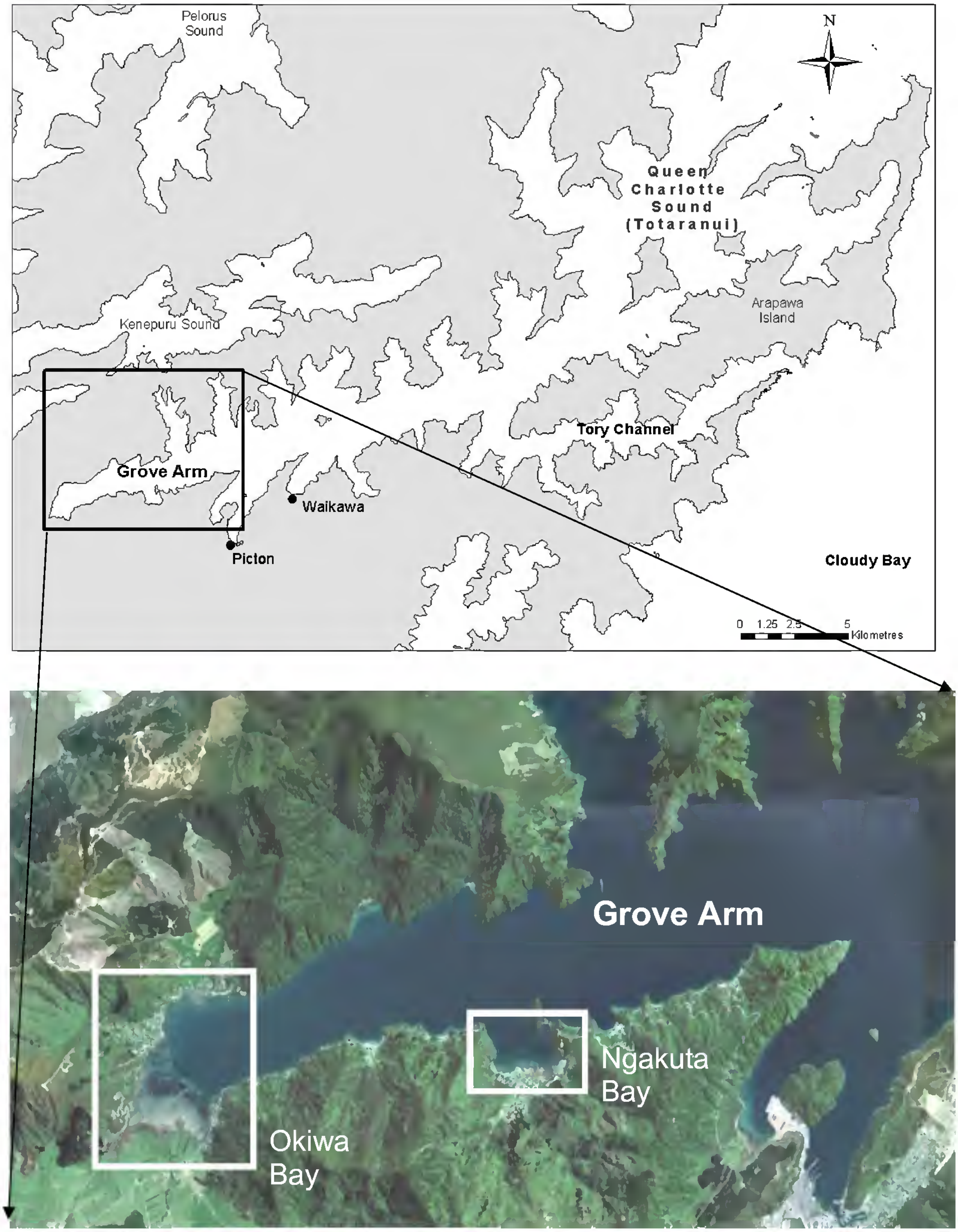

Figure 1. Location map of Okiwa and Ngakuta Bays within the Grove Arm region of the inner Queen Charlotte Sound, Marlborough Sounds.

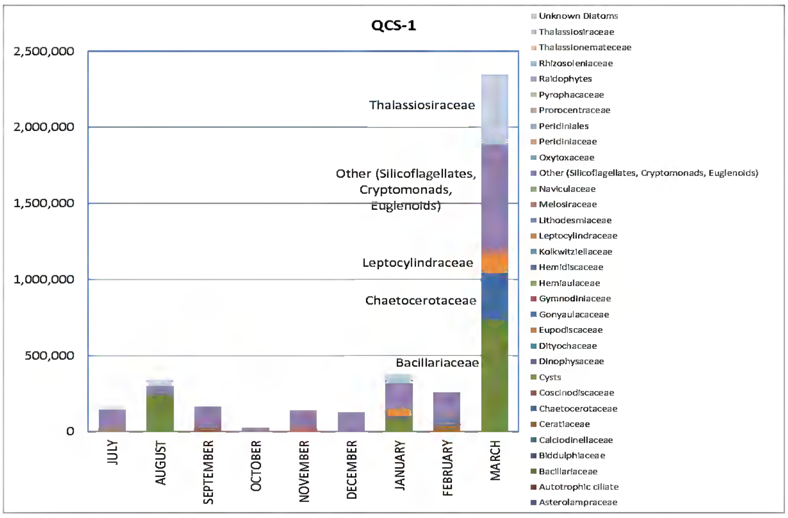

Figure 2. An example of high phytoplankton numbers (cells per litre) from the outer reaches of Grove Arm over 2011/2012 (1683310E, 5432890N NZTM – MDC unpublished data).

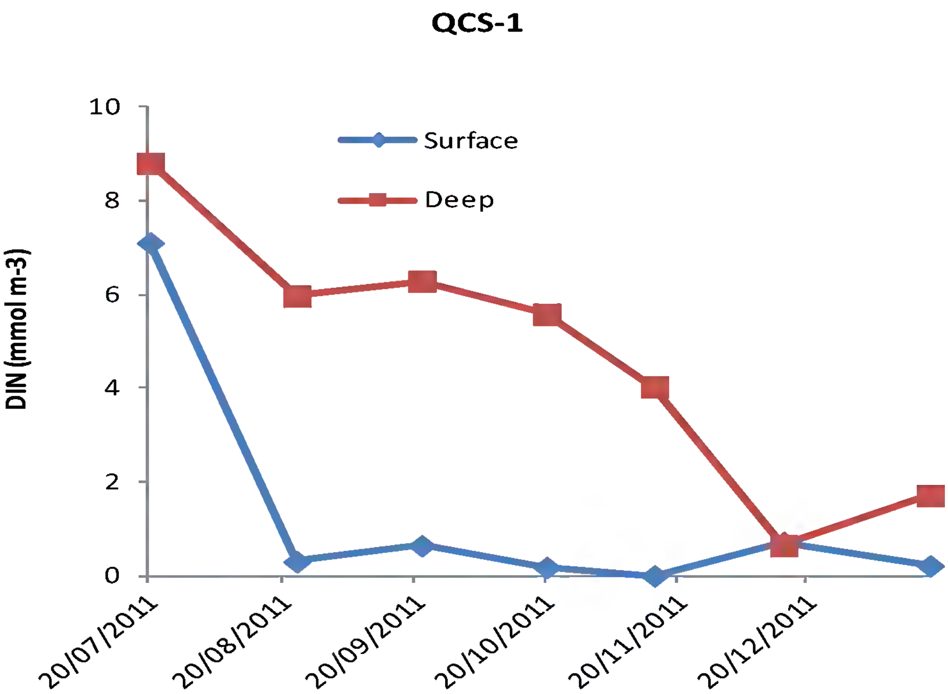

Figure 3. Dissolved inorganic nitrogen levels (DIN) measured in Grove Arm at 1683310E, 5432890N NZTM from July 2011 to January 2012. The surface sample is taken 1 m below surface and the deep sample at approximately 30 m (MDC and MacKenzie unpublished data).

Two intertidal sites within Grove Arm, Okiwa Bay and Ngakuta Bay, were identified as being significant sites in the Marlborough Sounds' marine environment by MDC and the Department of Conservation (DOC) based on the unique ecological values they provide and/or support (Davidson *et al*. 2011).

1.2.2. Okiwa Bay

Located at the head of Grove Arm (Figure 1), the intertidal habitat in Okiwa Bay receives runoff from the surrounding 35.3 km^2 catchment area via four main streams and a number of smaller tributaries (Figure 4). Sub-catchment areas for the regions drained by the streams are characterised by a variety of land uses (Table 1). These include significant proportions of native bush (57%), grassland (16%) and exotic forestry (25%) with a small proportion of built up area. The tidal wetlands in this bay are described by Davidson *et al.* (2011) as the largest in Queen Charlotte Sound and one of the larger wetlands found in the Marlborough Sounds region. These wetlands and associated tidal flats are considered important habitat for several species of waterfowl.

1.2.3. Ngakuta Bay

This small bay is situated approximately midway along the southern shore of Grove Arm (Figure 1). The surrounding catchment area (6.8 km^2) is dominated by indigenous forest species (83%) with smaller proportions (*i.e.* 4-6%) of grassland, gorse/broom and grey scrub and minor contributions from exotic forestry and built-up areas (Table 1, Figure 4). These sub-catchment areas drain into the bay through two main streams and several small tributaries. Tidal wetlands in this bay, although small, support a variety of birds and are considered an important non-breeding gathering area for some species (Davidson *et al*. 2011).

Table 1. Key land-use activities found within the catchments surrounding Okiwa and Ngakuta Bays. Land cover classes are from MfE's Land Cover Database version 2 (LCDB2).

Landuse Type	Okiwa Bay		Ngakuta Bay	
	Area (Ha)	% catchment	Area (Ha)	% catchment
Afforestation (not imaged)	52.19	1.48%		
Broadleaved Indigenous Hardwoods	890.66	25.26%	374.06	54.97%
Built-up Area	23.85	0.68%	10.07	1.48%
Forest Harvested	276.40	7.84%		
Gorse and Broom	21.83	0.62%	36.50	5.36%
Grey Scrub			31.98	4.70%
High Producing Exotic Grassland	555.31	15.75%	30.22	4.44%
Indigenous Forest	1013.93	28.76%	138.41	20.34%
Low Producing Exotic Grassland			0.22	0.03%
Manuka and/or Kanuka	88.39	2.51%	54.83	8.06%
Pine Forest - Closed Canopy	445.32	12.63%	4.21	0.62%
Pine Forest - Open Canopy	155.72	4.42%		
Saltmarsh	2.41	0.07%		
Total Area of Catchment	3526.01		680.5	

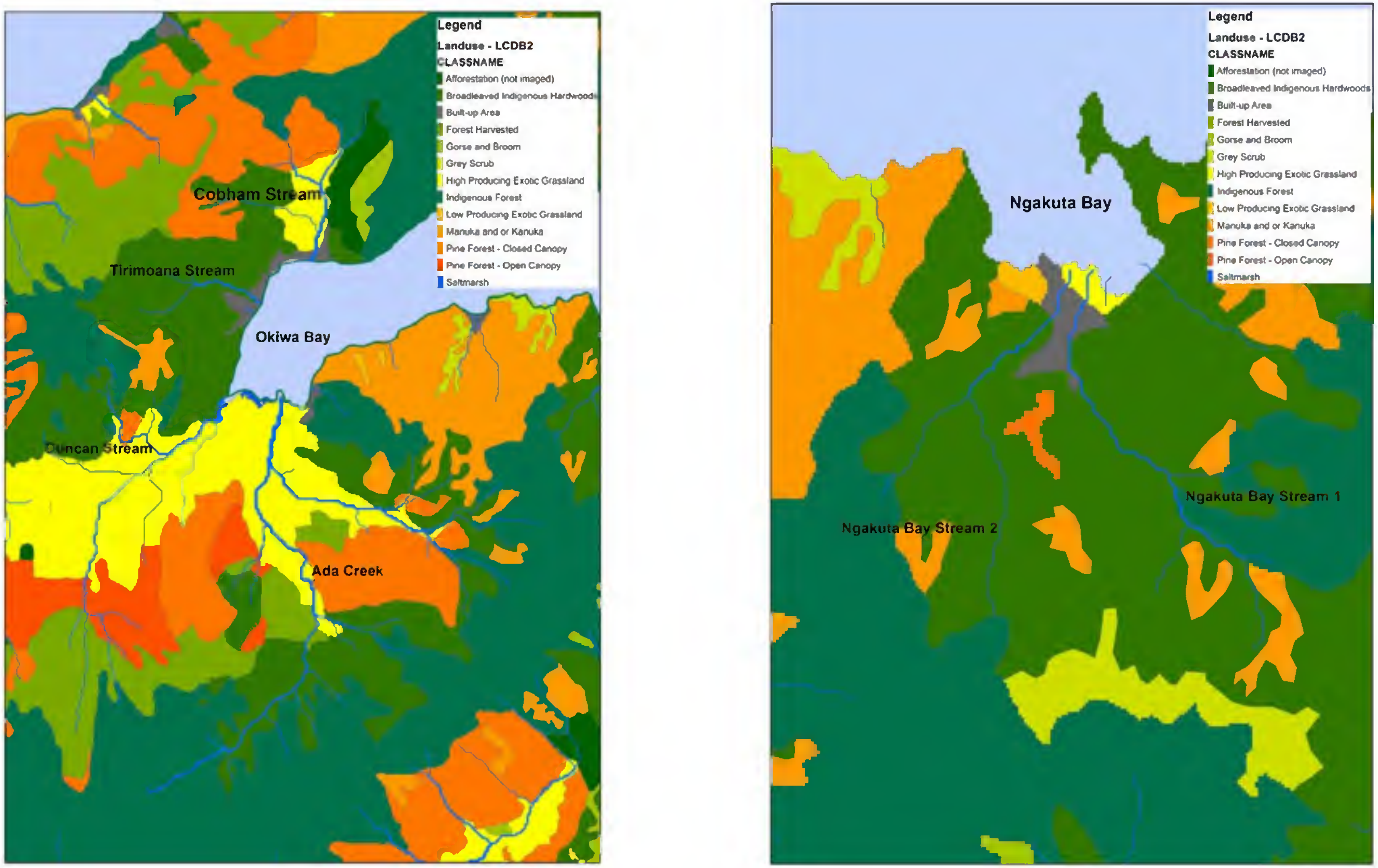

Figure 4. The streams and catchments that drain into Okiwa Bay (left) and Ngakuta Bay (right) from MfE LCDB2 database. The different colours denote different land uses as defined in the legend.

2. METHODS

2.1. Overview

The methodology used to collect data was based on the standardised Estuary Monitoring Protocol (EMP - Robertson *et al.* 2002), which uses field-verified broad-scale mapping of habitat zones as a monitoring tool. This procedure involved 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 (*e.g.* mud, sand, cobble, rock, shellfish beds *etc.*) and the vegetation present (*e.g.* rushes, seagrass, macroalgae *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 2001) can be assessed by repeating the mapping exercise over time. This information can then be used to evaluate changes associated with natural perturbations, such as flood/climatic events, and human impacts, such as land management practices (and related river water quantity and quality), on the structure of the intertidal ecosystem.

2.2. Mapping of habitat areas

2.2.1. Ground-truthing

High-resolution, colour aerial photographs of Grove Arm's intertidal zone were taken on 23 December 2011 for MDC and provided to Cawthron as rectified tiff files at a resolution of five metres. Aerial photographs, through different textural and tonal patterns, indicate the presence and spatial extent of different substrate and vegetation types. To identify the dominant habitats present and confirm the boundaries between substrates, field surveys were undertaken over the two estuary regions at low-mid tide during 19 and 20 March 2012. Dominant habitat types, including various categories of bare and vegetated substrate were recorded directly onto laminated copies of the aerial photographs using the codes listed in Appendix 1 and described in detail in Appendix 2.

The upper intertidal boundary was set at the apparent MHWS (Mean High Water Spring) level and the lower boundary was set at approximately MLWS (Mean Low Water Spring). A 10 m wide riparian strip above MHWS (called the supra-littoral fringe) was also assessed visually to enable general comment on the type of habitat surrounding the edge of the estuary.

2.2.2. Digitisation

Vegetation and substrate habitats were digitally mapped from the rectified photographs using ArcMap v10 GIS software. This procedure involved creating digital polygons of the field-verified habitat features as precisely as possible by tracing them directly from the rectified aerial photographs within the GIS software. The software was used to produce digital maps and calculate the area cover of each habitat type.

2.3. Classification and definition of habitat types

The classification of substrate and habitat areas was based on the estuarine national classification system (with adaptations), which was developed under a Ministry for the Environment SMF 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 (Appendix 1 and Appendix 2). The broad-scale mapping focuses on Levels III (Structural Class) and IV (Dominant Cover). Substrate classification is based on surface layers only and does not consider underlying substrates (*e.g.* gravel fields covered by sand would be classed as sand).

2.3.1. Habitat codes and terminology

Dominant biota with a spatial coverage of greater than 2 m in diameter was classified using an interpretation of the Atkinson (1985) system. In this report, biota and substrates 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).
- Subdominant species are indicated by an underscore (_); *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.
- Individual polygons in the GIS maps have been labelled in the same manner as that described above.

3. RESULTS

3.1. Intertidal Habitat and Substrate Characteristics

Approximately 74.6 ha and 9.8 ha of estuary habitat were mapped within the Okiwa and Ngakuta estuaries, respectively, during March 2012 based on colour aerial photographs collected in December 2011. Detailed maps show the intertidal areas covered by the dominant substrate and vegetation types (Figure 5-8) and their coverage areas are summarised in Table 2.

Out of the total intertidal region mapped in Okiwa Bay, 6% was subtidal (*i.e.* remained underwater), consisting mainly of permanent water channels located within the south-western regions of the bay (Figure 5). Intertidal areas were predominantly unvegetated (61 ha or 82%) with only 9 ha or 12% of surface habitats covered in some form of vegetation (Table 2).

Intertidal habitats within Ngakuta Bay (9.8 ha) were similar in composition to Okiwa Bay with most (7 ha or 73%) of the intertidal dominated by unvegetated habitats (Table 2). A higher proportion of Ngakuta was vegetated (2.5 ha or 26%) and fewer subtidal regions were present, 0.1 ha or 1%, compared to Okiwa (Figure 7-8). We note that some small habitat areas cannot be seen at the scale of the maps, however these areas are quantified in Appendices 3 and 4, and individual GIS layers can be accessed and evaluated through the CD-ROM in Appendix 5.

Table 2. Key broad-scale habitats mapped within Okiwa and Ngakuta Bays (December 2011)

Habitat Groupings	Okiwa Estuary		Ngakuta Estuary	
	Area (Ha)	Total Area%	Area (Ha)	Total Area%
Water	**4.49**	**6.02%**	**0.10**	**1.04%**
Unvegetated habitats	**61.08**	**81.94%**	**7.20**	**73.16%**
Mud habitats	54.96	73.73%	2.76	28.06%
Firm mud/sand	32.26		2.48	
Soft mud/sand	21.51		0.28	
Very soft mud/sand	1.19			
Sand habitats	0.92	1.23%	3.93	39.94%
Firm sand			3.12	
Firm shell/sand	0.25		0.31	
Shell bank	0.02		0.01	
Soft sand	0.65		0.49	
Cobble field	0.32	0.43%	0.43	4.39%
Gravel field	4.58	6.15%		
Rockfield	0.19	0.25%		
Vegetated habitats	**8.97**	**12.04%**	**2.54**	**25.80%**
Estuarine Shrubs	0.63	0.84%		
Herbfield	0.39	0.53%	0.26	2.59%
Macroalgal Bed	0.50	0.67%	0.60	6.05%
Rushland	5.29	7.10%	0.65	6.57%
Seagrass meadow	1.67	2.24%	0.72	7.28%
Terrestrial Shrub/Scrub	0.43	0.58%	0.30	3.05%
Total Area of Intertidal	**74.55**		**9.84**	

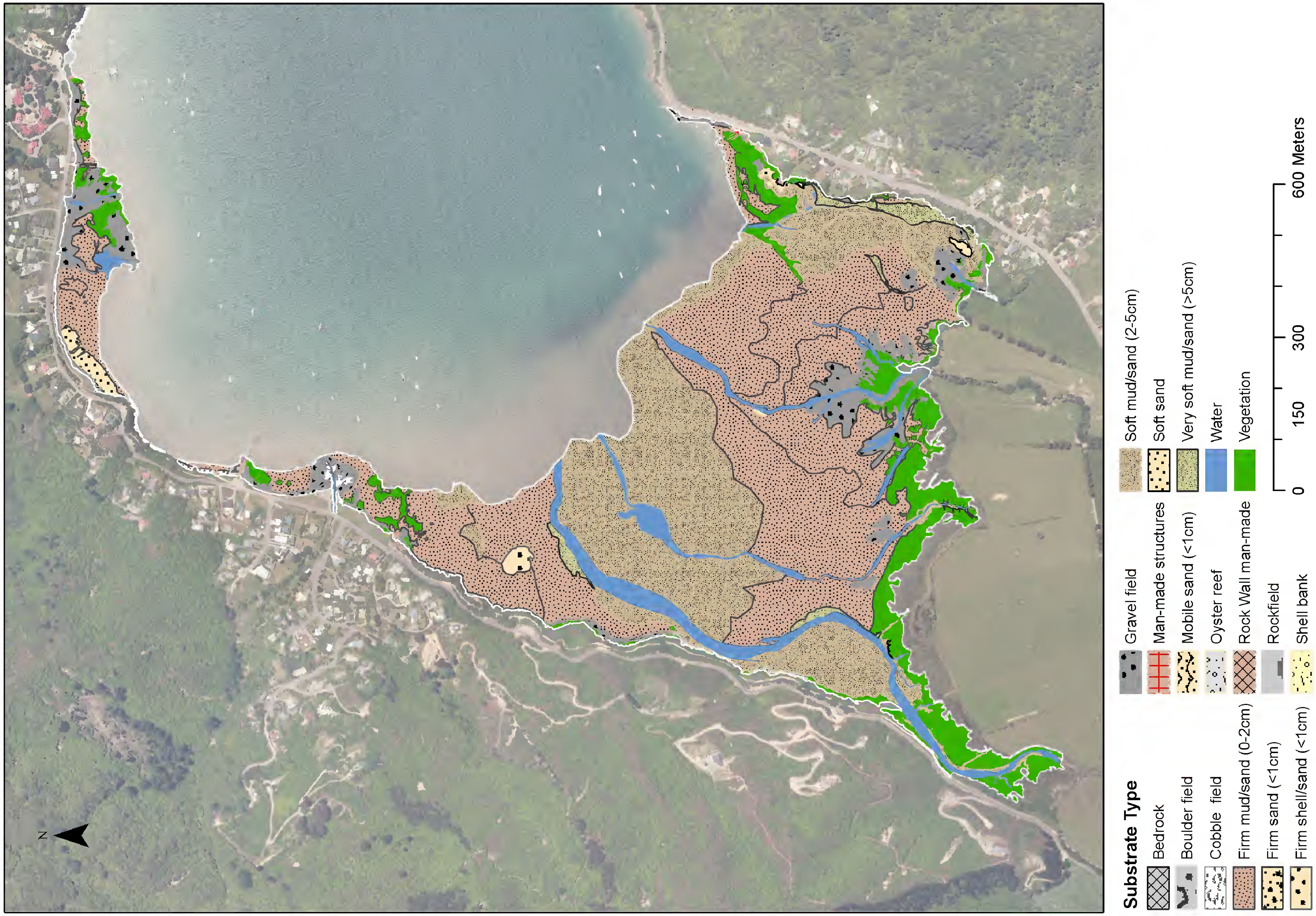

Figure 5. Aerial photograph of Okiwa Bay showing substrate characteristics in December 2011.

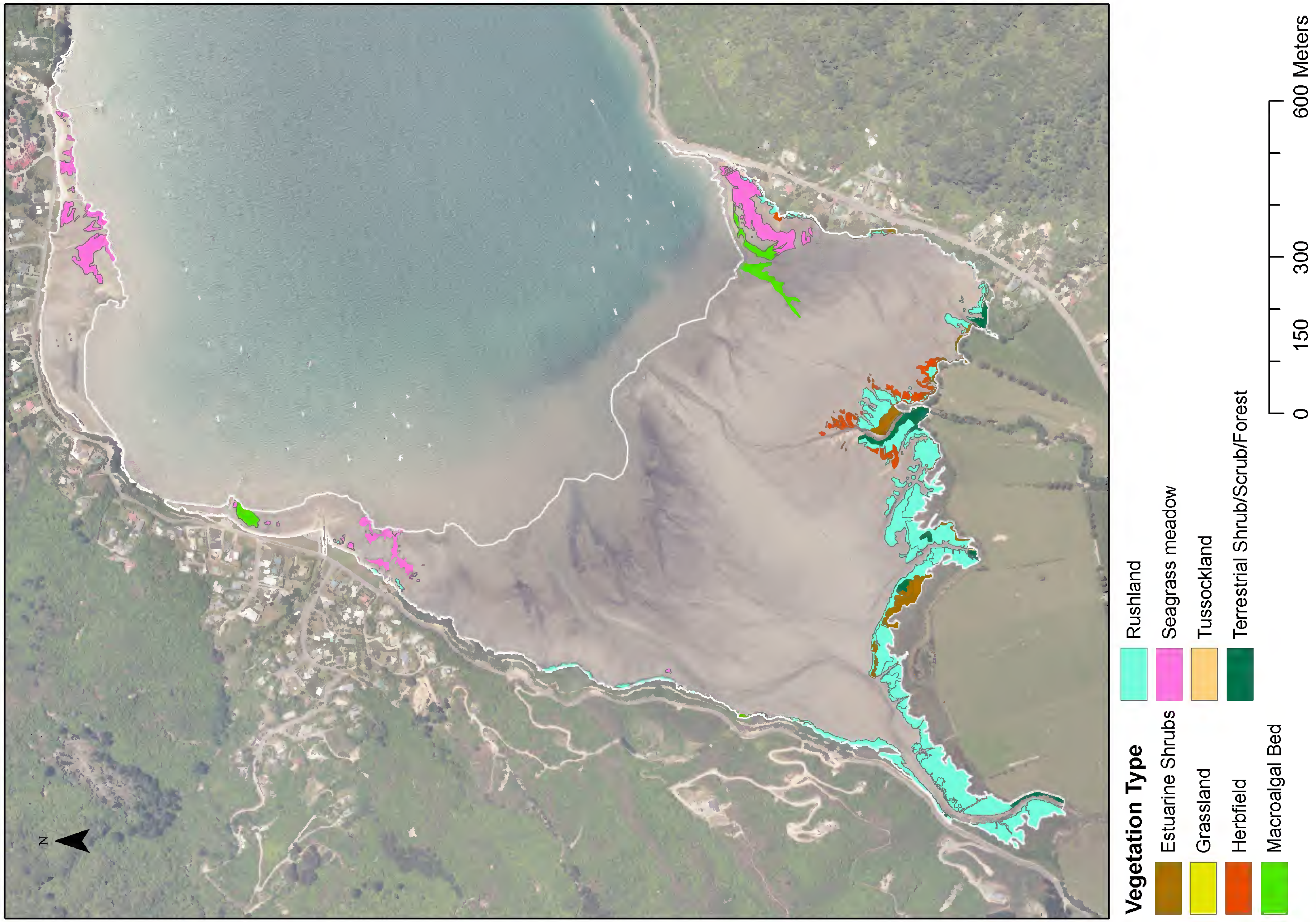

Figure 6. Aerial photograph of Okiwa Bay showing the vegetation present in December 2011.

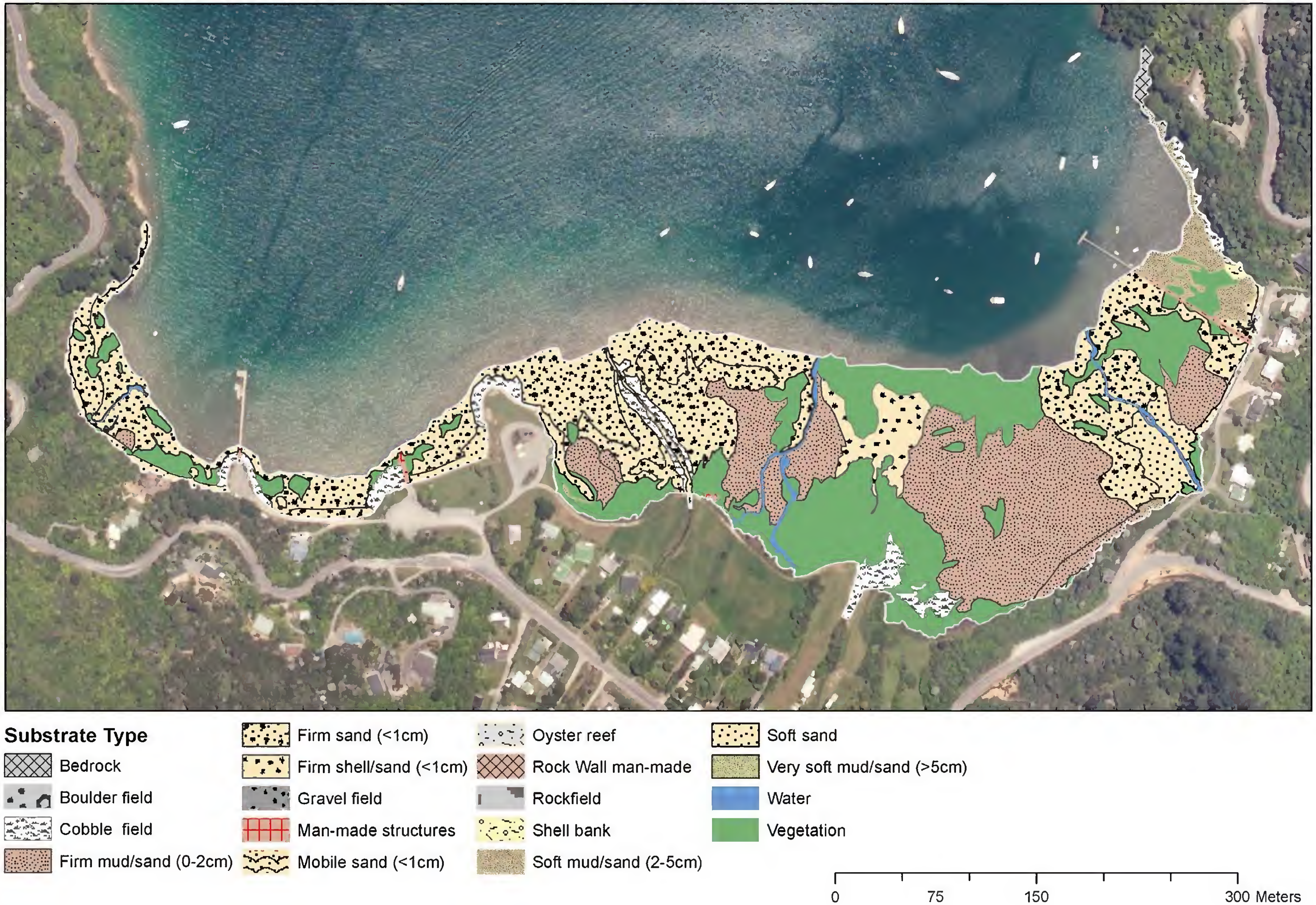

Figure 7. Aerial photograph of Ngakuta Bay showing substrate characteristics in December 2011.

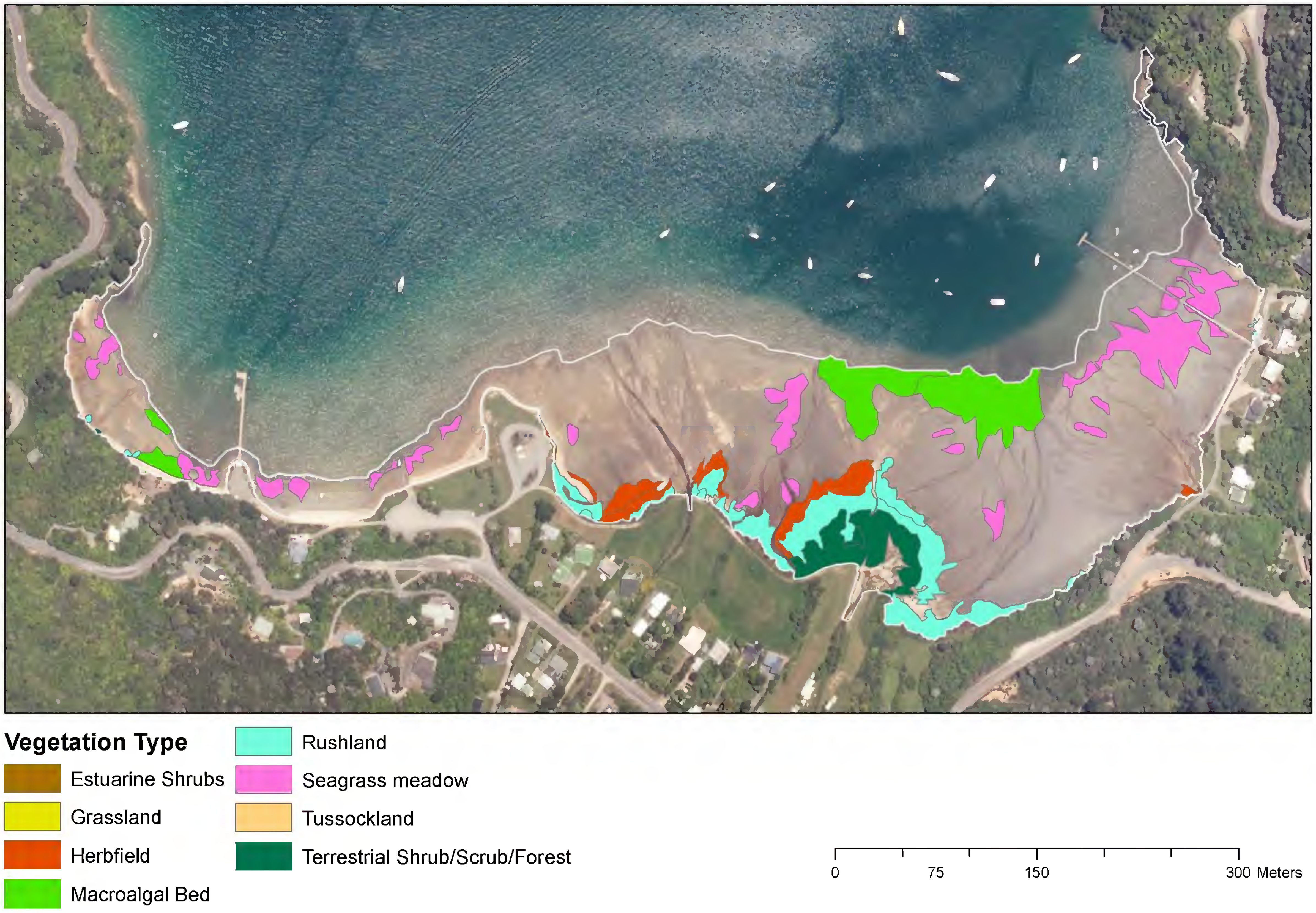

Figure 8. Aerial photograph of Ngakuta Bay showing the vegetation present in December 2011.

3.1.1. Unvegetated habitats

The unvegetated intertidal habitats of both Okiwa and Ngakuta estuaries were dominated by open tidal flats (Figure 9), which consisted primarily of soft substrates such as mud and sand (Table 2). Although further differentiation of the soft sediment habitats is difficult because the boundaries are often not discernible on the aerial photographs, we have attempted this through detailed ground-truthing (Figure 5 and 7). Mud and sand habitats in Okiwa and Ngakuta described as having firm consistency accounted for approximately 44% and 60%, respectively, of intertidal flats (Table 2). Habitats with softer consistencies (*i.e.* soft mud or soft/mobile sands) covered 30% and 3%, respectively, of the remaining tidal flat regions with only a small area (1.6% of the estuary) in Okiwa Bay classed as very soft.

Harder substrates, such as gravel or cobble fields, also covered parts of both estuaries; *i.e.* approximately 6.6% in Okiwa Bay and 4.4% in Ngakuta bay (Table 2). The remaining unvegetated habitats comprised a mixture of rock fields, bedrock, various shell banks and man-made structures (man-made rock or sea walls, wharves *etc.)*. For more details see Appendix 3.

Figure 9. Examples of the expansive unvegetated tidal flats within Okiwa's (left) and Ngakuta's (right) intertidal regions, March 2012.

3.1.2. Vegetated habitats

While a variety of vegetation categories are present in Okiwa estuary, the most extensive classes were rushland, seagrass meadows (eelgrass – *Zostera* sp.) and estuarine shrubs (Table 2, Figure 6, 10-11). Most of these habitats covered large areas near the estuary edges, consisting of rushlands (dominated by *Juncus* sp.) and estuarine shrub (mainly *Plagianthus divaricatus* -saltmarsh ribbonwood, 7.1% and 0.8%, respectively -Table 2). Other habitats typical of salt marshes covered smaller portions of the intertidal area and included herbfields (0.5%) along with reedland (0.08%) and sedgeland (0.01%) habitats (Figure 10-11).

Seagrass meadows covered moderate areas of Okiwa tidal flats totalling 1.7 ha (2.2%) at the time of the survey (Table 2, Figure 10-11). Macroalgae covering 0.5 ha (0.7%) were occasionally found in dense beds, but more generally were scattered sparsely over tidal flat regions of the estuary (Figure 6). Macroalgal beds consisted primarily of sea lettuce (*Ulva* sp.) and agar weed (*Gracillaria* sp.)

Intertidal vegetation in Ngakuta Bay was more evenly spread across five main habitat types; seagrass meadows, rushland, macroalgal beds and to a lesser extent, terrestrial scrub and herbfields (Table 2, Figure 8 and 10). Seagrass (0.7 ha) and macroalgal beds (0.6 ha) together covered a substantially large portion (13.4%) of intertidal flats given the estuary's relatively small size (Figure 10-11). A similar proportion of salt marsh habitats (9.2%) were present in Ngakuta as in Okiwa, and these consisted mainly of rushland (0.65 ha) and herbfields (0.26 ha). As with Okiwa, Ngakuta estuary had very few or no sedge and/or reed species present (Figure 10).

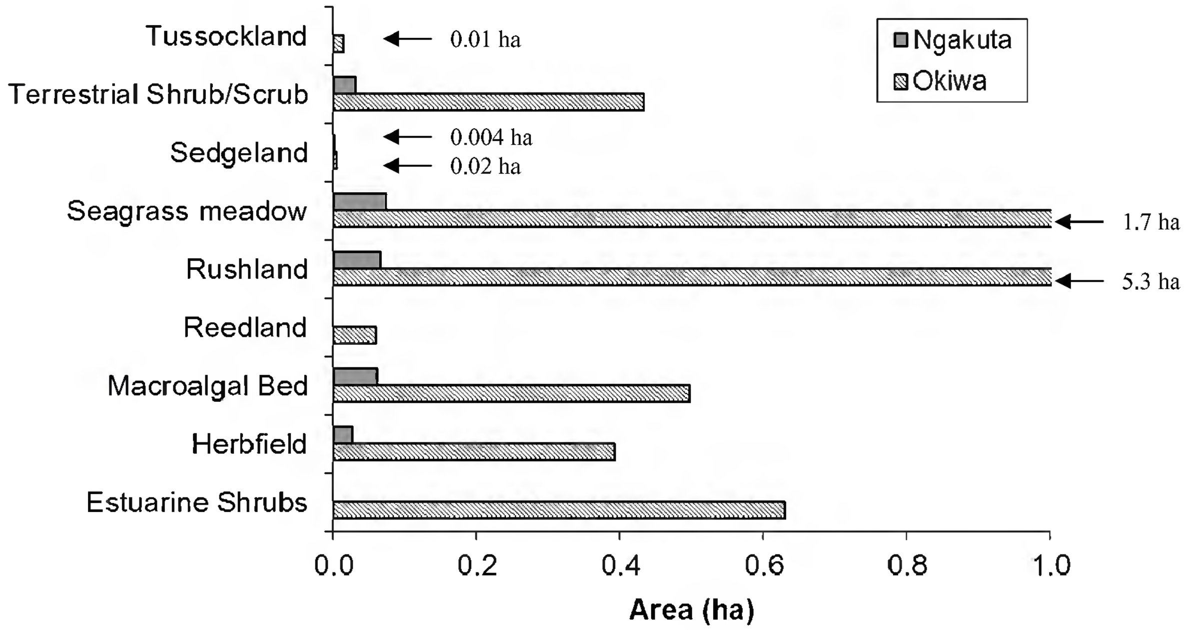

Figure 10. The overall area (ha) of vegetated habitats mapped within intertidal regions of Okiwa and Ngakuta Bays in December 2011.

Figure 11. Examples of Okiwa and Ngakuta intertidal habitats, March 2012.

3.1.3. Supra-littoral fringe (estuary margin habitats)

Around 9.6 ha and 2.3 ha of the Okiwa and Ngakuta estuarine habitats, respectively, were considered supra-littoral fringe (*i.e.* ~10 m wide strip above the high-tide line). The majority of these fringe habitats were vegetated in both bays (95% and 87%, Table 3). Vegetated habitats within the supra-littoral fringe serve as buffer zones between the estuary edge and developed regions, such as roads and residential properties. These habitats were substantially modified in both bays, consisting mainly of terrestrial shrub/scrub (a mixture of both exotic and native species) and grasslands dominated by *Festuca arundinacea* and unidentified grasses (Figure 12-14).

We note that those fringe habitats more typical of a natural land to sea plant succession (*e.g.* estuarine scrub, rushlands and reedlands) were only found in association with existing intertidal salt marsh habitats around larger stream outflows; the Duncan and Ada streams in Okiwa Bay and Stream 1 in Ngakuta Bay (Figure 4, 13-14). Much of the unvegetated supra-littoral margin in both bays constituted modified areas such as seawalls and wharves, or elevated regions consisting of roads and walking paths around the estuary margin (Table 3, Figure 13-14).

Table 3. Key broad-scale habitats mapped within the supra-littoral margins of Okiwa and Ngakuta Bays in December 2011.

Habitat Groupings	Okiwa Estuary		Ngakuta Estuary	
	Area (Ha)	Total Area%	Area (Ha)	Total Area%
Water	**0.18**	**1.89%**	**0.001**	**0.06%**
Unvegetated habitats	**0.20**	**2.11%**	**0.30**	**12.94%**
Bedrock	0.01	0.10%		
Gravel field	0.03	0.30%		
Soft mud/sand	0.01	0.09%		
Cobble field			0.07	2.97%
Soft sand			0.003	0.11%
Man-made structures	0.15	1.61%	0.23	9.85%
Seawalls	0.01		0.05	
Other structures	0.14		0.08	
Wharves	0.01			
Roads			0.09	
Vegetated habitats	**9.12**	**96.00%**	**2.01**	**87.01%**
Estuarine Shrubs	0.1977	2.08%	0.05	2.05%
Grassland	0.8183	8.61%	0.55	23.87%
Rushland	0.3496	3.68%		
Terrestrial Shrub/Scrub	7.5792	79.79%	1.41	61.08%
Total Area of Supra-Littoral	**9.50**		**2.31**	

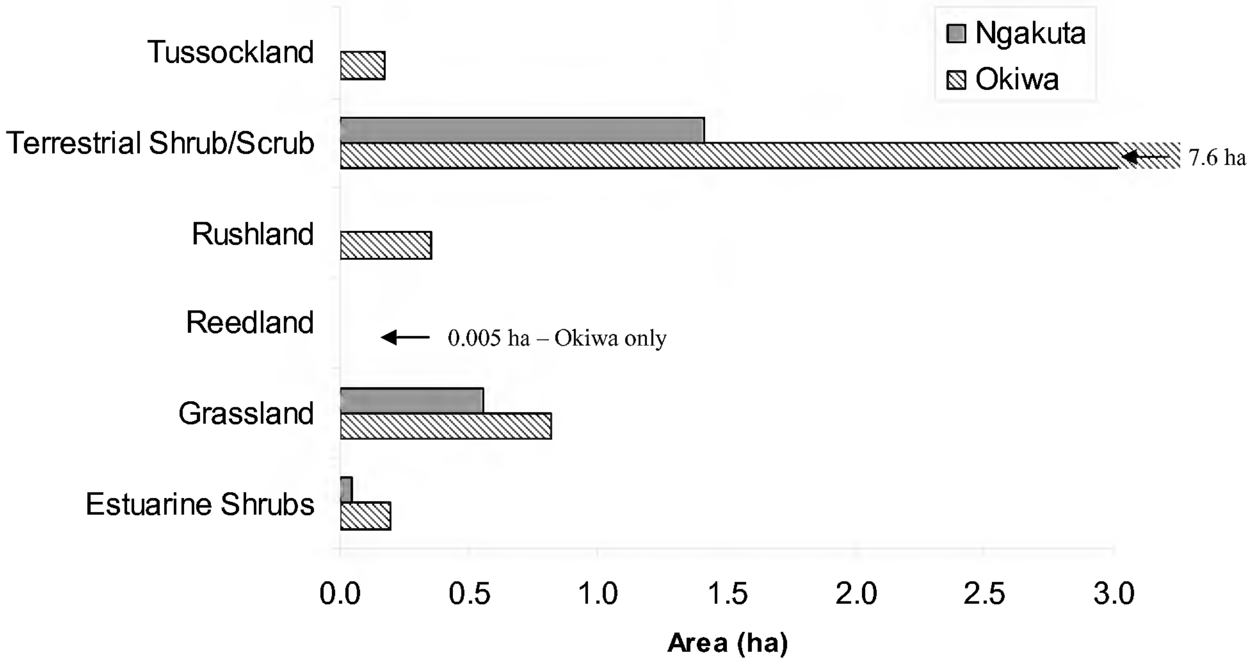

Figure 12. Vegetated habitats within supra-littoral regions mapped around Okiwa and Ngakuta Bays in December 2011.

Figure 13. Aerial photograph of Okiwa Bay showing supra-littoral fringe characteristics in December 2011.

Figure 14. Aerial photograph of Ngakuta Bay showing supra-littoral fringe characteristics in December 2011.

4. ESTUARY CONDITION

4.1. Habitat structural composition

The complex mixture of habitats documented within both Okiwa and Ngakuta estuaries is representative of a partially modified estuarine system. As such, the natural functions and values of an estuary, as described by Gillespie & MacKenzie (1981) and Gillespie (2009), are thought to have been largely preserved to date. Nevertheless, some apparent changes in intertidal habitat coverage, as discussed in the following subsections, could potentially indicate an increased risk for ongoing deterioration of ecosystem services/values in these bays and Grove Arm as part of the larger Queen Charlotte Sound.

4.1.1. Vegetative cover

It is difficult to ascertain if any significant reductions in intertidal extent might have occurred in Grove Arm regions, given the lack of detailed historical information. However, based on previous estuarine surveys in nearby Nelson Bays, the largest declines in estuarine vegetation generally occur along the estuary margin and upper intertidal salt marsh habitats due to infilling, reclamation or conversion to farmland (*e.g.* Nelson Haven - Gillespie *et al.* 2011b, Waimea Inlet - Clark *et al.* 2008). These salt marsh habitats are recognised as having important functional roles as a land to sea interface due to their ability to intercept inorganic nutrients and trap fine sediments as well as their productive contribution to the detrital food web. This ‘hardening’ of the land/sea interface is discussed further below.

Reduction in the coverage of seagrass meadows is also a concern for most top of the South Island estuaries (Delaware Inlet - Gillespie *et al.* 2009). Seagrass meadows are recognised as having high ecological and biodiversity values and, as such, represent a particularly important feature of Grove Arm estuaries. Although their photosynthetic contribution is relatively modest (Gillespie & Mackenzie 1981), they provide stable physical habitat and a localised food source to support a diverse community of animals, including a variety of fish species (*e.g.* juvenile snapper). Seagrass also helps filter nutrients and sediments, thereby maintaining water quality. It is important to recognise that while Grove Arm seagrass habitats are small (Okiwa -1.7 ha and Ngakuta-0.7 ha), they are locally and regionally important considering their relatively high coverage compared to other intertidal vegetation habitats (Figure 10) and the low percentages of seagrass habitats present in nearby estuaries (see Section 4.1.4).

We note that during the 2012 field verification surveys patches of blackened leaves within seagrass meadows were observed in both bays (Figure 15). This symptom is typical of a disease caused by a slime-mould (*Labrynthula* sp.) infestation. Such infestations, often referred to as the “*fungal wasting disease*”, have previously resulted in the decimation of over 90% of *Zostera* species along the Atlantic Coast of North

America (Ralph & Short (2002) and it is now seen as a growing global issue. This disease has also been detected in estuaries in the Nelson region (Gillespie *et al.* in prep; Gillespie *et al.* 2012), however, its relevance to eelgrass health in New Zealand is presently unknown.

Of additional concern were observations of physical damage to existing meadows as documented at one location along the south-western shoreline of the Ngakuta estuary (Figure 16). This damage was due to vehicle traffic across sand flats and into seagrass meadows. Such disturbances, although extremely localised, can take several seasons to regenerate and repeated disturbances could potentially result in long-term displacement of meadows.

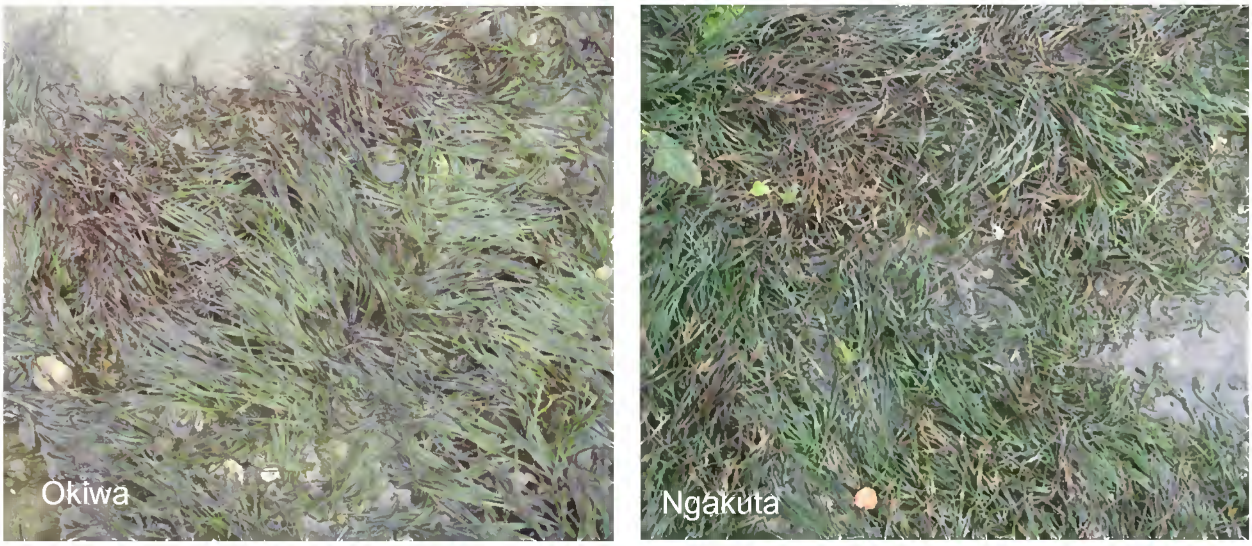

Figure 15. Examples of "*fungal wasting disease*" in seagrass meadows within Okiwa Bay (left – S41°16.576 E173°55.065) and Ngakuta Bay (right - S41°16.325 E173°57.528) photographed on 19-20 March 2012.

Figure 16. Vehicle tracks across seagrass habitats in the western side of Ngakuta Bay (S41°16.325 E173°57.528) photographed on 20 March 2012.

4.1.2. Extent of muddy substrata

The deposition of terrigenous sediments in estuarine intertidal zones is a natural process that occurs wherever there is substantial freshwater inflow. The rate of deposition within an estuary will depend on the sediment loading characteristics of the inflow stream(s) and the hydrodynamic characteristics of the receiving environment. In many catchments throughout New Zealand (including Grove Arm), human activities have likely resulted in increased erosion and flushing of fine-grained terrigenous sediments into the coastal environment. The resulting acceleration of depositional rates and increases in habitat '*muddiness*' can be considered a serious threat to estuarine health (Thrush *et al*. 2003).

Unvegetated mud habitats in Okiwa and Ngakuta Bays covered approximately 74% and 28%, respectively, of the total intertidal area in 2011. Out of these muddy regions, approximately 29% and 2.9% represented soft mud habitats (a proxy often used to indicate major sediment depositional zones). The overall proportion of mud habitats found within Ngakuta Bay is on the lower range of other estuaries (25 to 58% - see Table 4) in the northern South Island. Conversely, mud habitats represent a higher proportion in Okiwa Bay compared to other estuaries, however this increase might be expected due to Okiwa's location at the head of Grove Arm. Without historical estimates of the extent of mud flat habitats, particularly within salt marsh and river channel banks, it is not possible to ascertain how variations in sediment depositional rates over the past have altered these habitats.

4.1.3. Presence of exotic species

The colonisation of a number of coastal habitats in the Nelson region by Pacific oyster was reported during the early 1980s (Bull 1981), and this species has now become well established in a number of intertidal locations within the northern South Island. Another potential invader of intertidal estuarine habitats in the Marlborough region is the saltmarsh cordgrass, *Spartina anglica*. This pest species is presently being managed within the Marlborough Sounds by the Marlborough District Council in collaboration with the Department of Conservation. Neither of these species or other potential intertidal invaders were observed in the Okiwa/Ngakutu study areas, however a large number of exotic terrestrial plant species (*e.g.* pampas grass, gorse) were found within supra-littoral fringe habitats.

4.1.4. Regional comparisons

Comparing the relative 'health' of estuaries is not a straight-forward process due to differences in influencing factors, such as freshwater inflow rate, tidal flushing regime, geology and catchment characteristics. Hence, the absence or dominance of a particular habitat does not necessarily mean one estuary is 'healthier' than another. However, a general comparison between both local and regional estuaries can indicate trends and potentially signal problem areas that require further investigation.

A comparison of the percent coverage of the key structural and vegetative habitats within both Okiwa and Ngakuta estuaries with other estuaries in the Nelson/Marlborough region (Table 4) reflects a high habitat diversity with some indications of comparatively well to moderately functioning estuarine systems (*e.g.* relatively high seagrass presence and, in the case of Ngakuta Bay, low percent coverage of soft muddy habitats). We recognise, however, that such a comparison of small Marlborough estuaries with the much larger estuaries included in the table is of limited value and can only be interpreted in the broadest sense. Such comparisons will hopefully become more useful in the future as additional small estuaries within the region are investigated.

Table 4. A comparison of the percent coverage of dominant vegetated and unvegetated habitats in Okiwa and Ngakuta Bays with other Nelson/Marlborough estuaries. Note specific habitat percentages represent the proportion of that habitat out of total intertidal area.

Habitat	Okiwa Bay 2011 (%)	Ngakuta Bay 2011 (%)	Havelock 2002(%) [1]	Nelson Haven 2009 (%) [2]	Delaware Inlet 2009 (%) [3]
Water	6.02	1.0	27.9	31.5	6.2
Unvegetated	81.9	73.2	36.8	53.10	74.7
Mud Habitats	73.7	28.1	36.3	33.3	24.8
Sand Habitats	1.2	39.9	0.0	15.2	29.8
Gravel/Cobble	6.5	4.4	0.5	3.3	7.8
Vegetated	12.0	25.8	35.5	15.4	19.1
Herbfield	0.5	2.6	0.2	0.5	1.8
Reedland	0.08	0.0	6.2	0.0	0.2
Rushland	7.1	6.6	22.9	0.05	4.5
Seagrass meadow	2.2	7.3	0.1	9.6	1.3
Sedgeland	0.01	0.2	0.0	0.0	0.05
Total area of estuary (ha)	**75**	**10**	**817**	**1242**	**353**

[1] Robertson *et al.* 2002
[2] Gillespie *et al.* 2011b
[3] Gillespie *et al.* 2011a

When interpreting these comparisons, it is also important to recognise that none of the estuaries surveyed represent completely unmodified ("pristine") conditions. Historical mapping exercises carried out on some estuaries in the Nelson region (*i.e.* Waimea Inlet (Tuckey & Robertson 2003), Moutere Inlet (Clark & Gillespie 2007) and the Motueka Delta (Tuckey *et al.* 2004) identified significant losses in salt marsh vegetation (*i.e.* herbfields and rushlands) between the earliest available records in the 1940s and more recent estimates. In most cases, these losses were due to infilling of estuary margins for roading, flood control or other developments with consequent destruction of marsh habitats, primarily *Sarcocornia quinqueflora* and *Juncus kraussii*.

Losses since the 1980s have been far less. Historical comparisons of Okiwa and Ngakuta Bays to assess the earlier effects of development (*e.g.* catchment clearing, roading) were beyond the scope of this report, although it is likely that some losses of salt marsh habitats have occurred. If appropriate historical aerial photographs are available, it may be possible to document past changes in vegetative habitats.

4.2. Hardening of land/sea interface

In most estuaries in New Zealand, modification or development of the surrounding land has resulted in a loss of connectivity with freshwater wetland habitats. These wetland regions process inorganic nutrients, thereby reducing the potential for macro- and microalgal blooms, and are important sources of dissolved and particulate organic materials that contribute to the coastal food web. They also provide habitat for a wide range of species, including fish that migrate across salinity gradients and a variety of bird species.

There are a number of small streams bordering both Okiwa and Ngakuta estuaries where this connectivity has been compromised due to roading, agricultural uses and/or residential developments. Through this loss in land-sea connectivity, these modifications have likely had some impact on estuarine ecosystem processes. This form of inhibition of estuarine function is a common occurrence amongst estuaries in the Nelson/Tasman region (Clark & Gillespie 2007), and can be described in simple terms as the '*hardening*' of intertidal boundaries and an associated reduction in area of ecologically important peripheral estuary habitats.

5. SUMMARY AND RECOMMENDATIONS

5.1. Ongoing State of Environment monitoring

The estuaries within Grove Arm are an integral component of the coastal ecosystem of Queen Charlotte Sound that contribute to important ecosystem processes (*e.g.* maintenance of biodiversity and nourishment of the coastal food web). Both the intertidal and subtidal regions of Okiwa Bay and Ngakuta Bay are recognised as significant sites within the Marlborough Sounds based on their unique ecological values (Davidson *et al.* 2011). Although these two estuaries are small in size, they are of local importance within the Grove Arm region. Monitoring their health in conjunction with similar estuary habitats in other parts of the Sounds may be seen as important in the context of the values attached to the surrounding coastal regions.

The general characteristics of Okiwa and Ngakuta estuaries, and their contributing catchments, provide evidence of partially modified, yet high-value, estuarine environments. Despite suspected historical changes to estuary margins and more recent changes in catchment land-use activities (*e.g.* forestry and agriculture), most of the essential estuarine habitats are still present in both Okiwa and Ngakuta Bays.

Results of the broad-scale habitat mapping reported here, provide a point-in-time baseline that can be used to monitor changes over short and longer time periods. We recommend reassessment of baseline estuary characteristics at approximately five-year intervals. We also suggest that Council consider implementing a fine-scale assessment of individual reference sites as indicators of estuary condition/health as described in the EMP. This will enable evaluation of changes in estuary condition over time and comparison with the performance of other estuaries across the top of the South Island as an important step towards achieving integrated coastal management for the region. The suggested estuary monitoring will also provide context for ongoing consent and water quality monitoring in the region.

5.2. Further investigation of seagrass health

Due to the recognised ecological importance of seagrass habitat in coastal zones throughout New Zealand, and the preliminary observations of symptoms of the *Zostera* fungal wasting disease reported here, we recommend further investigation of this potential threat to estuaries in Marlborough, the top of the South Island and in New Zealand in general. This could be achieved in collaboration with other New Zealand councils who may be concerned about this potential issue.

5.3. Iwi estuary monitoring

We recognise the potential two-way benefit (and additional insight) that could be gained by coordinating estuary SOE surveys with community and/or iwi monitoring initiatives wherever possible. Through a separate Envirolink grant (NLCC 27), NCC has encouraged the development and implementation of a suite of iwi estuarine indicators designed to improve articulation of Maori cultural values and foster increased iwi participation in the environmental management of coastal habitats.

Integration of sites and cross-referencing of the results of parallel scientific and cultural monitoring programmes within Grove Arm estuaries (and elsewhere) would increase the spatial coverage of intertidal habitats in a synergistic manner thereby increasing the interpretive value of both. With further development, a multi-stakeholders approach could be implemented as a model for improved management of coastal environments in New Zealand.

6. ACKNOWLEDGEMENTS

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8. APPENDICES

Appendix 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	*Beilschmiedia tawa* "Tawa"	Beta
				Cordyline australis "Cabbage tree"	Coau
				Cytisus scoparius "Broom"	Cysc
				Dodonea viscosa "Akeake"	Dovi
				Exotic scrub/shrub/trees	Esst
				Knightia excelsa "Rewarewa"	Knex
				Leptospermum scoparium, "Manuka"	Lesc
				Metrosideros excelsa " Pohutukawa"	Meex
				Myoporum laetum "Ngaio"	Myla
				Native scrub/shrub/trees	Nsst
				Paraserianthes lophantha " Brush wattle"	Palo
				Pinus radiata, "Pine tree"	Pira
				Ulex europaeus, "Gorse"	Uleu
			Estuarine Shrubland	*Plagianthus divaricatus*, "Saltmarsh ribbonwood"	Pldi
			Tussockland	*Carex* spp. "Sedge"	Casp
				Cortaderia selloana "Pampas grass"	Cose
				Cortaderia sp. "Toetoe"	Cosp
				Phormium tenax, "New Zealand flax"	Phte
				Stipa stipoides	Stst
			Grassland	*Ammophila arenaria* "Marram grass"	Amar
				Festuca arundinacea, "Tall fescue"	Fear
				Unidentified grass	Ungr
			Sedgeland	*Cyperus eragrostis* "Umbrella sedge"	Cyer
				Schoenoplectus pungens "Three-square"	Scpu
			Rushland	*Isolepis nodosa*, "Knobby clubrush"	Isno
				Juncus kraussii, "Searush"	Jukr
				Leptocarpus similis, "Jointed wirerush"	Lesi
			Reedland	*Typha orientalis* "Raupo"	Tyor
			Herbfield	*Carpobrotus edilus* "Ice Plant"	Caed
				Samolus repens, "Primrose"	Sare
				Sarcocornia quinqueflora, "Glasswort"	Saqu
				Selliera radicans, "Remuremu"	Sera
				Suaeda novae-zelandiae "Sea Blite"	Suno
			Introduced weeds	Unidentified Introduced Weeds	Inwe
		Eelgrass meadow	Eelgrass meadow	*Zostera sp*, "Eelgrass"	Zosp
		Macroalgal bed	Macroalgal bed	*Enteromorpha* sp.	Ensp
				Gracilaria chilensis	Grch
				Ulva sp, "Sea lettuce"	Ulri
		Pine Debris	Pine Debris		Pidb
		Artificial Structure	Man-made structure		MM
			Road		Road
			Wharf		WHF
		Mud/sandflat	Firm sand		FS
			Soft sand		SS
			Mobile sand		MS
			Firm mud/sand		FMS
			Soft mud/sand		SM
			Very soft mud/sand		VSM
		Stonefield	Cobble field		CF
			Gravel field		GF
			Boulder-field (man-made)		BFmm
		Shellfish field	Shell bank		Shel
		Worm field	Sabellid field		Tube
	Subtidal	Water	Water		Wter

Appendix 2. 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 diameter at breast height (dbh). Tree ferns ≥10cm dbh are classified 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 (*cf.* FOREST). Shrubs are woody plants <10 cm dbh.
Shrubland: Cover of shrubs in canopy 20-80%. Shrubs are woody plants <10 cm 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 vary from grass by feeling the stem. If the stem is flat or rounded, it is probably a grass or a reed, if the stem is clearly triangular, it is a sedge. Sedges include many species of Carex, Uncinia, and Scirpus. Tussock-sedges and reed-forming sedges (*cf.* 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. 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. The flowers will each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata.*
Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.
Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and 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 identified 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 (including eelgrass) are the sole marine representatives of the class 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 will 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 will 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 will 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 will 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 will 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 ≥1%.

Boulder field: Land in which the area of unconsolidated bare boulders (>200 mm 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%.

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 ≥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 primarily by 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 oyster species.

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

Appendix 3. Unvegetated substrate present in intertidal zones of Okiwa and Ngakuta Bays, December 2011.

Okiwa Unvegetated Substrata

Class	Dominant Species	Primary Sub-dor	Area (Ha) Intertidal	% Total Intertidal	Area (Ha) Supra-littoral
Bedrock			**0.02**	**0.03**	**0.01**
	Bedrock		0.02		0.01
		Gravel field	0.004		
Cobble Field			**0.32**	**0.53**	
	Cobble Field		0.02		
		Gravel field	0.16		
		Rock field	0.03		
		Soft sand	0.11		
Firm Mud and Sand			**32.26**	**52.81**	
	Firm mud and sand		3.01		
		Cobble field	0.53		
		Gravel field	2.96		
		Gracilaria chilensis	22.95		
		Ulva lactuca (macroa	2.81		
Firm Sand					
	Firm Sand	Cobble field			
		Gravel field			
		Shell bank			
Firm Shell and Sand			**0.25**	**0.40**	
	Firm Shell and Sand	Firm mud and sand	0.25		
Gravel field			**4.58**	**7.50**	**0.03**
	Gravel field		0.06		
		Cobble Field	0.44		
		Firm mud and sand	0.75		
		Firm sand	0.73		0.01
		Shell bank	0.01		
		Soft sand	2.59		0.02
Man-Made Structures			**0.09**	**0.15**	**0.15**
	Man-Made Structures		0.07		0.14
		Rock wall man-made	0.003		
		Seawall			0.01
		Wharf	0.02		0.01
Rockfield			**0.19**	**0.30**	
	Rockfield		0.03		
		Cobble field	0.16		
Shell Bank			**0.02**	**0.03**	
	Shell Bank		0.02		
Soft Mud			**21.51**	**35.21**	**0.01**
	Soft Mud		0.30		0.01
		Cobble field	0.34		
		Gravel field	0.21		
		Gracilaria chilensis	20.66		
		Shell bank	0.01		
Soft Sand			**0.65**	**1.07**	
	Soft Sand	Firm mud and sand	0.07		
		Gravel field	0.58		
Very Soft Mud			**1.19**	**1.96**	
	Very Soft Mud		0.24		
		Gracilaria chilensis	0.94		
		Water	0.02		
Grand Total			**61.08**	**100.00**	**0.20**

Overall Summary		
Water	4.49	0.18
Unvegetated Substrata	61.08	0.20
Estuarine Vegetation	8.99	9.12
Grand Total	**74.56**	**9.50**

Ngakuta Unvegetated Substrata

Class	Dominant Species	Primary Sub-dominant	Area (Ha) Intertidal	% Total Intertidal	Area (Ha) Supra-littoral
Bedrock			**0.04**	**0.49**	
	Bedrock	Cobble field	0.04		
Cobble Field			**0.43**	**6.00**	**0.07**
	Cobble Field	Firm Sand			0.07
		Gravel field	0.10		
		Rock field	0.25		
		Shell bank	0.08		
Firm Mud and Sand			**2.48**	**34.46**	
	Firm mud and sand		0.37		
		Cobble field	0.002		
		Gravel field	1.63		
		Ulva lactuca (macroalgae)	0.27		
		Water	0.02		
		Zostera sp. (Eelgrass)	0.18		
Firm Sand			**3.12**	**43.28**	
	Firm Sand	Cobble field	1.25		
		Gravel field	1.41		
		Shell bank	0.45		
Firm Shell and Sand			**0.31**	**4.35**	
	Firm Shell and Sand	Gravel field	0.31		
Man-Made Structures			**0.04**	**0.56**	**0.23**
	Man-Made Structures		0.02		0.08
		Road			0.09
		Seawall			0.05
		Wharf	0.02		
Shell Bank			**0.01**	**0.19**	
	Shell Bank		0.01		
Soft Mud			**0.28**	**3.89**	
	Soft Mud		0.27		
		Water	0.01		
Soft Sand			**0.49**	**6.77**	**0.003**
	Soft Sand		0.03		0.003
		Cobble field	0.25		
		Shell bank	0.21		
Grand Total			**7.20**	**100.00**	**0.30**

Overall Summary		
Water	0.10	0.001
Unvegetated Substrata	7.20	0.30
Estuarine Vegetation	2.54	2.01
Grand Total	**9.84**	**2.31**

Appendix 4. Vegetated substrate present in in intertidal zones of Okiwa and Ngakuta Bays, December 2011.

Okiwa Estuarine Vegetation

Class	Dominant Species	Primary Sub-dominant	Area (Ha) Intertidal	% Total Intertidal	Area (Ha) Supra-littoral
Estuarine Shrubs			**0.63**	**7.00**	**0.20**
	Muehlenbeckia complexa (Maidenhair Vine)	*Plagianthus divaricatus* (Saltmarsh ribbonwood)	0.02		
	Plagianthus divaricatus (Saltmarsh ribbonwood)		0.08		
		Exotic scrub/shrub/trees	0.03		0.043
		Juncus kraussii (Searush)			0.117
		Leptospermum scoparium (Manuka)	0.13		0.038
		Leptocarpus similis (Jointed wirerush)	0.31		
		Native scrub/shrub/trees	0.06		
Grassland					**0.82**
	Festuca arundinacea (Tall grass)	Exotic scrub/shrub/trees			0.002
	Grassland				0.69
		Exotic scrub/shrub/trees			0.12
Herbfield			**0.39**	**4.36**	
	Sarcocornia quinqueflora (Glasswort)	*Juncus kraussii* (Searush)	0.02		
		Samolus repens (Primrose)			
		Shell bank			
	Samolus repens (Primrose)	Firm mud/sand (0-2cm)	0.000		
		Gravel field	0.37		
		Juncus kraussii (Searush)	0.01		
		Sarcocornia quinqueflora (Glasswort)			
Macroalgal bed			**0.50**	**5.52**	
	Gracilaria chilensis		0.01		
		Soft mud/sand (2-5cm)	0.23		
		Ulva sp. (Sea lettuce)	0.26		
Reedland			**0.06**	**0.65**	**0.005**
	Typha orientalis (Raupo)		0.02		0.005
		Phormium tenax (New Zealand flax)	0.04		
Rushland			**5.29**	**58.86**	**0.35**
	Juncus kraussii (Searush)		0.05		
		Cobble field	0.003		
		Exotic scrub/shrub/trees	0.01		
		Festuca arundinacea (Tall grass)	0.02		
		Firm mud/sand (0-2cm)	0.07		
		Gravel field	0.53		
		Leptocarpus similis (Jointed wirerush)	2.58		
		Plagianthus divaricatus (ribbonwood)	0.41		0.35
		Sarcocornia quinqueflora (Glasswort)	0.05		
		Samolus repens (Primrose)	0.55		
		Soft mud/sand (2-5cm)	0.31		
	Leptocarpus similis (Jointed wirerush)		0.14		
		Cobble field	0.01		
		Gravel field	0.01		
		Juncus kraussii (Searush)	0.54		
		Soft mud/sand (2-5cm)	0.02		

Class	Dominant Species	Primary Sub-dominant	Area (Ha) Intertidal	% of Total Intertidal	Area (Ha) Supra-littoral
Seagrass meadow			**1.67**	**18.59**	
	Zostera sp. (Eelgrass)		0.04		
		Firm mud/sand (0-2cm)	0.50		
		Gracilaria chilensis	0.63		
		Soft mud/sand (2-5cm)	0.04		
		Ulva sp. (Sea lettuce)	0.47		
Sedgeland			**0.004**	**0.05**	
	Schoenoplectus pungens (Thre	Gravel field	0.003		
		Soft sand	0.001		
Terrestrial Shrub/Scrub/Forest			**0.43**	**4.82**	**7.58**
	Exotic scrub/shrub/trees				0.02
		Native scrub/shrub/trees			0.50
	Leptospermum scoparium (Manuka)				0.004
		Exotic scrub/shrub/trees			0.14
		Festuca arundinacea (Tall grass)	0.180		
		Plagianthus divaricatus (Saltmarsh ribbonwood)	0.071		
	Native scrub/shrub/trees		0.042		3.31
		Exotic scrub/shrub/trees	0.068		1.91
		Festuca arundinacea (Tall grass)			0.68
		Juncus kraussii (Searush)	0.07		0.11
		Plagianthus divaricatus (Saltmarsh ribbonwood)			0.89
	Salix cinerea (Grey willow)				0.02
Tussockland			**0.01**	**0.14**	**0.17**
	Cortaderia selloana (Pampas grass)		0.002		
	Cortaderia sp. (Toetoe)	*Leptospermum scoparium* (Manuka)	0.007		0.08
	Phormium tenax (NZ Flax)				0.09
		Typha orientalis (Raupo)	0.004		
Grand Total			**8.99**	**100.00**	**9.12**

Overall Summary		
Water	4.49	0.18
Unvegetated Substrata	61.08	0.20
Estuarine Vegetation	8.99	9.12
Grand Total	**74.56**	**9.50**

Ngakuta Estuarine Vegetation

Class	Dominant Species	Primary Sub-dominant	Area (Ha) Intertidal	% Total Intertidal	Area (Ha) Supra-littoral
Estuarine Shrubs					**0.05**
	Plagianthus divaricatus (Saltmarsh ribbonwood)	Exotic scrub/shrub/trees			0.004
		Native scrub/shrub/trees			0.01
		Phormium tenax (New Zealand flax)			0.03
Grassland					**0.55**
	Unidentified grass				0.14
		Exotic scrub/shrub/trees			0.40
		Native scrub/shrub/trees			0.01
Herbfield			**0.26**	**9.99**	
	Sarcocornia quinqueflora (Glasswort)		0.00		
		Samolus repens (Primrose)	0.08		
		Shell bank	0.01		
	Samolus repens (Primrose)	*Isolepis cernua* (Slender clubrush)	0.01		
		Juncus kraussii (Searush)	0.11		
		Leptocarpus similis (Jointed wirerush)	0.04		
		Sarcocornia quinqueflora (Glasswort)	0.005		
Macroalgal bed			**0.60**	**23.33**	
	Gracilaria chilensis	*Ulva* sp. (Sea lettuce)	0.32		
	Ulva sp. (Sea lettuce)	Firm sand (<1cm)	0.05		
		Gracilaria chilensis	0.22		
Rushland			**0.66**	**26.01**	
	Isolepis nodosa (Knobby clubrush)	*Samolus repens* (Primrose)	0.05		
	Juncus kraussii (Searush)		0.002		
		Cobble field	0.19		
		Festuca arundinacea (Tall grass)	0.12		
		Firm sand (<1cm)	0.02		
		Sarcocornia quinqueflora (Glasswort)	0.04		
		Samolus repens (Primrose)	0.22		
		Soft sand	0.004		
	Leptocarpus similis (Jointed wirerush)		0.004		
		Juncus kraussii (Searush)	0.004		
Seagrass meadow			**0.72**	**28.09**	
	Zostera sp. (Eelgrass)		0.10		
		Firm mud/sand (0-2cm)	0.35		
		Firm sand (<1cm)	0.17		
		Soft mud/sand (2-5cm)	0.10		
Sedgeland			**0.02**	**0.83**	
	Isolepis cernua (Slender clubrush)	*Samolus repens* (Primrose)	0.02		
Terrestrial Shrub/Scrub/Forest			**0.30**	**11.76**	**1.41**
	Exotic scrub/shrub/trees				0.07
		Festuca arundinacea (tall grass)			0.01
	Native scrub/shrub/trees				0.05
		Exotic scrub/shrub/trees	0.001		1.29
		Festuca arundinacea (tall grass)	0.29		
	Pinus radiata (Pine tree)	Exotic scrub/shrub/trees	0.01		
Grand Total			**2.55**	**100.00**	**2.01**

Overall Summary		
Water	0.10	0.001
Unvegetated Substrata	7.20	0.30
Estuarine Vegetation	2.54	2.01
Grand Total	**9.84**	**2.31**

Appendix 5. DVD-ROM file containing a working version of the 2011 broad-scale habitat maps of Okiwa and Ngakuta Bays.