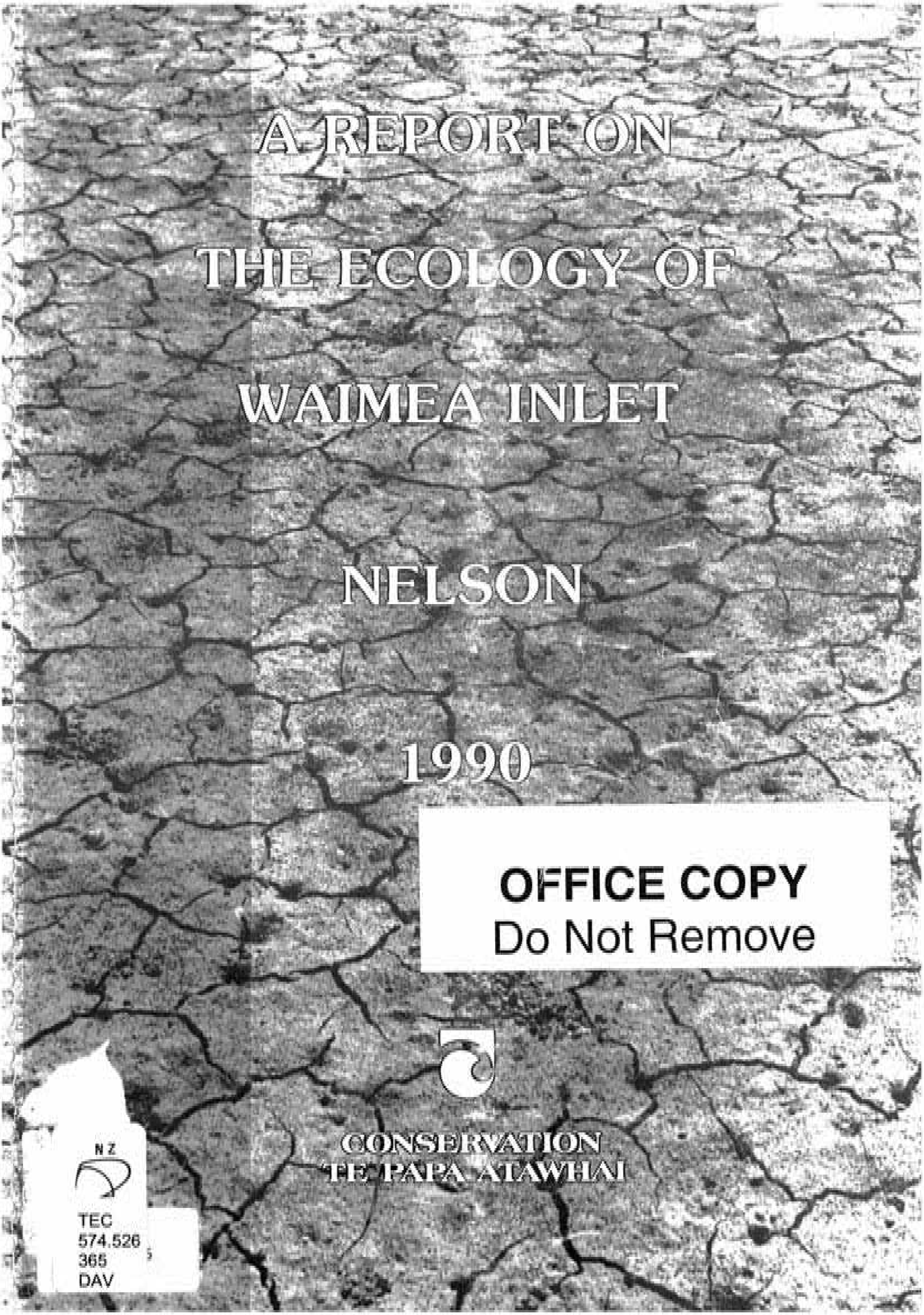

A REPORT ON THE ECOLOGY OF WAIMEA INLET NELSON

1990

CONSERVATION
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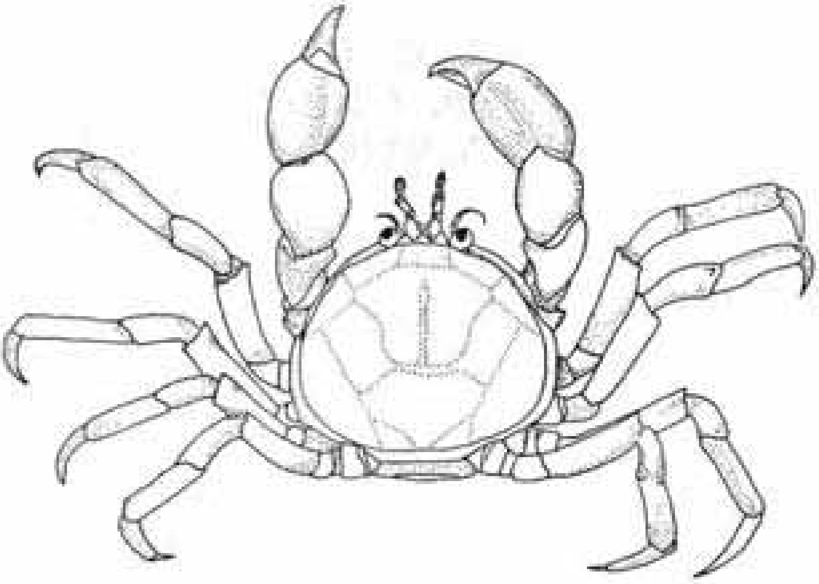
A REPORT ON THE ECOLOGY OF

WAIMEA INLET

NELSON



Robert J Davidson

C. Robert Moffat

Department of Conservation

Nelson/Marlborough Conservancy

Occasional Publication No. 1

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Lloyd Homer	Plate 1, 18
Garry Holz	Plate 6
Rob Davidson	All other plates

Cover : Highshore mudflats - Garry Holz

PREFACE

The coastal zone, in many senses, is the centre of New Zealand. Lying between land and sea, it defines the interaction between our terrestrial and our much larger marine environments.

In estuaries the boundary between land and sea is convoluted into a complex mosaic. These areas are rich in plant and animal life. They are the nurseries for inshore fisheries and their shallow waters are basins of high productivity. In this sense they are the cornerstone of coastal ecology.

Estuaries are also a focus of human activity. Sheltered from the direct buffeting of the sea, they have long been havens for vessels and a focus of settlement. Many of the most ancient Maori sites are located in and around estuaries.

Our estuaries are, however, also vulnerable and, in the last century, have been seriously under-valued. Seen as free land, they have been filled in, often just to dispose of rubbish or to act as a location for industries unacceptable in other localities.

In New Zealand, we have been fortunate in that, compared with other countries, the process has been slow. On the eastern seaboard of the United States people are now rebuilding estuaries by removing reclamations made for residential subdivisions in the hope of seeing a recovery of inshore fisheries.

The Waimea Estuary shares all of the value of the estuaries generally, and all of their vulnerability. Linked to a complex of coastal wetlands that stretches from Croisilles Harbour to Farewell Spit, it is the heart of the most complex and extensive estuarine system in New Zealand.

Much of the Waimea Estuary has, however, been filled in from its margins and made into a receptacle for waste. Approximately 200 hectares of the original estuary has been lost, mostly marginal vegetation which is the base of the estuarine food chain.

This report sets out a detailed survey of what remains, assesses its value and makes recommendations for its protection. This report will form the basis of input by the Department of Conservation into coastal planning in the Nelson/Marlborough Conservancy. The recommendations will be seen by some as hard hitting, we make no apology for that - our estuaries are too valuable to lose.

Ian Black
Regional Conservator

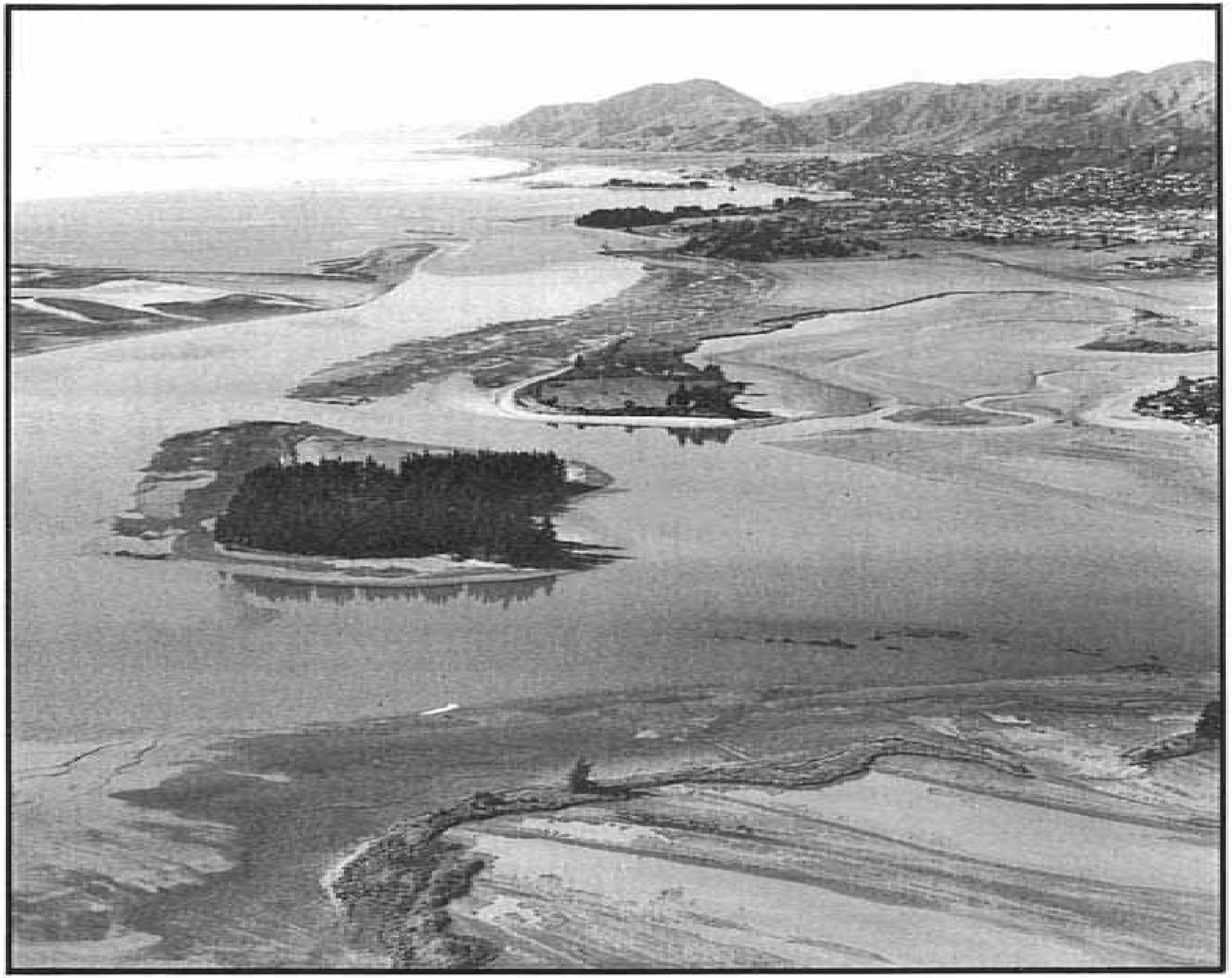

Plate 1 Eastern entrance to Waimea Inlet

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ACKNOWLEDGEMENTS

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Thanks are also due to staff who assisted with field work. They are in alphabetical order: Keri Adams, Jim Black, Amanda Ditzel, Sheryl File, Peter Gaze, Katrina Goad, Marian Hansen, Biddy Harnett, Alex Johnston (Field Staff Co-ordinator), Kendal Kelly, Bruce McKenzie, Dave Price, Simon Ridley, Gavin Rodley, Sharyn Taylor, Robyn Usmar and Ken Wright.

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We would also like to thank Andrew Baxter, Peter Lawless, Lianne Rich, Ian Millar and Kath Walker for constructive criticism and advice throughout this study and Helmut Janssen for binding of the report.

A big thanks to Keri Adams and Helen Price for accurately typing the manuscript and tables.

ABSTRACT

Waimea Inlet is the largest estuary in the South Island (3,455 ha). Within the inlet are ten islands and numerous shell banks.

The inlet has been occupied by man since the 1500's. A large Maori presence was associated with the Appleby Pa. The Maori population declined following invasion by Te Rauparaha's warriors.

Europeans colonised the area in the 1840's and began an intensive programme of land development. This resulted in significant changes to the estuary and surrounding land.

Ten major habitat types were recognised in Waimea Inlet (mobile sand, fine sand, eelgrass, mudflat, highshore flat, *Sarcocornia*, pebble and cobble, native rush and sedge, *Spartina*, and subtidal). A characteristic invertebrate community was recognised from each habitat.

The location and size of each habitat in Waimea Inlet were mapped. The most common habitat type was mudflat (1126 ha) followed by fine sand flat (784 ha), subtidal (587 ha), mobile sand (342 ha), pebble and cobble (197 ha), highshore (145 ha), *Sarcocornia* (93 ha), Rushes and sedges (75 ha), *Zostera* (58 ha) and *Spartina* (29 ha).

Invertebrates were collected from 61 sites and 305 core samples in Waimea Inlet. One hundred and twelve invertebrate species were recorded from intertidal and subtidal sites. This compared favourably with the productive estuaries in New Zealand. The highest density of benthic invertebrates was 76,340 per m^2, recorded near Grossis Point. Intertidally, the Mollusca were represented by 37 species, Polychaeta by 36 species, Crustacea by 27, Coelenterata 2, Nemertina 2, Platyhelminthes 1, Aschelminthes 1, Sipunculida 2 and Echinodermata 2. No rare or endangered invertebrates were recorded, but some species were restricted to small areas in Waimea Inlet.

Thirty-one marine and 11 freshwater fish species were recorded from the estuary or tidal reaches of streams.

Twenty estuarine vascular plants were recorded from Waimea Inlet.

Only 227 ha or 6.6% of the intertidal area of Waimea Inlet remains in native estuarine vegetation.

Fifty species of water bird were recorded from Waimea Inlet. The inlet is regarded as nationally important to waders; herons, egrets and spoonbills; and banded rail.

Comparison of Waimea Inlet with other New Zealand estuaries suggests that Waimea is ecologically important. The number of species of invertebrates, fish, birds and intertidal plants compared favourably with other estuaries.

Criteria based on conservation values were developed for evaluation of estuaries and areas within estuaries. Using these criteria, Waimea Inlet was compared with two other estuaries in the South Island. Waimea Inlet recorded the highest value of the three.

The whole western inlet is considered of outstanding biological importance. It is recommended that this area be protected.

Eleven intertidal and eight terrestrial areas of special biological interest were recognised in Waimea Inlet. These areas are recommended for protection status.

Human impact and the areas in Waimea Inlet where the greatest impacts have occurred are outlined.

Recommendations are made for the future management of Waimea Inlet.

1. INTRODUCTION AND OBJECTIVES

The Nelson/Marlborough coastline administered by the Department of Conservation stretches from Kahurangi Point on the West Coast to the Conway River on the East Coast of the South Island. Within this 2,000 km of coastline are approximately 38 estuarine systems (McLay, 1976). Only one estuarine wildlife refuge has been established in the region (Wairau River Estuary). Parapara Inlet (Knox et. al., 1977), Delaware Inlet (Gillespie and MacKenzie, 1981; Gillespie, 1983; MacKenzie, 1983; Franko, 1988), Moutere Inlet (Moffat, 1989), Whanganui Inlet (Davidson, in prep) and Waimea Inlet (Updegraff et. al., 1977; Bolton and Knox, 1977) are the only other estuaries in the Nelson/Marlborough Region investigated in detail. Whanganui (Westhaven) Inlet is the subject of a current biological survey run by the Department of Conservation. The remaining 32 estuaries have had little or no biological work.

Development around many of these estuaries has already degraded many important estuarine habitats (Knox, 1980). A number of rare and endangered plants once recorded from the region's estuaries are now locally extinct. All of the estuaries in the Nelson/Marlborough region are vulnerable to further degradation.

Waimea Inlet is close to the urban and industrial areas of Nelson, Stoke and Richmond and is probably the most threatened estuary in the Nelson/Marlborough Region. The margins of the inlet are prime sites for development and have been significantly modified over the last 150 years. Most of the original terrestrial vegetation and many large salt marshes have been destroyed, large areas of former estuary have been transformed by industry, farms, stopbanks and rubbish tips. Past pollution levels in Waimea Inlet resulted in low water quality, algal blooms and strong smells.

Despite extensive modification, Waimea Inlet is regarded as an area of outstanding biological value (Walker, 1987). A comprehensive ecological survey of Waimea Inlet was therefore considered important before more ecologically important areas within the estuary were lost. This present report investigates the ecology of Waimea Inlet and outlines a set of conservation guidelines for future management.

The study set out to achieve the following objectives:

1. map vegetation, substrates, structures and industry within and adjacent to the inlet;
2. obtain baseline biological information on vegetation, invertebrates, fishes and birds;
3. relate invertebrate species composition to habitat type and assess the accuracy of predicting species composition in non-sampled areas;
4. identify biologically important areas in Waimea Inlet;
5. identify threats to the estuary and suggest possible solutions; and
6. make recommendations for the management of Waimea Inlet.

2. WAIMEA INLET

Approximately 6,000 years ago, post-glacial sea levels rose to present day levels. Over the last 6,000 years sea levels have fluctuated above and below this level by +0.6 m and -0.4 m (Gibb, 1986). During this period sediments were transported from the north-west and east and deposited as storm beach ridges on the Waimea Plains. Since the post-glacial maximum sea level, sea and river erosion and human activity have removed much of the storm ridges (Johnston, 1979, 1986).

Waimea Inlet at present is a shallow bar-built estuary open to Tasman Bay at the western (Mapua) and eastern (Nelson) ends of Rabbit Island (latitudes 41° 15-20′S, and longitudes 173° 4-13′E) (Fig. 1). The sea enters this large tidal compartment twice daily, rising between 2.6 and 4.2 m. As much as 62 million m^3 of water enter the inlet on each spring tide (Westcott, 1975; Pemberton, 1976). A combination of large tidal volume and the shallow nature of the inlet result in a relatively quick flushing action (Heath, 1976). In the areas around the outlets, the strong tidal currents select for coarser substrates (mobile sand, pebbles and cobbles). Substrates in the main body of the inlet are dominated by extensive intertidal fine sand and mudflats. Remnants of salt marsh vegetation fringe the inlet.

The boundaries of Waimea Inlet were defined as a line drawn from the eastern and western tips of Rabbit Island across the outlets to the south-eastern end of Tahuna Beach and to Mapua Leisure Park. The margins of Waimea Inlet were assigned as the point where true estuarine plants were replaced by splash zone vegetation.

The total area of islands within the inlet (excluding Rabbit Island) constitutes 466 ha. The remaining tidal area (3454.6 ha) is dominated by intertidal flats (2867.3 ha) and 587.3 ha of subtidal and river channels. This total tidal area figure is 6.3 ha smaller than the Harbour Board's value (1978). The reduction of estuarine area by infilling probably accounts for the difference.

Waimea Inlet is the largest single estuarine unit in the South Island and falls into the 10% of New Zealand's estuaries larger than 1700 ha. (McLay, 1976). Within Waimea Inlet are ten islands including Bells (147 ha), Bests (132 ha), Bird (1.3 ha), Deadmans (4.1 ha), Saxton (7 ha), Oyster (4.7 ha), Pig (0.3 ha), Bullivant, Rough and No-mans Island.

Modification of the estuary shoreline has been greatest in the eastern or Nelson side of the inlet. Here the urban centres of Stoke and Richmond lie close to the estuary margins, while Nelson is only 3-8 km from the inlet. Over 42,000 people live within a radius of

8 km of Waimea Inlet. This relatively high population has lead to agricultural and industrial encroachment along the eastern boundaries. Significant reduction of marginal vegetation and mudflats has occurred. The Mapua or western inlet is surrounded by gently sloping hillsides used for agriculture, horticulture and forestry. The high tide boundaries of the western inlet remain relatively unchanged.

The Waimea River is the largest source of freshwater entering the inlet. The river flows behind Rabbit Island in an easterly direction and flows into the Blind Channel adjacent to the Aerodrome Peninsula (Fig. 1). Significant freshwater, however, enters the western inlet following high tide and during large flood events. Normal flows into the inlet are approximately 19 cumecs, however flood events of 2,000 cumecs have been recorded.

Approximately 22 small streams enter the estuary. The three largest are O'Connor Creek and the spring-fed Nieman and Pearl Creeks (Fig. 1). O'Connor, Neiman and Pearl Creeks are tidally influenced with estuarine plants and animals penetrating their reaches.

Waimea Inlet and the surrounding land has been occupied since the 1500's. A Pa and gardens are recorded near Appleby (Appendix 1) and numerous areas of Maori habitation have been identified around the inlet. European settlement began in the 1840's with the arrival of immigrant ships (Appendix 1). Since this time modification of estuary margins has been significant. Large swamps and areas of coastal forest have been drained, burned or logged. Today, much of the estuary margins bear little resemblance to the inlet prior to human arrival.

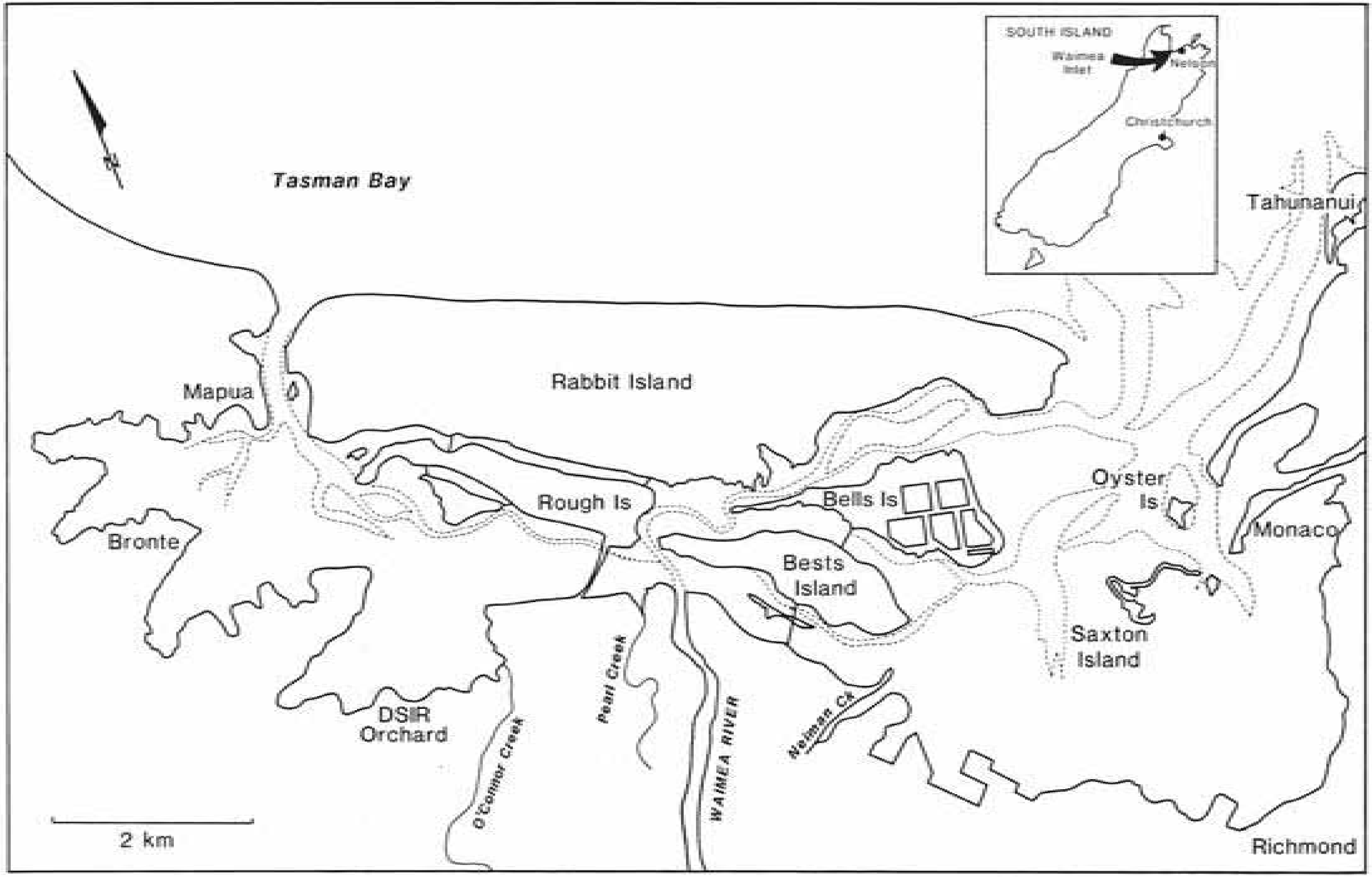


FIGURE 1.Waimea Inlet

3. HABITATS AND HABITAT MAPPING

Within Waimea Inlet, many physical and biological factors interact to form unique estuarine areas or habitats. Each area of habitat type is associated with a community consisting of plants and animals. Each community is able to cope with a particular set of environmental constraints. Recognition and mapping of the main habitats in Waimea Inlet (this chapter) and determination of characteristic flora and fauna associated with each habitat type (section 4.1.3) forms the basis of the report.

3.1 HABITAT TYPES

This section describes the major habitats in Waimea Inlet. Each habitat type was recognised using either physical factors (eg. substrate type, tidal height, and salinity), or on biological features such as the presence and abundance of certain plants and animals. Using the combination of physical and biological features ten basic habitats were recognised in the Waimea Inlet. A description of characteristic fauna from each habitat are summarized in section 4.1.3.

1. Mobile sand

   Mobile sand in Waimea Inlet is recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal currents and often forms bars and beaches.

2. Fine sand flats

   Fine sand flats are 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 (plate 2). Fine sand may have a thin layer of silt on the surface making identification from a distance impossible. Fine sand flats may be covered with a layer of sea lettuce (*Ulva*) or *Enteromorpha*.

3. *Zostera muelleri* (eelgrass beds)

   Eelgrass usually establishes on fine sand flats. The establishment of eelgrass may result in a build up of silt and clay around the roots and stems. Eelgrass grows below the mid-tide level and dies off in the winter months in Waimea Inlet.

4. Mudflats

   Mudflats below the high tide level appear brown on the surface with a black anaerobic layer below. Most mudflat areas in Waimea Inlet are composed of thick glutinous silt and clay which, when rubbed between the fingers appears soft and non-granular. Small pebbles or shell material within mudflats provide attachment for agar weed (*Gracilaria* sp.)(plate 3).

5. Pebbles and cobbles

Pebbles and cobbles range in size from 4-256 mm in diameter. This hard substrate is located at all tidal heights (plates 4, 5).

6. Highshore flats

A variety of substrates including mixtures of sand, mud, shingle and gravel are located in the high tide zone of Waimea Inlet. These areas dry out and may crack during the warm summer months (plate 6).

7. *Sarcocornia* (glasswort beds)

Sarcocornia quiqueflora or glasswort is located in the high tide zone of Waimea Inlet. The glasswort is succulent in appearance and grows on all substrate types present in the high tide zone (plate 7).

8. Native rushes and sedges

Two rushes (*Juncus maritimus*, *Leptocarpus similis*) and one sedge (*Schoenoplectus pungens*) were sampled in Waimea Inlet. Another sedge, *Bolboschoenus caldwellii* was recorded in the inlet but not sampled. Each species within this habitat grouping is easily distinguished and most often located near freshwater input around the margins of the inlet (plate 8, 9).

9. *Spartina*

Spartina anglica, the introduced cord grass is located around most of Waimea Inlet in the mid-high tide zone. *Spartina* is recognised by a tall grass-like appearance and characteristic reproductive flower spikes. *Spartina* dies off in winter and reappears in spring.

10. Subtidal and river channels

Subtidal and river channels are tidally influenced areas permanently covered by water.

Plate 2 Fine sand

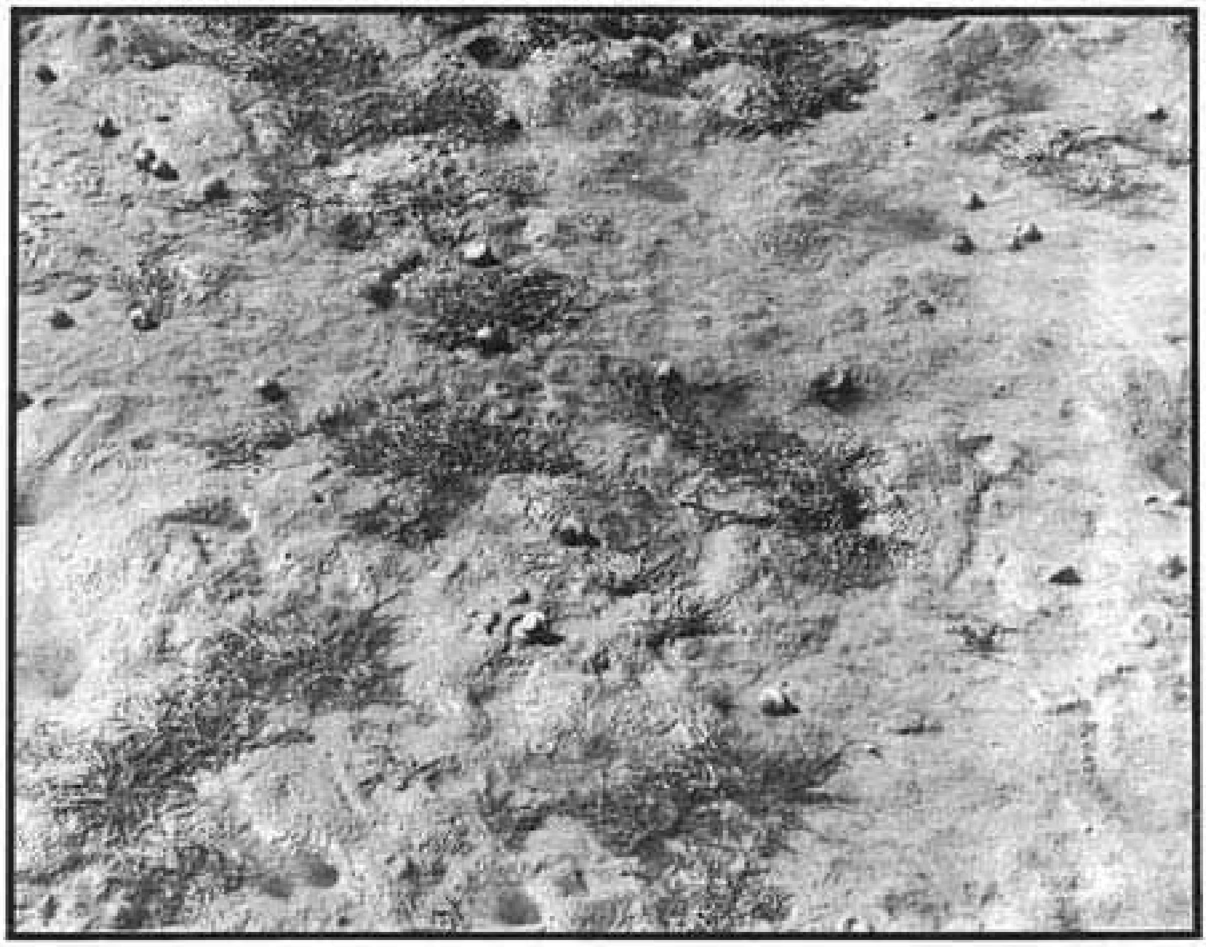


Plate 3 Agar weed *(Gracilaria)*

Plate 4 Pebble/cobble habitat at No-mans Island

Plate 5 Pebble/cobble habitat covered with the Pacific Oyster

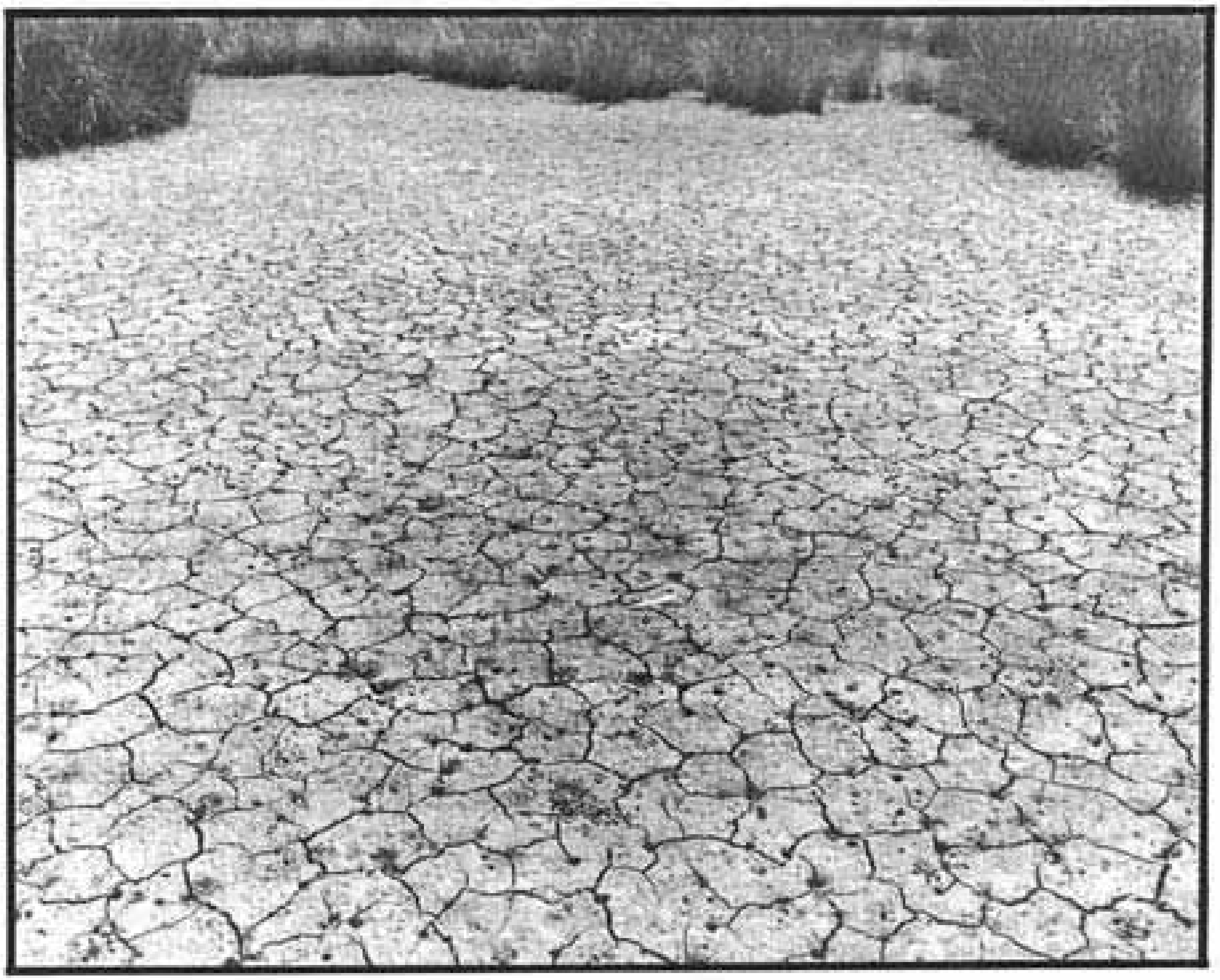


Plate 6 High shore

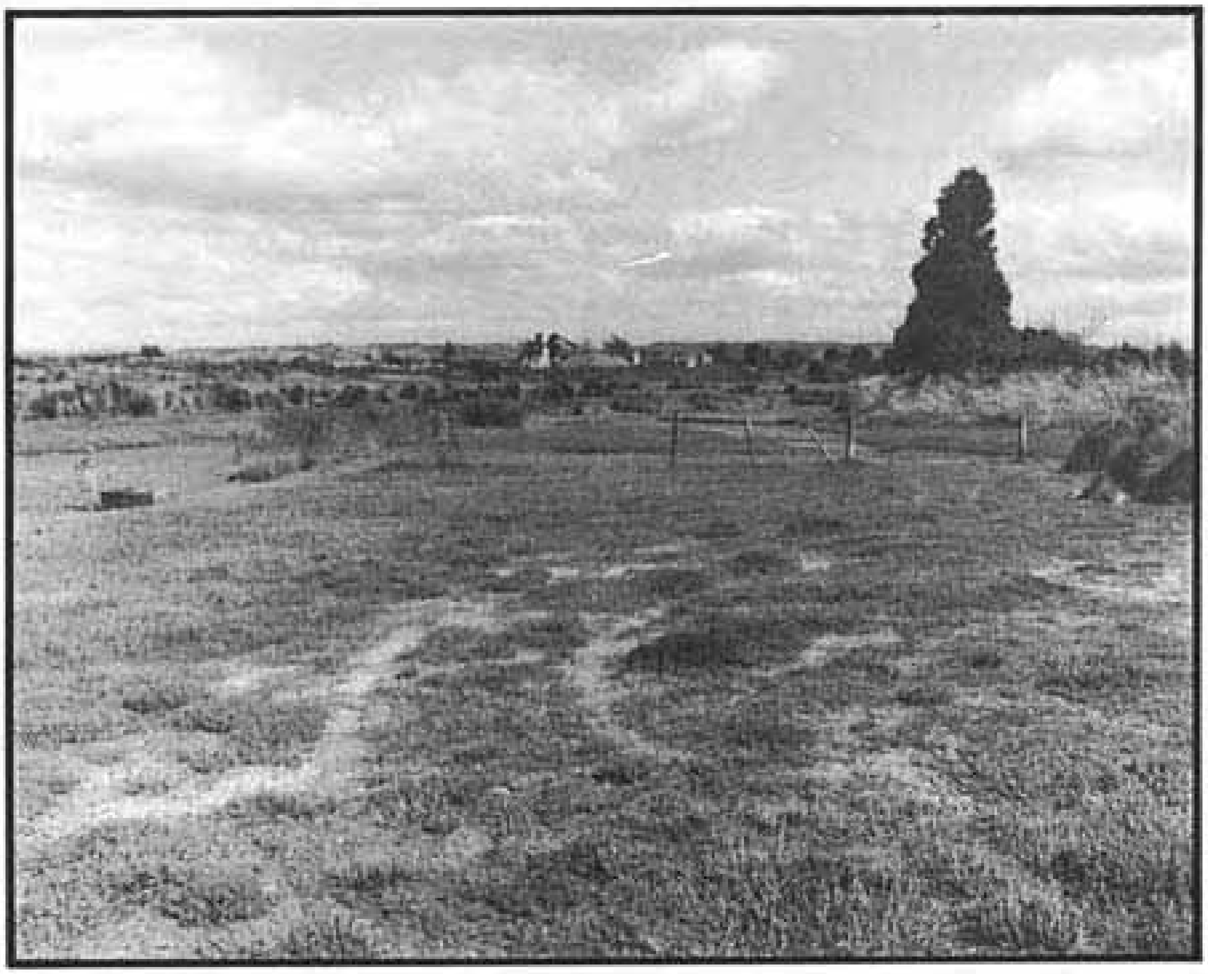


Plate 7 Glasswort *(Sarcocornia quinqueflora)*

Plate 8 Rushes *(Juncus maritimus* and *Leptocarpus similis)*

Plate 9 Native sedge *(Schoenoplectus pungens)*

3.2 HABITAT AND VEGETATION MAPS

The distribution of the major habitats and vegetated areas in Waimea Inlet were determined using aerial photographs flown on a 1.1 m low tide and enlarged to 1:10,000. Habitats were field verified and marked on aerial photographs using chinagraph markers. The inlet was divided into nine areas (Fig. 2), presented on A3 sheets with an accompanying key (Table 1, Maps 1-9).

3.3 AREA OF EACH HABITAT

Habitat areas were calculated using a planimeter and dot-grids. Biologically important and relatively rare plant species are presented in Table 2. Not all plant species were mapped but their presence was noted.

The largest habitat in Waimea Inlet was mudflat (1126 ha), followed by fine sandflats and subtidal and river channels. Vegetation was dominated by the glasswort *Sarcocornia quiqueflora* (93 ha), followed by the combined rushes and sedges (75 ha) and eelgrass (58 ha). The estuarine area covered by native vegetation was 227 ha or 6.55 % of all Waimea Inlet. The introduced cord grass *Spartina anglica* covered 29 ha of intertidal Waimea Inlet.

MAP INDEX

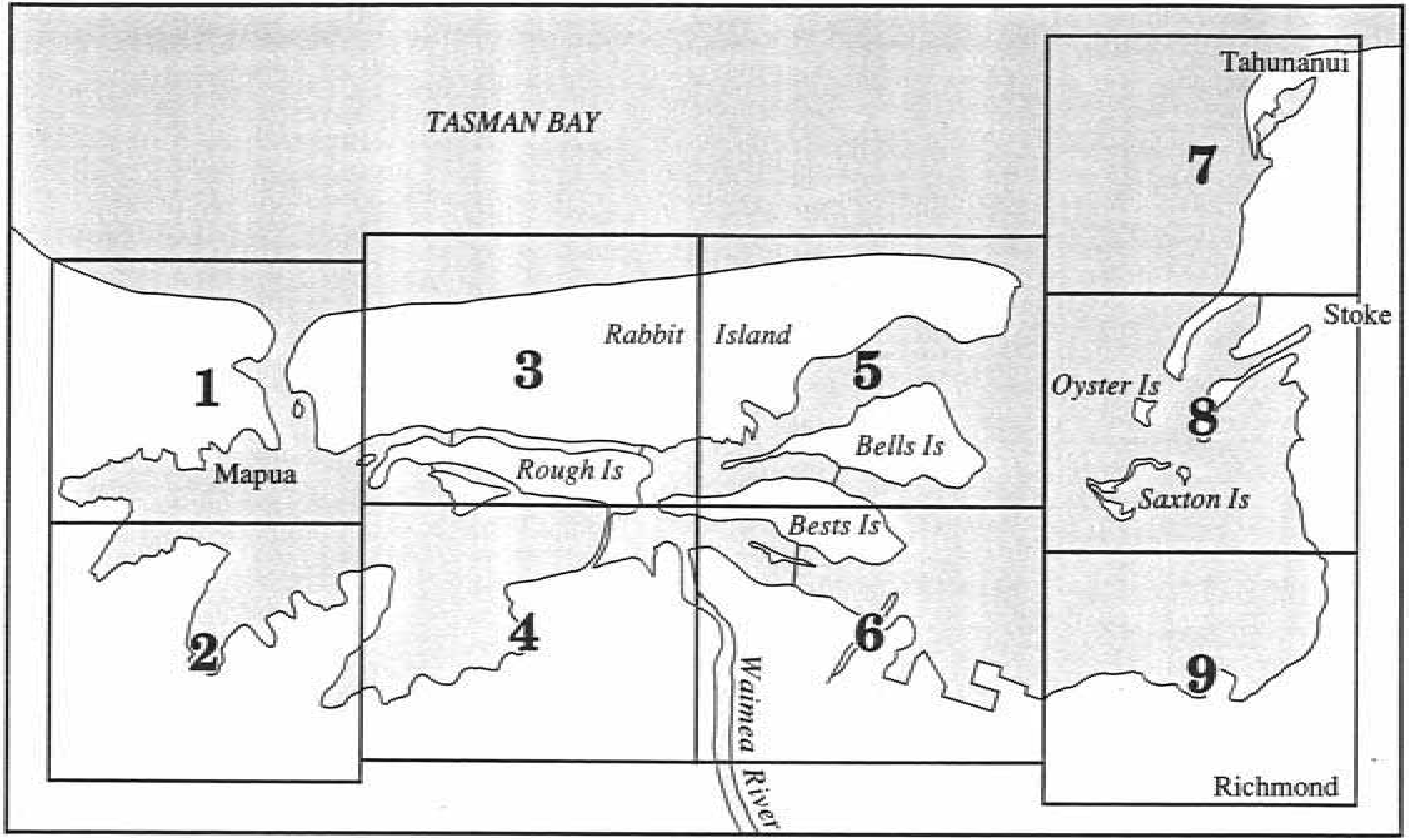


FIGURE 2

HABITAT TYPES - WAIMEA INLET

ESTUARINE SUBSTRATE

	Mobile Sand
	Fine Sand
	Mud
	Pebbles/Cobbles
	Highshore
	Subtidal

ESTUARINE VEGETATION

Z	*Zostera muelleri*
J	*Juncus maritimus*
L	*Leptocarpus similis*
Sc	*Schoenoplectus pungens*
G	*Gracilaria sp.*
S	*Sarcocornia quinqueflora*
Bc	*Bolboschoenus caldwellii*
Sp	*Spartina anglica*
Sv	*Schoenoplectus validus*
Ss	*Stipa stipoides*
En	*Enteromorpha sp.*

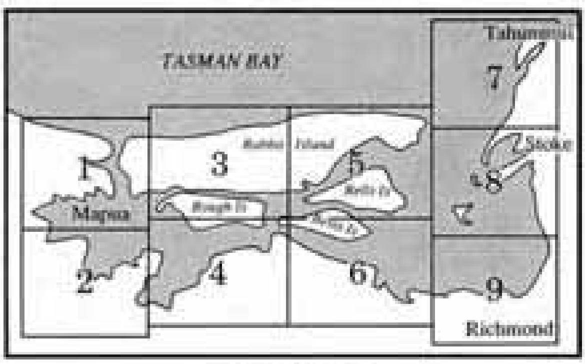
TERRESTRIAL VEGETATION

Br	Broadleaf	F	Flax
Be	Beech	T	Totara
M	Manuka	C	Cabbage Tree
K	Kanuka	Pl/p	*Plagianthus*/Pasture
R	Raupo		

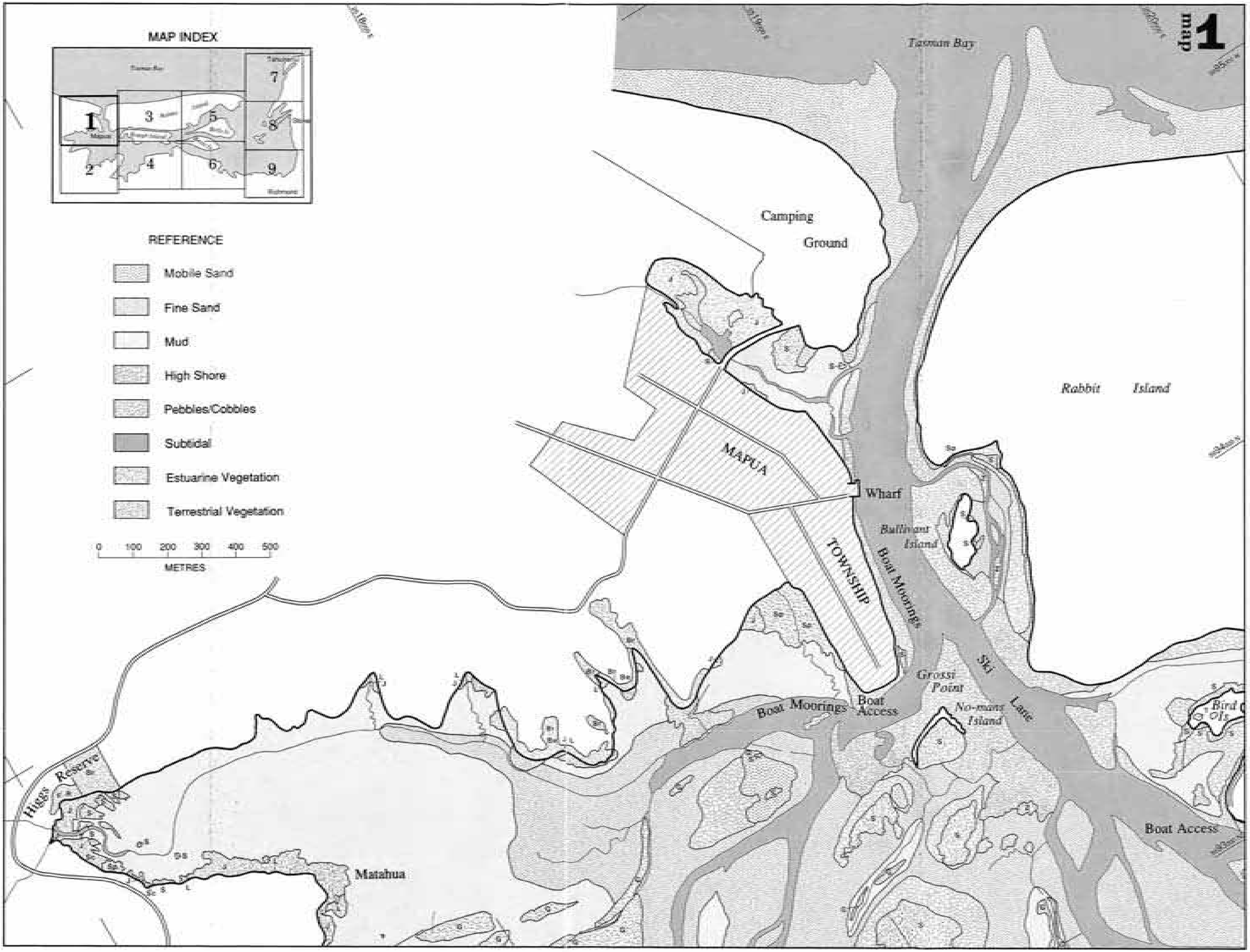
TOPOGRAPHY & LINE WORK

Roads	Residential Area
Buildings	
Estuary Boundary	
Vegetation & Substrate Boundary	
Waterway & Tidal Boundary	

The aerial photographs used in the compilation of these maps were flown on 8 May 1997. Sea level was at 1.1 metres above datum.
As they were unrectified, there may be a small amount of grid to ground position error.



MAP INDEX


map 1
MAP INDEX
1
2
3
4
5
6
7
8
9
REFERENCE
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
0 100 200 300 400 500
METRES
Tasman Bay
Camping Ground
Rabbit Island
MAPUA TOWNSHIP
Wharf
Bullivant Island
Boat Moorings
Grossi Point
Ski Lane
No-mans Island
Boat Access
Bird Is
Higgs Reserve
Matahua

Bronte
Bronte Road East
Hoddys Road
Stringer Creek
Coastal Highway
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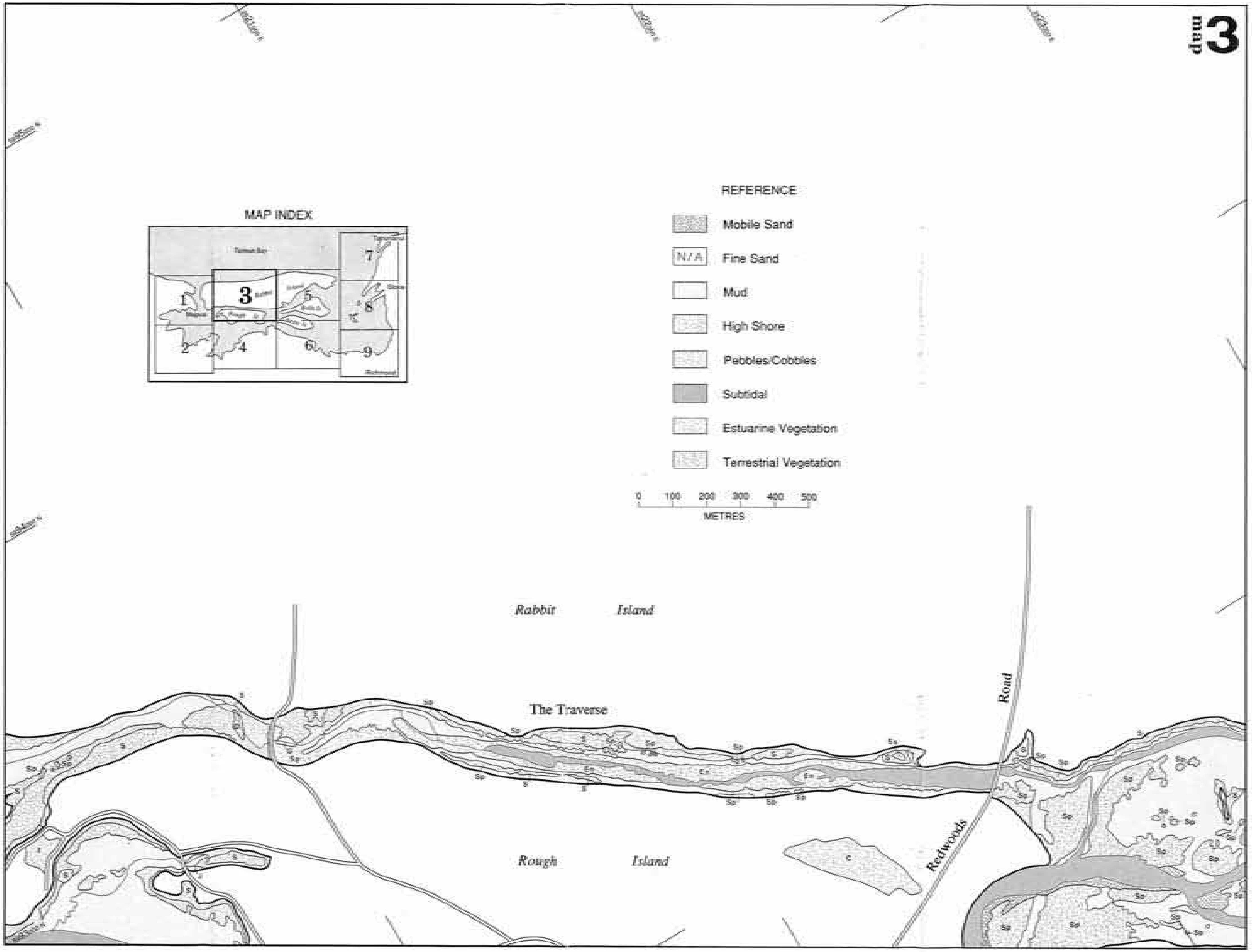
REFERENCE
N/A
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
0 100 200 300 400 500
METRES
map 2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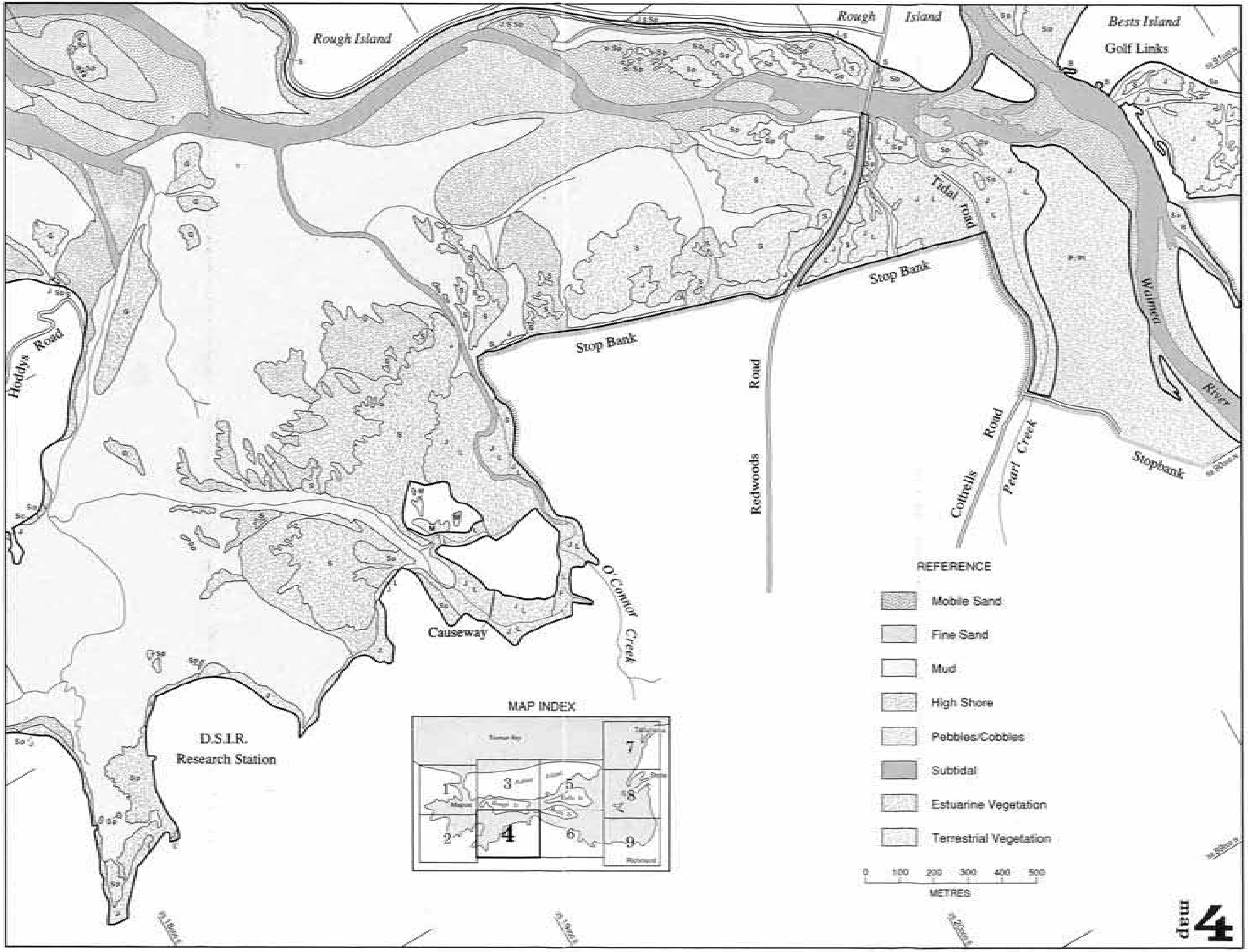
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
0
100
200
300
400
500
METRES
Rabbit Island
The Traverse
Rough Island
Redwoods Road


Rough Island
Rough Island
Bests Island
Golf Links
Tidal road
Stop Bank
Stop Bank
Hoddys Road
Redwoods Road
Cottrells Road
Pearl Creek
Waimea River
Stopbank
O'Connor Creek
Causeway
D.S.I.R.
Research Station
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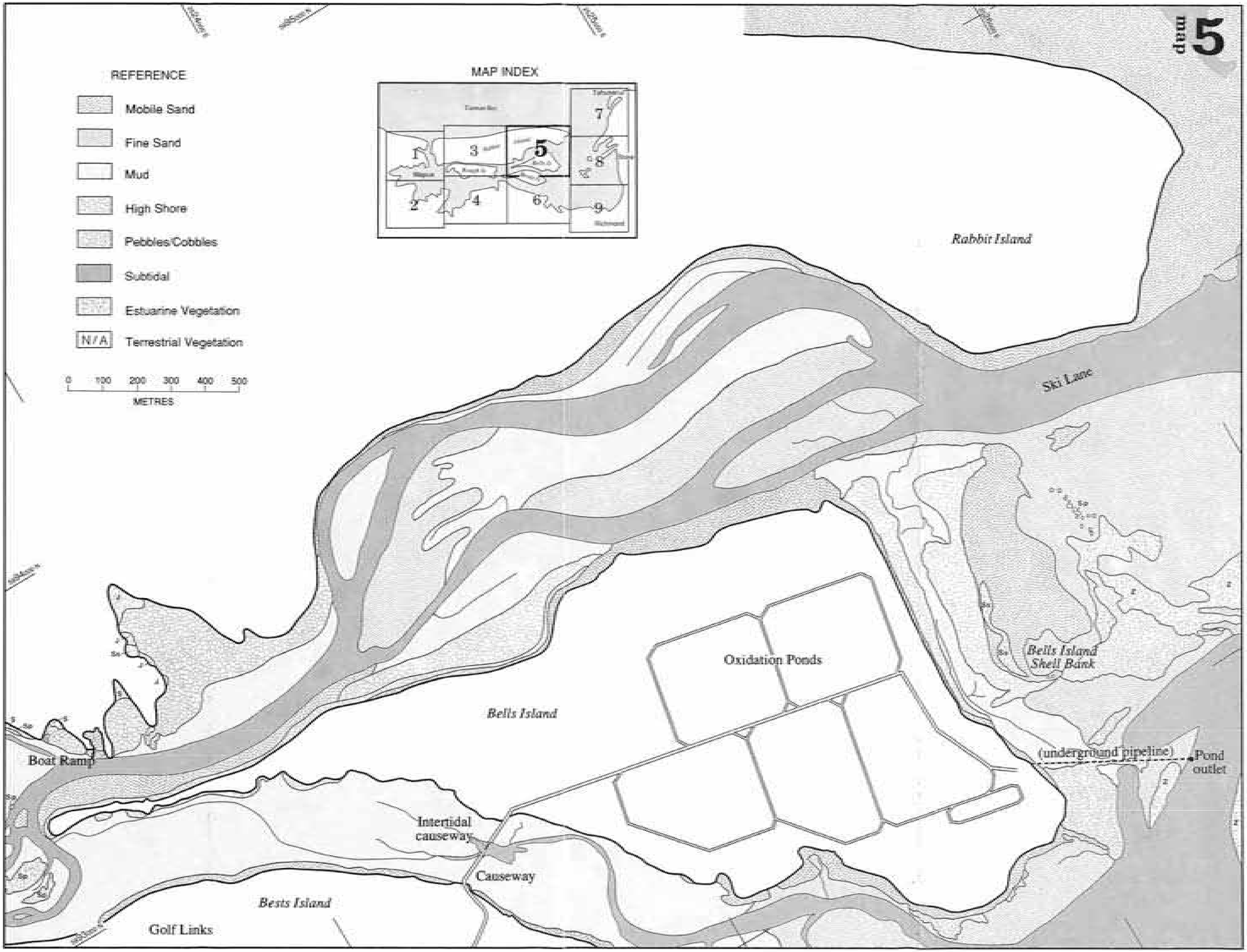
REFERENCE
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
0 100 200 300 400 500
METRES
map 4


map 5
REFERENCE
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
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Terrestrial Vegetation
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MAP INDEX
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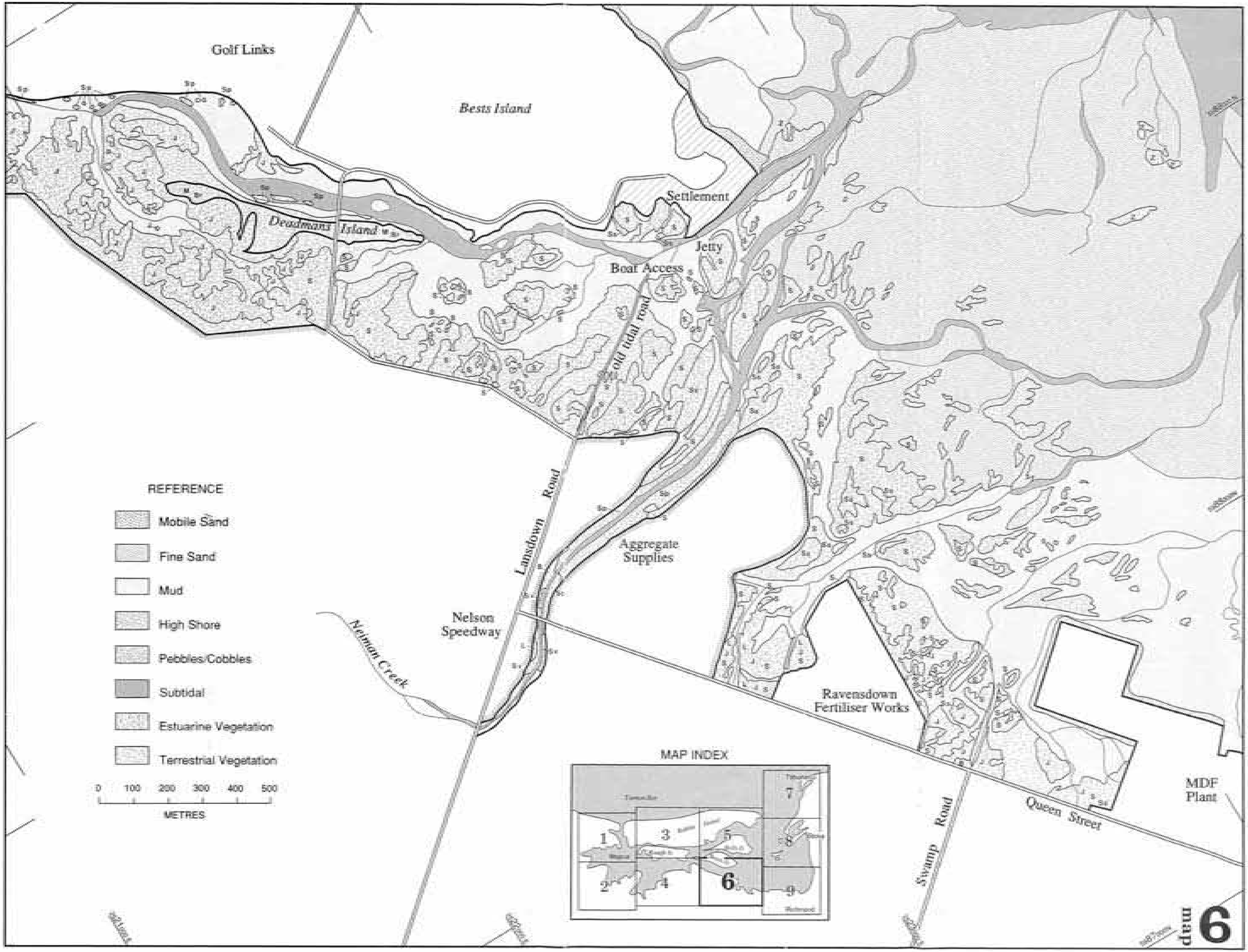
Rabbit Island
Ski Lane
Bells Island Shell Bank
Oxidation Ponds
Bells Island
(underground pipeline)
Pond outlet
Boat Ramp
Intertidal causeway
Causeway
Bests Island
Golf Links


Golf Links
Bests Island
Deadmans Island
Settlement
Jetty
Boat Access
old tidal road
Lansdown Road
Aggregate Supplies
Nelson Speedway
Neiman Creek
Ravensdown Fertiliser Works
Swamp Road
Queen Street
MDF Plant
REFERENCE
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
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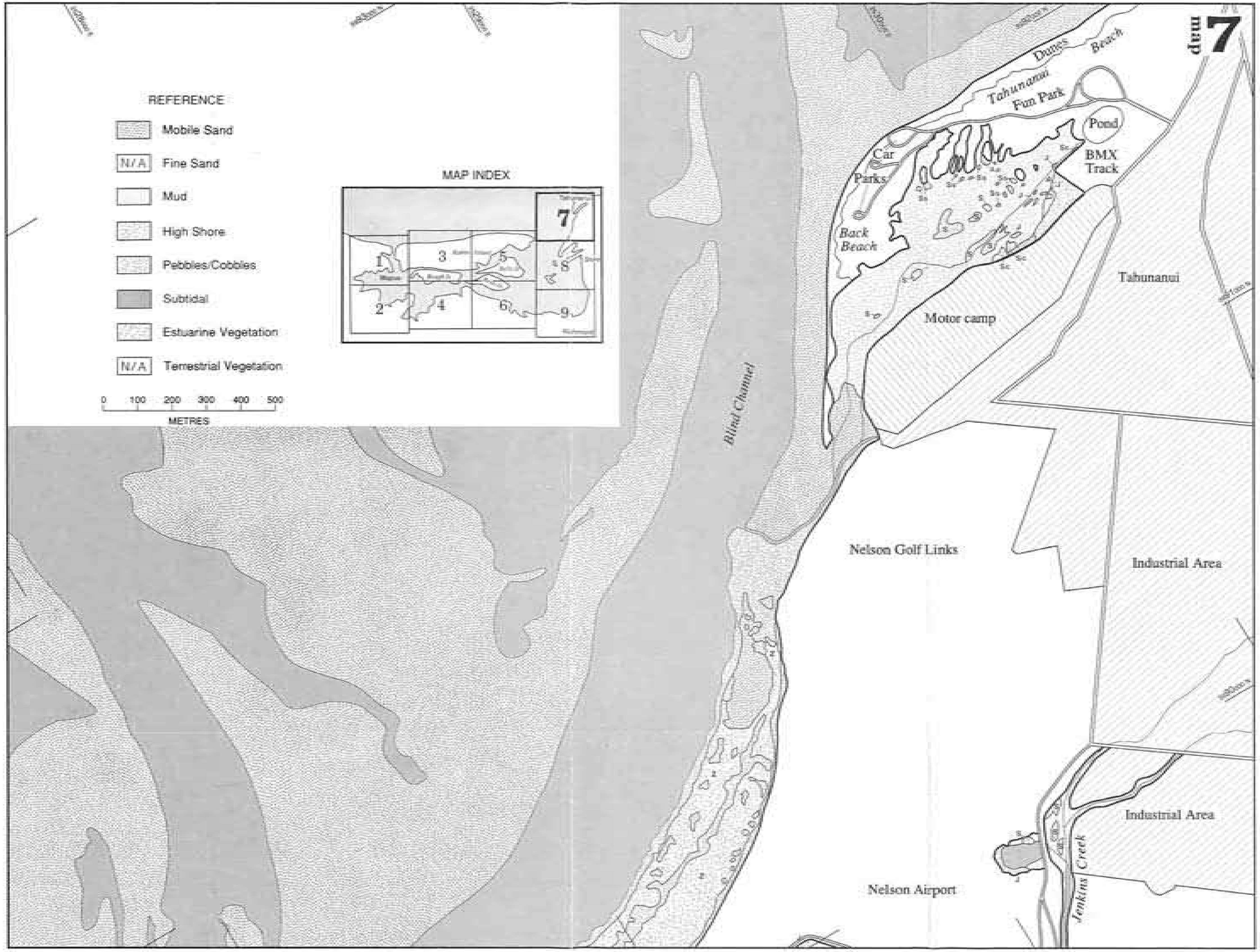
map 6


map 7
REFERENCE
Mobile Sand
N/A Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
N/A Terrestrial Vegetation
0 100 200 300 400 500
METRES
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Blind Channel
Tahunanui
Dunes
Beach
Fun Park
Pond
BMX
Track
Car
Parks
Back
Beach
Motor camp
Tahunanui
Nelson Golf Links
Industrial Area
Industrial Area
Nelson Airport
Jenkins Creek


map 8
Nelson Airport
Jenkins Creek
Poormans Valley Stream
Stoke
Aerodrome Penisular
Monaco
Ski Lane
Ski Jump
Oyster Island
Jetty
Boat Ramp
Martins Point
Saxton Island
Pig Island
Fruit Processing Factory
Nayland Road
Container Factory
REFERENCE
Mobile Sand
Fine Sand
Mud
High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
0 100 200 300 400 500
METRES

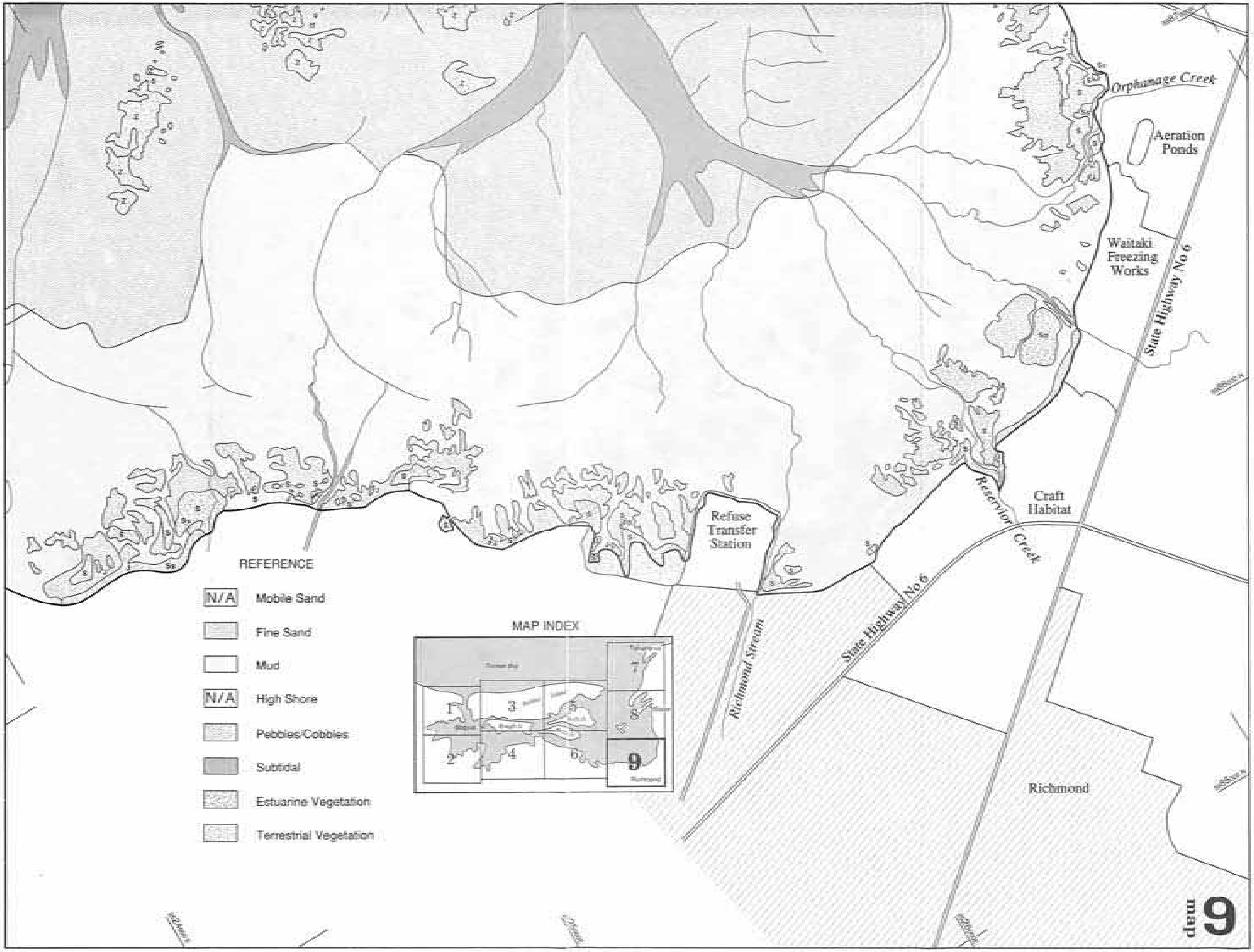
Orphanage Creek
Aeration Ponds
Waitaki Freezing Works
State Highway No 6
Reservoir Creek
Craft Habitat
Refuse Transfer Station
Richmond Stream
State Highway No 6
Richmond
REFERENCE
N/A Mobile Sand
Fine Sand
Mud
N/A High Shore
Pebbles/Cobbles
Subtidal
Estuarine Vegetation
Terrestrial Vegetation
MAP INDEX
1
2
3
4
5
6
7
8
9
map 9

Table 2. Area and percentage area covered by various habitats in Waimea Inlet.

	Habitat	Percentage Area	Hectares
(1)	Mobile Sand	9.9	342
(2)	Fine Sand flats	22.7	784
(3)	*Zostera* (eelgrass)	1.7	58
(4)	Mudflats	32.6	1126
(5)	Highshore Flats	4.2	145
(6)	*Sarcocornia* (glasswort)	2.7	93
(7)	Pebbles/cobbles	5.7	197
(8)	Rushes and Sedges	2.2	75
	Juncus maritimus	1.3	45
	Leptocarpus similis	0.5	16
	Schoenoplectus pungens	0.013	0.45
	Bolboschoenus caldwellii	0.012	0.4
(9)	*Spartina* (cord grass)	0.9	29
(10)	Subtidal	17.0	587
(11)	Others		
	Stipa stipoides (tussock)	0.14	4.8
	Gracilaria (agar weed)	0.32	11.1
	Enteromorpha	0.1	3.5

(3455)

4. FLORA AND FAUNA

4.1 INVERTEBRATES

Ecological estuarine studies traditionally investigate benthic invertebrate faunas (Bolton and Knox, 1977; Kilner and Akroyd, 1978; Knox, 1974; Knox et. al., 1977; Knox and Bolton, 1978; Knox et. al., 1978; Knox, 1983b). Species diversity, abundance, distribution and presence/absence data supply valuable information on the estuary under investigation (Barnes, 1984; Knox, 1986). Low species diversity or low invertebrate abundance may indicate stress on the system. The abundance of particular species may also suggest relatively high levels of pollution. Benthic invertebrates are an important source of food to higher trophic levels including fish, birds and man. This study emphasises the importance of the benthic invertebrates of Waimea Inlet.

4.1.1 Sampling Methods and Analyses

Invertebrates were sampled from 57 intertidal sites in Waimea Inlet between 11 and 29 January 1988 (Fig. 3; Table 3). Sample sites were restricted to the major habitat types in Waimea Inlet. Each habitat was sampled at a minimum of 4 sites and maximum of 14 sites in order to fulfill statistical requirements. Where possible a range of tidal heights for each habitat were sampled. Areas adjacent to industrial development were also selected.

At each site, five random core samples (15 cm in diameter and 15 cm deep) were collected, labelled and placed in plastic bags. All samples were sieved within 10 hours of collection. Samples of predominantly mud/silt were passed through 0.5 mm mesh, while samples containing coarse substrates were sieved through 1.0 mm mesh. A minimum of one replicate from each site was sieved through 0.5 mm mesh. Material remaining in the sieve was stored in 80% Isopropyl alcohol (IPA) for later sorting, counting and identification.

Macroinvertebrates within five random quadrats (250 x 250mm) were also counted and recorded at each site. Approximately 10 minutes was also spent searching for rare or widely distributed invertebrates. Their presence and approximate abundance were noted.

Subtidal Sampling

Four subtidal sites were sampled in Waimea Inlet during 25-26 February 1988 (Fig. 3; Table 3). Sites were selected in the main outlet channels at Mapua and Oyster Island and secondary channels at Rough and Bells Island (Fig. 3). At each site, 5 random core samples (15 cm diameter by 15 cm depth) were collected on SCUBA. Each core sample was labelled and placed in two plastic bags to ensure no water loss. Samples were sieved on the same day through 0.5 mm mesh and the invertebrates preserved in 80% IPA for later identification and counting.

Table 3. List of Benthic Invertebrate Sample Sites

1. Trafalgar Road Inlet : *Schoenoplectus* stand (high tide)
2. Trafalgar Road Inlet : *Juncus* stand (high tide)
3. Trafalgar Road Inlet : *Leptocarpus* stand (high tide)
4. Trafalgar Road Inlet : *Sarcocornia* bed (high tide)
5. Trafalgar Road Inlet : Mudflat (mid-high tide)
6. Western Rabbit Island : *Zostera* bed (mid-tide)
7. Mapua Channel : Pebble-cobble shore (low tide)
8. Grossi's Point : *Sarcocornia* bed (high tide)
9. Mapua Channel : Subtidal (6 m. below LWS)
10. Rough Island : Subtidal (1 m. below LWS)
11. Hoddy Road Channel : Mudflat (mid-tide)
12. Hoddy Road Channel : Mudflat with *Gracilaria* bed (mid-tide)
13. Hoddy Road Channel : Mudflat with *Ulva* bed (mid-tide)
14. Rabbit Island Causeway : *Sarcocornia* bed (high tide)
15. Rabbit Island Causeway : *Juncus* stand (high tide)
16. Rabbit Island Causeway : *Leptocarpus* stand (high tide)
17. Bells-Rabbit Island : *Leptocarpus* stand (high tide)
18. Bells-Rabbit Island Channel : Subtidal (2 m. below LWS)
19. Bests-Bells Island : Mudflat (mid-tide)
20. Mainland to Bests Island : *Sarcocornia* bed (high tide)
21. Mainland to Bests Island : Highshore (high tide)
22. Fertilizer Works : *Sarcocornia* bed (high tide)
23. Fertilizer Works : *Juncus* stand (high tide)
24. Fertilizer Works : Highshore (high tide)
25. Wood Chip Mill : Mudflat (mid-tide)
26. Eastern Tip of Rabbit Island : Sand flat (mid-tide)
27. Blind Channel : Subtidal (6 m. below LWS)
28. Bells Island : Sand flat (high tide)
29. Bells Island : Sand flat with *Ulva* bed (low tide)
30. Bells Island : *Zostera* bed (low-mid tide)
31. Saxton Island : *Zostera* bed (low-mid tide)
32. Saxton Island : Pebble and cobble shore (mid-tide)
33. Saxton Island : *Sarcocornia* bed (high tide)
34. Saxton Island : Mudflat with *Ulva* bed (low tide)
35. Saxton Island : Compacted pebble and cobble shore (mid-tide)
36. Saxton Island : Mud/sand flat (mid-tide)

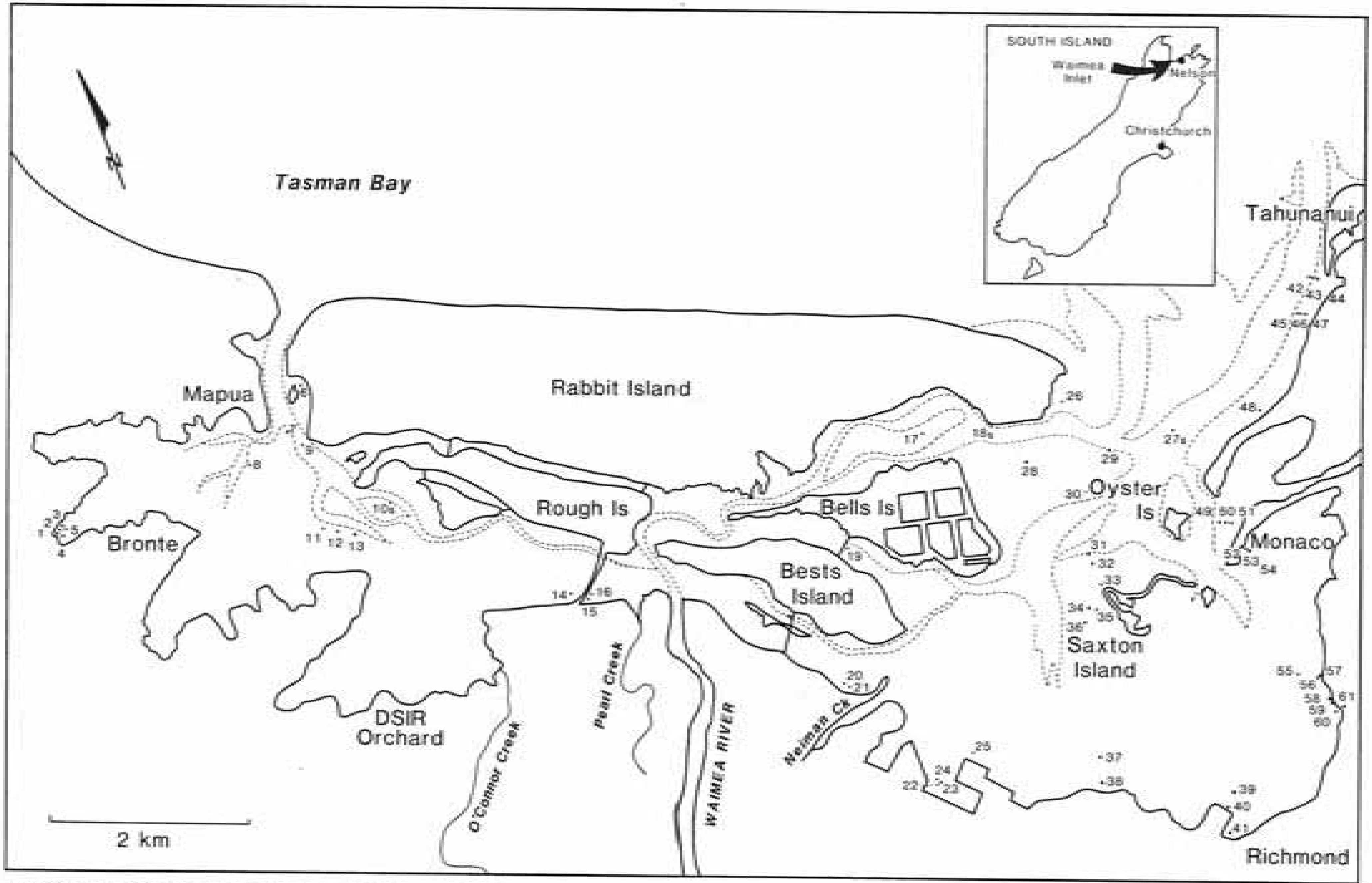

FIGURE 3. Sample sites in Waimea Inlet

Table 4. Species List of Benthic Invertebrates From Waimea Inlet

In the following list the locality type in which each animal occurred most frequently is recorded as:

Veg = Vegetation;
P/C = Pebbles/Cobbles;
M = Mud;
S = Fine sand;
Sub = Subtidal; and
Z = *Zostera*.

Feeding type is recorded as:

C = Carnivore;
H = Herbivore;
Scav = Scavenger.
D = Detritus feeder;
Sus = Suspension feeder;

Phylum Coelenterata			
Class Anthozoa (Sea Anemones)			
Anthopleura aureoradiata	Mudflat anemone	C	P/C, M
Edwardsia sp.	Burrowing anemone	C	M
Phylum Platyhelminthes (Flatworms)			
Class Turbellaria (Free-living Flatworms)			
Notoplana australis	Estuarine flatworm	C	P/C
Phylum Aschelminthes			
Class Nematoda (Round Worms)			
Unidentified sp.		H	M,P/C
Phylum Nemertina (Proboscis Worms)			
Unidentified sp.			S, M
Phylum Sipunculida (Acorn Worms)			
Dendrostomum sp.			S, M
Unidentified sp.			S
Phylum Uchiura			
Urechis novaezelandiae	Sausage worm		S
Phylum Mollusca (Molluscs)			
Class Amphineura (Chitons)			
Acanthochiton zelandica	Tufted chiton	H	P/C
Amaurochiton glaucus	Green chiton	H	P/C
Chiton pelliserpentis	Snakeskin chiton	H	P/C

Class Gastropoda (Univalve Molluscs)			
Amphibola crenata	Mudflat snail	D	M
Buccinulum vittatum	Lined whelk	C	P/C
Cellana radians	Radiate limpet	H	P/C
Cominella adspersa	Whelk	C	P/C
Cominella glandiformis	Mudflat whelk	C	M
Cominella maculosa	Spotted whelk	C	M, P/C
Cominella virigata virigata	Whelk	C	P/C
Diloma subrostrata	Mudflat topshell	H	M,S, Z
Haminoea zelandiae	Bubble shell	D, C	Z
Lepsiella scobina	Oyster borer	C	P/C
Littorina cincta	Brown periwinkle	H	P/C
Littorina unifasciata	Banded periwinkle	H	P/C
Melagraphia aethiops	Spotted topshell	H	P/C
Micrelenchus tenebrosus	Topshell	H	Z, P/C
Neoguraleus sinclairi		C	Z
Notoacmea helmsi	Estuarine limpet	H	Z, P/C
Onchidella nigricans	Shell-less snail	D	P/C
Ophicardellus costellaris	Snail	H, D	Veg
Potamopyrgus estuarinus	Estuarine snail	D	Veg
Taron dubius	Whelk	C	P/C
Turbo smargdus	Cats-eye	H	P/C
Zeacumantus lutulentus	Spire shell	H	M, Z
Class Pelecypoda (Bivalves)			
Aulacomya ater maoriana	Ribbed mussel	Sus	P/C
Chione stutchburyi	Cockle	Sus	S, M
Crassostrea gigas	Pacific oyster	Sus	P/C
Nucula hartvigiana	Nut shell	D	S, Z
Ostrea lutaria	Oyster	Sus	R
Paphies australis	Pipi	Sus	S,Sub
Perna canaliculus	Green lipped mussel	Sus	P/C
Soletellina siliqua		Sus	S
Tellina liliana	Wedge shell	D	S, M
Xenostrobus pulex	Little black mussel	Sus	P/C
Unidendified sp.#1.		Sus	S
Unidentified sp.#2.		Sus	S
Phylum Annelida (Segmented Worms)			
Class Polychaeta (Marine Worms)			
ERRANTIA			
Family Eunicidae			
Lumbrinereinae sp.		C	Z
Family Glyceridae		C	Z,Sub,
Glycera americana			
Glycera lamellipodia			
Hemipodus digitifera			
Hemipodus simplex			
Family Nereidae (Rag Worms)			S,M,Z
Nicon aestuariensis		D	
Perinerieis novae-hollandiae		C	
Perinereis nuntia var.brevicirris		C	
Perinereis nuntia var.vallata		C	
Family Nephtyidae			
Aglophamus macroura		D	M
Family Phyllodocidae (Paddle Worms)			
Eulalia microphylla		C,Scav	P/C

Family Polynoidae (Scale Worms)			
Lepidasthenia accolus		C	M, S
Lepidonotus polychroma		C	P/C
Family Syllidae			
* *Syllis anops*			S
* *Exogone heterosetosa*			S, M
SEDENTARIA			
Family Arenicolidae (Lug Worms)			
Abarenicola affinis affinis		D	S, M
Family Capitellidae			
Capitella capitata		D	M
Heteromastus filiformis		D	S, M
Family Cirratulidae			
* *Cirriformia tentaculata*		D	M
Family Magelonidae			
Magelona papillicornis		D	S, M
Family Maldanidae			
Axiothella quadrimaculata		D	S
Family Orbiniidae			
Haploscoloplos cylindrifer		D	S, M
Orbinia papillosa		D	S, M
Family Opheliidae			
Amandia maculata		D	S
Family Oweniidae			
Owenia fusiformis		D	Z
Family Pectinariidae (Sand Mason Worms)			
Pectinaria australis		D	M,S
Family Sabellariidae			
Sabellaria kaiparaensis		Sus	S, M
Family Serpulidae (Fan Worms)			
Pomatocercos caeruleus		Sus	P/C
Family Scalibregmidae			
* *Hyboscolex longiseta*		D	M
Scalibregma sp.		D	Z
Family Spionidae			
* *Aonides trifidus*		D	S
* *Boccardia syrtis*		D	S, M
Polydora polybranchia		Sus	Shell
* *Prionospio pinnata*		D	S, M
Scolecolepides sp.		D	Veg
Family Terebellidae			
* *Polycirrus* sp.		D	S
Phylum Arthropoda			
Class Cirripedia (Barnacles)			
Elminius modestus	Estuarine barnacle	Sus	P/C
Epopella plicata		Sus	P/C
Class Malacostraca			
Order Mysidacea (Shrimps)			
* *Tenagomysis chiltoni*		Sus	M
Order Cumacea (Cumaceans)			
Colurostylis lemurum		Sus	S, M

Order Amphipoda (Sand Hoppers)			
Talitridae sp.		D	M
* Eusiridae sp.		D	M
* *Paracalliope novizelandiae*		D	M, P/C
* *Paracorophium excavatum*		D,Sus	M
Phoxocephalidae sp.		D	M
Order Isopoda (Sea Lice)		Scav,C	
* *Cirolana arcuata*			P/C
* *Cymodocella tubicauda*			P/C
Euidotea sp.			
Isocladus armatus		Scav	P/C,M
* *Mesanthura maculata*			P/C
Paravireia sp.			M
Order Decapoda (Decapods)			
Cyclograpsus lavauxi	Smooth-shore crab	C	P/C
Halicarcinus varius	Spider crab	C	S,M,Z
Halicarcinus whitei	Spider crab	C	S,M,Z
Helice crassa	Mud crab	D	M,P/C
Hemigrapsus crenulatus	Hairy-handed crab	C	P/C
Hemigrapsus edwardsi	Purple crab	C	P/C
Macropthalmus hirtipes	Stalk-eyed crab	D	M,S
Ovalipes catharus	Paddle crab	C	Sub
Palaemon affinus	Estuarine prawn	D	Sub
Pagurus novizealandiae	Hermit crab	D	Sub
Petrolisthes elongatus	Half crab	Sus	P/C
Pinnotheres novizelandiae	Pea crab	Parasitic	
Class Insecta			
Chaerodes trachyconcolor	Sand dune beetle		S
Dipteran larvae sp.	Larval fly		M
Phylum Echinodermata			
* *Patiriella regularis*	Starfish	C	P/C
Erachnoides zelandiae	Sand-dollar	D	Sub

* Recorded from Bolton and Knox, 1977

Table 5. Invertebrates Recorded From Subtidal Collection Sites.

	Nemertina	(Ribbon Worm)
	Amaurochiton glaucus	(Green Chiton)
	Cominella glandiformis	(Mudflat Whelk)
	Notoacmea helmsi	(Estuarine Limpet)
	Taron dubius	(Whelk)
	Chione stutchburyi	(Cockle)
	Nucula hartvigiana	(Nut Shell)
	Paphies australis	(Pipi)
	Eulalia microphylla	(Polychaete)
	Glyceridae	(Polychaete)
	Nereidae	(Polychaete)
	Capitellidae	(Polychaete)
*	*Lepidonotus polychroma*	(Polychaete)
	Haploscoloplos cylindrifer	(Polychaete)
	Elminius modestus	(Estuarine Barnacle)
	Phoxocephalidae sp.	(Sand Hopper)
	Isocladus armatus	(Sea Lice)
	Halicarcinus varius	(Spider Crab)
	Hemigrapsus crenulatus	(Hairy-Handed Crab)
	Macropthalmus hirtipes	(Stalk-Eyed Crab)
	Pagurus novizealandiae	(Hermit Crab)
*	*Palaemon affinis*	(Estuarine Prawn)
*	*Patiriella regularis*	(Starfish)

* Indicates species recorded only from subtidal sites.

Representatives of sea anemones (Coelenterata), proboscis worms (Nemertina), flatworms (Platyhelminthes), round worms (Aschelminthes), acorn worms (Sipunculida), insects (Insecta), sea stars and sand dollars (Echinodermata) were also recorded from the intertidal zone of Waimea Inlet.

Most invertebrates found in Waimea Inlet were recorded from more than one site. A total of 18 species, however, were restricted to one site in the inlet. Of these, 17 were coastal species able to penetrate into the estuary where salinities were high.

4.1.3 Habitats and Associated Invertebrate Communities

Ten major habitat types were recognised in Waimea Inlet (chapter 3). Within each habitat, a characteristic group of invertebrates were recognised using the Bray-Curtis Dissimilarity Index (Appendix 2). Results suggested that the faunal assemblages from more than one habitat type were often very similar. These habitat types are therefore discussed together.

Mobile Sand

Large flat areas of mobile sand are located around the estuary outlets at Mapua and Tahunanui. Few invertebrate species were found on these expansive sand flats. No one invertebrate species was common to mobile sand sites (Appendix 4). Three species of polychaete, two bivalve species, an amphipod, a sand dune beetle and an isopod were recorded in relatively low densities. The sand dollar *Erachnoides zelandiae* became abundant in the channels between the mobile sandflats.

The mobile sandflats in Waimea Inlet represent an unstable, harsh environment for most intertidal animals. The invertebrates living in these areas are generally regarded as opportunistic species, resistant to physical disturbance (Marsden & Fenwick, 1986).

Fine Sand Flats and Eelgrass Beds

Eelgrass (*Zostera*) beds establish on gently grading, fine sand substrates below mid-tide level (Morton & Miller, 1968). Fine sand substrates may be replaced by a build up of silt trapped by the eelgrass fronds. In Waimea Inlet, *Zostera* beds are located adjacent to main channels swept by tidal currents. The strength of the tidal current is critical to eelgrass establishment and survival. Strong currents cause scour and removal of plants, while weak currents result in accumulation of silt and ultimate smothering of eelgrass beds (Morton and Miller, 1968). Most *Zostera* beds in Waimea Inlet are located adjacent to the Aerodrome Peninsula and Saxton and Bells Islands (Maps 5,8). Only two eelgrass beds exist in the western inlet adjacent No-mans Island.

Not all fine sandflats in Waimea Inlet are covered by eelgrass. The fine sand areas bare of eelgrass are located centrally in the inlet, often adjacent to the main channels. Large fine sandflats exist near Saxton, Bells and Pig Islands in the east and between Bird Island and Bronte in the western inlet.

The invertebrate fauna associated with *Zostera muelleri* and fine sandflats were grouped together by the Bray-Curtis Dissimilarity Index (Appendix 2). The Index suggested that the majority of benthic animals from *Zostera* beds were also present in similar densities in the fine sandflats. These areas, although mapped separately were biologically similar and are therefore discussed together in this section.

Fifty-three species of benthic invertebrates were recorded from fine sand and eelgrass areas (Appendix 5). This value was the highest recorded for any habitat in Waimea Inlet. The mean number of invertebrate species from eelgrass and fine sandflats (19.7) was 7 times greater than the value for the mobile sand sites (Table 6). The invertebrate fauna was dominated by the Mollusca (21 species), followed by Polychaeta (15 species), Crustacea (12 species) and others (5 species) (Table 7). One species of cumacean was unique to fine sand sites in Waimea Inlet, while the carnivorous bubble shell *Haminoea zealandiae* was unique to *Zostera* flats in front of the Airport Peninsula. *Haminoea* is relatively common in the *Zostera* beds of Golden Bay and is also recorded from Moutere Inlet, Motueka (Moffat, 1989). All other benthic invertebrates recorded from eelgrass and fine sandflats were found from other habitats in the inlet.

Benthic invertebrates characteristic of fine sandflats and *Zostera* were the wedge shell (*T. liliana*), the nut shell (*N. hartvigiana*), the gastropod snail (*M. tenebrosus*), the spider crab (*H. whitei*) and the cockle (*Chione*) (Table 8). Other invertebrates common to these sites were anemones (57-1007 per m^2), the topshell snails *Diloma subrostrata* (1-57 per m^2) and *Cominella adspersa* (0-34 per m^2), the pipi *Paphies australis* (0-226 per m^2) and nereid polychaetes (0-91 per m^2).

Mudflats

This report distinguishes two types of mudflat on the basis of invertebrate fauna and tidal height. Mud areas in the high tide or marginal areas of the estuary, termed "high shore flats" are discussed in section 5 4. This section deals with "mudflats" below the high tide level. These lower shore mudflats do not suffer desiccation during summer.

The western arms and eastern fringes of Waimea Inlet are dominated by 1126 ha of mudflat. Mudflats represents the largest single habitat in Waimea Inlet.

Mudflat sediments are made up of clay and silt deposited where tidal currents are minimal. Mudflats may be fringed with salt marsh vegetation, high shore flats, pebble/cobble flats or artificial stop banks and retaining walls.

An average of 14.6 species were recorded from mudflats in Waimea Inlet (Table 6). A total of 11 Crustacea, 17 Mollusca, 8 Polychaeta, one Anthozoa, one Sipuncula and a Nemertina were recorded (Table 7). Species characteristic of mudflats were the mudflat snail *Amphibola crenata* which lives on the surface of most mudflats, the spire shell *Zeacumantus lutulentus* and the topshell *Diloma subrostrata* (Table 8). Cockles were recorded from all mudflat sites, however, cockle density was dependent on tidal height and sediment composition. Other characteristic mudflat species were the stalk-eyed crab *Macropthalmus hirtipes*, the wedge shell *Tellina liliana* and nereid polychaetes (Table 14). Anemones (0-849 per m^2), the estuarine limpet *Notoacmea helmsi* (0-34 per m^2), and the clam shell *Nucula hartvigiana* (0-1268 per m^2) were also recorded from most mudflat sites (Appendix 6). All benthic invertebrates found from mudflat sites were also recorded from other habitat types in Waimea Inlet.

<u>High Shore Flats and Glasswort Beds</u>

High shore flats and *Sarcocornia quinqueflora* (glasswort) beds were grouped together on the basis of invertebrate faunal similarity (Appendix 2). These high tide or fringe areas in Waimea Inlet are characterised by few species of invertebrates found in low densities (Appendix 7). A total of 16 species were recorded from these sites: 3 Crustacea, 10 Mollusca, 1 Polychaeta, 1 Nemertina and a dipteran larva (Appendix 7). Two species of benthic invertebrate, the mud crab *H. crassa* and the mudflat snail *Amphibola crenata* were recorded from most sites.

High shore flats dry out during summer when warm temperatures, sea breezes, small tides and low rainfall combine. High shore flats are easily recognised in summer by the characteristic surface cracking (Allen 1985). *Helice crassa* and *Amphibola crenata* were the only species of invertebrate recorded from these areas during summer. *Helice* and *Amphibola* bury below the mud surface and avoid desiccation. Areas of pebbles or *Sarcocornia* plants offer some protection from desiccation and additional invertebrate species were recorded. Gastropod snails and polychaete worms were also recorded from these areas. All highshore areas were grouped together on the basis of low species diversity and domination by *Helice* and *Amphibola*.

<u>Pebbles and Cobbles</u>

Pebble and cobble areas were often found on exposed promontories adjacent to main channels where strong currents scour finer particles leaving the larger substrates. The substrate size varied between pebbles (4-64 mm) and cobbles (64-256 mm).

In Waimea Inlet, the largest pebble and cobble areas are located adjacent to the eastern main channels near Saxton and Pig Islands and the Airport Peninsula, and at Grossis Point. Pebble and cobble shores are also located in the upper tidal levels on peninsula points and areas exposed to wind generated wave action.

Fifty-one species of benthic invertebrate including 13 crustaceans, 27 molluscs, 8 polychaetes, 1 anthozoan, 1 sipunculid, 1 nemertine and a dipteran larva were recorded from the pebble/cobble habitat (Table 7, Appendix 8). The number of crustacean and molluscan species were the highest recorded for any habitat. Polychaetes were, however, poorly represented in this hard substrate habitat type (Table 7). A site record of 76,350 individual invertebrates per m^2 was recorded from a pebble/cobble habitat around No-mans Island. This was the highest recorded density of invertebrates in the present study.

The second highest mean number of species (15.7) was recorded from the pebble/cobble habitat (Table 6). The number of species recorded from each site varied considerably (9-25 species, SD = 6.2). Most of the between site variation was a factor of tidal height; the abundance and number of invertebrate species from pebble/cobble areas was highest below mid-tide.

Table 8 summarises the characteristic species recorded from pebble/cobble sites. The dominant invertebrate was often the small black mussel (*Xenostrobus pulex*), which often formed a dense mat with densities up to 13,173 per m^2. Other characteristic species were cockles, barnacles and the hairy handed crab *Hemigrapsus crenulatus*. The limpet *N. helmsi*, polychaetes (Nereidae and Capitellidae) and the half crab *Petrolisthes elongatus* were common under rocks.

Four species of benthic invertebrate were unique to this habitat. These species included the green chiton *Acanthochiton zelandiae*, the whelk *Cominella virigata*, the gastropod *Onchidella nigricans* and the serpulid polychaete *Pomatoceros caeruleus*. This was the highest number of species restricted to one habitat type in Waimea Inlet. Another 14 species of invertebrate, however, were most commonly recorded from the pebble and cobble shores in Waimea Inlet (Appendix 8).

Native Rushes and Sedges

Two rush species (*Juncus maritimus, Leptocarpus similis*) and the sedge *Schoenoplectus pungens* were separately sampled for benthic invertebrates in Waimea Inlet. The sedge *Bolboschoenus caldwellii* was not sampled because of a limited distribution and the damage caused by core sampling techniques.

The introduced grass *Spartina anglica*, the subject of an active eradication program, was not sampled. Benthic invertebrates associated with *Spartina* were recorded by Franko, (1987). Although no statistical tests were undertaken, the invertebrates found from *Spartina* were also recorded from native rushes and sedges in the present study.

Twelve species of benthic invertebrates were recorded from the native rush and sedge habitats in Waimea Inlet (Appendix 9). The low number of species was often balanced by large numbers of the estuarine snail *Potamopyrgus estuarinus* (up to 23,450 per m^2). Crustacea were represented by 3 species, Mollusca 4, Polychaeta 5 and dipteran larvae 1. Two species recorded from all sites were the estuarine snail *Potamopyrgus* (770-23,450 per m^2) and the mud crab *Helice crassa* (23-238 per m^2). These values represented the highest densities recorded for *Helice* and *Potamopyrgus* in Waimea Inlet (Table 8).

Subtidal and River Channels

Subtidal and river channels areas are defined as being permanently covered by water. The two largest channels originate at the Waimea River and flow along the inside of Rabbit Island leaving the Inlet at Mapua in the west and Tahunanui in the east. These channels provide the largest freshwater input into the estuary, with the eastern channel carrying the most freshwater. The benthic fauna from this eastern channel comprises three species: *Chione*, and glycerid and capitellid polychaetes. On average between 11-14 invertebrate species were recorded from the subtidal sites away from this river channel (Appendix 10). This low number of benthic invertebrates recorded from the river channel was probably due to wide fluctuation in salinity ranging from freshwater at low tide to sea water at high tide. Regular flushing of saline water with each tide restricts colonisation by freshwater species.

A total of 25 benthic invertebrates were recorded from all subtidal sites (Table 6). Crustacea were represented by 10 species, Mollusca 6, Polychaeta 7, Nemertina 1 and Echinodermata 1 (Table 7). Species characteristic of subtidal sites were the pipi (*P. austalis*), and the polychaetes (Glyceridae and Capitellidae) (Table 8).

Pipi densities from the Blind Channel adjacent to the Aerodrome Peninsula was the highest recorded for a New Zealand estuary. A large bed of the green-lipped mussel *Perna canaliculus* was visually recorded from subtidal channels around No-mans Island, but this bed was not sampled.

Table 6. Sample sites and mean number of invertebrate species associated with each habitat type

Habitat	Number of Sites	Mean Number of Species	SD	Sample Site Location Numbers
Mobile Sand	4	2.8	2.0	26, 42, 43, 44
Fine Sand and *Zostera* bed	9	19.7	4.6	6, 28, 29, 30, 31, 36, 48, 49, 50
Mudflat	14	14.6	3.0	5, 11, 12, 13, 17, 19, 25, 34, 37, 39, 52, 53, 54, 55
High Shore Flats and *Sarcocornia*	11	4.5	2.98	8, 20, 21, 22, 24, 33, 38, 41, 51, 57, 60
Pebbles/cobbles	9	15.7	6.2	7, 32, 35, 40, 45, 46, 47, 56
Rushes and native sedge	11	4.8	0.9	1, 2, 3, 4, 14, 15, 16, 23, 58, 59, 61
Subtidal	4	9.8	4.1	9, 10, 18, 27

Table 7. Major taxonomic groups from each habitat group in Waimea Inlet

Habitat	Crustacea	Mollusca	Polychaeta	Others	Total Species
Mobile Sand	2	2	4	2	10
Fine sand and *Zostera*	12	21	15	5	53
Mudflat	11	17	8	3	39
High shore flats and *Sarcocornia*	3	10	1	2	16
Pebbles and cobbles	13	27	8	4	52
Rushes and native sedge	3	4	5	1	13
Subtidal	10	6	7	2	25

Table 8. Invertebrates characteristic of each habitat type in Waimea Inlet

Habitat Type	Characteristic Species	Pseudo T-Text * Significance	Number per m^2
Mobile sand	None		
Fine sand/*Zostera*	*Tellina liliana* (Wedge shell)	< 0.01	136 - 815
	Nucula hartvigiana (Nut shell)	0.03	23 - 645
	Micrelenchus tenebrosus (Gastropod)	0.12	23 - 351
	Halicarcinus whitei (Spider crab)	0.11	0 - 147
	Chione stutchburyi (Cockles)	0.52	23 - 1846
Mudflat	*Chione stutchburyi* (Cockles)	0.52	34 - 215
	Tellina liliana (Wedge shell)	< 0.01	68 - 1846
	Nereidae (Polychaete worm)	< 0.01	0 - 509
	Macropthalmus hirtipes (Stalk-eyed crab)	1.19	0 - 102
	Amphibola crenata (Mud snail)	< 0.01	0 - 532
High shore and *Sarcocornia*	*Helice crassa* (Mud crab)	< 0.01	57 - 328
	Amphibola crenata (Mud snail)	< 0.01	0 - 204
Pebbles and cobbles	*Xenostrobus pulex* (Black mussel)	0.27	0 - 13173
	Chione stutchburyi (Cockle)	0.52	0 - 1596
	Elminius modestus (Barnacle)	0.54	0 - 69774
	Hemigrapsus crenulatus (Hairy hand crab)	0.70	0 - 566
Rushes and Native Sedge	*Potamopyrgus estuarinus* (Snail)	< 0.01	770 - 23450
	Helice crassa (Mud crab)	< 0.01	23 - 328
Subtidal	*Paphies australis* (Pipi)	< 0.01	0 - 3350
	Capitellidae (Polychaete worm)	0.03	57 - 4165
	Glyceridae (Polychaete worm)	0.15	11 - 158

* Significance level = 5.0

4.1.4 Invertebrates of Particular Interest

POLYCHAETA:

Ragworms (Family Nereidae)

Four species of ragworm were recorded from Waimea Inlet. This family of polychaetes was widely distributed, occurring at all tidal heights and from most substrata. Nereids occupy burrows which they often leave to feed or reproduce. Maximum densities were recorded from a hard substrate shore, adjacent to the eastern entrance channel (498 per m^2). Nereids recorded from Waimea Inlet were carnivores or surface sediment feeders.

Capitella capitata and *Heteromastis filiformis*

Both *Capitella capitata* and *Heteromastis filiformis* are regarded as universal indicators of pollution or environmental perturbations (Pearson and Rosenburg, 1978; Jones, 1983; Bilyard, 1987). These worms generally occurred throughout Waimea Inlet in relatively low numbers. The maximum densities recorded were from pebble/cobble substrata near the Bells Island oxidation pond outlet (4674 per m^2). Capitellids were also recorded from low tide and subtidal areas down stream of the oxidation pond outlet and mudflats adjacent to the chip mill (792 per m^2). These densities were low, however, compared with numbers of *Capitella* recorded from the Avon-Heathcote Estuary (36,585 per m^2). Numbers of *Capitella* and *Heteromastis* in Waimea Inlet may fluctuate throughout the year. Studies have shown that capitellidae numbers vary seasonally probably in response to food availability (Boesch, 1973; Davidson, 1989).

Bamboo Worm (*Axiothella quadrimaculata*)

Axiothella builds fine sand tubes that project above the surface layer. It is from these tubes that the worm feeds on the sediment surface organisms. The bamboo worm was most abundant from mud substrata where maximum densities of 508 per m^2 were recorded. The commensal terebellid *Thelepus spectabilis* was recorded from *Axiothella* tubes in Waimea Inlet.

Reef Building Worm (*Sabellaria kaiparaensis*)

Sabellaria build tubes using sand grains cemented together. These tubes may eventually become massed in hummocks with the old disused tubes buried beneath the terminal portions which contain the living worms. *Sabellaria* was recorded from two sites in eastern Waimea Inlet.

CRUSTACEA:

Estuarine Barnacle (*Elminius modestus*)

Elminius is the most common of the two barnacles in Waimea Inlet. *Elminius* reached high densities (up to 69,774 per m^2) on most hard substrate shores below mid-tide. Here, it often completely covered the upper surface of cobbles. The estuarine barnacle is a plankton filter feeder and is an important food source to many invertebrate predators.

Mud Crab (*Helice crassa*)

Mud crabs were found from all tidal heights and on all substrate types. The highest density recorded was 328 per m^2 from a *Sarcocornia* bed at the Richmond Tip. Mud crabs are especially abundant on small intertidal banks above mid-tide. Mud crabs feed on organic matter soon after the ebbing tide has exposed the mudflat (McLay, 1985). *Helice* is a common item in the diet of predatory birds and fish.

Hairy-Handed Crab (*Hemigrapsus crenulatus*)

Hemigrapsus are most common in hard substrates, penetrating well into the estuary. Maximum densities were recorded from No-mans Island opposite Grossis Point (566 per m^2). Crabs were collected among dead cockle shells, under cobbles and amongst little black mussel patches.

Stalk-Eyed Mud Crab (*Macropthalmus hirtipes*)

The stalk-eyed crab prefers mudflats below mid-tide. Maximum densities were recorded from a low tide mudflat adjacent to the Hoddy Road Channel (102 per m^2). Organic material and mud is passed to the mouthparts by the chelipeds during feeding. Flatfish stomach content analyses suggested that *Macropthalmus* is an important food in Waimea Inlet.

Paddle Crab (*Ovalipes catharus*)

Paddle crabs were recorded from subtidal areas near the main channels of Waimea Inlet. Paddle crabs are opportunistic predators and enter estuaries to feed on bivalves, crustacea, small fishes and polychaetes (Davidson, 1986, 1987). With the depletion of natural predators (snapper, rig), it has been suggested that crab numbers in the Nelson area have increased. Paddle crabs probably have a significant predatory impact in and adjacent to the main channels of Waimea Inlet.

MOLLUSCA: (Gastropoda)

Mudflat Snail (*Amphibola crenata*)

The mudflat snail is the most widely distributed gastropod in Waimea Inlet reaching densities of 532 per m^2 adjacent to the chip mill. *Amphibola* are tolerant of a wide range of salinities and occur at most tidal heights especially above mid-tide. They prefer mud substrates and are absent from most sand flats. The mudflat snail feeds on micro-organisms and organic detritus contained in the surface layer of estuarine sediments. Mudflat snails are often eaten by blackbirds, but few other animals eat them.

Estuarine Snail (*Potamopyrgus estuarinus*)

Potamopyrgus is a small brown snail (less than 6 mm length), abundant in the upper-tidal areas of Waimea Inlet. Densities up to 23,665 per m^2 were recorded from the native sedges. This snail also occupies native rush, macroalgae, hard substrata and mudflat areas in the estuary. Large numbers of the estuarine snail were often observed floating on the surface film of the incoming tide; it is by this means that the snail distributes itself around the inlet.

Mudflat Top Shell (*Diloma subrostrata*)

This top shell is widely distributed below high tide in the estuary, reaching a maximum density of 170 per m^2 on mudflats near Bird Island. *Diloma* occurs on substrates ranging from cobbles, mudflats, eelgrass to fine sand flats. These snails feed on micro-algae and macro-algae.

Small Black Top Shell (*Micrelenchus tenebrosus*)

Micrelenchus lacks tolerance to low salinities and was therefore restricted to the intertidal areas near the estuary outlets. This top shell occurred most often on eelgrass and hard substrates below high tide. The maximum density recorded was 396 per m^2. *Micrelenchus* browses on algae and diatoms.

MOLLUSCA: (Bivalves)

Wedge Shell (*Tellina liliana*)

This common bivalve showed similar distribution patterns to the cockle. Maximum densities for the wedge shell (815 per m^2) were recorded from fine sand flats adjacent to Saxton Island. Wedge shells burrow between 15 and 20 cm deep in the substrate, through which they extend two siphons to the surface. Wedge shells feed on the microflora and fauna in the surface sediment using a long siphon. *Tellina* is a significant part in the diet of many wading birds and fish.

Pipi (*Paphies australis*)

Pipis were most abundant in the subtidal channels of Waimea Inlet (up to 3,350 per m^2). Limited tolerance to dilute sea water and fine sediments prevent pipis penetrating further into the estuary. The largest individuals were recorded from subtidal channels, while smaller individuals were found intertidally. It is in the intertidal areas that pipis become an important part of many wading birds diet.

Little Black Mussel (*Xenostrobus pulex*)

The little black mussel is restricted to hard substrates adjacent to the main channels of Waimea Inlet. These mussels often form characteristic black bands on the shore. Although they only grow to a maximum size of 30 mm, densities up to 13,173 per m^2 were recorded. These mussels are suspension feeders, ingesting food which passes by in the tidal currents. The little black mussel is an important food source to many invertebrate predators (oyster borers, mudflat whelk) and to wading birds.

Cockle (*Chione stutchburyi*)

Cockles are the most abundant mollusc in the estuary. Highest cockle densities were recorded from Grossis Point and Pig Island (3168 per m^2). Cockles bury themselves 2-4 cm below the surface and feed indiscriminately on food suspended in the water column. *Chione* forms a major part of the diet of several animals including the mudflat whelk (*Cominella glandiformis*), the sand flounder (*Rhombosolea plebeia*) and the South Island oystercatcher (*Haematopus ostralegus finschi*) (Jones, 1983). Like most suspension feeders, the cockle is one of the first species to show effects of pollution or reduced water quality and may therefore become unfit to eat.

4.1.5 Cockle Distribution, Abundance and Size

The Cockle (*Chione stutchburyi*) is an important member of the estuarine community because:

1. It supports a traditional recreational fishery and has recently become part of the commercial shell fishery;
2. It is an animal of wide distribution in areas subject to increasing environmental pressure and may be valuable as an indicator species;
3. It is representative of a niche common to most estuarine systems and the importance of the role of occupants of this niche has been stressed many times (Stephenson, 1981).

Several environmental factors influence the distribution, abundance and size of cockles. The most important environmental factors are exposure time (ie. height on the shore), sediment composition (mud, silt, clay) and salinity.

In several different localities in the South Island a positive relationship between cockle size and period of tidal immersion has been observed (Larcombe, 1971). In the present study, cockle density and size declined towards the upper tidal levels of the inlet.

Substrate type is important to many benthic organisms in estuaries, especially filter feeders. Cockles cannot survive if they are buried or exposed, nor can cockles survive in areas where fine sediments clog the gills and interfere with feeding and respiration. Many workers have reported that suspension feeders are abundant in well-sorted fine grain deposits, however the abundance of cockles decreases as the silt-clay content increases. In Waimea Inlet, cockle density was highest from mudflat, eelgrass and pebble/cobble substrates.

Voller (1973) found that in salinities less than 18% *Chione* would not feed, and if subjected to salinities of 4% or lower for protracted periods, death would result. The distribution of *Chione* over most of Waimea Inlet suggests salinity is not a limiting factor. Cockles were, as expected, recorded in low densities from the river channels where salinities would be low.

Although cockles occur over much of the intertidal area of Waimea Inlet (Fig. 4) they were not found in mobile sand areas (Table 9). Strong currents, especially on the outgoing tide, make mobile sand an unsuitable habitat for cockles. Cockles are also absent from high shore habitats including native rushes, sedges, *Spartina*, *Sarcocornia* and high shore flats (Table 9).
Cockles are generally restricted to shores below the lowest high water neap (Stephenson, 1981). It is thought that a minimum time of immersion per tide determines the upper limit of cockle habitation.

In Waimea Inlet, the highest densities of *Chione* beds occur along the edges and on the tips of islands covered by the tide and adjacent to the major channels (Fig. 4). These channel areas are swept by currents ensuring cockles are not clogged by fine sediments. In these beds, cockle density ranged from 973-3168 per m^2 with a mean cockle density of 2058 per m^2.

Mudflat areas had a mean cockle density of 302 per m^2, ranging between 68-758 per m^2. This value was higher than fine sand and *Zostera* flats (Table 9). Cockle densities from fine sand and eelgrass habitats were between 34-215 per m^2 and overall averaged 93 per m^2.

The size of cockles and the proportion of edible individuals (greater than 30 mm length) varies in Waimea Inlet (Table 9). In the Waitemata Harbour, largest cockles occurred towards the sea entrance around low water mark (Larcombe, 1971). The maximum cockle length in Waitemata Harbour varied depending on tidal height and the quantity of food cockles received. Poor growth conditions in particular areas of Waimea Inlet may be responsible for populations of cockles dominated by small individuals. The largest number of edible cockles recorded in Waimea Inlet was 1593 per m^2. This figure was, however, almost three times higher than any other density of edible cockles recorded from Waimea Inlet. The average number of edible cockles in the cockle beds of Waimea Inlet was 387 per m^2 and ranged between 0-1593 per m^2.

4.1.6 Factors Influencing Invertebrate Distribution

Physical factors have the greatest influence on the distribution of the fauna within an estuary. The most important of these are salinity, substrate type, and tidal height and exposure (Knox, 1983b).

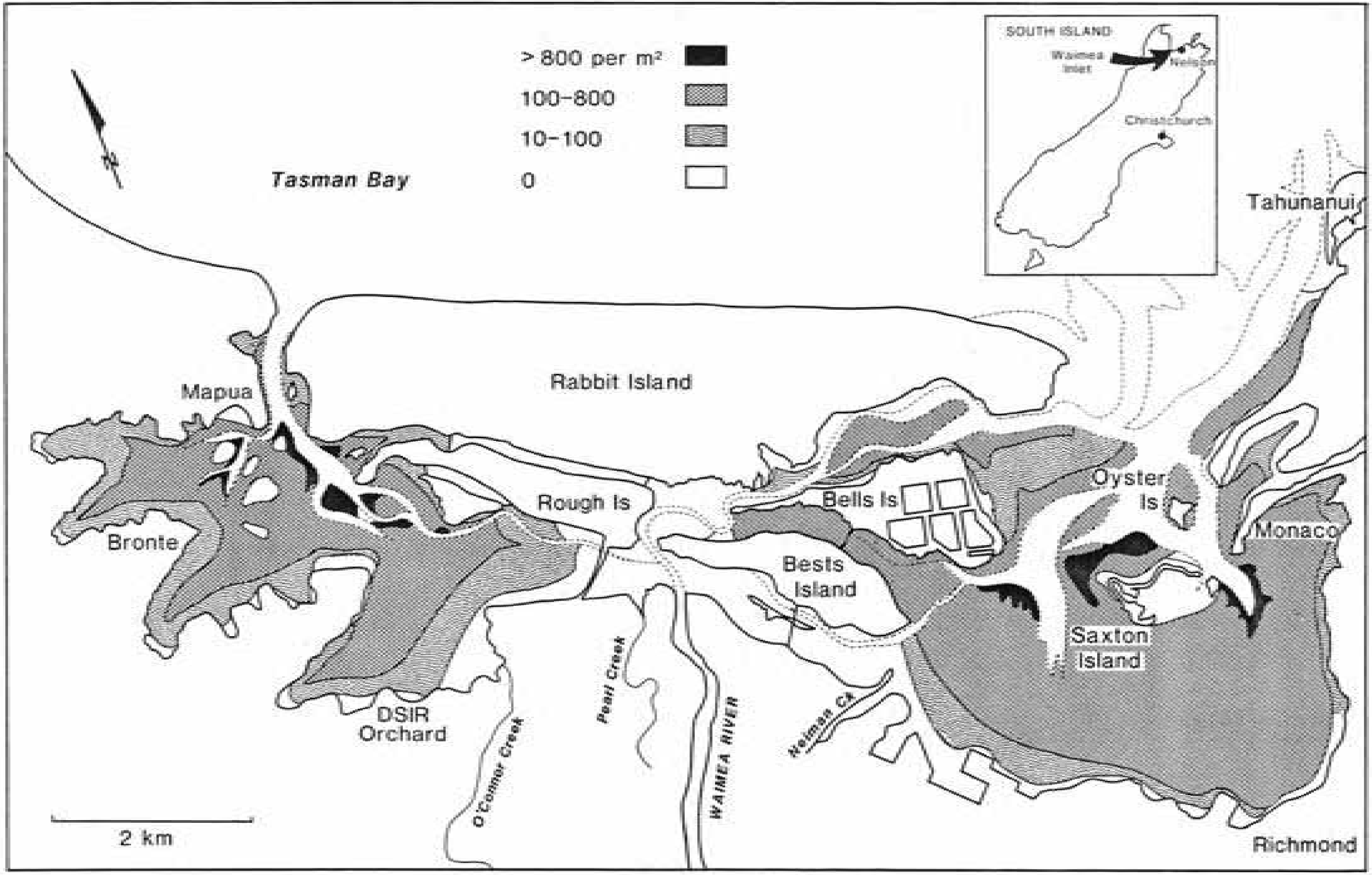

FIGURE 4. Distribution of cockles in Waimea Inlet

Table 9. Density and size of cockles recorded from Waimea Inlet

Habitat	Mean No. per m^2	Mean Size (mm)	Percent < 10 mm	Percent 10-30 mm	Percent > 30 mm
Mobile Sand	0	-	-	-	-
Eelgrass	102	25	6%	35%	59%
Fine Sand Flats	95	15.1	24%	55%	21%
Mudflats	302	16	24%	62.3%	13.7%
Highshore	18	10.8	0	100%	0
Sarcocornia	0	-	-	-	-
Pebbles and Cobbles	91	11.7	41.6%	58.4%	0
Native Rushes and Sedge	0	-	-	-	-
Spartina	0	-	-	-	-
Subtidal	14.3	26	0	66%	34%
Cockle Bed	2058	21	14.2%	65.7%	20.1%

Salinity

Estuary salinity grades from freshwater in the Waimea River (<0.5 parts per thousand (ppt)) to seawater at the estuary mouth (35-37ppt). In general, estuaries have low invertebrate diversities compared with open coast environments. This is largely due to the inability of many freshwater species to inhabit more saline media and marine species to withstand dilute media (Barnes, 1984).

Very few freshwater species survive in salinities in excess of 5ppt and few marine species are found in salinities of less than 18ppt. There are therefore three groups of benthic estuarine invertebrates. The first type are the marine species which penetrate the estuary to varying degrees. In Waimea Inlet, marine dwelling invertebrates include the sand dollar *E. zealandiae*, the cats-eye *Turbo smaragdus* and the topshell *Melagraphia aethiops*. The second group are freshwater species such as the tubificid oligochaete worms which may be found within the estuary. Tubificids are generally restricted to river channels but were not recorded from Waimea Inlet. The last group of invertebrates are the true estuary inhabitants. These invertebrates are able to tolerate a wider range of salinities, however, their degree of tolerance varies. In Waimea Inlet, some invertebrates are distributed over much of the estuary. These species, which tolerate the widest range of salinities include the estuarine snail *P. estuarinus*, the mud crab *H. crassa*, the mud snail *A. crenata* and nereid polychaetes. Estuarine species less tolerant of low salinities were recorded closer to the outlets. In Waimea Inlet, these species include the pipi *Paphies australis*, wedge shell *Tellina liliana*, and the stalk-eyed crab *Macropthalmus hirtipes*.

The eastern side of Waimea Inlet receives significantly more freshwater input than the western arm due to the freshwater influence of the Waimea River. Invertebrates unable to tolerate low salinities were not recorded from the river channel. Only three species of invertebrate, found in low densities (103 per m^2) were recorded from this channel. The number and abundance of invertebrates from subtidal sites is greatest towards the estuary mouth and in the western inlet (Appendix 10).

Substrate

Most fine sediments are deposited in Waimea Inlet by the Waimea River. Silt particles carried by the river tend to flocculate when they meet salt water and under the comparatively sheltered conditions of Waimea Inlet, settle out. This occurs at high water slack tide over the littoral areas and leads to the establishment of mudflats around the edge of Waimea Inlet. This process is greatly accelerated by the presence of salt-marsh vegetation especially the introduced cord grass *Spartina anglica*. *Zostera* present in central Waimea Inlet also traps these fine sediments transported by tidal currents.

Sediment type is one of the factors which influence the distribution of invertebrates in Waimea Inlet. No one species of benthic invertebrate was recorded from all substrate types. However certain species, including the topshells *Diloma subrostrata* and *Micrelenchus tenebrosus* and nereid polychaetes, were recorded from most sediment types.

The type of substrate found in many estuaries is often restricted to a few uniform or homogeneous areas (eg. mudflats). This may contribute to the poor invertebrate faunas recorded from some New Zealand estuaries. In Waimea Inlet, a wide variety of habitats (eg. fine sand, *Zostera* or eelgrass beds and pebble and cobble shores) are utilized by species absent from many of the other estuaries in the Nelson/Marlborough Region. The diverse invertebrate fauna in Waimea Inlet is largely due to the variety of substrate types within the estuary boundaries.

Tidal Height and Exposure

Tidal height and air exposure has an important role in the distribution of some invertebrate species (Morton and Millar, 1968). Many animals are not able to survive air exposure for any great length of time, while other animals prefer to be exposed for most of the tidal cycle (Knox, 1983b). Tidal height are an important environmental factors in Waimea Inlet as Nelson tides are some of the largest in New Zealand.

In Waimea Inlet, the barnacle *Elminius modestus* is more abundant on hard shores below the mid-tide level. The bivalves *Nucula hartvigiana* and *Paphies australis* tolerate a wide range of exposure times, however, their abundance increases towards low tide levels. In contrast to these species, the estuarine snail (*P. estuarinus*), mud crab (*H. crassa*), mud snail (*A. crenata*) and the banded periwinkle (*Littorina unifasciata*) tolerate exposure for most of the tidal cycle. Unlike many estuaries in the Tasman and Golden Bay area, Waimea Inlet has the full range of tidal heights from subtidal to extreme high water spring. This increases the range of niches available to invertebrates.

4.2 FISH

A number of workers have shown associations between estuaries and fisheries (Moore et. al., 1970; Turner, 1976; Day et. al., 1982). Reasons for this association is based on the availability of food for fish and areas for juvenile development, and on the importance of estuaries as spawning areas.

In North America, investigations have shown that over half the total United States commercial catch is made up of estuarine dependent species (Clark, 1967; McHugh, 1966, 1976). In New South Wales, the estuarine dependent portion of the total fisheries catch has been recorded as high as 66%. In New Zealand, approximately 40 fish species utilize estuaries at some stage of their life cycle (Bradstock, 1985). Of these, about 30 species are either commercial, recreational or traditional fisheries (Kilner and Akroyd, 1978). In the Ahuriri Estuary (Napier), Kilner and Ackroyd (1978) found that six commercially valuable species were common and another 12 species used the estuary at some stage of their life history. The extent and importance of Waimea Inlet to fish populations in Tasman Bay is difficult to assess as little information is available on the behaviour and movements of fish in New Zealand estuaries. Biologists agree, however, that if estuaries disappeared, many coastal fish populations would be a small fraction of their present level. This chapter summarizes known information on marine and freshwater fishes recorded from Waimea Inlet.

4.2.1 Methods

Much of the information on marine fishes was gathered through liaison with local recreational fishermen. Field work was undertaken to assess the importance of invertebrates as food to fish. Flatfish were netted at night on an incoming tide at Aerodrome Peninsula and their stomachs removed and stored in 80% IPA for later analysis.

Freshwater fish inhabiting the tidal reaches of selected streams around Waimea Inlet were sampled at night using lights and dip nets. The tidal riffles of the Waimea River were sampled using dip nets. Fish collected were preserved in 80% IPA for later identification. Relevant details on location of capture, tidal extremity, sediment, flow regime and relative numbers of each fish were also recorded. All the larger freshwater inputs into Waimea Inlet were assessed for their suitability as adult and spawning habitat.

4.2.2 Marine fish

In Waimea Inlet, 31 marine fish species were recorded (Table 10). Eighteen of these species are commercially fished in Tasman Bay. Most fish recorded from the inlet enter from the sea at irregular intervals (eg. kahawai, gurnard, snapper), while the others may spend their juvenile or adult life in the inlet (eg. sand flounder, yellow bellied flounder, sole, grey mullet, stargazer, yellow-eyed mullet).

Some of the most common fish species entering Waimea Inlet are:

Flatfish

The young and many adult flatfish are strongly dependent on estuarine areas (Webb, 1968; Kirk, 1985). Most flatfish live on sand or mud bottoms and forage on tidal flats at high water. Four marine flatfish were recorded from the Waimea Inlet: the yellow-bellied flounder (*Rhombosolea leporina*), sand flounder (*Rhombosolea plebeia*), common sole (*Peltorhamphus novaezealandiae*) and the witch (*Arnoglossus scapha*). The sand flounder was the most common species of flatfish recorded in the inlet. The diet of sand and yellow bellied flounders were dominated by the mud crab (*Helice crassa*) and the stalk-eyed crab (*Macropthalmus hirtipes*). Other invertebrates eaten included the spider crab (*Halicarcinus whitei*) and nereid polychaetes. Flounder diet probably varies seasonally, reflecting the availability of food (Webb, 1967). Flatfish are the mainstay of the inshore commercial trawl fishery for most of the year (Kirk, 1985). They are fast growing and the fishery is relatively dependable from year to year. Flatfish are also an important recreational fishery in Waimea Inlet.

Snapper (*Chrysophrys auratus*)

Snapper spawn in Tasman Bay during the summer months and the juvenile fish live in inshore waters and estuaries. Juvenile snapper surveys run by MAFFISH, Nelson have suggested that large numbers of these fish inhabit the shallow waters seaward of Rabbit Island. These young snapper probably enter the estuary where they feed and gain refuge from predation (Drummond, MAF Fish, pers. comm.). An increase in Tasman Bay snapper stocks may rely, at least in part, on the protection of juvenile fish and their feeding areas in Waimea Inlet.

Yellow-eyed Mullet (*Aldrichetta forsteri*)

Yellow-eyed mullet are common in Waimea Inlet during all seasons. Large shoals penetrate the estuary considerable distances into many freshwater streams, where they feed on algae and detritus. Although not commercially important, yellow-eyed mullet are a very important source of food for birds and larger fishes.

Kahawai (*Arripus trutta*)

Although Kahawai spawn and spend most of their life history at sea, they enter Waimea Inlet during spring and summer where they feed on the plentiful supplies of small bait fish (mullet, anchovy, sprat). Kahawai are an important commercial and recreational fishery in Tasman Bay.

Grey Mullet (*Mugil cephalus*)

Grey mullet enter the estuary to feed and breed. Recreational fishermen commonly net these fish in the Traverse (Rabbit Island Channel) and in the main channel adjacent to Bells Island. Grey mullet penetrate into most of the inlet, feeding on detritus and algae.

Rig (*Mustelus lenticulatus*)

Female rig enter shallow coastal waters to breed (Kirk, 1985). Adults use estuaries after the young have pupped before moving back into deeper waters. The young use estuaries as a nursery where they feed and grow.

The Importance of Waimea Inlet to Marine Fish

Waimea Inlet serves as a nursery for young flatfish, yellow-eyed mullet, grey mullet, stargazer and rig. Most of these fish are commercial species or important food for commercial fish.

Waimea Inlet represents a favourable habitat for young fish. The quiet waters and streams in the inlet provide young fish with food and refuge from predation. Areas in Waimea Inlet important to juvenile fish include:

(1) streams and rivers;
(2) marginal vegetation;
(3) intertidal pools; and
(4) tidal channels.

The abundance of food in Waimea Inlet attracts large numbers of fish which migrate daily to feed in the shallow tidal flats. This behaviour has been capitalised on by commercial and recreational fishermen, who place nets in the path of the feeding fish. Commercial fishing in Waimea Inlet has been discouraged by MAFFISH, however, no regulations apart from national restrictions on mesh sizes and methods of setting nets for recreational netting exist. Restrictions during spawning or breeding migrations would ensure recruitment for future years. Further research is needed to assess the importance of estuaries to marine fishes in New Zealand.

Table 10. Marine Fish Recorded from Waimea Inlet.

Blue shark	*Prionace glauca*
Bronze whaler	*Carcharinus brachyurus*
Hammerhead shark	*Sphyrna zygaena*
Spiny dogfish	*Squalus* sp.
* Rig	*Mustelus lenticulatus*
Eagle ray	*Myliobatis tenuicaudatis*
* Pilchard	*Sardinops neopilchardus*
* Anchovy	*Engraulis australis*
* Red cod	*Pseudophycis bacchus*
Garfish	*Reporhamphus ihi*
Seahorse	*Hippocampus abdominalis*
* Gurnard	*Chelidonichthys kumu*
Rockfish	*Acanthoclinus fuscus*
* Trevally	*Caranx lutescens*
* Kahawai	*Arripis trutta*
* Kingfish	*Seriola grandis*
* Snapper	*Chrysophrys auratus*
* Tarakihi	*Nemadactylus macropterus*
Yellow-eyed mullet	*Aldrichetta forsteri*
* Grey mullet	*Mugil cephalus*
* Barracouta	*Thyrsites atun*
Spotty	*Pseudolabrus celidotus*
* Stargazer	*Leptoscopus macropygus*
Cockabully	*Tripterygion* sp.
* Jack mackerel	*Trachurus novaezelandiae*
* Blue mackerel	*Scomber australasicus*
* Yellow bellied flounder	*Rhombosolea leporina*
* Sand flounder	*Rhombosolea plebeia*
* Common sole	*Peltorhamhus novaezealandiae*
Witch	*Arnnoglossus scapha*
Pufferfish	*Contusus richei*

* Commercial Fish Species

4.2.3 Freshwater fish

In New Zealand, 63% percent or 17 species of freshwater fish migrate between fresh and salt water at some stage of their life history (McDowall, 1979). River-estuary confluences represent pathways through which most freshwater fishes must pass during migrations. Although the estuary may play a minor and temporary role in their lives of most freshwater fishes, they are an essential link in the life histories that must not be interfered with (McDowall, 1976b). Pollution, culverts and habitat modification must be kept to a minimum to ensure migration routes are kept open.

A total of 11 freshwater fish species were recorded from the Waimea River and the tidal reaches of most streams entering the Inlet (Table 11). Two fish, the banded kokopu and the koaro were recorded only as juveniles (whitebait). Adult fish of these species may live in the upper reaches of the Waimea River.

Some freshwater fish species included:

Koaro (*Galaxias brevipinnis*)

Koaro were recorded as whitebait in the Waimea River during October, 1988. Juvenile koaro migrate inland and as adults inhabit rapid flowing, tumbling streams often in forested areas (McDowall, 1980; Moffat, 1984). These fish spawn in freshwater, however, egg-laying sites have yet to be recorded.

Banded Kokopu (*Galaxias fasciatus*)

Banded kokopu were recorded as whitebait in the Waimea River during early November, 1988. Juveniles migrate from the sea and are found as adults far inland in rocky streams and in pools under overhanging banks (McDowall and Eldon, 1980). Adults are usually restricted to forested areas, sometimes forest swamps.

Common Smelt (*Retropinna retropinna*)

Large numbers of smelt were recorded entering the Waimea River and Pearl Creek from the estuary during spring and summer. Adults spawn in slow moving areas and then die (McDowall, 1980). The larvae return to the sea where they remain until almost mature.

Torrentfish (*Cheimarrichthys fosteri*)

Torrentfish were recorded from tidal riffles in the Waimea River. Torrentfish live in swift-flowing broken waters and feed on stream insect larvae (Scrimgeour and Davidson, 1988). The lifecycle of this fish is largely unknown, however, it is thought that torrentfish spawn in spring and the larvae spend some time in the marine environment before returning to freshwater.

Inanga (*Galaxias maculatus*)

In many rivers throughout New Zealand, approximately 90% of the whitebait catch is composed of juvenile inanga (*Galaxias maculatus*). Inanga grow into adults inslow moving, low gradient river systems where they inhabit backwaters, pools and swamps. Adults return to estuarine areas in autumn where they lay their eggs in marginal vegetation during the spring tides (McDowall and Eldon, 1980). The majority of spawning occurs on the third day after the largest tide (Eldon, pers. comm.). Once spawning is completed, most adults die. The larvae hatch on the next large tides and are washed out to sea where they grow and return as whitebait 5-6 months later.

Juvenile (whitebait) and adult inanga numbers have declined compared with former times (McDowall, 1984). The reason for the whitebait decline has been attributed to the loss of spawning and adult habitat through stopbanking, infilling, rubbish dumping, drainage of swamps and cattle grazing (McDowall and Eldon, 1980; McDowall, 1984; Stancliff et. al., 1988). Recognition of spawning and adult habitat is, therefore, an important management consideration. McDowall (1985) recognised inanga spawning habitat as having some or all of the following features:

(1) freshwater flow;
(2) immediately upstream of the saline surface water, to well past the upstream limit of the salt water wedge (the lower limit of spawning is also identified by the upper limit of mud-crab burrows);
(3) often in small tributaries of main rivers;
(4) drained bankside vegetation which retains some moisture content;
(5) Plants preferred by inanga include tall fescue (*Festuca arundinacea*), flax (*Phormium tenax*) and long, dense grasses.

Freshwater Habitats

Many streams around Waimea Inlet have been modified to the point where they lack any spawning vegetation (Table 12). Those streams with suitable vegetation are often grazed by cattle, thereby reducing the quality of spawning sites. Many freshwater streams represent probable spawning sites for inanga, however, their quality varies considerably. Neiman, Pearl and O'Connor Creeks are probably the most important adult and spawning habitats in Waimea Inlet (Table 12) (plate 10, 11). The largest probable area of inanga habitat is at O'Connor Creek where a significant area of flax swamp remains. Whitebait migrate into these creeks from the main channels of Waimea Inlet and begin to feed and grow. These growing fish continue to be caught along with the migrating fish and are discarded, usually dead, by whitebaiters.

Table 11. Freshwater Species Recorded from the Waimea River and Streams Flowing into Waimea Inlet (M = Migrant, R = Resident).

Brown trout (R)	*Salmo trutta*
Short-finned eel (R)	*Anguilla australis schmidtii*
Long-finned eel (M)	*Anguilla dieffenbachi*
Common smelt (R)	*Retropinna retropinna*
Inanga (R)	*Galaxias maculatus*
Banded Kokopu (M)	*Galaxias fasciatus*
Koaro (M)	*Galaxias brevipinnis*
* Giant Kokopu (R)	*Galaxias argenteus*
Common bully (R)	*Gobiomorphus cotidianus*
Giant Bully (R)	*Gobiomorphus gobioides*
Torrentfish (R)	*Cheimarrichthys fosteri*

* Recorded by Mace Ward (Acclimatisation Society).

Table 12. Summary of Inanga Habitat in the Tidally Influenced Streams Entering Waimea Inlet.

Stream	Catchment	Type	Diameter	Flow	Marginal Veg.	Rank
1 Golf Course	urban	stream	30cm	var.	grass	10
2 Jenkins Cr.	industrial	stream	50cm	var.	grass/glassw.	10
3 Poorman St.	native	stream	50cm	var.	*Juncus*/grass	8
4 Orphanage Cr	rural	stream	1m	var.	marsh/grass	5
5 Saxton Cr.	rural	stream	30cm	var.	grass	10
6 Reservoir Cr.	rural	stream	50cm	var.	marsh/grass	5
7 Rich. Tip	industrial	stream	40cm	var.	soil/glassw.	12
8 Headingly L.	rural	stream	1-2m	var.	grass	9
9 Swamp Rd.	rural	stream	30cm	var.	grass	10
10 Fert. works	rural	stream	40cm	var.	marsh/grass	6
11 Neiman Cr.	rural	spring	2-3m	stable	wetl.marsh	3
12 Waimea R.	pine,rural	river	15-20m	var.	marsh/grass	7
13 Pearl Cr.	rural	spring	2.5m	stable	wetl.marsh	2
14 O'Connor Cr.	rural	stream	3-4m	var.	wetl.swamp/marsh	1
15 DSIR Cr.	rural	stream	40cm	var.	marsh/grass	6
16 Stringer Cr.	rural	stream	40cm	var.	marsh/grass	6
17 Hoddy Rd.	rural	stream	40cm	var.	marsh/grass	5
18 Higgs Res.	rural	stream	40cm	var.	marsh/flax/grass	5
19 Mapua flax/grass	5	rural	stream	60cm	var.	marsh/

Rank: 1 = best representative site;
12 = poorest site/sites.

Plate 10 Neiman Creek downstream of main road

Plate 11 Neiman Creek upstream of main road

4.3 BIRDS

4.3.1 Introduction

The Waimea Estuary was rated as a wildlife habitat of "outstanding" value by the Wildlife Service, largely as a result of what was known of its birdlife (Walker, 1987). It contains populations of banded rail, a species for which the Nelson Region is of national significance, and supports a wide range of estuarine birds and waterfowl.

This section combines the results of Owen & Sell (1985), which are based on monthly bird counts of the estuary from 1976 to 1978 and other records from 1955 to 1984, with the results of more recent surveys by the Ornithological Society of New Zealand and other local ornithologists. (Sources for OSNZ data are the annual "Classified Summarised Notes" published in the journal "Notornis", annual wader counts presented in the Society's newsletter "OSNZ News", and records held by the OSNZ Regional Recorder for Nelson). No specific fieldwork was undertaken so detailed information on bird feeding areas, for example, is lacking.

The bird species recorded in the estuary are listed below under the four habitat headings used by Knox (1983). The status of each is given as one of the following:

(a)	Resident	-	Present in the estuary year-round. (Breeding = known or suspected to breed)
(b)	Visitor	-	Typically only visits the estuary during the (Summer) seasons specified though a few individuals of some species may be present at other times.
(c)	Occasional	-	Five or more individuals recorded, occurs most years.
(d)	Rare	-	Less than five individuals ever recorded.

4.3.2 List of Bird Species Recorded from the Waimea Estuary

<u>Aquatic Zone</u>

The aquatic zone relates to habitat 10 of section 3.1 and habitats 1-5 and 7 when covered by tide.

<u>Black Shag *(Phalacrocorax carbo)* - Resident</u>

Common all year with the peak flock counted (1976 to 1978) of 155 on sandbanks off the SE end of Rabbit Island (Owen & Sell, 1985). More recently c.400 were recorded on the estuary during the 1985 winter census by OSNZ.

Pied Shag *(Phalacrocorax varius)* - Resident

Present all year but in smaller numbers than the black shag. The nearby breeding colony at Rocks Road, Nelson, that began with one pair in the years 1979 to 1981 (Owen & Sell, op. cit), has increased rapidly to support up to 40 pairs breeding and 170 birds roosting (pers. obs.). As some of these birds feed in the Waimea estuary there has probably been an increase in birds there over the same period.

Little Black Shag *(Phalacrocorax sulcirostris)* - Resident

This species is seen regularly in the estuary, particularly in summer, but in fairly low numbers (Owen & Sell, op.cit.). Recent counts have included 16 birds on 29 August 1984 and at least 11 in April 1983 (OSNZ).

Little Shag *(Phalacrocorax melanoleucos)* - Resident

Little shags are present year-round at Waimea inlet. The numbers counted by Owen & Sell (1985) varied from 2 to 179, with fewest present in late spring/summer during the breeding season. Up to 66 have been counted at roost in the pied shag colony at Rocks Road and 90 at Fifeshire Rock in recent years, and birds may occasionally breed at the former site. Like pied shags, this species may be on the increase in the area.

Spotted Shag *(Stictocarbo punctatus)* - Visitor (late autumn to spring)

Spotted shags show a more pronounced seasonal pattern in their use of the estuary than the other shags and are typically present from late autumn to early spring (Owen & Sell, op. cit.). Relatively few are recorded, though large numbers may use winter roosts further east, eg. >500 at Fifeshire Rock, Nelson and c.2000 at Pepin Island (Recent OSNZ counts).

Australasian Gannet *(Sula bassana serrator)* - Rare

One gannet was recorded by Owen & Sell (op. cit.) near Bells Island in 1977. They are common in Tasman Bay and are occasionally recorded off Tahuna Beach, in Nelson harbour and Haven.

Arctic Skua *(Stercorarius parasiticus)* - Rare

An unidentified skua was recorded at the estuary by Owen & Sell (1985) in August 1977 and two were seen chasing a white-fronted tern off Rabbit Island on 8 January 1986 (OSNZ). These were most likely arctic skuas for this species is often seen in small groups around Nelson harbour in summer, harrying the same tern species.

Southern Black-backed Gull *(Larus dominicanus)* - Resident (breeding)

Black-backed gulls are one of the most abundant species at the estuary with regular counts of over 1500 and a peak of c.3500 in May 1977 (Owen & Sell, 1985). Part of the reason for the large numbers in the inlet lies in the presence of the Richmond rubbish tip on the southern margin and temporary dumps for fish waste on Rabbit Island. Nesting traditionally occurs on Rabbit Island where the colony moves to take advantage of areas recently cleared of pines, at the northern end of the sewage ponds on Bells Island until the area became overgrown with vegetation, and in recent years on Bells Island shellbank. There were 175 nests at the latter site in 1988 (OSNZ), though many of these were subject to flooding in November.

Red-billed Gull (*Larus novaehollandiae*) - Resident

Red-billed gulls are present at the estuary all year though numbers are lowest between September and December when adults move elsewhere to breed. Owen & Sell (1985) combined this species with black-billed gulls in counts and the peak total for the two was c.1750. The vast majority of these would have been red-billed gulls.

Black-billed Gull (*Larus bulleri*) - Resident

Like the previous species, black-billed gulls occur at Waimea all year, but in much lower numbers (Owen & Sell, op. cit.).

White-winged Black Tern (*Chlidonias leucoptera*) - Occasional

Five of this rare overseas visitor have been recorded at the estuary in the past decade, all in the months of January or February (Owen & Sell, op. cit.)

Caspian Tern (*Hydroprogne caspia*) - Resident (breeding)

Caspian terns are present at the estuary all year in relatively low numbers (Owen & Sell, op. cit.). The peak count recorded was 34 on the Bells Island shellbank in February 1978. Nesting has occurred most years on this shellbank since 1978. Only one or two pairs were involved until recently, but in 1988 at least 21 nests were present and about 15 chicks raised (G. Wilkinson, pers. comm.). Establishment of a larger colony here has apparently coincided with cessation of nesting on the Boulder Bank where up to four pairs were found until two years ago (J. Hawkins, pers. comm.).

Black-fronted Tern (*Sterna albostriata*) - Occasional

This species moves from inland sites to the coast after breeding and is seen fairly regularly at the Waimea estuary. Owen & Sell (op. cit.), however, record only five sightings and the highest number of birds involved was 15 in February 1978.

Eastern Little Tern (*Sterna albifrons*) - Occasional

There are three recent records for this rare species at Waimea; a single bird in February 1977 (Owen & Sell, op. cit.), 4 near Bells Island in June 1984 and 4 on Grossis Point on 10 November that same year (OSNZ).

White-fronted Tern *(Sterna striata)* - Resident

This species was recorded regularly at the estuary with highest numbers, up to 150, in summer (Owen & Sell, 1985). Nesting has been recorded at No-mans Island and the Bells Island shellbank, but it is highly irregular (JM Hawkins, pers. comm.).

Intertidal Sand/Mud Zones

The intertidal sand/mud zones relates to habitats 1-5 & 7 (section 3.1).

White-faced Heron *(Ardea novaehollandiae)* - Resident

White-faced herons are present year-round at the estuary though fewest are found in spring when breeding birds are inland (Owen & Sell, 1985). Numbers varied from 20-140 birds.

White Heron *(Egretta alba)* - Resident

White herons are an important feature of the estuary. They are recorded throughout the year in relatively small numbers, reaching a maximum in winter. These birds are however significant in terms of the national population. In a national census in August 1977 (Heather, 1978), 7.2% of the total (6 of 83 birds) were counted at Waimea. There appears to have been a decline of the species here in recent years, from a maximum count of 11 in August 1977, through 5-6 birds regularly during 1978, 4 during the June 1984 census and only single birds during the November 1986 and June 1988 counts (OSNZ).

Little Egret *(Egretta garzetta)* - Visitor (Winter)

This species was noted as apparently showing an increased use of this estuary by Owen & Sell (1985), however numbers are small. In August 1977 9% of the national total (2 of 22 birds) were counted here (Heather, 1978, 1982, 1984). The highest recent count was of 4 on 22/9/85, but 2-3 is more usual (OSNZ).

Reef Heron *(Egretta sacra)* - Rare

One bird was recorded in the estuary in June 1978 (Owen & Sell, 1985), another on 24 March 1986 (OSNZ), and others are occasionally seen in Nelson Haven to the east.

Cattle Egret *(Bubulcus ibis)* - Visitor (Winter)

Flocks of up to 40 birds are regularly present in winter on farmland adjacent to the estuary, often in fields beside Neiman Creek. However the regional total is less significant nationally than for white herons or little egrets, eg. 7.1% (55 of 771) in Nelson region in 1980 census and 1.9% (29 of 1531) in 1984 (Heather, 1984). One bird was recorded on the estuary in September 1977 and 6 in August 1984 (OSNZ), however, recent observations suggest that in autumn soon after their arrival in New Zealand birds may use the mudflats more frequently. In the early morning many of the flock can be found there, particularly between Bests Island and the mainland (JM Hawkins, pers. comm.).

Glossy Ibis *(Plegadis falcinellus)* - Occasional

A total of five individuals have been recorded visiting the estuary briefly during the period 1970 to 1977 (OSNZ).

Royal Spoonbill *(Platalea regia)* - Resident

Royal spoonbills are typically recorded year-round at the estuary though few occur in summer. In winter birds move about as a single group of upwards of 20 individuals. The numbers build up to a peak in August/September, but in June and July birds tend to move away to Moutere Inlet and Motueka Sandspit (OSNZ), probably as a result of disturbance by waterfowl shooters. The estuary may hold a significant proportion of the national population, eg. in August 1977 census, 18% (9 of 49) (Heather, 1977). The maximum count in recent years has been 36 in 1988 which may represent almost half the national total.

Black Swan *(Cygnus atratus)* - Resident

Up to four birds were recorded as very occasional visitors to the estuary by Owen and Sell (1985), and since that study, six were seen on Bells Island sewage ponds in April 1985 and 15 counted on the estuary in June 1985 (OSNZ). A pair has attempted to breed on these ponds during the past four years and has successfully reared young in the last two.

Paradise Shelduck *(Tadorna variegata)* - Visitor (Late Summer/Autumn)

Paradise shelduck are abundant at the inlet in late summer/autumn with a peak count of 352 in April 1978, as part of their post-breeding dispersal (Owen & Sell, 1985). More recently the establishment of the Bells Island sewage ponds has provided a site for birds during the moult and up to 1200 have been counted there in the past year (Ward, M, pers. comm.).

Mallard *(Anas platyrhynchos)* and Grey Duck *(Anas superciliosa)* - Resident

These two species were combined in counts by Owen & Sell (op. cit.) and apparently show the same seasonal pattern of occurrence at the estuary. They are most abundant from late summer to winter, with a peak count of 1390 in April 1977. Like the paradise shelduck, their post-breeding influx just precedes the start of the waterfowl shooting season, but a proportion remain after this, using the areas subject to least hunting (ibid).

Grey Teal *(Anas gibberifrons)* - Visitor (Winter)

This species was not recorded at Waimea by Owen & Sell, (1985), but now uses the newly-created Bells Island sewage ponds in winter with a count of 60+ on 20 April 1985 and up to 100 in 1987 (OSNZ).

NZ Shoveler (*Anas rhynchotis variegata*) - Visitor (Winter)

Like the previous species, shoveler use of the area has increased dramatically with the construction of the Bells Island sewage ponds. Owen & Sell, (1985) reported two sightings of birds on the fringe of the estuary, but flocks now regularly overwinter on the ponds, the largest counted being 60 in 1985 (OSNZ). Acclimatisation Society staff have estimated over one hundred birds there at times (Ward, M, pers. comm.).

NZ Scaup (*Aythya novaeseelandiae*) - Rare

Owen & Sell, (1985) record a single scaup shot at the estuary in April 1980.

South Island Pied Oystercatcher (*Haematopus ostralegus finschi*) - Resident

The South Island pied oystercatcher (SIPO) is the most abundant wader in the estuary with numbers ranging from 332-2885 in the counts of Owen & Sell, (1985). Since that survey a maximum of 6098 was counted in February 1980 (3646 in May 1980), indicating a build up of birds as they pass through on their northward migration (JM Hawkins, pers. comm.). Figures from the most recent twice-yearly censuses by OSNZ are given in Table 13. These five counts indicate that fields (Airport & Greenacres) are of greatest importance in winter. This is probably a reflection of the generally wetter conditions in June compared to November leading to good feeding in fields then. The recent June totals are less than those recorded in the 1977 winter by Owen & Sell, (1985), but similar to those of 1978, indicating no clear trend in numbers in recent years.

Variable Oystercatcher (*Haematopus unicolor*) - Resident

Variable oystercatchers are present at the estuary all year with numbers varying from 4 to 41 between 1976 and 1978 (Owen & Sell, op. cit.). In recent years the highest count has been 49 in June 1985 (OSNZ). They nest on hard shores around the estuary at Grossis, Bells, Bird, Rabbit and Saxton Islands.

Least Golden Plover (*Pluvialis fulva*) - Occasional

Golden plovers are rare visitors to the Waimea. Owen & Sell, (1985) record three sightings from 1958 to 1976 totalling 12 individuals. Two were seen in January 1980 and three in November 1988 (JM Hawkins, pers. comm.).

Banded Dotterel (*Charadrius bicinctus bicinctus*) - Resident

Banded dotterel were most common at Waimea from late summer to mid-winter with a peak count (1976 to 1978) of 102 (Owen & Sell, 1985). More recently almost no birds have been recorded in November counts and up to a 100 in June, a large proportion of those typically at Nelson Airport. Nesting sites are not known around the estuary and the nearest ones are at the top of Nelson Haven and the Motueka Sandspit (JM Hawkins, pers. comm.).

Table 13. Recent Counts of SIPO at Waimea Inlet

	NUMBER OF BIRDS				
Date	**Bells Is.**	**No Mans**	**Airport**	**Greenacres**	**Total**
November 1986	400	148	0	0	548
June 1987	236	670	560	509	1975
November 1987	540	170	0	0	710
June 1988	1030 #	453	357 *	840	3680
November 1988	90	220	0	0	310

* Includes fields near Stoke freezing works
# Combined Bells Island and Grossis counts

NOTE: These are high-tide counts and the birds are divided up between roosts at Bells Island shellbank, Grossis Point or nearby islands, Nelson airport and fields at Tahuna, Greenacres golf course and nearby fields).

Wrybill *(Anarhynchus frontalis)* - Visitor (Autumn/Winter)

Wrybills were recorded in small numbers in autumn and winter by Owen & Sell, (1985). More birds have been recorded in recent winters, with a maximum of 45 in June 1987 (OSNZ), though this may be an effect of the build up of the Bells Island sandbank roost or improved coverage there rather than a real change in numbers at Waimea.

Far-eastern Curlew *(Numenius madagascariensis)* - Occasional

Curlews were only recorded in ones or twos on four occasions during the study of Owen & Sell, (1985). Three larger groups have been seen in recent years, three birds in October 1985, seven on 22 December that year and seven in December 1986 (OSNZ).

Asiatic Whimbrel *(Numenius phaeopus variegatus)* - Rare

Whimbrels have been recorded at Waimea on four occasions in recent years, single birds three times in the 1970's (Owen & Sell, 1985) and seven on 22 September 1985 (OSNZ).

Eastern Bar-tailed Godwit *(Limosa lapponica)* - Visitor (Summer)

Bar-tailed godwit visit the estuary in large numbers in spring/summer and a few birds overwinter. Between 1976 and 1978, peak counts were c.1150 in December 1976, c.1050 in October 1977 and c.750 in March 1978 (Owen & Sell, 1985). There is an indication of more birds passing through on their return north in February, eg. 2100 in February 1980 compared to 1612 in the previous November, but no counts have been made in this month in recent years. Spring numbers appear to have increased in recent years to judge by counts of 2800 in November 1987 and 2930 in November 1985 (OSNZ). As for wrybill, this may be a result of the expansion or improved coverage of Bells Island sandbanks.

Greenshank *(Tringa nebularia)* - Rare

A single bird in April 1978 (Owen & Sell, 1985) is the only report of this species at the estuary.

Siberian Tattler *(Tringa brevipes)* - Rare

Tattlers have been recorded on several occasions in the 1970's and once in the present decade (Owen & Sell, op. cit.).

Turnstone *(Arenaria interpres)* - Visitor (Summer)

Turnstone were recorded on three occasions during the study of Owen & Sell, (1985), the largest flock being of 29 birds, and they have occurred regularly at Bells Island sandbank during more recent counts (OSNZ). The largest gathering of this species in Tasman Bay is at the Motueka Sandspit (OSNZ).

Knot *(Calidris canutus)* - Visitor (Summer)

Prior to the discovery and build up of the Bells Island shellbank, only a single knot had been recorded at the estuary (Owen & Sell, 1985). However this site now holds a significant number of birds every spring/summer, the highest count being 750 in November 1987 (OSNZ).

Sharp-tailed Sandpiper *(Calidris acuminata)* - Rare

Sharp-tailed sandpipers have not yet been recorded at the estuary though birds have occurred nearby in a creek at Richmond (Owen & Sell, 1985) and at Nelson Haven (OSNZ).

Pied Stilt *(Himantopus himantopus)* - Resident (Breeding)

Pied stilts are present at the estuary all year, numbers averaging up to 70 in spring and up to 379 in autumn (Owen & Sell, 1985). The high tide roost counts made twice-yearly in recent years do not provide effective coverage for this species with maximum totals in June of only 70 birds (OSNZ). Nesting birds are scattered around the fringes of the estuary, seven specific sites being recorded by Owen & Sell, (1985). Several of these are known to still be used, but infilling or drainage have destroyed some and this is a continuing threat.

Marsh Zone

The marsh zone relates to habitats 6, 8 & 9, (section 3.1).

Canada Goose *(Branta canadensis)* - Rare

Canada geese are rare on the Nelson coast, one being recorded at the estuary in September 1976 (Owen & Sell, op. cit.) and six at nearby Nelson Haven in winter 1982 (OSNZ).

Australasian Bittern *(Botaurus stellaris)* - Resident (Breeding)

Four bittern were recorded by Owen & Sell, (1985) at the following sites: Neimans Creek, Pearl Creek, Rough Island saltmarsh and the mouth of Redwoods Valley stream. One has been seen in recent years at Wakapuaka to the east (OSNZ) and it is anticipated that a specific survey for this species would record more birds.

Banded Rail *(Rallus phillipensis)* - Resident (Breeding)

During a regional survey of banded rails in 1982 to 1983, Elliott (1983) recorded up to 14 pairs at the estuary. The largest concentration of at least three breeding pairs was at Stringers Creek saltmarsh, while three pairs by the road to Rabbit Island were also considered of particular importance as the easternmost birds in Nelson. Two pairs were located at Trafalgar Road saltmarsh and single pairs or individuals were found at seven other sites (ibid). The estuary is of national importance to the species.

Marsh Crake *(Porzana pusilla)* - Resident (Breeding)

Marsh crake are present in low numbers around the margins of the inlet, twelve birds being recorded between 1963 and 1977 (Owen & Sell, 1985). Elliott (1983) recorded birds in the vicinity of Neiman Creek and near the DSIR orchard during his rail survey, and three were also seen at Appleby in February 1983 (OSNZ).

Spotless Crake *(Porzana tabuensis)* - Absent

Elliott (1983) found no spotless crake in Nelson or Marlborough during his banded rail survey and concluded that there was no resident population of this species in either region. There are no records of the species at the inlet though it is possible that they visit occasionally.

Pukeko *(Porphyrio porphyrio)* - Resident (Breeding)

Pukeko are resident in the upper saltmarshes at the estuary and on surrounding farmland, up to 22 birds being counted during the study of Owen & Sell, (1985).

Kingfisher *(Halcyon sancta vagans)* - Resident

Kingfishers occur year-round at the estuary but there is a clear peak of numbers in autumn and winter (Owen & Sell, 1985) co-inciding with a movement of birds from inland to the coast generally (Taylor, 1966).

South Island Fernbird *(Bowdleria punctata punctata)* - Rare

Fernbird were last recorded at the estuary in 1980 at the mouth of Stringer Creek (Owen & Sell, 1985), and may now be extinct there. Freshwater wetlands situated inland from the estuary have been destroyed in recent years (Elliott, GP, pers. comm.) and there is probably insufficient habitat left for this species in the whole area. Owen & Sell, (1985) considered that sites at the mouths of Waimea River and Redwoods Valley Stream might be suitable for re-introduction.

Welcome Swallow *(Hirundo tahitica neoxena)* - Resident

Welcome swallows are frequently recorded at the estuary. They have been seen to use the Bells Island sewage ponds as a feeding and roosting area, over 300 birds being counted there in April 1984 (OSNZ).

Grass-scrub Zone

The following species were recorded by Owen & Sell (1985) using areas on the fringe of the estuary:

Australasian harrier *(Circus approximans gouldi)*
California quail *(Lophortyx californica)*

Pheasant (*Phasianus colchicus*)
Spur-winged plover (*Lobibyx miles novaehollandiae*)
Domestic rock pigeon (*Columba livia*)
Skylark (*Alauda arvensis*)
Pipit (*Anthus novaeseelandiae*)
Hedge sparrow (*Prunella modularis*)
Grey Warbler (*Gerygone igata*)
South Island fantail (*Rhipidura fuliginosa*)
Song thrush (*Turdus philomelos*)
Blackbird (*Turdus merula*)
Yellow-breasted tit (*Petroica macrocephala macrocephala*)
Silvereye (*Zosterops lateralis*)
Bellbird (*Anthornis melanura*)
Tui (*Prosthemadera novaeseelandiae*)

Recent additions to these are:
A single Indian myna (*Acridotheres tristis*) found in a bedraggled state at Rabbit Island in August 1985 (OSNZ). Cirl buntings (*Emberiza cirlus*) have been seen nearby at Appleby (pers. obs.) and probably visit the fringe of the estuary on occasions. Chaffinches (*Fringilla coelebs*) and starlings (*Sturnus vulgaris*) are regularly seen foraging near the high tide mark.

4.3.3 Use of Waimea Inlet by its Major Bird Groups

The Inlet is of most significance regionally for three groups of birds: waders; herons, egrets and spoonbills; and rails, crakes and bitterns.

Waders

It has been shown that the wader species occurring at the estuary in highest numbers are the bar-tailed godwit and South Island pied oystercatcher, with peak counts of almost 3000 birds of each, and the knot, up to 750 birds. A further eleven species have been recorded.

The different wader species are adapted to utilise different components of the estuary's invertebrate fauna. The major foods of South Island pied oystercatcher (SIPO) are bivalve molluscs obtained typically by probing in soft substrates, the main species in this area being probably cockle, pipi and wedge shells. The highest feeding rates are found when these molluscs are covered by shallow water (Baker, 1969). Secondary foods are small crabs, polychaete worms, amphipods and gastropod molluscs. Owen & Sell, (1985) recorded the highest concentration of feeding SIPO in their zones in the western inlet, north and south of Bells Island and between the airport and Rabbit Island.

These zones encompass areas of the major substrates found in the inlet (Figs. 3-11) and also coincide with the major roosts. A close relationship between roosts and feeding areas has been demonstrated for SIPO by Baker (1969) with both concentrated around areas of higher prey concentration. Feeding and roosting on paddocks adjacent to the estuary is an important feature of this species, particularly in winter.

Bar-tailed godwits' major foods are crustacea, small molluscs, and polychaete worms, usually obtained by probing at the edge of the tide or in water up to 15 cm deep (Cramp, 1983). Owen & Sell, (1985) recorded a seasonal change in use of the estuary by feeding godwits, birds congregating first in the zone south of Bells Island and west of the Rabbit Island causeway, then spreading over most of the inlet, before finally using the first two zones plus the western end of the inlet at the end of the season. These zones are mostly of fine sand and are again close to the major roosts.

Knot feed mainly on small bivalve and gastropod molluscs obtained from surface or shallow probing and are expected to show similar feeding patterns to the previous two species.

The key wader roosts were identified by Owen & Sell, (1985). At present the most important ones are Grossis Island and Bells Island shellbank, the latter holding increasing numbers. Nelson Airport has at times been important both as a feeding area and a roost. Several seasons of insecticide treatment by New Zealand Wildlife Service reduced feeding activity, but the area is still used regularly by banded dotterel and may hold roosting oystercatchers in winter.

Herons, Egrets and Spoonbills

The national importance of the estuary to white herons, little egrets and royal spoonbills was indicated in section 4.3.2. All three species were shown to have a clear preference for the intertidal area to the west of the Rabbit Island causeway by Owen & Sell, (1985). This area was favoured both for feeding and roosting, a pattern of use that has continued in recent years (pers. obs.). The previous authors explained this preference by the combination of suitable feeding areas and minimal human disturbance in this area. This zone encompasses areas of mud and fine sand (maps 1-9) with occasional tidal channels.

White-faced herons are the most numerous of this group of birds and tend to use most parts of the inlet. They show a preference for the central and eastern parts (Owen & Sell, 1985) but also feed on the edge of tidal channels in other areas. This species is now abundant in New Zealand and the numbers found at the Waimea are of no more than regional significance.

Rails, Crakes and Bitterns

Infilling of estuary or clearance of much of the coastal vegetation fringe in the region have restricted this group of birds to a few sites, of which the Waimea Inlet is one of the most important. All areas with an intact fringe vegetation of rushes backed by manuka, flax, raupo and shrubs must now be considered worthy of protection. The best such sites are identified in chapter 9.

The dependence of banded rails and marsh crake on the fringe vegetation is shown by their diet, as analysed from faecal material collected at the inlet by Elliott (1983). Fifty percent (by volume) of rail faeces and 80% of crakes' consisted of remains of the snails *Ophicardelus costellaris* and *Potamopyrgus estuarinus*, species that are more or less restricted to areas of sedges and rushes (Appendix 9).

4.4 ESTUARINE AND TERRESTRIAL VEGETATION

4.4.1 Estuarine Vegetation

An intertidal area of approximately 200 ha in Waimea Inlet containing mostly vegetation has been permanently lost by infilling. The largest areas were principally where the Waimea River enters the inlet. At nearby Delaware Inlet the typical pattern of zonation from flax and raupo swamp through to salt meadow, salt marsh down to mudflat and finally to eelgrass beds still exists (Franko, 1988). Around much of Waimea Inlet, the upper tidal levels (flax, raupo, salt meadow) have been most significantly modified by development. In many areas, only mudflat remains where estuarine plant zonation once existed.

A total of 8 algae and 20 vascular plant species were recorded from the intertidal zone of Waimea Inlet (Table 14). The most common algae in the inlet are sea lettuce (*Ulva lactuca*), and the agar weed (*Gracilaria*). Both species occur in intertidal areas adjacent to the main estuary channels often attached to cockles or dead shells. These algae grow rapidly and are seasonally variable.

The most common vascular plants in the inlet are the glasswort (*Sarcocornia quinqueflora*), the sea rush (*Juncus maritimus*) and the jointed rush (*Leptocarpus similis*). Two native sedges are also found in Waimea Inlet, the triangular sedge (*Schoenoplectus pungens*) and the club rush (*Bolboschoenus caldwellii*). The club rush is relatively uncommon in the Nelson/Marlborough region, especially in the Tasman/Golden Bay area. The club rush was often recorded from small isolated patches close to freshwater inputs. In Waimea Inlet, the largest stands of this sedge are around Neiman and Pearl Creeks.

The estuarine tussock *Stipa stipoides* was recorded from many locations in the inlet. The largest patches are adjacent to the mouth of Neiman Creek, Saxton Island and in the Tahunanui Embayment. Elsewhere this tussock is known from the Boulder Bank (Nelson Haven), three plants in Moutere Inlet (J. Preece, pers. comm.) and in the North Island reaching as far south as the Bay of Plenty. Waimea Inlet represents the southern limit of this tussock.

4.4.2 Terrestrial and Freshwater Vegetation

Pre-Human Cover

There is scant information about the pre-human vegetation cover of the Waimea Inlet and surrounding areas. The very small remnants that still exist around Waimea Inlet and other estuaries in the Nelson Region, although highly modified and now bearing little resemblance to original communities, provide the main clues to the nature and extent of this cover.

Before the arrival of humans, Waimea Inlet was surrounded by extensive and continuous areas of coastal forest and shrublands, freshwater wetlands, and dunelands. As in most natural coastal ecosystems the vegetation structure and composition of these communities would have been determined by:

a) the type of landform and substrate;

b) the extent and duration of freshwater and seawater inundation; and

c) exposure to the coast.

Most of the southern and eastern parts of the inlet, west of Richmond and Stoke-Tahunanui, graded from the estuarine salt marshes and meadows into a broad low-lying zone of freshwater communities dominated by flax, raupo, toetoe, manuka and cabbage tree. Other species which may have been common associates in these wetlands are swamp coprosma (*Coprosma tenuicaulis*), *Coprosma propinqua*, karamu, *Carmichaelia arborea*, and a variety of sedges *(Carex, Baumea, Eleocharis)*, rushes *(Juncus)*, and reeds. These vegetation types would have also been associated with the small river systems which flow into the western part of the inlet through the Moutere hill country (eg. Seaton Dominion, and Stringer Valleys).

In low-lying areas further inland these communities would have graded into tall swamp forests of kahikatea and perhaps pukatea which is near its southern limit here. Associates would have probably been swamp maire, marbleleaf, kamahi, toro, lancewood, cutty grass *(Gahnia)*, wheki, supplejack, kiekie, and a variety of divaricating shrub species. Lianes, climbers, and perching ferns, orchids and lilies *(Collospermum, Astelia)*, would have been major forest components.

The nearby fertile, freely-draining silts of the Waimea Plains, and gentle fans east of Richmond and Stoke would have supported a diverse and extensive forest dominated by matai, totara, titoki, white and narrow-leaved maire, pokaka, supplejack, and, in the more sheltered sites tawa, nikau, and karaka. The main understorey species would include broadleaves such as mahoe, pigeonwood, kawakawa, kaikomako, tarata, raurekau and a diverse assemblage of small-leaved trees and shrubs (turepo, rohutu, poataniwha, swamp mahoe, weeping mapou,(*Coprosma areolata, C. rotundifolia, C. rubra*). Perching plants, lianes, and climbers such as kiekie would have been abundant.

Table 14. List of Plant Species Recorded from Waimea Inlet.

Intertidal:	
Phylum Phycophyta (Algae)	
Class Chlorophyta (Green Algae)	
Enteromorpha sp.	
Euglena obtusa	
Ulva lactuca	Sea Lettuce
Class Rhodophyceae (Red Algae)	
Corallina officinalis	
Gelidium sp.	
Gigartina sp.	
Gracilaria sp.	Agar Weed
Class Phaeophyceae (Brown Algae)	
Colpomenia sp.	Air Cushion
Phylum Spermatophyta	
Class Angiospermae (Seed Plants)	
Apium prostratum	Sea Celery
Bolboschoenus caldwellii	Club Rush
Cotula coronopifolia	Button Weed
Isolepis cernua	
Isolepis nodosa	Knot Sedge
Juncus maritimus	Sea Rush
* *Lepidium banksii*	Coastal Peppercress
Leptinella dioica	
Leptocarpus similis	Jointed Rush
* *Plagianthus divaricatus*	Coastal Ribbonwood
Plantago coronopus	Buck's-horn Plantain
Puccinellia sp.	erect salt grass
Ruppia polycarpa	Horse Mane Weed
Samolus repens	Sea Primrose
Sarcocornia quinqueflora	Glasswort
Schoenoplectus pungens	Three Square
Selliera radicans	remuremu
Spartina anglica	Cord Grass
Spergularia rubra	Sea Spurry
Stipa stipoides	Estuary Tussock
Suaeda novae-zelandiae	Sea Blite
Triglochin striatum	Arrow Grass
Zostera muelleri	Eel Grass
Terrestrial:	
Asplenium bulbiferum	hen and chicken fern
Asplenium flaccidum	hanging spleenwort
Asplenium oblongifolium	shining spleenwort

Cont/d...

Table 14. List of Plant Species Recorded from Waimea Inlet.

Terrestrial:

Astelia fragrans	ground lily
Atriplex cineria	grey salt bush
Azolla filiculoides	
Baumea articulata	jointed twig rush
Blechnum discolor	crown fern
Blechnum minus	swamp kiokio
Blechnum procerum	
Blechnum 'reduced pinnae'	kiokio
Carex coriacea	
Carex geminata	
Carex fagellifera	
Carex virgata	
Carmichaelia arborea var	native broom
Chenopodium glaucum	goosefoot
Clematis paniculata	bush clematis, pua wanganga
Coprosma crassifolia	
Coprosma grandifolia	raurekau
Coprosma lucida	shining karamu
Coprosma propinqua	
Coprosma rhamnoides	
Coprosma robusta	karamu
Cordyline australis	cabbage tree, ti kouka
Cortaderia richardii	toetoe
Cyathea dealbata	ponga, silver fern
Cyathea medullaris	mamaku
Cyathodes juniperina	prickley mingimingi
Cyperus ustulatus	upoko tangata
Deparia petersenii	
Dianella nigra	blue berry, turutu
Dicksonia fibrosa	wheki ponga
Gahnia pauciflora	cutty grass
Griselinia littoralis	broadleaf, papauma
Haloragis erecta	
Histiopteris incisa	waterfern
Hebe 'squalida'	narrow-leaved koromiko
Hypolepis ambigua	
Juncus australis	
Juncus pallidus	
Juncus sarophorus	
Kunzea ericoides	kanuka
Lastreopsis glabella	
Leptospermum scoparium	manuka
Leucopogon fasciculatus	mingimingi
Melicytus ramiflorus	mahoe
Muehlenbeckia australis	pohuehue
Muehlenbeckia complexa	pohuehue
Myoporum laetum	ngaio
Myriophyllum triphyllum	water milfoil

Cont/d...

Table 14. List of Plant Species Recorded from Waimea Inlet.

Terrestrial:

Myrsine australis	mapou
Nothofagus solandri	black beech
Nothofagus solandri x truncata	beech hybrid
Nothofagus truncata	hard beech
Phormium tenax	swamp flax, harakeke
Phymatosorus diversifolius	hound's tongue
Pittosporum eugenioides	kohuhu
Pittosporum tenuifolium	
Poa anceps	
Poa imbecillus	
Podocarpus totara	totara
Polystichum richardii	lowland shield fern
Prumnopitys taxifolia	matai
Pseudopanax arboreus	five finger
Pseudopanax crassifolius	lancewood
Pteridium esculentum	bracken
Pyrrosia eleagnifolia	leatherjacket fern
Rubus cissoides	bush lawyer
Schoenoplectus validus	lake clubrush, kapungawha
Senecio glomeratus	
Senecio hispidulus	
Senecio minimus	
Sophora microphylla	kowhai
Typha orientalis	raupo
Uncinia banksii	
Uncinia uncinata	hookgrass
Wahlenbergia gracilis	
Weinmannia racemosa	kamahi

* Species above mean high water but covered during spring tides (tidal wetland).

The most fertile of the free-draining alluvial sites, such as along river banks and on higher ground amongst swamp forest, would have also supported a distinctive component of the deciduous trees, kowhai, lowland ribbonwood *(Plagianthus regius)* and narrow-leaved lacebark *(Hoheria angustifolia)*.

The dune country fringing Tahunanui and the Rabbit Island outer coast were much larger in size and more active than they are today. They would have supported dune-building species of pingao *(Desmoschoenus spiralis)* and spinifex *(Spinifex sericeus)*, and perhaps sand coprosma *(Coprosma acerosa)*, sand daphne *(Pimelea arenaria)*, sand spurge *(Euphorbia glauca)*, knot sedge *(Isolepis nodosa)*, coastal flax *(Phormium cookianum)*, and shrubs of tauhinu *(Cassinia leptophylla)* and akeake. Today, these indigenous dunelands have completely disappeared.

The more stable, beach ridges and hollows behind the dunes of Rabbit Island, and those which form the bulk of the Mapua and Tahunanui flats, and Bests, Bells, Rough, and Saxton Islands, would have formed parallel strips of alternating wetland and dryland communities. The excessively drained crests would most likely have been covered in dryland forest and shrublands of totara, ngaio, kowhai, akeake, akiraho, mapou, kanuka, *Coprosma crassifolia*, mingimingi, and prickly mingimingi. The beach hollows, which in places may have had standing water, would have been either rushlands, reedlands and flaxlands, or swamp forest similar to those already mentioned.

Peninsulas of low hill country project into the estuary along the margins of the eastern parts of the Waimea Inlet. In contrast to the adjacent Waimea Plains, this hill country is composed of relatively infertile Moutere gravels and clays. The main vegetation type that originally fringed the inlet here was tall podocarp-beech forest mainly comprised of dense rimu emergent over black and hard beeches, miro, kamahi, hinau, broadleaf, and perhaps toro. Common associates would have been those species typical of lowland beech forest: shining karamu, lancewood, pokaka, ponga, mingimingi, inaka, *Gahnia*, crown fern and a number of small-leaved shrubs. Epiphytes and lianes would have been a conspicuous element on emergent rimu.

Together, these coastal communities would have comprised an incredibly rich and diverse assemblage of plants, and would have provided an array of habitats of high productivity for a wealth of animal species.

All but a few tiny remnants of this terrestrial and freshwater vegetation still exist today. Without exception they are highly modified and only remotely resemble the previous vegetation cover at these sites. All the alluvial and swamp forests have completely disappeared as have the dunelands and much of the freshwater wetlands.

Methods

During the biological survey of the intertidal areas of Waimea Inlet, sites of terrestrial vegetation that adjoined the inlet and which were dominated by indigenous species were identified.

Near the completion of the intertidal survey, these terrestrial sites were revisited and a detailed account of landform, substrate, vegetation type, and species present was made. With these data, aerial photographs (1:10,000), topo maps and geological information (Johnston, 1979, 1982), the areas were then assessed for their importance to conservation with respect to ecological values in the context of the rest of Waimea Inlet, and where appropriate, in a regional and national setting. The dominant vegetation within each of these areas was mapped (habitat type maps 1-9, section 3.2).

Species, vegetation type, and landform information gathered from these sites also provided valuable clues as to the past indigenous vegetation cover around the inlet and the distribution of these vegetation types with respect to the variety of substrates and landforms.

All the areas described below are inadequately protected or are not managed appropriately to protect their conservation values. Recommendations for adequate legal protection are discussed in Chapter 10).

Higgs Reserve

This 3 ha area is situated at the head of the northernmost arm of the inlet (Map 1). It comprises a small southfacing stand of secondary forest on Moutere Gravels and clays. It is similar to the fringe of forest near Mapua, 1.5 km to the east and is dominated by a broadleaf mix of mahoe, kohuhu and five finger.

Although beech species are all but absent, the occurrence of a suite of typical beech forest associates such as *Dianella nigra*, kamahi, crown fern, mingimingi, prickly mingimingi, cutty grass, ponga and shining karamu all indicate that this site and other Moutere Gravel substrates around the inlet would once have been mainly under beech forest.

The reserve also suports a small manuka wetland, and a raupo-flax reedland flush around the mouth of Dominion Road stream and above the saline influence of the estuary. The reedland grades seaward into sea rush and jointed rush communities with typical estuarine herbs (glasswort, sea primrose). Despite its small size the importance of this reserve is highlighted by the facts that:

1) it supports one of the few stands of raupo reedland and native woody vegetation left in Waimea Inlet, and is therefore one of the few examples of continuous gradation from forest to freshwater and estuarine wetlands; and
2) provides one of the few remaining clues as to the original natural cover of the Moutere gravel country bordering the inlet.

Mapua Foreshore

This area consists of a narrow fringe of remnant and regenerating native vegetation in an almost continuous 1.5 km estuarine strip with two small associated gully remnants about 1 km west of Grossi Point, Mapua (Map 1).

The vegetation is growing on the Moutere Gravel formation which consists of well-weathered cobbles and boulders in a matrix of silty clay. This geology has produced the gently-rolling hill country and peninsulas which are characteristic of the land that adjoins the western shores of Waimea Inlet.

The main vegetation type is five finger - kohuhu forest, with occasional large isolated trees or small stands of mature black and hard beech and planted eucalypts. There are a diverse number of broadleaf associated including mahoe, mapou, mingimingi, shining karamu, lemonwood, ponga and lancewood, while ground cover, although sparse, mainly consists of shining spleenwort, hound's tongue and *Polystichum richardii*. On the steep faces just behind the foreshore a distinct shrub community of prickly mingimingi, *Hebe* '*squalida*', flax, *Carex flagellifera*, karamu and gorse dominates.

The presence of scattered beech and a few plants each of typical beech forest species such as broadleaf, crown fern, cutty grass, and *Blechnum procerum* indicate that this area was originally covered in hard beech and black beech forest down to the edge of the estuary. This strip of secondary forest and the nearby Higg's Reserve secondary forest are the last vestiges of tall native vegetation around the inlet. The few beech trees here are the sole survivors of the original forest which once completely covered the hill country around the western shores of the inlet.

The small gully systems adjoining the coastal forest strip is also largely secondary, but because of the moister condition supports a larger diversity of species including matai, kanuka, and totara. The fern *Deparia petersenii* also occurs here - this is one of the few occurrences of this species in the South Island. The gullies enter the inlet in small embayments which support a sparse fringe of estuarine vegetation including coastal ribbonwood, jointed rush, sea rush, knot sedge, sea primrose and sea celery.

Bullivant Island

This island is situated in the western outlet of Waimea Inlet, between Rabbit Island and Mapua wharf (Map 1). At its eastern side it is connected to Rabbit Island at low tide, but slopes gradually westward into the main channel.

Most of the 2 ha island is covered in kanuka forest and scattered macrocarpa and radiata pine trees. The rest is a mixture of exotic and native regenerating scrub and fernland. The vegetation beneath the forest is largely indigenous and is comprised of an unusual combination of mingimingi over a ground cover of coral lichen (*Cladia* sp) growing on a dry sandy substrate. If left to regenerate the island will begin to resemble the type of forest community that once have covered the dry, sandy beach ridges of Rabbit Island. It is the only kanuka forest surviving in Waimea Inlet.

Hunter Brown Peninsula

This 3 ha peninsula lies at the extreme western end of Rough Island (Map 3). It is a remnant beach ridge comprised of cobbles and pebbles derived from the Motueka River delta, within a silty sand matrix. The resultant soils are very stony, moderately fertile and excessively drained. The vegetation at this site is dominated by totara which forms a treeland with smaller statured shrubs and saplings of mapou, mahoe, mingimingi, matai, broadleaf, karamu, five finger, kanuka, hawthorn, broom and barberry.

Totara is a species which thrives on well-drained, fertile soils. Apart from the few trees on nearby Bird Island, the Hunter Brown totara are the sole survivors of the totara forests that originally covered the extensive beach ridges of Mapua, Tahunanui, and the larger islands of Waimea Inlet.

This treeland remnant is therefore extremely important in that is the last remaining area of native vegetation that has retained representative elements of the original cover of Waimea's beach ridge.

Rough Island Wetland

This is a narrow coastal freshwater wetland of about 2 ha which extends 400m along a depression on the eastern side of Rough Island (Map 3). It supports a cabbage tree - manuka treeland over a dense ground cover of *Juncus australis*, *Juncus sarophorus*, *Carex virgata*, *Carex coriacea*, spearwort (*Ranunculus flammula*) and rank grasses. It is seasonlly very wet with standing water supporting the floating fern *Azolla filiculoides*, and water milfoil (*Myriophyllum triphyllum*). A small 2m high reedland of the indigenous jointed twig rush (*Baumea articulata*) is confined to the wettest part of the wetland. This is the only known occurrence of this species in the South Island.

This is one of the few remaining natural freshwater wetlands in and around Waimea Inlet - the numerous and once-extensive flax swamps and dune depression wetlands bordering the inlet having all been drained or infilled long ago.

Because of the swampy nature of the area, it has been spared conversion to exotic forestry - now the dominant land use on Rabbit and Rough Islands. However, it has not escaped the recent burning off of surrounding foresty slash such that most of the manuka and some of the cabbage trees and other woody vegetation are now dead. Also, a recently contructed logging road has bisected the wetland. Only adequate buffering and a recognition of this area's importance will ensure that future recovery is permanent.

O'Connor's Creek

This spring-fed creek enters the inlet at the eastern extent of the Moutere gravel hill country which flanks the inlet's south-west shoreline (Map 4). The area is composed of recent alluvial gravels and silts mainly from the Waimea River. The mouth froms a delta system of channels around two stop-bank created islands of grazed pasture which are above riverine and tidal influence. The largest of these supports small remanant treelands of manuka.

The channels at the creek mouth support indigenous vegetation which grades from freshwater to estuarine wetland communities. Swamp flax lines the stream sides and forms a large sward where the channels divide. This grades into extensive coastal ribbonwood shrubland with important associates of kohuhu, manuka, toetoe, and *Coprosma propinqua*.

With increasing salinity along the delta channels, jointed rush and sea rush rushlands become dominant and extensive. These give way to continuous open carpets of glasswort on the estuarine flats proper.

The importance of this areas lies in the fact that it supports one of the largest areas of swamp flax remaining in the Waimea Inlet. This species once formed one of the main vegetation types within the extensive swampland surrounding the southern parts of the inlet. It also supports the largest stands of coastal ribbonwood shrublands in the inlet and a diverse sequence of communities grading from freshwater to saline environments.

Pearl Creek

This creek enters the inlet west of Waimea River (Map 4) and is similar to O'Connor's Creek to the west in that it is spring-fed and flows over recent alluvial gravels and silts derived from the Waimea River.

The mouth supports a delta of sea rush, jointed rush and some *Spartina*, with herbfields of arrowgrass, sea primrose and glasswort. On higher ground further east are about 1 hectare of scattered, healthy stands of coastal ribbonwood.

A strip of land extends inland between Pearl Creek and the Waimea River. It is contiguous with the creek mouth vegetation and supports an extensive semi-tidal mosaic of sea rush, jointed rush, coastal ribbonwood and tall fescue communities.

The creek itself is fringed on both sides with lake clubrush known elsewhere in the inlet only from Neiman Creek. One large ngaio, probably from a former forest, has managed to survive on the bank.

Because of stop banking, drainage, reclamation and grazing only a fraction remains of the estuarine rushlands and shrublands that would once have fringed almost the entire inlet. Pearl Creek and adjacent O'Connors Creek between them support the largest area of these communities and should be protected as representative examples of their type.

Dead Man's Island

This area is a small island (c. 5 ha) situated between Best's Island and the shores of the inlet, and is bisected by a service causeway to Best's Island (Map 6). It is a remnant part of a series of ridges which also make up the larger Rabbit, Bells and Bests Islands, and is composed of sea-smoothed pebbles and cobbles as well as river silt and shell fragments.

The terrestrial vegetation is a mosaic of indigenous shrublands and exotic treeland. The island is fringed with a narrow, discontinuous strip of coastal ribbonwood and estuary tussock. The island's western end supports a treeland of manuka and ngaio.

Gorse and radiata pine are frequent associates here. On the eastern side of the island is a dense shrubland, largely native in composition, of *Hebe 'squalida'* and *Coprosma crassifolia*. Other associates include: mapou, kohuhu, and manuka.

Although highly modified by past human activity, it supports one of the very few remaining areas of native woody vegetation in the inlet. These communities, and those of Hunter Brown Recreation Reserve, on Rough Island, now provide the only clues of the past natural vegetation cover of the islands and beach ridge systems of the Waimea Inlet. Many plant species wich would have once fringed the inlet have now become locally extinct. Dead Man's provides the sole refuge in the inlet of: *Coprosma crassifolia* as well as a single old kowhai tree which is probably related to the distinct and rare variety on the nearby Haulashore Island.

Neiman Creek

This creek is spring-fed from the Waimea Plains and enters the inlet east of Best's Island (Map 6). From about 1.5 km above the mouth it is lined with a raupo - swamp flax wetland which grades through to semi-tidal communities downstream which are dominated by lake clubrush, coastal ribbonwood, *Bolboschoenus caldwellii*, and tall fescue. Below the Queen Street culvert these semi-tidal communities give way to true estuarine vegetation dominated by glasswort and *Spartina*.

The mouth of Neiman Creek, and the higher ground in the upper tidal reaches directly to the south, support an extensive area of estuary tussock (*Stipa stipoides*), with intertussock species of sea blite and glasswort.

This estuarine tussock community is nationally rare. In the North Island *Stipa* is uncommon, and only found north of Bay of Plenty where it forms similar tussocklands around the high tide zone. In the South Island it is restricted to Tasman Bay and is concentrated in Waimea Inlet - its southern limit. The population around Neiman Creek is the largest in the inlet and is the best remaining example of this community in Tasman Bay.

Neiman Creek is also important in supporting the best example of a continuous gradation of wetland vegetation types from freshwater to estuarine conditions.

Saxton Island

A low-lying, very narrow, V-shaped island of about 1.5 km in length west of Monaco peninsula, which on the east side comprises a series of embayments and long narrow spits (Map 8). The substrate is mixture of excessively drained gravels overlain in places by silt and coarse sand.

Large areas of estuarine tussock cover the low-lying areas around mean high tide especially along the island's spits. These tussocklands adjoin large areas of intertidal herbaceous succulents such as sea blite, remuremu and glasswort. The largest areas above tidal influence are covered in a mixture of native and exotic tree species mainly comprised of mapou and ngaio, but also including taupata, five finger, cabbage tree, tree lucerne, broom, gorse and manuka. Most of the native species are naturally occurring on the island and are the seral stages of the original coastal forest which would have covered the island.

These low forest stands are fringed in places by intertidal areas of coastal ribbonwood, sea rush, erect salt grass and herbaceous succulents. The common skink (*Leiolopisma nigriplantare* var *polychroma*) is found along the strand zone. Another notable feature about the island is that it is free of rabbits and hares, which elsewhere in Waimea Inlet are reponsible for inhibiting or preventing plant establishment.

In the past, nearby Monaco, Oyster Island, and the Nelson Airport and golflinks would have had similar terrestrial vegetation to Saxton Island, but unlike Saxton have lost all trace of this indigenous cover. Despite major human modifications, plant species introductions and the secondary nature of the existing vegetation it is the only naturally occurring forest remaining around the shores of eastern Waimea Inlet from Blind Channel to Neiman Creek.

Richmond

This small natural area (1.2 ha) occurs immediately west of the Richmond refuse tip (Map 9). It comprises a zonation of communities still dominated by native species grading from a highly saline environment through to the interface of the estuarine and terrestrial environments. The vegetation grades inland from estuarine herbfields of glasswort, sea primrose, sea blite and buck's-horn plantain to a shrub-rushland of sea rush and coastal ribbonwood, and a narrow strip of estuary tussock.

Minor asscoiates at the Richmond site include jointed rush, remuremu, *Cotula coronopifolia*, sea celery, erect salt grass, and a few patches of *Spartina*. With decreasing salinity further inland, the sea rush is gradually replaced by the exotic tall fescue so that above the mean high tide a shrub-grassland of coastal ribbonwood and tall fescue dominate. Beyond this community the vegetation becomes entirely induce with scattered gorse amongst solid grassland of tall fescue which extends inland to the Richmond race course. Although small in size this area is one of the last remaining natural areas bordering the eastern Waimea Inlet. It has added importance in that it contains a sequence of vegetation types along a landward gradient from low to high salinity. Nearly all of the natural vegetation that once occupied the lower salinity zones of Waimea Inlet such as coastal ribbonwood shrublands have been destroyed by reclamation.

Plate 12 Estuarine tussock *(Stipa stipoides)*

Plate 13 Dead-mans Island

5. COMPARISON WITH OTHER NEW ZEALAND ESTUARIES

5.1 INVERTEBRATES

A comparison of benthic invertebrate species in Waimea Inlet and selected New Zealand estuaries is summarised in Table 15. Highest numbers of estuarine invertebrates has been recorded from the Avon-Heathcote Estuary (134 species). Waimea Inlet compares favourably with 111 benthic invertebrates. The lowest number of invertebrate species was recorded from the Wairau River Estuary (20 species), a value less than 20% of the number found in Waimea Inlet. Knox (1983b) suggested low diversity at the Wairau River Estuary was due to stress on the estuarine system. It may also be a factor of the restricted sample area of the study.

Density of common benthic invertebrates from Waimea Inlet are compared with other New Zealand estuaries in Table 15. Numbers of invertebrates from Waimea Inlet are in the middle to upper levels recorded for other estuaries. Densities of the pipi *Paphies australis* (3530 per m^2), the mudflat snail *Amphibola crenata*, the estuarine snail *Potamopyrgus estuarinus* and the hairy-handed crab *Hemigrapsus crenulatus* are high compared with other estuaries. Numbers of the stalk-eyed crab *Macropthalmus hirtipes* and the topshell *Diloma subrostrata* are, however, comparatively low in Waimea Inlet.

The number of species (Table 15) and the number of individuals (Table 16) recorded for the other Tasman and Golden Bay estuaries (Moutere Inlet, Nelson Haven and Parapara Inlet) are low compared with Waimea Inlet. Fifty-nine and 36 invertebrates were recorded from Moutere Inlet and Nelson Haven respectively while 54 species were recorded from Parapara Inlet. The intensity of the sampling program may, however, influence the number of invertebrates recorded. Estuaries with high records of invertebrate species have usually been sampled thoroughly (eg. Avon-Heathcote). It is probable, however, that the number of invertebrates recorded for Waimea Inlet will be the highest for any estuary in Tasman and Golden Bays.

Results suggest that Waimea Inlet compares favourably with other estuaries in New Zealand. This may be partially explained by the absence of hard substrata in many estuaries (Barnes, 1984). Eighteen species of benthic invertebrate in Waimea Inlet were restricted to the pebble and cobble habitat. These areas also supported the highest invertebrate densities in Waimea Inlet (76,350 individuals per m^2).

All the major feeding types were recorded within Waimea Inlet. Thirty-nine detritivores, 32 carnivores, 18 suspension feeders, 15 herbivors, 6 scavengers and 1 parasite make up the estuarine community. The range and abundance of the various feeding types suggest

Waimea Inlet receives a significant input of organic detritus. Most of this organic input into the estuary is derived from river input and fringe vegetation (Knox and Kilner, 1973; Gillespie and MacKenzie, 1981; Gillespie, 1983; MacKenzie, 1983; Barnes 1984). The need to protect saltmarsh vegetation from further loss by infilling is critical if the structure of food webs is to be maintained (Chapter 6).

5.2 FISH

Fish species recorded from Waimea Inlet are compared with selected New Zealand estuaries in Table 17. The highest number of fish species were recorded from Porirua and Pauatahanui inlets (43 species) closely followed by Waimea Inlet and the tidal portions of the Waimea River and inflowing streams (42 species). Waimea Inlet has the highest number of commercially fished species and the highest number of freshwater species recorded for a New Zealand estuary.

The variety and abundance of fish using Waimea Inlet is a reflection of the importance of Tasman Bay and associated estuaries for the feeding and reproduction of many coastal fish species.

5.3 BIRDS

The size of an estuary, or more specifically the area it provides for birds to feed and roost in, is a major factor determining the number of bird species it holds. Other factors will include productivity, geographical location, degree of disturbance and modification, and absence of pollutants.

Waimea Estuary is compared with other estuaries in New Zealand using three criteria:

1. Number of waterbird species recorded (Table 18). Waterbirds are defined as members of the following groups: penguins; oceanic seabirds; gulls, terns and skuas; shags; herons, egrets and bittern; ibises and spoonbills; waders; waterfowl; rails and crakes; and fernbird; ie. it includes birds that make specific use of the estuary's water system or the vegetation fringe that itself depends on this system.
2. Number of wader species recorded and maximum numbers of the most abundant waders: South Island pied oystercatcher, bar-tailed godwit and knot (Table 19).
3. Maximum density of waders, expressed as numbers per intertidal hectare (Table 19).

Waders are an important bird group for whom estuaries are the major or only habitat. Criteria 2 and 3 allow two further ways of looking at the importance of estuaries to this group. The number of different species recorded at a site may give some indication of the diversity of habitats and food items available. However, its geographic location and the frequency of visits by birdwatchers may be equally important in determining this total. Numbers of the more common species and overall estimates of density may be of more value when comparing the importance of different sites.

The results of Table 18 place Waimea Inlet near the top of New Zealand estuaries in terms of waterbird species in general, due in part to the presence of relatively uncommon species in several groups, eg. waders, herons and egrets, ibises and spoonbills, and rails and crakes. In terms of waders, Waimea Inlet is one of less than 20 estuaries in New Zealand supporting over 1000 waders at any time. It is not visited by the variety of waders found at Farewell Spit or the northern harbours nor are densities of waders recorded there particularly high (about the middle of the range of recorded sites)(Table 19). The seasonal pattern of wader density is very similar to the nearby Motueka Estuary, and intermediate between Farewell Spit and Whanganui Inlet, which support more waders in summer than in winter, and the northern harbours, which support roughly similar numbers in each season (Table 19).

Overseas banding studies have shown that during the course of a season an estuary may support many more birds than are counted at any one time, for individuals are continually moving through. Such a throughput of waders has been demonstrated at Nelson Haven to the east by counts made at dawn and dusk (J. Hawkins, pers. comm.). The importance of many estuaries to waders is thus underestimated by counts at any one time.

The importance of the Waimea in national terms for white herons, little egrets, royal spoonbills and banded rails has already been mentioned. The estuary and the Boulder Bank to the east are major nesting sites for the black-backed and red-billed gulls, and white-fronted and Caspian terns that use Tasman Bay. Numbers and sites vary considerably from year to year influenced by disturbance, changes in vegetation and probably the location of food supplies. The other main nesting site in the region used by these species is Farewell Spit.

Table 15. Number of Macroinvertebrate Species Recorded from Waimea Inlet and Other Estuaries in New Zealand

	Crustacea	Mollusca	Polychaeta	Others	Total
Waimea Inlet (Nelson) 1	27	37	36	12	112
Nelson Haven (Nelson) 2	5	11	17	3	36
Parapara Inlet (Nelson) 3	4	21	24	5	54
Moutere Inlet (Motueka) 4	11	27	16	5	59
Wairau River Estuary (Blenheim) 5					
- intertidal	10	3	7	0	20
- subtidal	8	3	8	1	20
Brooklands Lagoon (Canterbury) 6	13	8	10	9	40
Avon-Heathcote Estuary (Canterbury) 7	30	49	27	29	134
Okarito Lagoon (Westland) 8	15	7	3	17	42
Ahuriri Estuary (Napier) 9	6	11	14	2	33
Upper Waitemata Harbour (Auckland) 10	21	31	25	10	87

1. Present Study
2. Knox, 1979a
3. Knox et al., 1977a
4. Moffat, 1989
5. Knox, 1983b
6. Knox and Bolton, 1978
7. Knox and Kilner, 1973
8. Knox et al., 1976
9. Knox, 1979b
10. Knox, 1983a

Table 16. Maximum densities (per m^2) of selected species from Waimea Inlet and other New Zealand estuaries

	Waimea Inlet	Parapara Inlet	Moutere Inlet	Wairau River Estuary	Avon-Heathcote Estuary	Ahuriri Estuary
Bivalves						
Chione stutchburyi	3168	1426	1347	1340	3050	7270
Paphies australis	3530+	-	4494	452	2547*	Present
Tellina liliana	815	230	419	-	1337*	730
Gastropods						
Amphibola crenata	532	230	68	129	977*	580
Diloma subrostrata	170	63	79	-	1146*	360
Potamopyrgus estuarinus	23450	Present	Present	10449	884000	2500
Zeacumantus lutulentus	147	150	226	-	-	740
Polychaetes						
Capitellidae	4674	50	691	12040	36584*	Present
Nereidae	509	230	464	602	1350*	Present
Decapods						
Helice crassa	328	180	430	516	250*	420
Hemigrapsus crenulatus	566	Present	260	-	255*	Present
Macropthalmus hirtipes	102	-	215	516	250*	Present

* Jones, 1983

\+ Subtidal

Table 17. Number of Fish Species Recorded Living, Visiting or Migrating into Waimea Inlet and Other Estuaries in New Zealand.

Estuary	Marine Species	Freshwater Species	Commercial Species	Total Species
Waimea Inlet 1	31	11	20	42
Ahuriri Estuary 2	21	8	18	29
Avon-Heathcote 3	24	10	19	34
Porirua, Pauatahanui 4	36	7	14	43
* Wairau River Estuary 5	13	9	7	22
Upper Waitemata Harbour 6	20	1	10	21

1. Present Study
2. Kilner and Akroyd, 1978
3. Knox and Kilner, 1973
4. Jones and Hadfield, 1985
5. Knox, 1983b
6. Biggs, 1980

* Includes Vernon Lagoons

Table 18. Number of Waterbird Species from Waimea Inlet and Other New Zealand Estuaries.

Estuary	Number	Source
Waimea Inlet	50	Present Study
Wairau	56	Knox, 1983
Avon-Heathcote	53	Holdaway, 1983
Whanganui (Westhaven)	42	Butler, in prep
Kaipara Harbour	42	Veitch, 1979
Pauatahanui	30	Healy, 1980

Table 19. Comparison of New Zealand estuaries in terms of numbers of the four most common wader species, average wader densities, and the number of different wader species recorded

Site	Intertidal Area (ha)	SIPO	Maximum No. of: Bar-t Godwit	Knot	Banded Dotterel	Mean No. Waders/ Intertidal Hectare Summer	Winter		No. Wader Species Recorded	Months Counted	
Nelson Region											
Whanganui Inlet	2350	442	1702	371	204	0.60	0.19	(32.5)	15	Nov 1984-8	June 1984-8
Farewell Spit	9430	8046	16080	24227	1442	3.50	1.08	(31.0)	30	"	"
Waimea Inlet	2867	3065	2930	750	84	0.98	0.82	(84.1)	14	"	"
Motueka Estuary	1783	2791	2500	100	53	1.51	1.31	(86.9)	8	"	"
Other South Island											
Wairau Estuary	1200	200	400	25	27 +	(not recorded)			21	(Over several years)	
Avon/Heathcote	c800	4000	3000	2	150 +	(not recorded)			14	(Over several years)	
Auckland Region											
Manukau Harbour	c18000*		(not analysed)			1.80	1.85	(102.8)	42	Nov 1983-6	June 1984-7
Firth of Thames	c7700*		"			1.59	2.18	(137.1)		"	"
Kaipara Harbour	c28400*		"			0.56	0.57	(101.8)	18	"	"
						(Brackets give winter mean as a % of summer mean)					

* The northern harbours hold extensive areas of mangroves (*Avicennia resinifera*) which are rarely utilised by waders. The area of Manukau Harbour was obtained from Veitch (1978) and includes an unknown but relatively small area of mangroves. The intertidal area of the Firth of Thames is 8500 ha, 800 ha of which is mangrove (ibid), and that of the Kaipara is c40,900 ha including 12500 ha of mangroves (Veitch, 1979).

Sources:			
	Wanganui Inlet	-	OSNZ counts & Classified Summarised Notes.
	Farewell Spit	-	OSNZ counts & Lands & Survey (1983)
	Waimea Inlet	-	OSNZ counts & Butler (1989)
	Motueka Estuary	-	OSNZ counts
	Wairau Estuary	-	Knox (1983b) - (includes Vernon Lagoons)
	Avon/Heathcote Estuary	-	Baker (1973), Holdaway (1983)
	Manukau & Firth of Thames	-	Veitch (1979)
	Kaipara Harbour	-	Veitch (1978)

6. FOOD WEBS AND ESTUARINE PRODUCTIVITY

6.1 INTRODUCTION

Estuaries are productive environments with typical productivity values between 500-1,000 grams Carbon m^2 year. These values compare favourably with open sea phytoplankton (50 g C m^2 year) and inshore waters (100 g C m^2 year) (Ryther, 1969). Productivity or food available to estuarine consumers is produced from three sources: phytoplankton, benthic algae and detritus (Barnes, 1984). Most of the organic matter available to estuarine organisms, however, is included under the general category of detritus. Detrital input into estuarine ecosystems arises from two sources: autochthonous (originating inside the estuary) and allochthonous (originating outside the estuary) (Fig.5). Rivers and streams are usually the largest source of allochthonous detrital material, especially dissolved organic matter (DOM). Largest organic inputs from rivers occur during autumn freshlets (Knox, 1983b). In Waimea Inlet, the largest freshwater input comes from the Waimea River. Most normal river flow enters the eastern inlet, while the western inlet receives most of its river derived organic matter during flood events.

Primary autochthonous production in estuaries is from macro-algae (eg. *Ulva*, *Enteromorpha*, *Gracilaria*.), salt marsh vegetation (eg.*Juncus*, *Leptocarpus*, *Schoenoplectus*, *Spartina*), seagrass (*Zostera*), phytoplankton and the epibenthic microalgae (eg. diatoms, euglenoides). Most plant production becomes available as food in an estuary during a period of consumption, not by herbivores but by micro-organisms. Teal, (1962) showed that in the *Spartina* marshes of North America only 5% of *Spartina* production was eaten by herbivores, the remainder entered the detrital food chains (Darnell, 1961, 1967).

The importance of vascular plants in the detrital pathways is well documented (Mann, 1972; Odum and Fanning, 1973; Odum et. al., 1983). Following the initial period of autolysis during which the soluble materials leech out, bacteria and fungi colonise the dead plant material. Populations of ciliates and nematodes begin to build up. Macrobenthic animals consume pieces of this plant material and strip the micro-organisms off as the plant material (detritus) passes through their digestive tract. The plant material is passed out as psuedofaeces and recolonised by micro-organisms (Fenchel, 1970). This process results in a steady reduction in the particle size and an increase in the surface area to volume ratio.

A greater surface to volume ratio results in greater microbial populations. Much of this detrital material becomes incorporated in the sediments and is available to deposit feeders. In Waimea Inlet, 36 species of deposit feeders were recorded. The most abundant were the mudflat snail (*Amphibola*), wedge shell (*Tellina*), nutshell (*Nucula*), estuarine snail (*Potamopyrgus*), stalk-eyed crab (*Macropthalmus*), and mud crab (*Helice*). Deposit feeding polychaetes and fishes were also abundant in the inlet.

Detritus from the sediment surface is brought into suspension in the water column by currents, wave action and the activities of animals. Suspended detritus is an important source of food for suspension feeders in Waimea Inlet. The rich source of suspended detritus supports large populations of mussels (*Xenostrobus*), cockles (*Chione*) and barnacles (*Elminius*).

Both deposit feeders and suspension feeders are potential prey for higher trophic levels (Fig.5). A large diversity of invertebrate predators, especially gastropods, were recorded from Waimea Inlet. Large numbers of birds and fishes also rely on estuarine productivity (Teal, 1962; Odum and de la Cruz, 1967). Populations of fishes and birds, largely regarded by man as "more important" than estuarine plants and invertebrates, are ultimately dependent on detrital production at the base of the food chain.

6.2 PRIMARY PRODUCTIVITY IN WAIMEA INLET

Evidence of high estuarine productivity has been based on estuaries with mangroves or extensive salt marsh and subtidal areas (McCarthy et. al., 1974; Correll, 1978; Southwick and Pine, 1975; Orth, 1977). Few studies have investigated the productivity of shallow estuaries typical of Tasman and Golden Bay. Nelson estuaries have no mangroves, limited areas of salt marsh and small subtidal areas.

Primary productivity values have been calculated for Delaware Inlet, a local and similar type of estuary to Waimea Inlet (Gillespie and MacKenzie, 1981; MacKenzie, 1981) and Kaituna Marsh, Pelorous Sound (Odum et. al., 1983). Values from these estuaries were used to calculate primary production in Waimea Inlet (Table 20).

Salt marsh species (*Juncus, Leptocarpus, Sarcocornia, Bolboschoenus* and *Schoenoplectus*) cover approximately 4.9% of the total inlet and contribute 43% of the total yearly primary production. *Spartina* increases the total salt marsh production to almost 60% of total estuarine plant production.

Epibenthic microalgae colonise the entire surface area of rocks, plants, mud and sand flats in Waimea Inlet. Microalgae consist primarily of diatoms, euglenoids and, in some areas, nitrogen fixing bacteria (MacKenzie, 1983). Although production per unit area for epibenthic microalgae is low, the large area involved provides an estimated 24.5% of all calculated primary production.

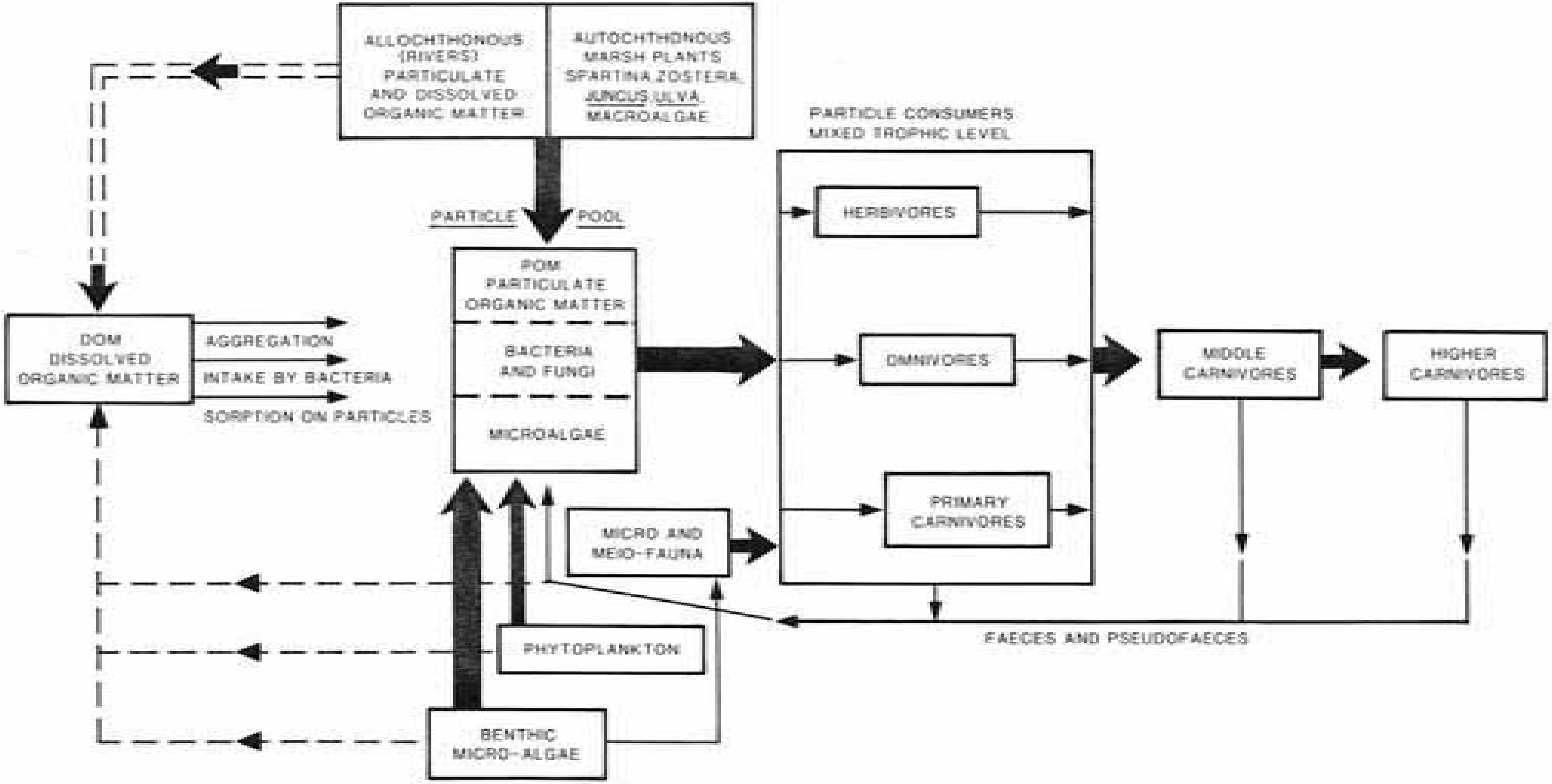

FIGURE 5. A conceptual model of a salt marsh-fringed estuary showing the most important energy flows as broad arrows, less important food chains as narrow arrows, and the pathway of dissolved organic matter as dotted lines.

Macroalgae beds are seasonal in abundance and distribution in Waimea Inlet. This makes accurate assessment of the area covered by macroalgae difficult. An estimated 30 ha of dense macroalgae exists in the inlet, however, this figure fluctuates seasonally. The dominant species include *Ulva lactuca* (sea lettuce), *Gracilaria* sp. and *Enteromorpha* sp. These macroalgae colonise the central areas of Waimea Inlet between mid and low tidal levels.

Dense beds of *Ulva* grow on mudflats near the sewage treatment pond outlet, while *Enteromorpha* grows in many of the small stream outlets around the inlet. Beds of *Gracilaria* dominate the main channels near Bronte and Rough Island in the western inlet. These dense macroalgae beds occupy less than 1% of the estuary, however, this estimate is conservative due to seasonal variation. Macroalgae are very productive per unit area and overall are responsible for a conservative 8.4% of primary production (Table 20).

Phytoplankton production is difficult to estimate in Waimea Inlet. Productivity per unit area is low and overall production in the estuary arising from phytoplankton is estimated to be approximately 6%.

Zostera or eelgrass represents less than 2% of the total estuarine area (Table 20). Most eelgrass occurs in the eastern inlet, with two small patches in the western inlet. Primary production figures from Delaware Bay suggest that eelgrass may contribute 1.24% of primary production in Waimea Inlet.

The most productive photosynthetic intertidal areas in Waimea Inlet are salt marsh and macroalgae beds (438-959 g.C.m^2 year). Based on Delaware Inlet figures, productivity in Waimea Inlet compares favourably with overseas estuaries (Knox, 1986). However, over 90% of Waimea Inlet is characterised by large expanses of mud, sand or pebble/cobble areas. These areas have relatively low primary production values (3.7-14.6 g.C.m^2 year). Consequently, the mean primary productivity for Waimea Inlet is 49.4 g.C.m^2 year. This figure is low compared with the relatively unmodified Delaware Inlet (Nelson), where a primary productivity value of 109.5 g.C.m^2 year was recorded (MacKenzie, 1983).

Results suggest the salt marsh community in Waimea Inlet is the largest source of primary productivity (Table 20). Development around the edges of Waimea Inlet has substantially reduced salt marsh areas and has lead to a reduction in primary productivity. The infestation of *Spartina* grass may have offset the reduction of natural productivity, however, with the eradication of *Spartina*, primary productivity in the inlet will fall. Protection and enhancement of native saltmarsh is necessary to ensure estuarine productivity within Waimea Inlet is maintained or improved.

Table 20. Primary productivity in Waimea Inlet

Photosynthetic Producer	g. C. m^2 year (above ground)	Area in Estuary (ha)	Percentage Total Estuary	Total Production (tonnes C. year)	Percentage of Production
Salt Marsh	438 $_1$	168	4.86	735.8	43.14%
Spartina anglica	959 $_2$	29	0.84	281.6	16.51%
Zostera muelleri	36.5 $_1$	58	1.68	21.2	1.24%
Macroalgae	475 $_1$	30	1.68	142.5	8.35%
Epibenthic Microalgae	14.6 $_1$	2867	82.98	418.6	24.54%
Phytoplankton	3.7 $_1$	3455	100.00	106.1	6.22%
Total	49.4 *	3455		1705.8	

1. Mackenzie, 1983; 2. Odum et. al., 1983.

Note * data expressed in terms of g.C.m^2 year for total area of estuary.

7. HUMAN IMPACTS

Estuaries are extremely vulnerable to human impact (Knox, 1980; Barnes, 1984; Knox, 1986). Estuaries most at risk lie close to populated areas where pollution and rubbish dumping are commonplace. Land requirements for industrial, domestic and recreational developments are also high. The ecological values of Waimea Inlet have suffered as a direct result of badly planned development (Struik, 1972). The following sections discuss human impacts and uses of Waimea Inlet.

7.1 POLLUTION AND NUTRIENT INPUT

Estuaries in many parts of the world have suffered from pollution and misuse. In New Zealand, 33 estuaries were classified as moderately (26) or grossly (7) polluted by McLay (1976). However, some of these systems have improved since this classification. Treatment of sewage and industrial waste has improved the quality of water discharged into Waimea Inlet since McLay classified it as moderately polluted.

Unfortunately, those factors which enable estuaries to concentrate and recycle nutrients naturally also trap pollutants. Fine sediment particles have been shown to concentrate pollutants from petroleum by-products, persistent pesticides and heavy metals (Odum et. al., 1969; Stephenson, 1980). Pollutants may influence Waimea Inlet in a variety of ways. These impacts include:

(a) smothering of organisms by excess sediments discharged into the estuary during very limited periods of time (Schafer, 1972);

(b) toxic substances which may kill or harm estuarine organisms, especially agricultural sprays, petrol spillages and industrial leachates; and

(c) deoxygenation of estuarine water due to discharge of sewage, organic residues or chemicals.

7.1.1 Sewage Treatment

Sewage disposal is probably the most significant source of pollution in Waimea Inlet. Prior to the installation of the Bells Island treatment station in November 1983, industrial and domestic wastes were discharged directly into the estuary (Updegraff et. al., 1977). There are currently no water rights for the discharge of sewage or harmful wastes in Waimea Inlet. All potential pollutants must pass through treatment stations.

Between 8,000-10,000 m^3 of treated effluent per day is discharged from Bells Island into the eastern inlet. Treated water is discharged subtidally into the channel between Bells and Saxton Island for up to three hours after high tide.

No recent studies have investigated water quality or nutrient levels in Waimea Inlet, however, Catchment Board figures gathered up until 1984 suggested that the standard of water in Waimea Inlet had improved since the implementation of the sewage treatment station. Regular monitoring of waste water quality prior to discharge is carried out by the Cawthron Institute. Figures for heavy metals, nitrogen, phosphorus and faecal coliform counts are well below standards set by the Catchment Board.

An increase in population, agriculture and industry in the Nelson region may result in larger volumes of effluent being discharged into the estuary. The inclusion of outlying districts into the Bells Island station may also add stress to the system. The ability of the estuary to cope with increased discharges is unknown. Therefore, any increase in the level of discharge into Waimea Inlet should be thoroughly investigated. Discharge of waste water into any estuarine system should be discouraged. A program monitoring nutrient levels in the estuary is also suggested.

7.1.2 Nutrient Levels

Nutrient input into Waimea Inlet is derived from five sources:

(a) Freshwater drainage from surrounding land;
(b) Input from Waimea River and numerous streams;
(c) Sewage input from Bells Island treatment station;
(d) Decay of marginal vegetation;
(e) Release from bottom sediments and decay of organic matter.

The largest input of nutrients is in the eastern inlet, from the Waimea River and the sewage ponds. Knox (1983b) stated that the degree of utilization of nutrients for plant production was dependent upon the nutrient residence time in the system. Release of treated wastes from Bells Island on the outgoing tides is intended to reduce nutrient residence time in Waimea Inlet, but dye studies have suggested that a significant proportion of estuary water returns with each tide (Westcott, 1981). This returning water brings a proportion of the diluted nutrients back into the estuary.

Nutrient enrichment or eutrophication in estuaries may be detected from a range of symptomatic changes including increased production of macroalgae (*Ulva*, *Gracilaria*), deterioration of fisheries, deterioration of water quality, and other undesirable effects. Algal blooms of sealettuce (*Ulva*) during the summer months represent the most visual form of nutrient enrichment in estuaries (Ketchman, 1969).

Investigations on algal growth have attempted to determine critical nutrient concentrations for growth. Based on these overseas studies and intensive work in the Avon-Heathcote

Estuary, Knox and Kilner (1973) suggested average upper limits of 400 mg/m^3 for total inorganic nitrogen (TIN) and 40 mg/m^3 for total phosphorus (TP) for estuarine waters. Values for Delaware Bay, a relatively unmodified, unpolluted estuary are 40mg/m^3 TIN and 27mg/m^3 TP (Unpub. Cawthron Inst.). For Waimea Inlet, mean values of 100 mg/m^3 TIN and 23 mg/m^3 TP (Unpub. Catchment Board) gathered in 1984, fall well within the standards set by Knox and Kilner (1973).

7.1.3 Faecal Coliform Bacteria

Faecal coliform measurements are used to estimate the level of hazardous bacteria in water samples. Specifications for water used recreationally (swimming) demand that counts of these bacteria do not exceed 200 bacteria per 100 ml of water. Prior to the sewage treatment at Bells Island, coliform counts in Waimea Inlet averaged between 10 to 186,000 per 100 ml. Faecal coliform counts taken after sewage treatment were down to an average figure of 26.8 per 100 ml (Unpub. Catchment Board). These figures represent a significant improvement in water quality in the estuary.

Outbreaks of human bacterial infection resulting from the consumption of sewage-polluted shellfish have been reported from many localities around the world (Metcalf, 1976). Health Department Restrictions for faecal coliform concentrations in waters where shellfish are commercially harvested are set at 14 bacteria per 100 ml. Most faecal coliform counts in Waimea Inlet fall above this figure.

7.1.4 Leachate

A number of benthic sample sites in Waimea Inlet were situated adjacent to potential sources of Leachate. Sites were located at the Richmond Refuse Tip, Ravensdown Fertilizer Works and Nelson Pine Forests (Fig.3). Invertebrate faunal composition from only one of these sites (Nelson Pine Forests) was separated out by the Bray-Curtis Dissimilarity Index (Appendix 2). Brown colouration of the surface sediments at this site suggested the presence of leachates from the tree storage area. The number of pollutant-indicating capitellid polychaetes were also the highest recorded for the mudflat habitat (792 per m^2).

7.2 *SPARTINA* SPRAYING

Spartina anglica has been the subject of an active eradication program run by the Waimea Catchment Board. A combination of the herbicides Amitrole and Dalapon have been used around much of the inlet. Environmental impact assessments (MacKenzie and Gillespie, 1985; Franko and Gillespie, 1986; Franko, 1987) and a three year investigative program monitoring the impact of spraying were commissioned by the Nelson Catchment Board. Results of the impact assessment suggested that, with adequate precautions during herbicide spraying, "a low environmental impact was expected in the short term" (Franko, 1987). The report suggested that caution be taken when spraying in areas with sensitive species (eg. sedges, *Zostera*, whitebait) and habitats (eg. backwaters, streams). The success of the spraying program has, to date, been lower than early expectations suggested.

Spartina removal in the estuary will probably have a larger impact than the spraying itself. Productivity studies using *Spartina* have suggested that up to 10 tonnes dry weight per year per hectare of plant material may be available to an estuary (Odum et. al., 1983). Loss of 29 ha of *Spartina* from Waimea Inlet, therefore, represents a significant reduction of primary production. Eventually, some of the *Spartina* habitat may be recolonised by native estuarine plants.

Spartina traps fine sediments between its stems and leaves causing a general build up of estuarine flats. The removal of *Spartina* will therefore result in the displacement of large quantities of sediment. This will probably have a significant impact on sediment type, faunas and estuarine productivity in Waimea Inlet.

Spartina significantly reduces the intertidal area available to feeding waders and is also unsuitable for rails and crakes which prefer native vegetation.

Financial and other constraints may ultimately place limitations on the spraying programme. Should spraying be scaled down it is suggested that biologically important areas be given priority (Chapter 9).

7.3 INFILLING OF INTERTIDAL AREAS

Conversion of mudflats and areas of marginal vegetation into land destroys the habitat of many resident animals and plants. This may cause the loss of local populations of some species. Fishes and migratory birds may also suffer from loss of feeding and breeding sites. Loss of vegetation also reduces the area of one of the important sources of estuarine production and may therefore cause a decline in productivity of the estuary. Removal of estuarine habitat has been continual in the past and represents a serious threat to Waimea Inlet.

Approximately 200 ha of intertidal Waimea Inlet has been infilled for agricultural, industrial, housing and roading requirements (Owen and Sell, 1985). Infilling of Waimea Inlet using *Spartina* species has been encouraged in the past by the DSIR who introduced the grass in the 1900's.

7.4 REFUSE DISPOSAL

Estuaries were once regarded as ideal sites for the disposal of rubbish particularly because dumps usually ended as industrial land. Today, however, the remaining mudflats and vegetated areas are regarded as biologically valuable and productive and refuse disposal is seen as an unacceptable use of estuarine areas.

Waimea Inlet has been used for rubbish disposal legally and illegally. The Richmond Tip is the largest area where rubbish is legally disposed of in the inlet. Small illegal rubbish dumps regularly appear around the inlet.

Concern over possible leaching of toxic substances from the Richmond Tip has been expressed by the public. Studies by the Catchment Board and Cawthron Institute have found little evidence of leachate entering the estuary. These areas are, however, visually unpleasant and detract from estuarine aesthetics. Rubbish tips and discarded rubbish have been responsible for much of the public distaste for estuaries in the past.

7.5 LAND DEVELOPMENT

Most land adjoining Waimea Inlet has been developed for agriculture, industry, forestry, recreational structures or roading. The largest environmental impacts on the estuary margins have come from industry and roading. The largest industries include the Apple and Pear Factory, Fibre Factory, Waitaki Freezing Works, Nelson Pine Forests Ltd, Aggregate Supplies and Ravensdown Fertilizer Works.

The rate of developmental pressure around Waimea Inlet is expected to increase, particularly through housing, roading, and recreation. Management of estuary margins must take into account estuarine ecological values. In general, development should give priority to low impact recreational activities with areas set aside for bird-watchers and casual walkers.

7.6 TRANSMISSION LINES

Transmission lines cross Waimea Inlet at numerous points. Although these power poles do not have a detrimental impact on the ecology of the estuary, they have a visual impact. Prior to installation or replacement of powerlines, consideration of the siting, materials and design of the structures should be given. Underground cables would provide a more suitable long-term solution.

Disused lines and poles are located at various points within and adjacent to Waimea Inlet. These should be removed as they present a navigational hazard and are unsightly (eg. Higgs and Trafalgar Road embayments).

7.7 POWER BOATING

Power boating, particularly waterskiing, is a popular pastime in Waimea Inlet. Three ski lanes are situated around the inlet; (1) Monaco; (2) Rabbit Island; and (3) Mapua. Minor erosion problems occur around the ski lanes and the noise of power boats also disturbs breeding, roosting and feeding birds. Power boating at Mapua may threaten the endangered peppercress plants on No-mans Island. Power boating also conflicts with other recreational pursuits (bird-watching, fishing, walking).

Further restrictions on the use of power boats in Waimea Inlet are suggested. The limits of boat penetration into the inlet and the areas of low impact should be assessed.

7.8 WATERFOWL SHOOTING

Waterfowl shooting is a popular pastime in Waimea Inlet. The majority of hunting occurs early in the season with many hides being constructed around the inlet. These structures detract aesthetically from the estuary throughout the year. This problem would be overcome if hunters were required to remove their hides at the end of each season.

7.9 LIVESTOCK GRAZING

Many boundaries of Waimea Inlet are grazed by cattle, sheep and goats. This grazing inhibits survival and regeneration of native vegetation around the margins of Waimea Inlet. Although most grazed land is fenced some areas of estuary are grazed by livestock. Areas of greatest concern are Pearl, Neiman and O'Connor Creeks. Fencing of particular areas around Waimea Inlet would reduce these impacts.

8. EVALUATION OF WAIMEA INLET

Schemes for ranking terrestrial habitats (Spect et. al., 1974; Ratcliffe, 1977; Wright, 1977; Imboden, 1978; Park and Walls, 1978; Ogle, 1982; Myers et. al., 1987), wetlands (Morgan, 1982; Angel and Hays, 1983; Pressey, 1985) and lagoons (Barnes, 1989) have been developed in response to a growing need for conservation input into environmental management. These evaluation methods are not directly applicable to estuarine systems, and a system for the evaluation of whole estuaries and parts of estuaries has not been previously developed for use in New Zealand.

The conservation value of Waimea Inlet is compared with two other South Island estuaries (Parapara Inlet, Avon-Heathcote Estuary) using proposed evaluation criteria outlined in appendix 11.

Using the proposed criteria for the evaluation of an estuary, Waimea Inlet and two other South Island estuaries were ranked for conservation status (Table 21). Parapara and the Avon-Heathcote have been the subject of relatively intense biological surveys, and are therefore comparable using the criteria.

Results show that Waimea Inlet ranks highest of the three estuaries. Waimea Inlet scored well on representativeness in the region, size, number of invertebrates, fish, birds and vascular estuarine plants. Waimea scored poorly in criteria related to man-made impacts. A significant part of the inlet has been modified by farming, industry and pollution. The Avon-Heathcote also scored poorly on similar grounds. Parapara Inlet has had relatively low levels of human impact, but is typical of small inlets in the Golden Bay area where species diversity is generally low.

Table 21. Evaluation of Waimea Inlet and Two South Island Estuaries

Criteria	Waimea Inlet	Parapara Inlet	Avon-Heathcote
(1) Representativeness	80	27	80
(2) State of estuary	40	40	40
(3) Pollution status	30	45	15
(4) Terrestrial veg.	15	45	15
(5) Salt marsh	45	45	30
(6) Area of estuary	60	24	36
(7) Invertebrate sp.	32	16	32
(8) Waterbird sp.	24	8	32
(9) Fish species	40	30	40
(10) Cockle density	40	24	40
(11) Plant species	20	15	20
Total	426	304	380
Percent	76%	54%	68%

9. AREAS OF BIOLOGICAL IMPORTANCE

Waimea Inlet is a large and topographically diverse area with many islands, peninsulas, channels and substrate types. Associated with most areas are particular groups of plants and animals. Even the thick glutinous mudflats contain a typical fauna. Most habitats in Waimea Inlet are threatened by development, pollution, infilling or recreational misuse. The intertidal areas listed below are considered the most important ecological sites in Waimea Inlet and are therefore recommended for protected status. Terrestrial areas and freshwater wetlands of biological importance are discussed in section 4.4.2.

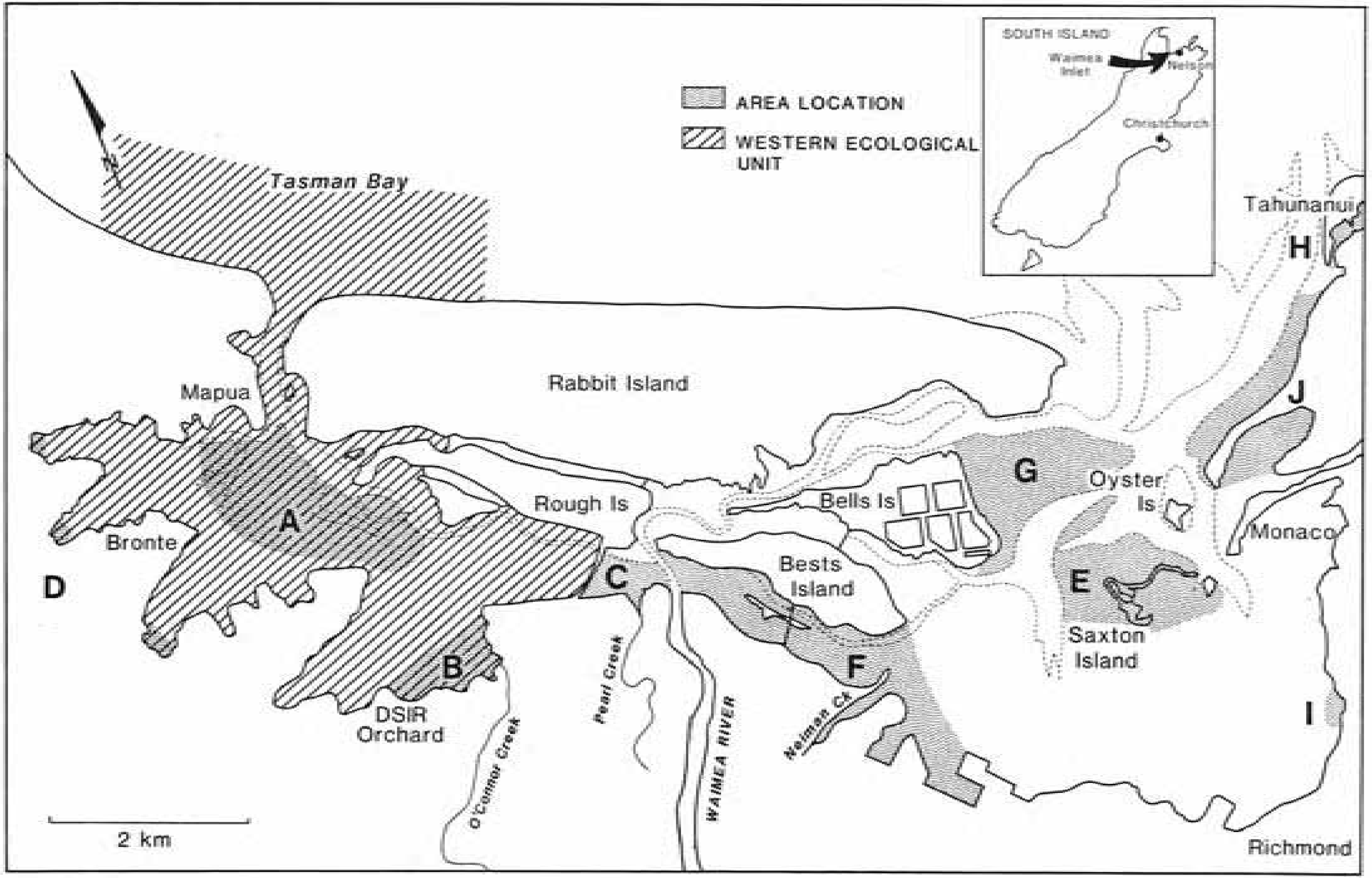

FIGURE 6. Biologically important areas in Waimea Inlet

9.1 WESTERN WAIMEA INLET

Western Waimea Inlet, stretching from the Waimea River to a 4 km^2 area at the Mapua outlet, is an important ecological unit (Fig.6). Within this area are a range of habitats vital for the survival of estuarine plants, animals and the ecosysytem itself. Areas particularly important intertidal areas in the western inlet include:

9.1.1 No-mans Island and Intertidal Flats and Channels (Area A)

No-mans Island and the surrounding intertidal flats and channels are located opposite Grossis Point (Fig. 6)(plate 14, 15). The intertidal flats extend into four large embayments bounded by salt marsh vegetation. At the head of each embayment is a small salt marsh community and an inflowing stream. No-mans Island also supports a diverse community of salt flat vegetation including a small population of the endangered peppercress plant (*Lepidium banksii*). This represents approximately 80% of the total known population of this plant (Davidson et.al., 1990). The intertidal flats surrounding No-mans Island support large cockle beds and rich invertebrate faunas. These flats represent an important source of food for fish and birds. The island is also an important high tide roost for many wading birds. Nesting white-fronted terns have been recorded on No-mans Island. The main and minor channels represent an important nursery and feeding ground for fish. The area is also important to white heron, little egret and royal spoonbill.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital habitat for endangered plant	60
(2)	Representativeness/uniqueness within Estuary		
	(b)	better area of kind in estuary	40
(3)	Representativeness/uniqueness in Conservancy		
	(b)	better area of kind in Conservancy	40
(4)	Biological and Physiological State of Margins		
	(b)	isolated modification	45
(5)	State of Surrounding Terrestrial Vegetation		
	(b)	small areas of important vegetation	40
TOTAL			245
PERCENT			82%

9.1.2 O'Connor Creek and Salt Marsh (Area B)

This large salt marsh and wetland is located where O'Connor Creek enters the western inlet (Fig. 6). O'Connor Creek salt marsh is the largest salt marsh without significant infestations of *Spartina*. The salt marsh grades from large expanses of glasswort and *Samolus repens* beds, through extensive native rush stands (*Juncus*, *Leptocarpus*) to coastal ribbonwood (*Plagianthus*), *S. stipoides*, flax and manuka stands. The flax swamp represents the last remnant of swamps that once stretched from Richmond to O'Connor Creek. The O'Connor Creek area is therefore one of the most important areas of fringe vegetation in Waimea Inlet.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital habitats for rare birds and native fish	60
(2)	Representativeness/uniqueness within Estuary		
	(a)	best area of kind in estuary	60
(3)	Representativeness/uniqueness in Conservancy		
	(b)	better area of its kind in Conservancy	40
(4)	Biological and Physiological State of Margins		
	(c)	margins modified by infilling and stopbanks	30
(5)	State of Surrounding Terrestrial Vegetation		
	(b)	pockets of original vegetation, some regeneration	40
TOTAL			230
PERCENT			77%

Plate 14 No-mans Island

Plate 15 No-mans Island

9.1.3 Pearl Creek (Area C)

Pearl Creek is spring fed and flows into the western inlet approximately 1 km east of the Rabbit Island causeway (Fig.6). In the upper tidal reaches, Pearl Creek is a salt marsh area important to banded rail, pukeko, waterfowl and other bird life. In the lower reaches, there are extensive native rush beds including the largest stands of *Bolboschoenus caldwellii* in the inlet. The lower reaches have a large infestation of *Spartina*. Both reaches are used by bird watchers, whitebaiters and duck hunters.

The wildlife values of Pearl Creek may be improved. Land between Pearl Creek and the Waimea River may recover naturally or with supplementary planting. At present, half of the land is harbour board endowment, while the remaining 16 ha is privately owned. The area is grazed by cattle. Removal of a culvert on Pearl creek will allow migration of native fish.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital habitat for rare birds	60
(2)	Representativeness/uniqueness Within Estuary		
	(a)	best area of kind in estuary	60
(3)	Representativeness/uniqueness in Conservancy		
	(b)	better area of kind in Tasman Bay	40
(4)	Biological and Physiological State of Margins		
	(c)	margins modified by stopbanks	30
(5)	State of Surrounding Terrestrial Vegetation		
	(b)	regenerating, limited by occasional grazing	40
TOTAL			230
PERCENT			77%

9.1.4 Intertidal Higgs Reserve, Trafalgar Road Embayment and Stringer Creek (Area D)

These intertidal areas are located in the western embayments of Waimea Inlet (Fig.6). These areas are unique in Waimea Inlet as *Juncus, Leptocarpus, Schoenoplectus* and often *Bolboschoenus* grow together in close proximity. The land adjacent to these areas are farmed and the intertidal flats subject to occasional grazing by cattle (plate 16). Higgs Reserve borders the western-most of the three intertidal areas and contains some broadleaf vegetation (section 4.4.2). These intertidal areas and adjacent terrestrial vegetation represent remnants of the zone between land and estuary. Higgs Reserve and the nearby Stringer Creek are also important to banded rail.

The Higgs Reserve area has considerable potential for improvement. Replanting of the extreme high water and terrestrial margins may offer better habitat for banded rail and native fish species. Establishment of an area representative of original Waimea Inlet habitat is also desirable.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital habitat for breeding banded rail	60
(2)	Representativeness/uniqueness within Estuary		
	(b)	better area of kind in estuary	40
(3)	Representativeness/uniqueness in Conservancy		
	(c)	similar areas in Conservancy	20
(4)	Biological and Physiological State of Margins		
	(b)	isolated development of estuarine margins	45
(5)	State of Surrounding Terrestrial Vegetation		
	(b)	significant area of broardleaf vegetation	40
TOTAL			205
PERCENT			68%

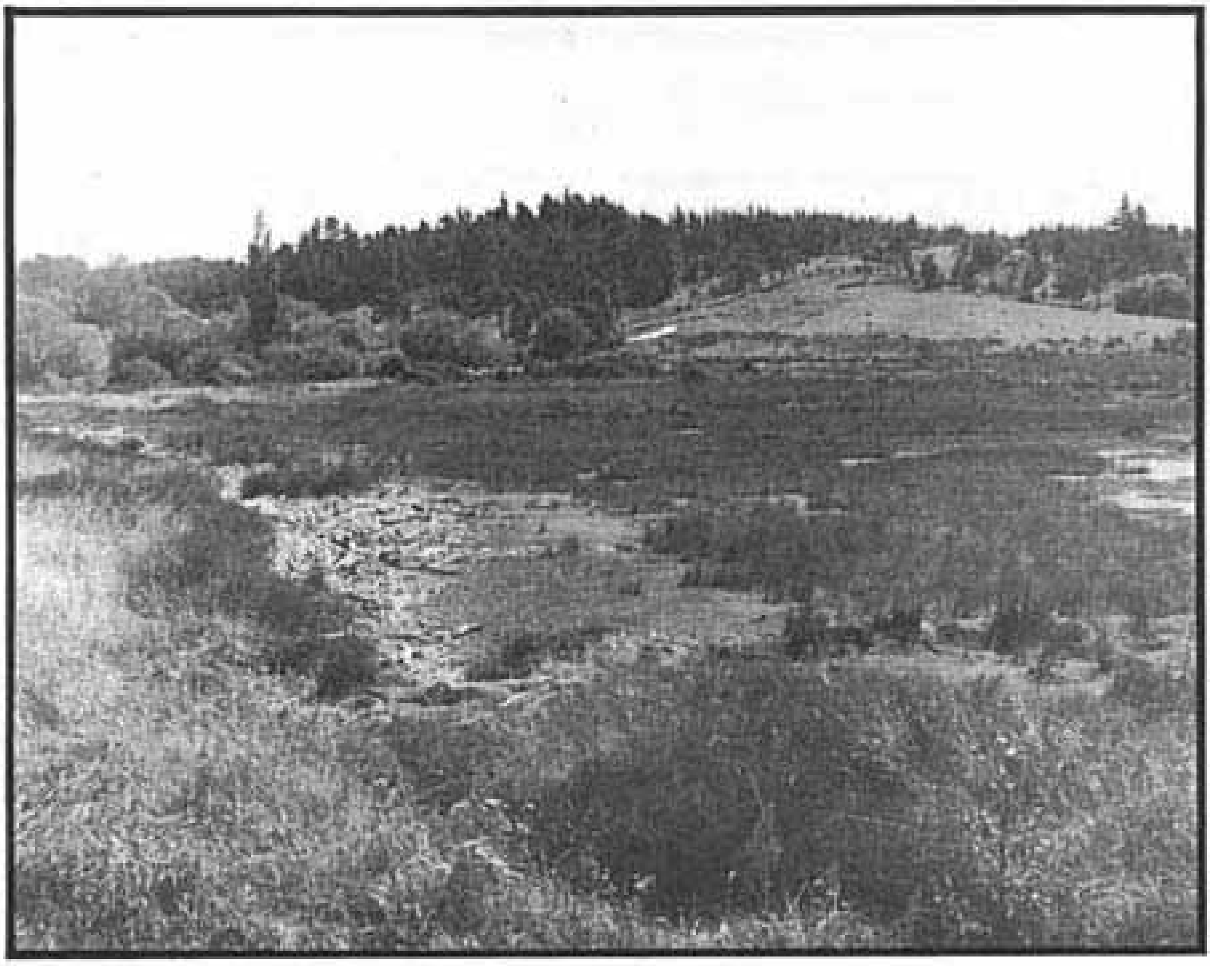

Plate 16 Stringer Creek saltmarsh

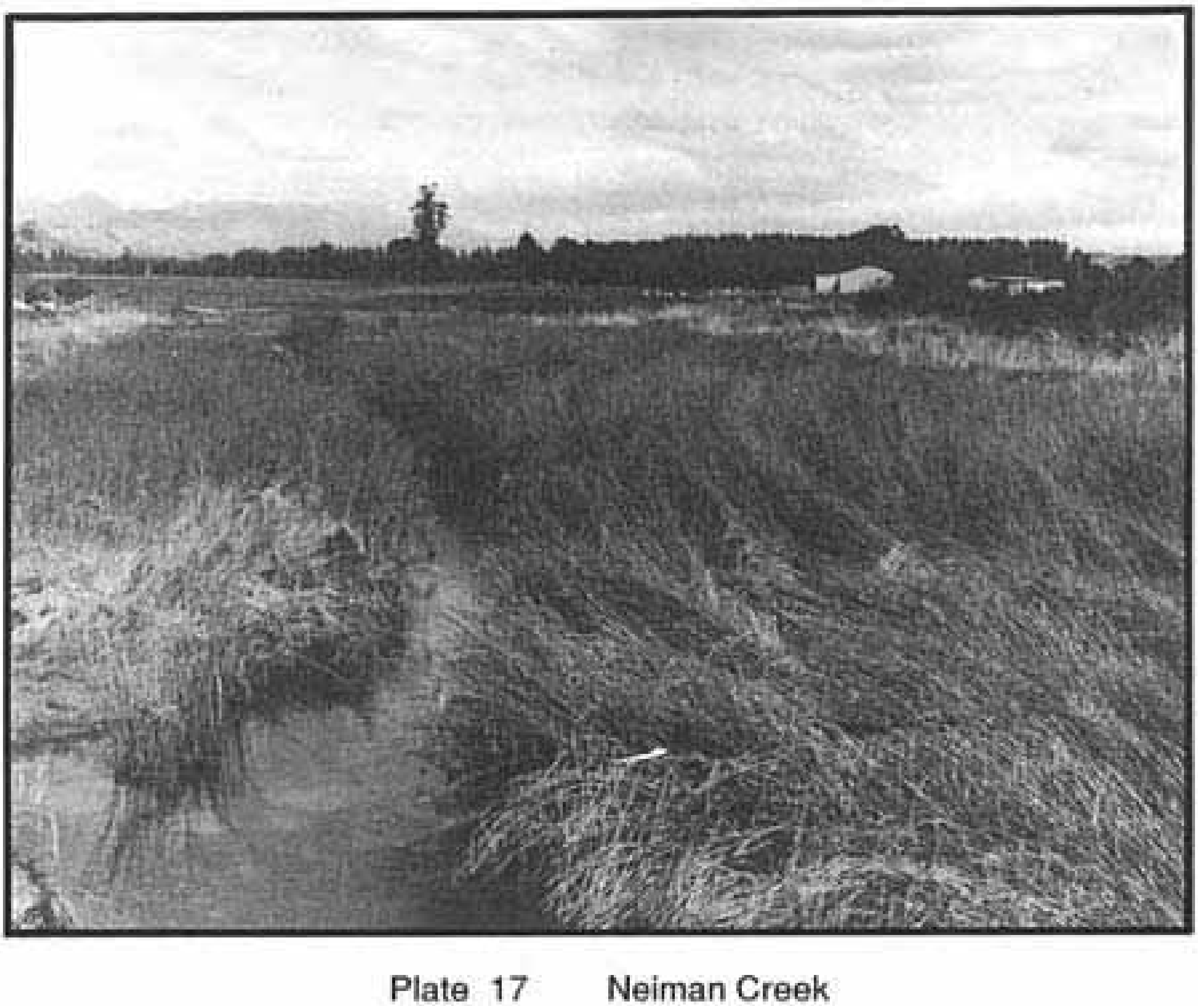

Plate 17 Neiman Creek

9.2 EASTERN WAIMEA INLET

Eastern Waimea Inlet stretching from the Waimea River to Tahunanui Beach has been extensively modified. Infilling and industrial and agricultural development has been most destructive around the estuarine margins. The eastern inlet has, however, areas of biological importance (Fig.6).

9.2.1 Saxton Island and Adjacent Intertidal Flats (Area E)

Saxton Island is a seven hectare island surrounded by many habitat types including eelgrass, salt marsh, fine sand flats, pebbles and cobbles, cockle beds, subtidal channels and mudflats (Fig.6). Most habitats support rich invertebrate faunas including the largest of the two estuarine colonies of the tube worm *Sabellaria kaiparaensis*. The area is an important feeding area for fish and birds. Saxton Island represents a biologically rich and relatively isolated island, an area seldom found in New Zealand estuaries. Threats include pollution from the sewage treatment plant, (should present levels be exceeded) and development by the land owners.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(b)	vital habitats for invertebrates, fishes and birds	60
(2)	Representativeness/uniqueness within Estuary		
	(a)	unique, only area of kind in estuary	60
(3)	Representativeness/uniqueness in Conservancy		
	(b)	one of only areas of kind in Conservancy	40
(4)	Biological and Physiological State of Margins		
	(b)	isolated modification	45
(5)	State of Surrounding Terrestrial Vegetation		
	(c)	modification of vegetation types	20
TOTAL			225
PERCENT			75%

9.2.2 Chip Mill to Waimea River (Area F)

This high tide or fringe area stretches from the Richmond Chip Mill, along the inside of Bests Island to the Waimea River 3.6 km to the west (Fig. 6). This area includes the spring fed Neiman Creek up to the speedway (plate 17). The chip mill to Waimea River area supports some of the largest remaining *Juncus maritimus* and glasswort (*Sarcocornia*) beds in the estuary. The largest areas of the tussock *Stipa stipoides* in the South Island are located at the junction of Neiman Creek and Waimea Inlet (plate 19). Isolated patches of the native sedge *Bolboschoenus caldwellii* were found in Neiman Creek and adjacent to the Swamp Road Creek. The regionally rare sedge *Schoenoplectus validus* is recorded from above the Lower Queen Street culvert.

This area has been substantially modified by infilling and wetland drainage. At present it is threatened by further infilling and pollution from existing industrial development. The land on the eastern bank of Neiman Creek is privately owned and grazed by goats, preventing growth of brackish water plants and causing damage to whitebait spawning areas and egg masses.

EVALUATION RANKING:		SCORE
(1)	Importance of Flora, Fauna and Habitats	
	(a) vital habitat for important plants and spawning fish	60
(2)	Representativeness/uniqueness within Estuary	
	(b) one of the better areas of kind in estuary	40
(3)	Representativeness/uniqueness in Conservancy	
	(b) one of the better areas of kind in Conservancy	40
(4)	Biological and Physiological State of Margins	
	(c) margins modified by infilling and stopbanks	30
(5)	State of Surrounding Terrestrial Vegetation	
	(b) pockets of regenerating vegetation	40
TOTAL		210
PERCENT		70%

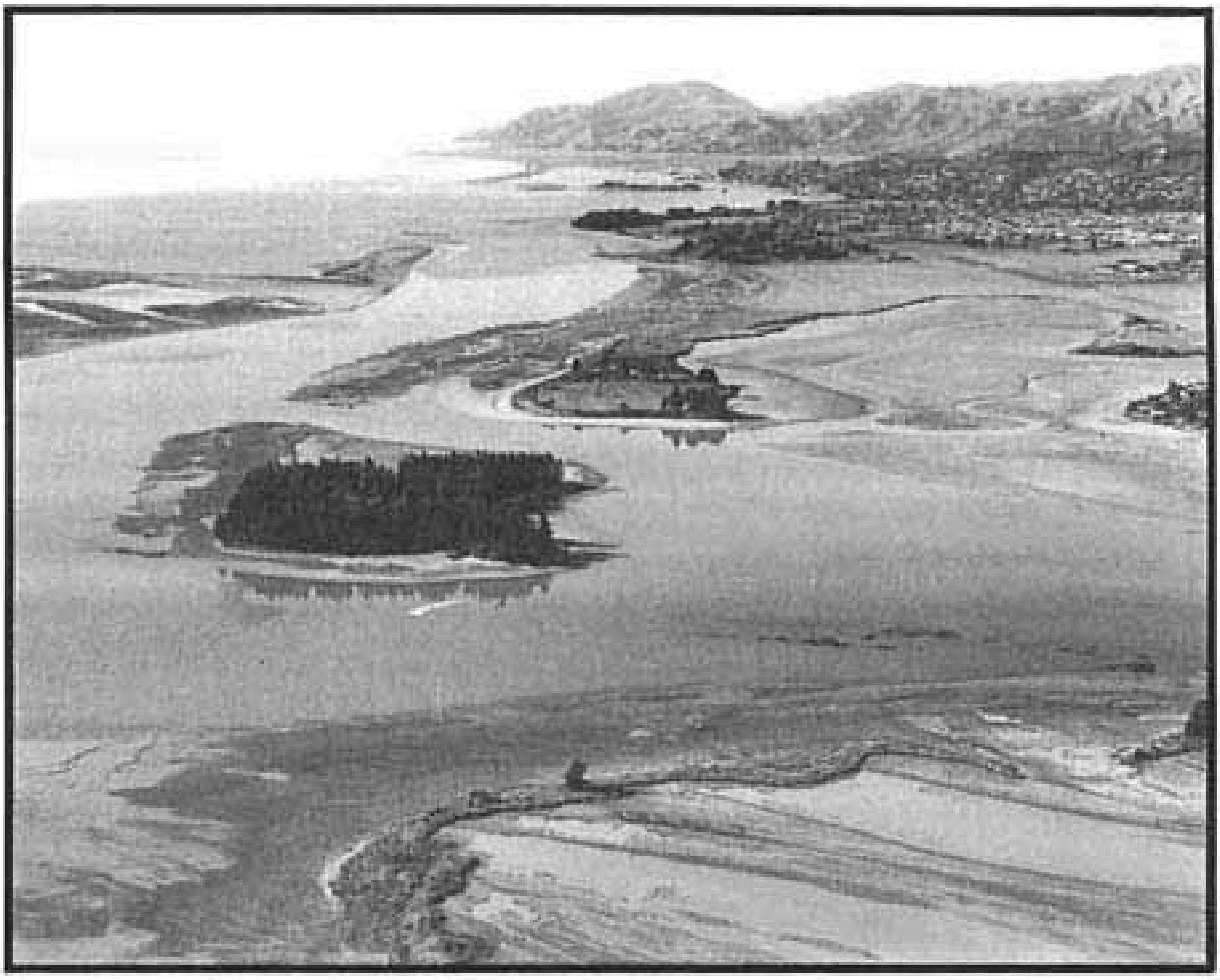

Plate 18 Saxton Island in foreground, Aerodrome Peninsula centre

Plate 19 Chip mill to Waimea River area with the estuarine tussock *(Stipa stipoides)*

9.2.3 Bells Island Intertidal Flat (Area G)

Bells Island flat is a large intertidal area located on the eastern side of Bells Island (Fig.6). Habitat types include fine sandflats, eelgrass beds and pebble-cobble flats. All habitats support large populations of invertebrates. Large numbers of oyster catchers, pied stilts and godwits feed on the Bells Island flat. A small shell bank represents the largest breeding colony in Tasman Bay for Caspian terns, white-fronted turns and black-backed gulls. The shell bank is also an important wader roost during high tide. A small infestation of *Spartina* threatens the area, however, the largest threat is from the sewage treatment ponds on the island should present levels of discharge be increased.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital breeding and feeding area for birds	60
(2)	Representativeness/uniqueness within Estuary		
	(b)	one of better areas of kind in estuary	40
(3)	Representativeness/uniqueness in Conservancy		
	(b)	one of better areas of kind in Conservancy	40
(4)	Biological and Physiological State of Margins		
	(b)	margins modified only slightly	45
(5)	State of Surrounding Terrestrial Vegetation		
	(c)	little buffering vegetation	20
TOTAL			205
PERCENT			68%

9.2.5 Orphanage Creek Salt Marsh (Area I)

Orphanage Creek salt marsh represents the best remnant salt marsh community along the eastern edge of the Waimea Inlet (Fig.6)(plate 21). Important plant species include the tussock *S. stipoides* and the sedge *Schoenoplectus pungens*. *Spartina* infestation is restricted to a few isolated points. The biggest immediate threat to the area is livestock grazing and infilling. A significant proportion of the salt marsh is privately owned and will continue to be degraded by further development.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	bird roosting site, important vegetation site	40
(2)	Representativeness/uniqueness within Estuary		
	(a)	unique area in eastern estuary	60
(3)	Representativeness/uniqueness in Conservancy		
	(b)	areas similar in Conservancy	20
(4)	Biological and Physiological State of Margins		
	(b)	stock grazing and inappropriate fencing	45
(5)	State of Surrounding Terrestrial Vegetation		
	(c)	little buffering vegetation, land farmed	20
TOTAL			200
PERCENT			67%

Plate 20 Tahunanui embayment

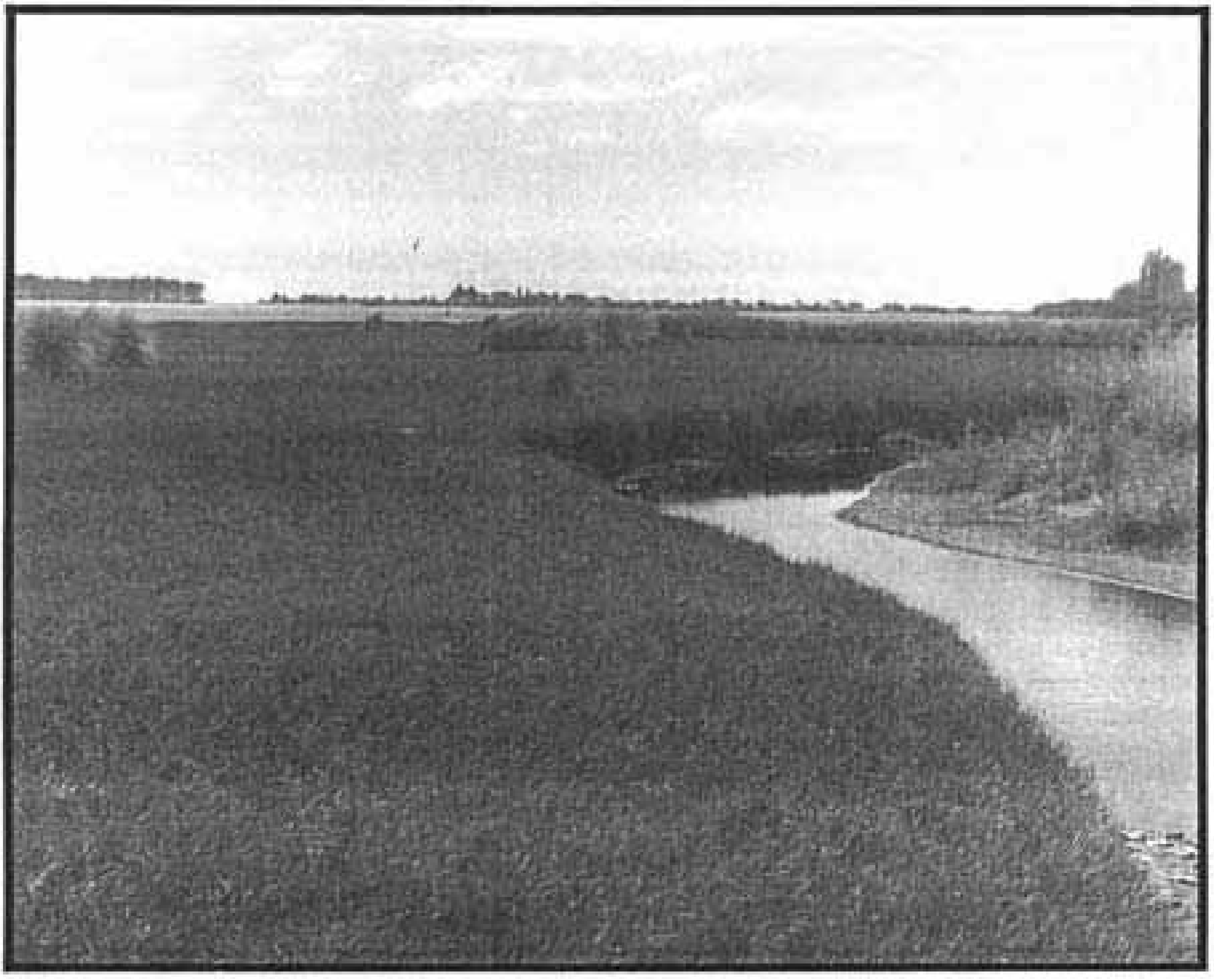

Plate 21 Orphanage Creek Saltmarsh

9.2.6 Tahunanui Embayment (Area H)

This intertidal area is situated next to Tahuna Motor Camp and Fun Park (Fig.6)(plate 20). Flushing by seawater occurs on large tides and only for short periods. The Tahuna Embayment is an important recreational resource for walkers, joggers and dog excercisers.

The area supports a variety of estuarine plants including two areas of the native sedge *Schoenoplectus pungens*, uncommon in the eastern inlet. The area also supports a large area of the creeping *Samolus repens*. A healthy stand of the native rush *Juncus maritimus* is located next to the motor camp. A relatively large stand of the estuarine tussock *Stipa stipoides* grows around the high tide mark near the fun park. The area has the only dune system in the estuary not planted with pine trees. This dune system represents the first line of defence to erosion which threatens the Tahunanui Beach area. Threats to the intertidal and dune system include infilling, rubbish dumping and fires. Significant damage to the area comes from private and organised vehicle operation. Annual motor cycle racing and periodic off-road competitions should be discouraged and adequate fencing of the area installed. The Tahuna area is controlled by the Nelson City Council.

EVALUATION RANKING:			SCORE
(1)	Importance of Flora, Fauna and Habitats		
	(a)	vital dune system which protects estuarine area	60
(2)	Representativeness/uniqueness within Estuary		
	(b)	only area of its kind in estuary	60
(3)	Representativeness/uniqueness in Conservancy		
	(b)	similar areas of its kind in the Conservancy	40
(4)	Biological and Physiological State of Margins		
	(c)	extensive modification	15
(5)	State of Surrounding Terrestrial Vegetation		
	(c)	little buffering vegetation, land developed	20
TOTAL			190
PERCENT			63%

9.2.7 Aerodrome Peninsula Flat (Area J)

Aerodrome Peninsula Flat is a tidal area on the western side of Nelson Airport (Fig.6)(plate 18). Habitat types are dominated by pebble/cobble and *Zostera* (eelgrass) beds. These habitat types support a large number of invertebrate species (approximately 48 from pebble/cobble and 52 from eelgrass beds). The Aerodrome Flat is an important feeding ground for fish and birds visiting and resident in the inlet. This area is important to juvenile flounder which inhabit the intertidal pools. The intertidal flats are regularly used for school educational trips as the area is accessible, has firm footing and large numbers of easily identified invertebrates and birds can be observed. Recreational users include fishermen, joggers, dog exercisers and walkers.

EVALUATION RANKING:		SCORE
(1)	Importance of Flora, Fauna and Habitats	
	(a) vital habitats for invertebrates, fish and birds	60
(2)	Representativeness/uniqueness within Estuary	
	(b) better areas of its kind in estuary	40
(3)	Representativeness/uniqueness in Conservancy	
	(b) better areas of its kind in conservancy	40
(4)	Biological and Physiological State of Margins	
	(d) Margins modified by infilling and concrete rubble	20
(5)	State of Surrounding Terrestrial Vegetation	
	(c) little buffering vegetation, land grassed	20
TOTAL		180
PERCENT		60%

10. MANAGEMENT RECOMMENDATIONS

Human activity around much of Waimea Inlet has resulted in modified estuarine margins, dumped rubbish material and unsightly developments. This activity has effectively reduced flora and fauna values, and created a public eyesore rather than a visual and recreational resource. This chapter outlines management recommendations based on conservation values in Waimea Inlet. These recommendations will ultimately require consideration in a management plan for the inlet.

Reserve Proposals

Waimea inlet is conveniently divided into an eastern and western half by the Waimea River. The western inlet from the Waimea River to Mapua (excluding the area called the Traverse between Rabbit and Rough Islands) is a biologically important area on the following grounds. The area:

(1) represents a large, relatively unmodified estuarine system with all the habitat types recorded from Waimea Inlet;
(2) contains a diverse and abundant invertebrate fauna;
(3) contains small areas of remnant terrestrial forest;
(4) contains the two largest wetlands in the inlet;
(5) contains an endangered species of plant;
(6) contains the second largest bird roost in Waimea Inlet;
(7) contains the largest saltmarsh not infested by *Spartina*;
(8) supports threatened bird species (spoonbills, white heron, little egret, banded rail); and
(9) contains large shellfish beds.

On the grounds that the western inlet from the Waimea River to Mapua is of outstanding biological importance, it is recommended that the area be given protective status (chapter 9).

Management recommendations for the western inlet include:

- prohibit marine farming, commercial fishing, gill and drag netting, infilling, stopbanking, roading, port development and rubbish dumping;
- prohibit powerboating, motorbikes and cars on the estuary and shooting;
- set out in a management plan, areas where passive recreation (eg. sailing and boating, walking, dog excercise, bird watching) can be undertaken without problems of conflicting use;
- construction of adequate fencing around sensitive areas;
- provide protection to land adjacent to biologically important areas listed in chapter 10 through management agreements or land purchase; and
- replant vegetation both intertidally and immediately above the high tide zone, thereby creating a buffer strip around the whole western inlet.

These measures may conflict with the activities of many interested groups and individuals. However, the protection of one of the most important estuarine areas in Tasman and Golden Bays outweighs the loss of this area to activities with known environmental impacts.

Areas of Special Biological Importance

Within the western and eastern inlet 10 intertidal areas of special biological significance are recognised (chapter 9, Fig. 6). These estuarine areas represent the most important habitats, wildlife areas and recreational sites in Waimea Inlet. The areas and suggested protection status are as follows:

- O'Connor Creek: Wildlife refuge
- Pearl Creek: Wildlife refuge
- No-mans Island: Wildlife sanctuary
- Saxton Island Flats: Wildlife reserve
- Chip Mill to Waimea River (includes Neiman Creek): Wildlife reserve
- Higgs Reserve and Stringer Creek Flat: Wildlife reserve
- Bells Island Flats: Wildlife refuge
- Tahunanui Embayment: Wildlife reserve
- Orphanage Creek Salt Marsh: Wildlife reserve
- Aerodrome Peninsula: Wildlife reserve

Fisheries

It is recommended that measures to protect and enhance native freshwater fish in the streams entering Waimea Inlet be established. These measures should include:

- recognition of spawning sites;
- establiment of plants suitable for spawning;
- discourage drainage of wetlands;
- minimizing of stopbanking, especially around the saltwater wedge;
- removal, and discouragement of the use of culverts or other structures which interfere with migration pathways;
- fencing of spawning areas to prevent grazing of habitat; and
- education of local body organisations.

It is recommended that Neiman, Pearl and O'Connor Creeks and the surrounding vegetation be made whitebait refuges* on the grounds that:

- whitebait migrate into these streams to live and eventually spawn;
- adult and post-whitebait juveniles are caught along with the migrating whitebait catch;
- spawning vegetation is damaged by whitebaiters and grazing livestock;
- whitebait are vulnerable to fishing pressure in these areas.

* Area where whitebaiting is prohibited and damage to vegetation, grazing and pollution of water are discouraged.

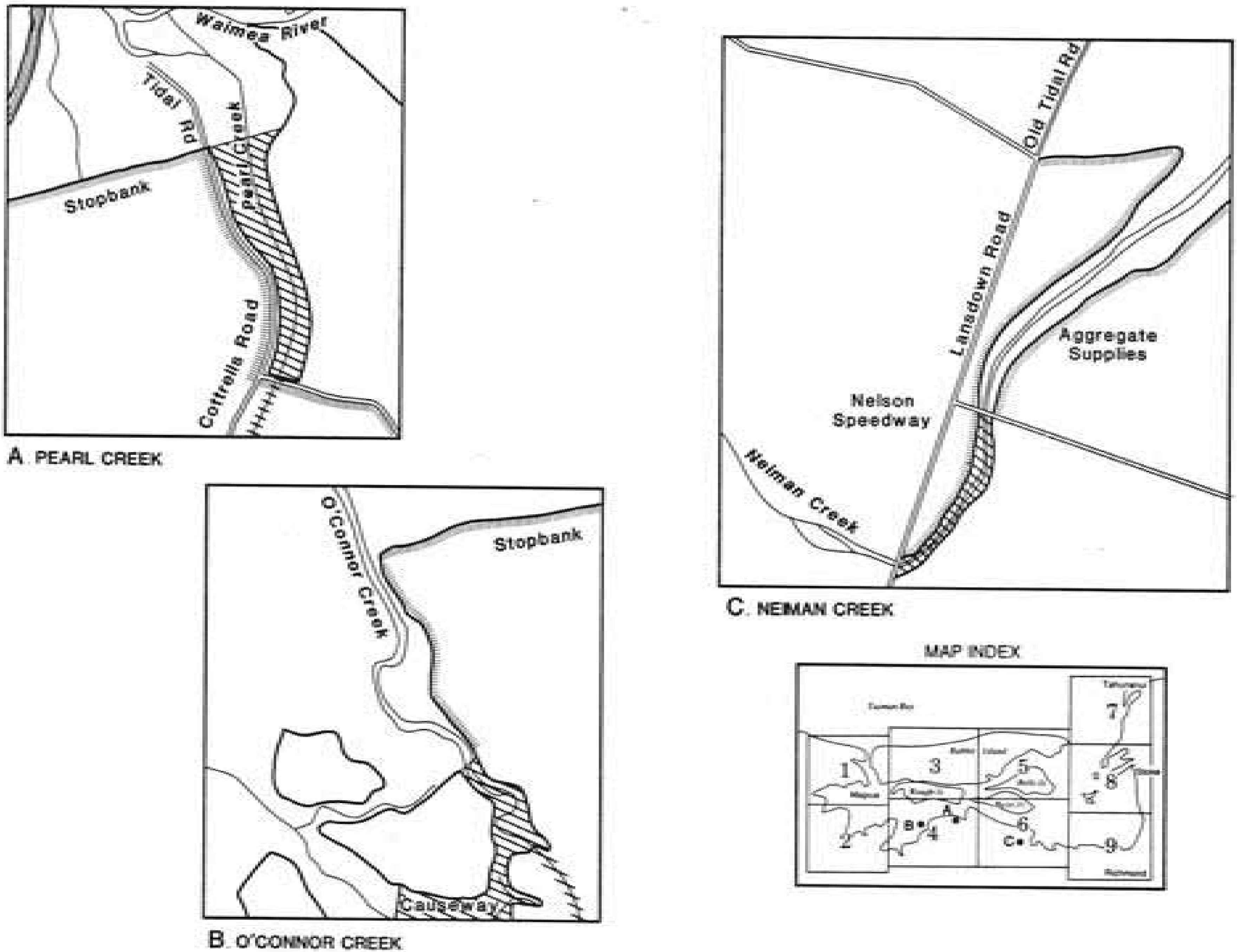

FIG 7. Proposed Whitebait Sanctuaries.

Boundaries of the refuges are suggested as (Fig.7):

(1) Neiman Creek above the Lower Queen Street culvert;

(2) Pearl Creek above the confluence with the estuary proper; and

(3) O'Connor Creek above the estuary proper.

Vegetation

Estuarine plants within Waimea Inlet grow where particular environmental conditions are fulfilled. These conditions are complex associations between freshwater and saltwater, high tide and low tide, between silt, sand, shingle and hard substrates and between calm and scoured channels. The survival of estuarine plants around the inlet will depend on the maintenance of these conditions.

Revegetation of salt marsh communities and the protection of existing plants is recommended because intertidal plants:

- provide the bulk of primary production;
- provide an important habitat for wildlife;
- buffer the coastal zone from erosion and storm events; and
- purify flood waters and buffer against nutrient, heavy metals, organic toxins and waste water inputs.

Planting or encouragement of estuarine plants must take into account the conditions required by each species. School parties, interested environmental groups or government funded schemes could be enlisted to achieve these aims.

Education

It is recommended that educational material and use of the estuary by school groups be encouraged. Waimea Inlet is already used by many schools for educational field trips. The estuary is ideal for the observation of invertebrates and birds in their natural environment (Norriss and Davidson, 1989). Education about estuarine systems is an important part of estuarine management. The realization that estuaries are an important environment is relatively new in the scientific community and is not widely understood by the public. Lack of awareness may be overcome by educational programs.

Estuarine Walkways

Access around much of Waimea Inlet is restricted to walking in the mud at low tide. Most of the adjacent land is privately owned with no provision for walking access. Establishment of a walkway system around the entire margin of Waimea Inlet would have numerous benefits including education, recreation, tourism and increased detection of illegal activities. Where appropriate, industry and land owners should be encouraged to donate land adjacent to the foreshore. Local environmental groups and school parties could be encouraged to assist with walkway construction.

Buffer Strips and Sea Level Rise

Development on the flat land of the Waimea Plains is inevitable. Establishment of a strip around the estuary would buffer the inlet from land based impacts and similarly buffer the land from erosion threats. Aesthetically, a buffer strip would improve the visual aspect of Waimea Inlet, especially if appropriate vegetation was established. With an predicted sea level rise of 0.4 m by 2050, buffer strips become an essential part of planning. The natural consequence of sea level rise is to cause estuaries to move inland. Where the landward margin of an estuary has been stabilized with stopbanks and reclamations this cannot happen. The consequence for the ecology of the estuary will be loss of intertidal habitat. The consequence for developed land on the estuary margin will be increased flooding and increasing expensive drainage and protection schemes. It is essential that an active program of retirement around the estuary margin is instituted immediately. The extent of each buffer strip would depend on location as the extent of sea level rise will be far greater in flat areas (eg. Appleby, Lower Richmond, Mapua).

Developments

Restrictions on the type and form of development around Waimea Inlet should be formulated. The following guidelines are suggested.

- Infilling (reclamation) of intertidal areas, particularly marginal vegetation, should only be approved in exceptional circumstances.
- No refuse tips or rubbish disposal schemes should be established in or adjacent to the estuary.
- Roadways should be discouraged in or adjacent to the inlet.
- Coastal subdivision should be discouraged from areas adjacent to the inlet.
- Housing and industry should be gradually relocated away from the edges of the inlet.
- The 20 m reserve formed if subdivision occurs should be retained as a reserve, not as a road substitute.
- Structures which destroy marginal vegetation or disrupt the natural flow of water or sediments should be discouraged.

Erosion

- Control of erosion using buffer strips and planting of marginal vegetation should be encouraged.
- Wherever possible erosion should be left to take its natural course. This is possible only if development around the estuary edges is kept to a minimum.

Pollution

- Present discharge levels of treated sewage into the inlet should not be significantly increased without an investigation into the probable impacts on the inlet (section 7.1).
- Faecal coliform bacteria, viral levels and nutrients should be monitored.
- Industry, regional government and local farmers and residents should be encouraged to remove rubbish which has been deposited into the inlet. Areas of particular concern are Waitaki Freezing Works, Apple and Pear Board, Nelson Fibre Containers, Richmond Tip and the Tahunanui Motor Camp.

Aquaculture and Shellfish Harvesting

At present there are no marine farms in Waimea Inlet. Aquaculture development has the potential for considerable ecological impact. The environmental implications of aquaculture in Waimea Inlet should be thoroughly assessed being before allowed to proceed.

Commercial cockle harvesting in Waimea Inlet should be discouraged because of:

- disruption of estuarine food chains;
- importance of cockles as food for birds, fishes and invertebrates;
- increased sediment load in estuarine water due to harvesting methods resulting in reduced light penetration, clogging of animal gills and feeding appendages and depressed phytoplankton production;
- disturbance and displacement of intertidal islands and channels; and
- disturbance of bird breeding and feeding sites often adjacent to cockle beds.

It is unlikely, however, that aquaculture or commercial shellfish operations in Waimea Inlet would be approved by the Health Board. Faecal coliform levels in the estuary exceed those stipulated for commercial operations (Nelson Area Health Board).

Recreation

A future increase in recreational pressure in Waimea Inlet may require additional facilities. The construction of such facilities in or adjacent to the estuary requires careful consideration of the following factors:

- the suitability of alternative land;
- the flora and fauna of the area;
- effect on the overall ecology of the estuary;
- impact on the physical processes in the estuary;
- visual impact;
- impact on reserves; and
- effect on public recreation and access.

Other

It is recommended that:

- power boating be restricted to particular areas in the estuary (section 7.7);
- the use of underground transmission lines be encouraged and the gradual replacement of existing aerial lines be encouraged (section 7.6);
- disused lines and poles be removed from the inlet and estuary margins (eg. Higgs and Stringer embayments);
- efforts be made to reduce sediment load from sources including catchment use, gravel extraction and dredging;
- construction of fences to limit livestock grazing be encouraged (chapters 6 & 7);
- the flow of Waimea River, small streams and ground seepage into the estuary not be significantly interrupted or altered;
- *Spartina* spraying in biologically important areas be prioritized; and
- further biological surveys be undertaken at regular intervals. Areas of specific interest include: the distribution and changes in abundance of the Pacific oyster; impact of *Spartina* loss on sediments and habitat classification; spread of vegetation cover over time; and the impact of sea level rises on estuarine boundaries and erosion rates.

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Appendix 1. Historical

Waimea Inlet and the surrounding land has been occupied since the 1500's. Favourable climate, plentiful food, flat arable land and navigable waterways have encouraged Maori and European settlement. Since the first occupation in the area, the estuary and adjacent land has changed. This chapter discusses many of the changes that have occurred over the last several hundred years.

Pre-European

Some of the earliest Maori people to live close to Whakatu (Nelson) were the Ngaitara tribe, close relations of the Ngaitahu. The Ngaitara tribe originated from the southern part of the North Island. They lived at the mouth of the Waimea River, and elsewhere along the Tasman coast. This tribe was annihilated and the following story offers an explanation.

Tumaro, the son of a Ngaitara chief from Hataitai, Wellington, decided to join his relations at the Waimea Pa after he discovered his wife was unfaithful. At his departure for Waimea he left behind an infant son called Tu Ahuriri. When Tu Ahuriri was an adult he decided to visit his father at the Waimea Pa (approximately 1 km south east of the present Appleby School). When Tu Ahuriri and his fellow travellers arrived at Waimea, his fathers people, not knowing who he was, imprisoned them with plans to kill them. On overhearing this, Tu Ahuriri made his connection known and the Ngaitara were very sorry and ashamed. The visitors were then guests of honour for the remainder of their stay. It was calculated that this visit was made in the late 1500's.

Tu Ahuriri returned to Haitaitai and later in that year revisited his father, at a time when he knew that food stores (kumara) would be low. The reason for Tu Ahuriri's untimely visit was to seek vengeance on the Ngaitara's earlier inhospitality. The visitors were customarily treated with the best of the remaining food. Soon the food stores ran low and after Tu Ahuriri's party left all the people of the Waimea Pa died. They died after they violated a Tapu. The Tapu was violated when green vegetables growing in the ashes of the burnt hut that Tu Ahuriri had stayed in were eaten.

When Abel Tasman visited in 1642, the tribes of Golden Bay and Waimea were the Ngati Tu Mata Kokiri but over time they were defeated by Ngaitahu and then Ngati Apa. The Ngati Tu Mata Kokiri retreated into the Paparoa Ranges.

In 1828 Te Rauparaha's warriors led by Te Puoho stormed the Waimea Pa, having previously raided the Croisilles Harbour and Whakapuaka Pa. The warriors entered the Waimea Inlet in canoes via the Blind Channel. The Ngati Apa survivors of the battle fled to the Buller area, pursued by Te Puoho's warriors. When the Ngati Apa reached the head waters of the Maruia River they found themselves cornered and victims of cannibalism (Cannibal Gorge).

The Maori gardens of Waimea were approximately 400 hectares in size. The soil in these gardens had been prepared specially by the Maori cultivators presumably to grow kumara. The top 25-35 cm of soil was treated with fine gravel, silt and coarse and fine sand. Huge borrow pits still present near the gardens indicate the many tonnes of material excavated and added to the gardens. Great quantities of wood ashes were also added to the gardens. These modifications gave the soil long term fertility and an earlier season for growing kumara. Research has shown that the Maori soils heat up 13% faster in the spring than unmodified soils.

Waimea Inlet provided supplies of food and materials for the Waimea Pa residents. Captain Arthur Wakefield of the New Zealand Company noted in 1841 Maori folk at the mouth of the Waimea River dressing flax for manufacture into cloaks and other garments. Nets were made of finely spun flax, weights of rock and floaters of a light wood, usually whau (*Entelea arborescens*). Eel (tuna) were either trampled out of the mud or netted using flax nets. Whitebait were caught using fine stripped flax nets, while flounder were speared with sharpened manuka sticks. Grayling (pokororo), now extinct, and barracuta were netted near the mouth of the Waimea River. Duck, pukeko, bittern, weka, native quail (koreke) and pigeon (kereru) were captured around the edges of the estuary. The importance of Waimea Inlet to the Maori is indicated by the 35 archaeological site records, 27 of which are midden or oven sites (Table 26, Fig. 8).

European

Tasman Bay has been known on European sailing charts since the exploration voyages of Abel Tasman in 1642, Captain Cook in the 1770's and Dumont D'Urville in the 1820's. Colonisation of the Waimea area was encouraged by members of the New Zealand Company. Colonel William Wakefield and his younger brother Edward Gibbon Wakefield sailed for NZ from England in search of land for the new colonies. On August 16, 1839 the Wakefields' ship "Tory" arrived at the Nelson Coast, just south of Cape Farewell. The Wakefields purchased land in the Nelson region from the local Maori.

On October 9, 1841 the preliminary expedition led by Captain Arthur Wakefield, agent for the NZ Company, arrived at Astrolabe Island (Abel Tasman National Park) with the fleet Whitby, Willwatch, and the supply ship Arrow. Originally, Kaiteriteri was planned for the NZ Company Settlement, however, Captain Wakefield was not satisfied with the amount of pastoral land in the vicinity. Frederick Tuckett, Charles Heaphy and three Maori guides canoed up the Waimea River in search of a more suitable area on 18 October and returned with good reports of land. At this point in history, Waimea Inlet was bordered by vast flax swamps and manuka stands containing rich bird and fish life.

On 21 October, 1841 Nelson Haven was discovered and on 4 November 1841 the Whitby, Willwatch and Arrow sailed into the Haven and established Nelson as the New Zealand Company Settlement. The first batch of immigrant ships arrived in 1842 (Fifeshire, Maryanne, Lloyds, Lord Auckland). By September 1842 the majority of Nelson, Waimea and Motueka was purchased from the Maori by the NZ Company.

Access to the Waimea Plains was hindered by the limits of estuarine channels and vast swamps. The extent of the swamps was never mapped, but it can be concluded that the lowlands at Mapua, Appleby, Richmond and Stoke were largely covered with tall flax swamp. Two large flax mills, one in Appleby in the 1850's and the other at Mapua between 1906-1908 produced excellent quality flax fibre which was exported to England.

Shipping access within the Inlet was limited to small vessels, with the main landing places being:

(1) the Richmond Landing where the present Richmond Refuse Tip is sited; and
(2) Cotterells Landing at Pearl Creek on Cotterells Road (Fig. 8).

Pearl Creek, formally bisected by the Waimea River, became an important access point in the 1840's. John Cotterell and H W Burt ran a ferry service from Nelson to Cotterells Landing mondays and saturdays. "This was a boon for Waimea settlers as it saved many hours of walking through swampy land to Nelson, ensured a two way transportation of supplies and meant that goods could be collected by bullock cart and taken to their destination. The adult fare each way was three shillings".

The first European resident of Mapua was a Mr J H Thomas. Thomas bought land around Grossi Point from Captain James Cross, Nelson's Harbour-Master and built the first house, a cob cottage in Mapua. This has long since disappeared.

The horticultural industry in the district has utilised the inlet over the years. Tasman's first orchard was established in 1910, however, Arthur McKee planted the first major orchards in 1912. The Moutere Hills were recognised as potential horticultural land. Arthur McKee wisely purchased a large portion of land in the District for 10 shillings per acre and sold it later for £10 per acre. In the Journal of Agriculture

15 July 1910 McKee advertised his land for sale saying: "The nature of the soil and subsoil, the perfect climate, the natural shelter, the average rainfall, the wealth of sunshine, the winter frosts (the district is immune from spring frosts), the lie of the land, the contour of the country and last, but not least, the excellent shipping facilities, combine to make Tasman the Fruitgrowers paradise."

Larger ships could only venture as far as the Mapua wharf, built 1912. (The previous wharf serviced Chaytor's Flax Mill and timber shipments.) Smaller vessels were used for transporting apples from the Moutere Hill orchards to Mapua prior to the formation of the coastal road. By 1965 the Fruit Industry had grown to a size where larger ships were required for the larger quantities of fruit so all produce was taken to Port Nelson. Waimea Inlet also provided dredge oysters for the Nelson settlement. Closed seasons for the Waimea oysters were invoked in 1886 for two years and 1911 for four years.

The inlet has always been looked at in terms of utilisation for either access or infilling. In 1887 Surveyor John Barnicoat drew up a plan for the infilling of 3649 acres or most of the western inlet. This proposal was never adopted. A similar plan for the eastern inlet was proposed by the Nelson City Council on the advice of a Dutch engineering firm. This also was never adopted. Nevertheless large areas of land were gained by many local farmers from the estuary and wetlands around the margins of Waimea Inlet. The largest land gains were established in the O'Connor Creek - Pearl Creek - Lower Queen Street sections of the inlet. These land gains were principally achieved by stopbanking followed by infilling behind the wall.

Roading may have had a greater impact in Waimea Inlet if plans to build a road from Mapua to Tahunanui via Rabbit Island had eventuated. In the past a number of routes across the inlet were used by horse and carts. The gravel ridge which ran from Grossi Point to Rough Island provided a natural track. The section from Grossi Point to No-mans Island is known as Thomas' Crossing, and from No-mans Island to Rough Island, Tony's Crossing. Tony was Tony Weller a Portugese fisherman who lived on Rough Island in the 1890's. The gravel ridge continued past Rough Island for a short distance and eventually connected with lower Queen Street.

Since the 1840's European settlers have cleared and drained land and built roads and homes. The large flax beds and swamps surrounding much of the eastern inlet have disappeared. Large areas of estuary vegetation and mudflat have also been infilled, especially in the Waimea River and Lower Queen Street area. Gone are the days of getting lost in the Richmond Flax swamps or waiting for tides for access.

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Archaeological Site: Management Considerations

All archaeological sites registered or unregistered, are protected by the Historic Places Trust Act, 1980. Under this act, damage or destruction of any archaeological site is an offence.

Archaeological sites are historically important. Many sites have layers of cultural and ecological material which span up to 600 years of Maori occupation. If these layers are destroyed, the information is permanently lost.

Archaeological sites around Waimea Inlet are typically midden (Table 26, Fig. 8). Most sites occur on the interface between land and the high water mark. These sites often present management problems, especially when sites are threatened by coastal erosion.

Proposals for coastal development which threaten archaeological sites must have the prior expressed permission of the Historic Places Trust before they proceed. The Historic Places Trust has the right to either grant an authority (with any conditions it sees fit) or decline to grant an authority to modify a site.

For further advice, please contact:
Megan Huffadine (File Keeper)
26 Athol Street
NZ Archaeological Association
The Glen RD1,
NELSON.
PH. 520 252

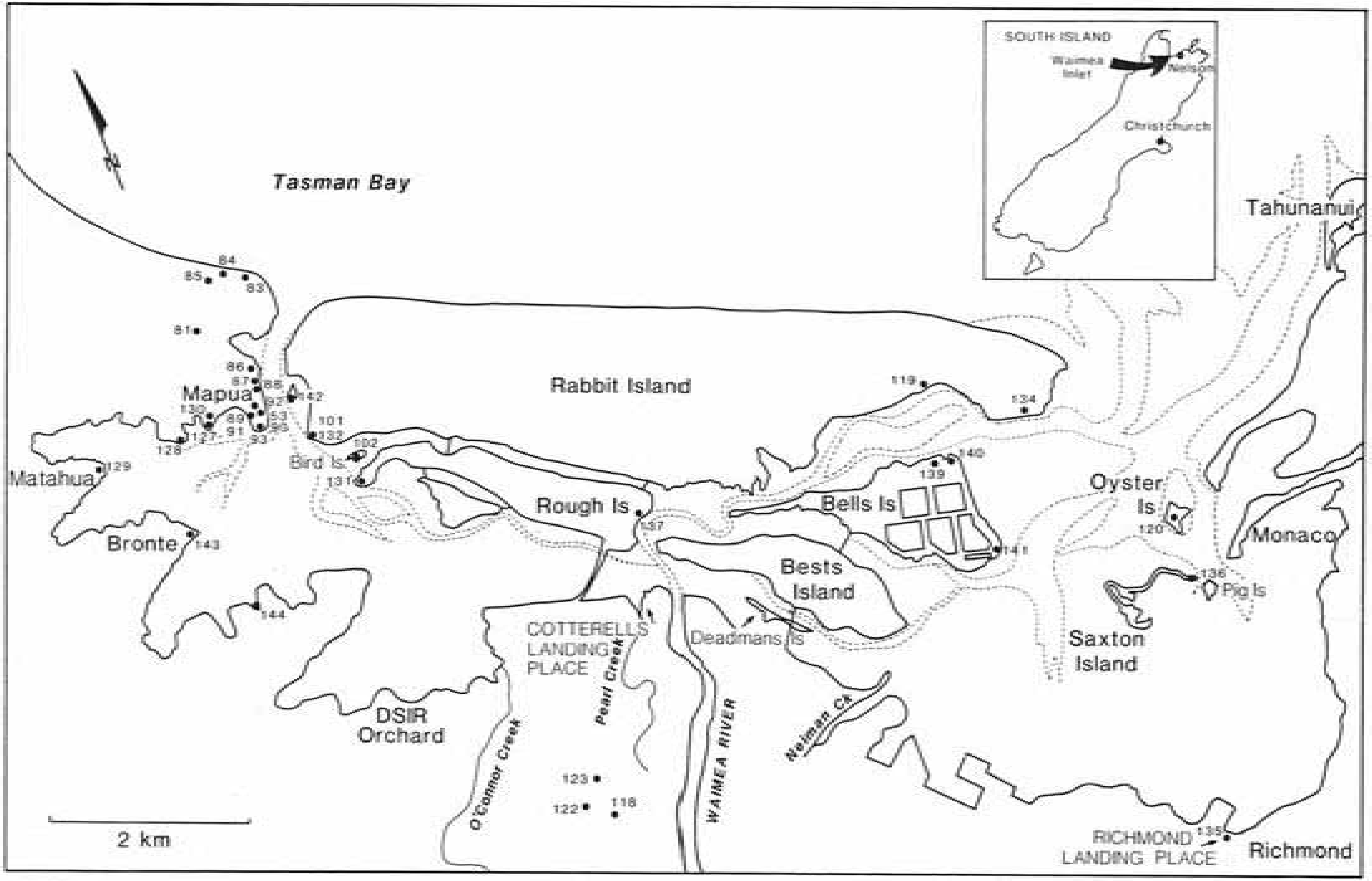
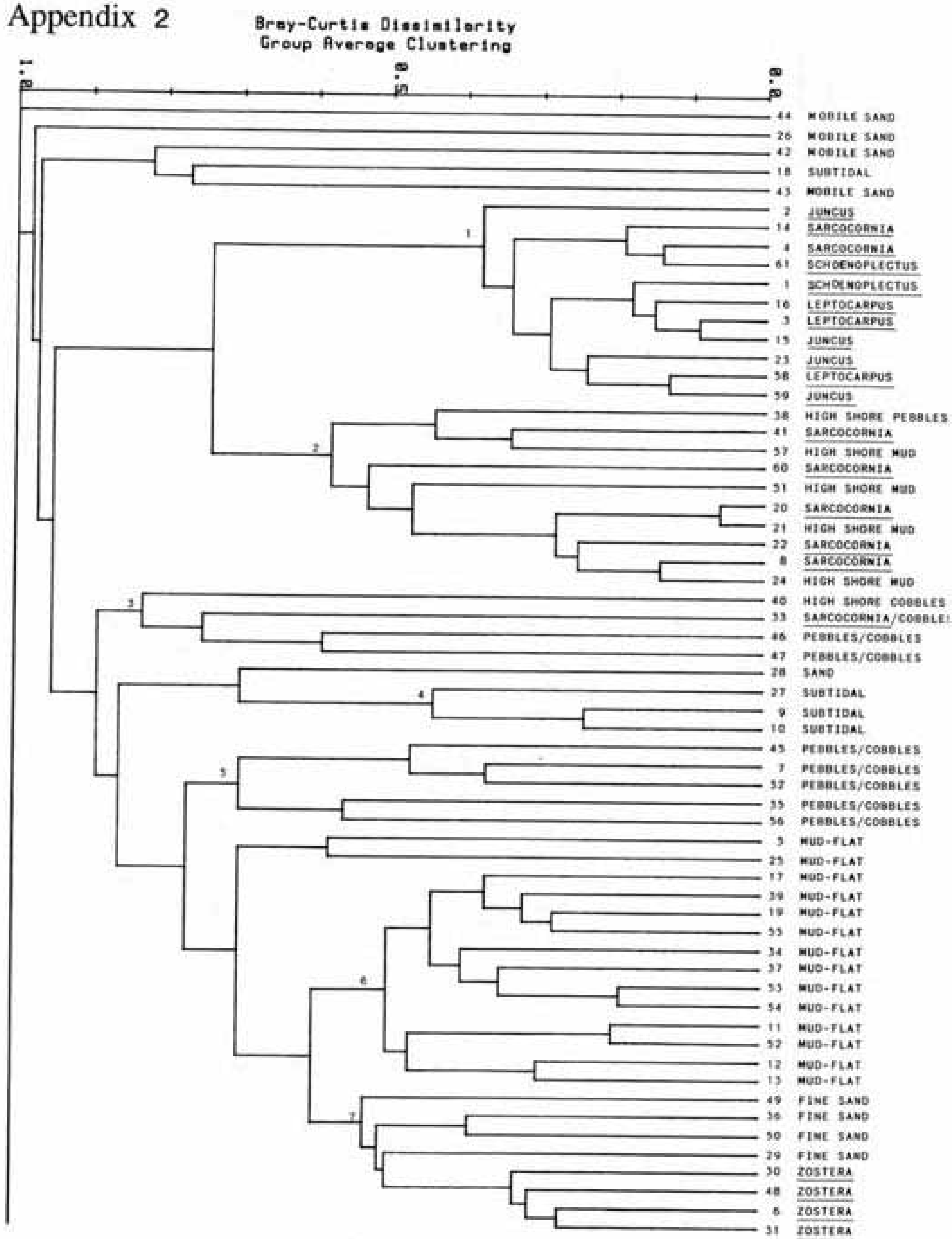


FIGURE 8 . Archeological sites in Waimea Inlet

Table 26. Waimea County Historic Sites Inventory - N27.

SITE	LOCATION	FEATURE
53	Grossi Point	Find Spot & Cultivation
81	Mapua	Midden
82	Mapua	Ovens
83	Mapua	Find Spot
84	Mapua	Find Spot
86	Mapua	Midden & Ovens
87	Mapua Wharf	Midden & Ovens
88	Mapua Wharf	Midden, Ovens & Artefacts
89	Tahi Street	Made Soil & Midden
90	Tahi Street	Midden, Ovens & Working Area
91	Tahi Street	Find Spot & Ovens
93	Grossi Point	Middens, Ovens & Working Area
101	Rabbit Island (west)	Middens, Ovens & Working Area
102	Bird Island	Midden
118	Appleby	Pa
119	Rabbit Island	Midden & Ovens
120	Oyster Island	Midden & Working Area
122	Appleby	Gravel Soils
123	Appleby	Occupation
127	West of Grossi Point	Find Spot
128	West of Grossi Point	Midden
129	Matahua Point	Middens & Ovens
130	West of Grossi Point	Middens & Ovens
131	Rough Island	Middens & Ovens
132	Rabbit Island (west)	Midden & Ovens
134	Rabbit Island (east)	Midden & Ovens
135	Richmond Tip	Find Spot
136	Saxton Island	Midden & Ovens
137	Rough Island	Midden & Ovens
139	Bells Island	Middens
140	Bells Island	Midden
141	Bells Island	Midden & Ovens
142	Bullivants Island	Middens & Ovens
143	Bronte Peninsula	Middens & Ovens
144	Hoddys Peninsula	Middens & Ovens

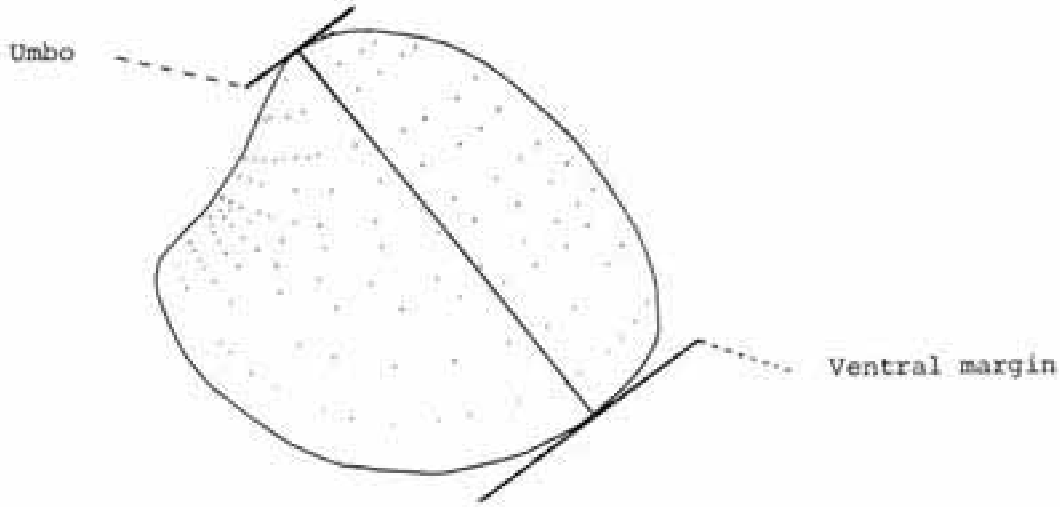
Appendix 2



Dendrogram of benthic invertebrate sample sites based on five replicate core samples or transects. The seven groupings reflect differences in invertebrate communities between:

(1) rushes and sedge; (2) highshore and *Sarcocornia*;
(3) highshore pebbles and cobbles; (4) subtidal;
(5) pebbles and cobbles; (6) mudflat; and (7) fine sand and eelgrass

Appendix 3



Measurement of cockles Chione stutchburyi from the umbo to the furtherest point on the ventral margin.

Appendix 4. Invertebrate fauna (per m^2) averaged from 5 samples from the mobile sand habitat.

	26	42	43	44
Bivalves				
Soletellina siliqua	11	-	-	-
Tellina liliana	11	-	-	-
Worms				
Glyceridae	-	11	11	-
Lepidasthenia accolus	11	-	-	-
Orbina papillosa	23	-	-	-
Unident. Polychaeta	-	45	-	-
Crustacea				
Amphipod sp.#3	147	-	-	-
Isopod sp.#3	23	-	-	-
Insects				
Chaerodes trachyconcolor	-	-	-	11
Echinoderms				
Erachnoides zelandiae	-	68	-	-
Number of Species	6	3	1	1
Number of Individuals (per m^2)	226	124	11	11

Appendix 5.

Invertebrate fauna (per m^2) averaged from 5 core samples from fine sand and *Zostera* habitats (*Zostera* = sites 6, 30, 31, 48)
* = Invertebrate recorded from quadrats or from observations.

SITES	6	28	29	30	31	36	48	49	50
Anthozoa	57	-	68	1007	57	622	*	*	113
Notoplana australis	-	-	-	-	-	*	-	-	-
Nemertina	-	-	-	11	-	-	-	-	-
Amaurochiton glaucus	*	-	-	*	11	-	-	34	-
Gastropods									
Amphibola crenata	-	-	-	-	-	-	-	-	11
Cominella adspersa	*	-	*	34	*	23	*	-	-
Cominella glandiformis	23	-	-	-	34	-	*	23	-
Diloma subrostrata	23	11	23	57	*	*	*	23	*
Haminoea zelandiae	-	-	-	-	-	-	11	-	-
Lepsiella scobina	-	-	-	*	-	-	-	-	-
Micrelenchus tenebrosus	396	-	34	272	351	*	249	23	*
Muricidae sp	-	-	-	23	11	-	23	-	-
Notoacmea helmsi	-	-	*	-	23	11	-	-	79
Chiton pelliserpentis	-	-	-	-	-	-	*	-	-
Taron dubius	34	-	-	23	23	*	11	-	-
Turbo smaragdus	*	-	-	*	*	-	-	-	-
Zeacumantus lutulentus	-	-	-	-	-	*	*	-	-
Bivalves									
Chione stutchburyi	68	34	34	113	57	215	170	*	192
Crassostrea gigas	-	-	-	-	-	-	*	-	-
Nucula hartvigiana	204	11	23	238	238	645	192	204	306
Paphies australis	11	226	-	45	-	23	34	11	-
Perna canaliculus	-	-	-	*	*	-	-	-	-
Tellina liliana	364	34	407	373	136	815	238	204	272
Xenostrobus pulex	*	*	-	-	-	-	*	-	-

Contd/...

Appendix 5. (Contd/) Invertebrate fauna (per m^2) averaged from 5 core samples from fine sand and *Zostera* habitats (*Zostera* = sites 6, 30, 31, 48)
* = Invertebrate recorded from quadrats or from observations.

SITES	6	28	29	30	31	36	48	49	50
Worms									
Aglaophamus macoura	-	-	-	11	-	11	-	11	-
Glyceridae	-	11	45	-	79	-	-	-	-
Lepidasthenia accolus	-	-	-	-	-	23	-	-	-
Lumbrinereinae sp	-	-	-	124	23	-	-	-	-
Nereidae	-	11	34	11	11	45	45	91	-
Axiothella quadrimaculata	-	11	-	-	-	136	-	-	-
Capitellidae	-	-	-	-	-	679	-	-	-
Haploscololos cylindrifer	-	-	-	-	23	-	23	-	-
Magelona papillicornis	-	-	-	-	-	11	-	-	-
Owenia fusiformis	-	-	11	34	-	-	-	11	-
Orbina papillosa	-	11	-	-	-	-	-	-	-
Pectinaria australis	-	-	-	-	-	-	-	11	-
Pomatoceros caeruleus	-	-	-	11	-	-	-	249	-
Scalibregma sp	34	-	-	215	91	-	23	-	-
Unident Polychaetes	-	57	34	-	11	-	45	102	124
Crustacea									
Elminius modestus	*	11	-	-	-	-	*	90	*
Cumacea	-	-	-	-	-	*	-	-	-
Amphipod No. 3	-	136	11	-	-	-	-	-	-
Isocladus sp	-	90	-	-	*	-	-	11	-
Cyclograpsus lavauxi	*	-	-	-	-	-	*	-	-
Halicarcinus varius	45	-	-	45	23	11	-	-	-
Halicarcinus whitei	91	-	11	11	-	45	147	-	45
Helice crassa	-	-	-	-	-	-	-	-	*
Hemigrapsus crenulatus	*	-	*	*	-	-	-	-	-
Macropthalmes hirtipes	23	-	-	-	*	-	23	-	-

Contd/...

Appendix 5. (Contd/)

Invertebrate fauna (per m^2) averaged from 5 core samples from fine sand and *Zostera* habitats (*Zostera* = sites 6, 30, 31, 48)
* = Invertebrate recorded from quadrats or from observations.

SITES	6	28	29	30	31	36	48	49	50
Pagurus novizealandiae	-	-	-	*	*	-	-	-	-
Petrolisthes elongatus	-	-	-	-	-	-	11	-	-
Insects									
Dipteran larvae	-	-	-	11	-	-	-	-	-
Echinoderms									
Erachnoides zelandiae	-	-	34	-	-	-	11	-	-
Number of species	20	14	16	26	23	23	25	17	13
Number of individuals (per m^2)	1371	654	769	2669	1179	3349	1222	1008	1165

Appendix 6.

Invertebrate fauna (per m^2) averaged from 5 core samples from the mud-flat habitat (Group H & G)
* = Records from quadrat and visual investigation

SITES	5	11	12	13	17	19	25	34	37	39	52	53	54	55
Anthozoa	-	68	396	79	45	45	*	158	57	45	124	226	849	23
Sipuncula	-	-	11	-	34	11	-	-	-	-	-	-	-	11
Nemertina	-	-	-	-	-	-	-	11	45	-	-	-	-	-
Amaurochiton glaucus	-	-	-	-	-	-	-	-	-	23	-	-	-	-
Gastropods														
Anphibola crenata	124	57	23	*	-	68	532	-	11	91	91	113	11	45
Cominella glandiformis	-	-	*	34	-	-	-	*	*	-	11	11	11	-
Cominella virigata	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Diloma subrostrata	-	23	170	45	-	-	-	*	*	-	23	11	11	*
Micrelenchus tenebrosus	-	-	34	124	*	-	-	45	-	-	-	-	-	-
Notoacmea helmsi	-	11	11	23	-	-	-	11	*	*	11	11	23	34
Potamopyrgus estuarinus	323	-	-	-	-	-	-	-	45	-	-	-	-	-
Taron dubius	-	-	-	-	-	*	-	11	*	-	-	-	11	*
Turbo smaragdus	-	-	11	-	-	-	-	-	-	-	-	-	-	-
Zeacumantus lutulentus	*	*	-	-	*	*	11	*	*	*	-	-	-	*
Bivalves														
Chione stutchburyi	68	577	385	226	249	147	79	1846	237	181	758	317	351	351
Crassostrea gigas	-	-	-	23	-	*	-	-	-	-	-	-	-	-
Nucula hartvigiana	-	-	34	-	-	124	1268	-	124	11	-	328	419	-
Paphies australis	-	-	-	11	-	-	-	23	23	-	11	-	-	-
Tellina liliana	11	91	124	102	453	215	34	91	23	11	34	45	23	124
Xenostrobus pulex	-	-	-	-	*	-	-	-	-	-	-	-	-	-

Contd/...

Appendix 6. (Contd/)

Invertebrate fauna (per m^2) averaged from 5 core samples from the mud-flat habitat (Group H & G)
* = Records from quadrat and visual investigation

SITES	5	11	12	13	17	19	25	34	37	39	52	53	54	55
Worms														
Eulalia microphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	11
Glyceridae	-	-	57	68	-	-	-	11	-	-	-	-	11	-
Nereidae	-	23	23	91	170	407	136	-	-	-	-	373	430	238
Axiothella quadrimaculata	-	11	-	-	79	-	-	509	498	158	-	-	-	-
Capitellidae	124	-	113	34	23	23	792	45	34	-	-	11	-	-
Haploscoloplos cylindrifer	-	-	-	-	-	-	-	-	-	-	-	-	11	-
Pectinaria australis	-	-	-	-	-	-	-	-	-	11	-	23	-	-
Unident. Polychaetes	23	34	11	45	79	11	11	45	-	-	11	11	-	-
Crustacea														
Elminius modestus	-	34	-	-	11	*	11	-	57	-	57	-	-	*
Talitridae sp.	-	-	-	-	*	-	11	-	-	-	-	-	-	-
Amphipod sp.# 2	-	-	-	-	-	-	-	-	-	-	-	11	-	-
Amphipod sp.# 3	-	-	-	-	-	11	-	-	-	-	-	-	-	-
Phoxocephalid sp	-	-	-	-	-	-	147	-	-	-	-	23	11	-
Halicarcinus varius	-	-	45	45	-	-	-	11	-	-	-	-	-	-
Halicarcinus whitei	-	-	11	-	23	11	-	-	-	-	-	-	-	11
Helice crassa	23	-	-	-	*	*	*	-	-	-	23	23	-	113
Hemigrapsus crenulatus	-	-	-	*	-	-	-	*	-	-	-	-	-	11
Hemigrapsus edwardsi	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Macropthalmus hirtipes	45	-	102	79	-	11	-	-	*	*	34	11	23	23
Number of species	9	11	18	17	15	17	13	17	17	9	14	15	14	19
Number of individuals (per m^2)	746	929	1561	1029	1166	1084	3032	2817	1154	497	1210	1525	2207	1006

Appendix 7. Invertebrate fauna (per m^2) recorded from core samples from pebble and cobble habitats

* Records from quadrat and visual investigations

SITES	7	32	35	40	45	46	47	56
Anthozoa	68	34	204	-	11	-	-	11
Sipuncula	-	-	-	-	-	1211	-	238
Chitons								
Acanthochiton zelandica	-	11	-	-	-	-	-	-
Amaurochiton glaucus	23	*	-	-	23	11	-	-
Chiton pelliserpentis	-	-	11	-	-	11	-	-
Gastropods								
Amphibola crenata	-	-	-	*	-	-	-	68
Cellana radiata	-	-	-	-	-	*	-	-
Cominella adspersa	-	-	-	-	23	-	-	-
Cominella glandiformis	11	23	-	-	34	11	-	11
Cominella virigata	-	-	-	-	79	-	-	-
Diloma subrostrata	102	147	11	-	-	-	-	*
Lepsiella scobina	-	*	-	-	11	-	-	-
Littorina unifasciata	-	-	-	-	-	860	373	11
Melagraphia aethiops	-	-	-	-	-	91	-	-
Micrelenchus tenebrosus	396	306	-	-	-	-	-	-
Neoguraleus sinclairi	-	-	11	-	-	-	-	-
Notoacmea helmsi	1460	260	272	-	45	57	-	23
Onchidella nigricans	-	-	-	-	-	23	-	-
Taron dubius	68	170	11	-	23	-	-	-
Turbo smaragdus	*	23	-	-	23	-	-	-
Zeacumantus lutulentus	-	-	147	-	-	-	-	23

Contd/...

Appendix 7. (Contd/) Invertebrate fauna (per m^2) recorded from core samples from pebble and cobble habitats
* Records from quadrat and visual investigations

SITES	7	32	35	40	45	46	47	56
Bivalves								
Chione stutchburyi	3124	1596	68	11	11	34	238	181
Crassostrea gigas	204	11	-	11	-	*	-	*
Nucula hartvigiana	498	306	-	-	-	-	-	-
Paphies australis	-	-	-	23	-	11	860	-
Perna canaliculus	-	-	23	-	-	-	-	-
Tellina liliana	-	11	11	-	-	-	-	-
Xenostrobus pulex	2411	9541	*	-	13173	10876	464	*
Worms								
Axiothella quadrimaculata	-	-	11	-	-	-	-	-
Eulalia microphylla	-	124	-	-	-	57	-	-
Glyceridae	-	57	-	-	11	-	-	-
Nereidae	306	91	23	68	498	57	-	-
Capitellidae	407	4674	136	-	917	11	-	-
Haploscoloplos cylindrifer	11	113	-	-	11	-	-	34
Magelona papillicornis	11	-	-	-	-	-	-	-
Pomatoceros caeruleus	11	-	-	-	-	-	-	-

Cont/d...

Appendix 7.

(Contd/)

Invertebrate fauna (per m^2) recorded from core samples from pebble and cobble habitats

* Records from quadrat and visual investigations

SITES	7	32	35	40	45	46	47	56
Crustacea								
Elminius modestus	69774	57	5614	11	24412	11	11	1030
Amphipod sp.# 1	-	-	-	113	-	79	-	*
Isopod sp.# 2	-	-	-	-	-	57	34	-
Isocladus sp.	-	-	-	-	23	34	-	-
Cyclograpsus lavauxi	-	-	-	11	-	-	11	-
Halicarcinus varius	23	-	-	-	-	-	-	-
Helice crassa	-	57	113	-	-	-	-	-
Hemigrapsus crenulatus	566	272	-	147	11	79	11	-
Hemigrapsus edwardsi	-	-	-	-	*	11	-	-
Macropthalmus hirtipes	-	11	-	-	-	-	-	-
Pagurus novizealandiae	-	-	-	-	11	-	-	-
Petrolisthes elongatus	*	102	-	-	11	124	23	-
Dipteran larvae	-	-	-	-	-	-	-	-
Patiriella regularis	-	-	-	-	-	*	-	-
Number of species	21	25	16	9	23	22	9	14
Number of individuals (per m^2)	76350	17997	6666	395	39261	13716	2035	1630

Appendix 8.

Invertebrate fauna (per m^2) recorded from highshore flats and *Sarcocornia* beds (*Sarcocornia* = 8, 20, 22, 41, 60)
* = Records from quadrat and visual investigations

SITES	8	20	21	22	24	33	38	41	51	57	60
Nemertinea								34			
Gastropods											
Amphibola crenata	34		*		11		34	68	*	204	11
Cominella glandiformis									*	*	
Diloma subrostrata								*			
Littorina unifasciata						2252	*				
Ophicardellus costellaris						419		11			
Potamopyrgus estuarinus							57	113		*	
Notoacmea helmsi									*		
Zeacumantus lutulentus							*			*	
Bivalves											
Chione stutchburyi							11		45	34	
Paphies australis										11	
Worms											
Nereidae							57	23		11	
Crustaceans											
Elminius modestus							*		*	*	
Amphipod No. 1				11		90				136	
Helice crassa	102	68	57	124	91	170	102	328	45	283	204
Insects											
Dipteran larvae						23	23				
No. of species	2	1	2	2	2	6	9	6	7	9	3
No. of individuals (per m^2)	136	68	57	135	2965	102	284	577	90	543	351

Appendix 9.

Invertebrate fauna from *Juncus* (2, 15, 23, 59), *Leptocarpus* (3, 16, 58), *Schoenoplectus* (1, 61) and two *Sarcocornia* beds (4, 14).

	1	2	3	4	14	15	16	23	58	59	61
Gastropods											
Amphibola crenata		11	23	*	23	*		23			11
Cominella glandiformis						*					
Ophicardellus costellaris		91						91	238	385	
Potamopyrgus estuarinus	23450	12653	17746	770	2252	14294	4289	1992	2331	7832	781
Worms											
Nereidae	136	102	11								
Capitellidae					11						11
Scolecolepides sp				57							
Unid. Polychaeta			11	45							
Crustacea											
Calliopiidae sp.	11		45			57	34	34	113	124	
Amphipod sp.# 2		543									
Helice crassa	68	238	158	226	147	68	68	23	158	68	57
Dipteran larvae						11					
Number of species	4	6	6	5	4	6	3	5	5	4	5
Number of individuals (per m^2)	23665	13638	17994	1098	2433	14430	4391	2163	2851	8409	871

Appendix 10. Invertebrate fauna from the subtidal habitat. Number per m^2 averaged from 5 core samples

	9	10	18	27
Nemertina	11	-	-	-
Gastropods				
Cominella glandiformis	11			
Notoacmea helmsi	11	11	-	-
Taron dubius	11			
Bivalves				
Chione stutchburyi	11	23	23	
Nucula hartvigiana				11
Paphies australis	3350	1449		192
Worms				
Eulalia microphylla				11
Glyceridae	124	11	23	158
Nereidae	11	23		
Capitellidae	4165	4018	57	713
Lepidonotus polychroma				45
Haploscoloplos cylindrifer				11
Unident. Polychaetes	23			11
Crustacea				
Elminius modestus		611		
Mysidacea sp.		11		
Amphipod # 1	11	11		23
Phoxocephalid sp.				11
Isocladus sp.	34			
Halicarcinus varius	34			91
Hemigrapsus crenulatus	45	34		
Macropthalmus hirtipes		23		
Pagurus novizealandiae				11
Palaemon affinis				23
Patiriella regularis				11
Number of species	14	11	3	14
Number of individuals (per m^2)	7852	6225	103	1322

Appendix 11. Estuarine Evaluation by R.J. Davidson

Schemes for ranking terrestrial habitats (Spect et. al., 1974; Ratcliffe, 1977; Wright, 1977; Imboden, 1978; Park and Walls, 1978; Ogle, 1982; Myers et. al., 1987), wetlands (Morgan, 1982; Angel and Hayes, 1983; Pressey, 1985; Davis, 1987) and lagoons (Barnes, 1989) have been developed in response to a growing need for conservation input into environmental management. These evaluation methods are not directly applicable to estuarine systems, and a system for the evaluation of whole estuaries and parts of estuaries has not been previously developed for use in New Zealand. Two methods for the assessment of estuarine environments are therefore proposed in this section.

The first method evaluates the total estuary, while the second method deals with specific areas within the estuary. The criteria are based on either modified terrestrial criteria or directly on estuarine values. Information of this type, as well as being descriptive, allows estuarine systems to be assessed on conservation grounds. Evaluation is therefore an important tool for developing estuarine management guidelines.

Evaluation of an Estuary

The criteria proposed here for estuary evaluation incorporate assessments of habitats, species diversity, productivity and degree of human modification (Table 22). Criteria used are:

(1) representativeness/uniqueness of the estuary, compared with other estuaries in the Conservancy. Representativeness/uniqueness may be classified using flora, fauna, vegetation and/or geological and physical data. In the Nelson Marlborough Conservancy, Waimea Inlet was classified as unique principally because of the diversity and rarity of the flora and fauna and on the physical structure of the estuary;

(2) the state of the estuary. This is an assessment of the degree to which the estuary has been physically modified from its pristine condition. It ranges from pristine through minor or localised modification to major modification and habitat loss;

(3) pollution status of an estuary. This may range from no pollution through minor effluent discharge in localised areas to nutrient enrichment influencing large areas of estuary;

(4) degree of modification of the terrestrial vegetation surrounding the estuary. Intact terrestrial vegetation scores highly, while farmed, industrial or stopbanked estuarine margins rank lowly;

(5) state and intactness of salt marsh vegetation;

(6) size of the estuary. Large estuaries are rare in New Zealand: only ten are larger than 2000 ha (McLay, 1976). Approximately 68% of estuaries in this country are less than 500 ha in size;

(7) total number of invertebrate species in the estuary;

(8) number of water bird species present in the estuary for all or part of the year;

(9) number of fish species living, visiting or migrating through the estuary at some stage of their life history;

(10) maximum density of cockles recorded from the estuary; and

(11) number of intertidal vascular plant species present. Values above 20 species is considered high, while less than 10 species is regarded as low.

This evaluation therefore incorporates scientific and subjective assessments and requires that a full biological study be undertaken before all criteria can be accurately answered. Small or limited biological surveys would give lower scores than could be achieved with a large survey and can not therefore be used with any confidence.

Evaluation of Part of an Estuary

The assessment of a part of a single estuary is based on an objective assessment using five criteria (Table 23):

(1) flora, fauna and habitat importance of that part of the estuary. Areas with endangered or breeding species are rated highly;areas with a relatively poor or sparse fauna are rated lowly. Estuarine habitats vital for the survival of estuarine organisms or the estuary itself are also ranked highly;

(2) representativeness/uniqueness of the area within the estuary compared with other areas within the same estuary. The area may be unique, similar to a few areas or similar to numerous areas in the estuary;

(3) representativeness/uniqueness of that part of the estuary compared with other estuaries in the conservancy;

(4) the biological and physiological state of the estuary. This is ranked from a pristine condition through isolated development to extensive modification and/or industrial development; and

(5) state of surrounding terrestrial vegetation, which is ranked from intact original vegetation, to greater than 50% of the land farmed (Table 23).

Assessment of an estuarine area requires a good knowledge of the estuaries in the region and the part of the estuary in question. A full biological survey is not required.

An important part of the evaluation process is a description of the estuarine area involved. Topics for discussion and description may include:

Habitats:	Description of the habitat types present in the area.
Fauna:	Comment on notable invertebrate, fish or bird communities and note important feeding, breeding, roosting, migrating, juvenile or living sites.
Vegetation:	Comment on any notable species or communities in the area. State quality of vegetation with notes on cultural and historic use.
Human Use:	Note works or structures with notes on location, status (legal) and description of structure. Comment on types and intensity of recreational use, commercial use and adjoining land use. Note any conflicts in use patterns.
Administration:	Record zoning and land tenure of adjacent land.
Cultural/Historic:	Record any traditional Maori food or material gathering sites. Note historic or archaeological sites (note sensitivity of information).
Threats:	Record threat status of area using modified scale proposed by Saenger and Bucher, 1986. (1) Immediate threat (requires immediate action, damage to area already occurring).

(2) Cause for concern (area threatened in the long term).

(3) None (no potential threat identified, area adequately protected).

Management Options: An area with low conservation values may have potential for improvement. The area may therefore be awarded a higher score at a later date. Suggestions for the improvement of estuarine areas should be made where appropriate (eg. fencing, replanting, spraying of noxious plants).

Contacts: Record names and addresses of persons or organisations with interests in the area.

Not all categories may be applicable for an area under investigation. It is at the discretion of the surveyor which categories require description and discussion.

Numerical Score

A numerical value for the estuary or the part of an estuary was derived using a number ranking system similar to that used by Park and Walls (1978). Each criterion was assigned a possible score, which was divided evenly by the number of ranks within that criterion. The value of each possible score was arbitrarily assigned on the basis of the assumed relative importance of criteria (Table 24, 25).

Criteria for the assessment of areas within an estuary received equal scores, while whole estuary criteria were scaled (80-20 points) according to conservation values. Highest scores were awarded for overall estuary values. The total score was calculated by addition of all the criteria scores and represented as a percentage of the total possible score (Table 24, 25).

Although the numerical value is a convenient management tool, it should not be regarded separately from the individual criteria scores which make up the overall value. A low overall score does not necessarily mean there are no valuable areas, nor does it mean that the estuary is of no biological value.

Table 22. Evaluation of an Estuary as One Unit

CRITERION 1
Representativeness/uniqueness of estuary compared with other estuaries in the conservancy
(a) Unique, only one of its kind in conservancy.
(b) One of the few estuaries of its kind in conservancy.
(c) Typical of many estuaries in conservancy.

CRITERION 2
State of estuary
(a) Pristine condition.
(b) Minor development or modification in localised areas.
(c) Significant areas of estuary modified.
(d) Extensive development of the estuary.

CRITERION 3
Pollution status
(a) Pristine condition.
(b) Minor pollution in localised areas.
(c) Significant areas of estuary polluted.
(d) Extensive pollution of estuary.

CRITERION 4
State of terrestrial vegetation
(a) Original terrestrial vegetation intact.
(b) Some areas of original zonation present, or under present regeneration.
(c) Little or no buffering vegetation, <50% of land farmed or developed.
(d) >50% of land adjacent to estuary developed into urban areas, industrial development or farming.

CRITERION 5
State of salt marsh vegetation
(a) Original salt marsh vegetation around >90% of the estuary.
(b) Significant areas of salt marsh vegetation intact.
(c) Small areas of original salt marsh intact.
(d) Remaining salt marsh modified.

CRITERION 6
Size of intertidal and subtidal areas
(a) >2000 ha
(b) 1001-1999 ha
(c) 501-1000 ha
(d) 100-500 ha
(e) <100 ha

CRITERION 7
Number of invertebrate species recorded from estuary
(a) >125
(b) 101-125
(c) 76-100
(d) 50-75
(e) <50

Table 22. Evaluation of an Estuary as One Unit. (Cont.)

CRITERION 8
Number of waterbird species recorded from estuary.

(a)	>60
(b)	51-60
(c)	41-50
(d)	30-40
(e)	<30

CRITERION 9
Number of fish species

(a)	>36
(b)	26-35
(c)	15-25
(d)	<15

CRITERION 10
Maximum recorded density of cockles (per m^2)

(a)	> 3000
(b)	2000-3000
(c)	1000-2000
(d)	500-1000
(e)	< 500

CRITERION 11
Number of intertidal vascular plant species

(a)	>20
(b)	15-20
(c)	10-14
(d)	<10

Table 23. Evaluation of Part of an Estuary for Conservation Status.

CRITERION 1

Importance of flora, fauna and habitats

(a) Area with unique or rare species or area with breeding or roosting sites of important species; area which provides essential resource for particular species, provides nutrients to the estuarine system or provides physical protection for the ecosystem;

(b) Area with a rich or diverse flora and fauna, breeding feeding or roosting sites for common species.

(c) Area with moderate to sparse flora and fauna.

CRITERION 2

Representativeness/uniqueness of the area within the estuary

(a) Unique, only area of kind in estuary.

(b) One of the few areas of kind in estuary.

(c) One of many similar areas in the estuary.

CRITERION 3

Representativeness/uniqueness of area compared with other estuarine areas in the conservancy

(a) Unique, only area of its kind in conservancy.

(b) One of the few areas of its kind in conservancy.

(c) One of many similar areas in the conservancy.

CRITERION 4

Biological and physiological state of area

(a) Pristine condition.

(b) Isolated development or modification.

(c) Significant parts of an area modified.

(d) Extensive modification and/or industrial development.

CRITERION 5

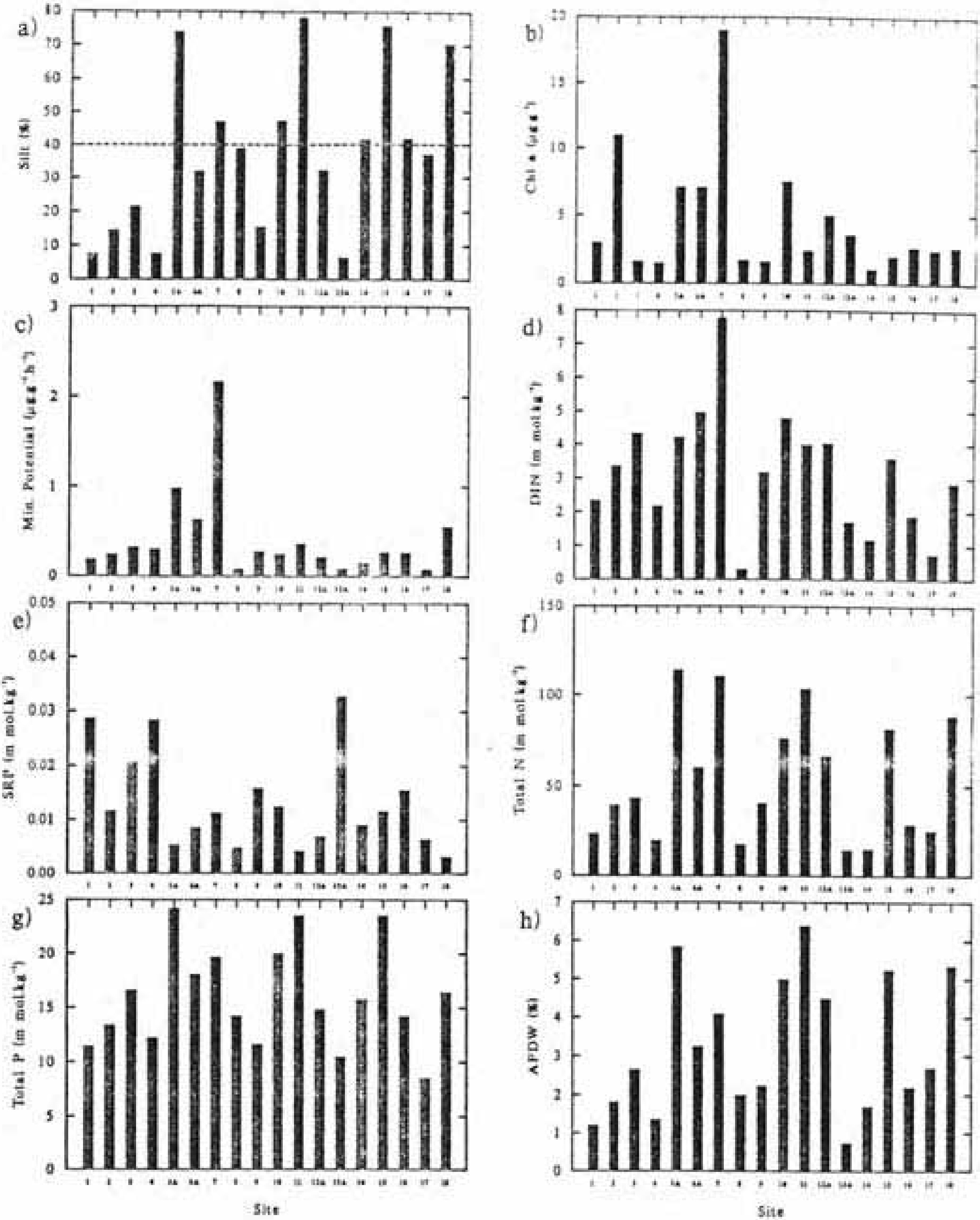
State of surrounding terrestrial vegetation

(a) Original surrounding terrestrial vegetation intact.

(b) Some areas of original vegetation intact, or under regeneration.

(c) Little or no original vegetation, <50% of land farmed or developed.

(d) >50% of land adjacent to the estuary developed for urban, industrial or farming practices.



Appendix IV: Physical, chemical and microbiological characteristics of intertidal sediments from Moutere Inlet, March 1991 (Gillespie *et. al*, 1992). a) percentage silt composition, b) chlorophyll *a*, c) microbial mineralisation potential, d) dissolved inorganic nitrogen, e) soluble reactive phosphorus, f) total nitrogen, g) total phosphorus, h) total organic content.

COASTAL AND MARINE PUBLICATIONS, NELSON/MARLBOROUGH CONSERVANCY

1.	Coastal resources inventory manual for Nelson/ Marlborough Conservancy	L Rich	1988	56 pp	*
2.	Preliminary assessment of the ecological state of Moutere Inlet, Motueka	CR Moffat	1989	26 pp	NZ$15.00
3.	Waimea Inlet Study: An Education Kit	E Norriss and RJ Davidson	1989	11pp (12 cards)	NZ$10.00
4.	Conservation values of the Otuwhero/Riwaka coastal area	J Preece and L Rich	1989	43 pp	*
5.	A marine reserve for Whanganui (Westhaven) Inlet, North-west Nelson. Public handout	AS Baxter and RJ Davidson	1989	6 pp	Free
6.	Ecological study of the Wairau River Estuary and the Vernon Lagoons	GA Knox	1990	60 pp	NZ$15.00
7.	First order coastal resource inventory Nelson/Marlborough Conservancy	RJ Davidson, L Rich, D Brown, K Stark, B Cash, J Preece, E Waghorn, G Rennison	1990	217 pp	*
8.	A report on the ecology of Waimea Inlet	RJ Davidson and CR Moffat	1990	165pp	NZ$30.00
9.	Abel Tasman Newsletter No.1: Marine Survey	RJ Davidson	1990	2pp	Free

In Preparation

A report on the ecology of Whanganui Inlet, North-west Nelson	RJ Davidson
A preliminary report on the shallow benthos of the Marlborough Sounds	C Duffy, S Cook and K Briden
An investigation of the intertidal and subtidal environment of the Abel Tasman National Park	RJ Davidson

* Internal reports only

Table 24. Scores for conservation status of an estuary

Each criterion has been assigned a possible score. The value of the score depends on the assessed relative importance of each criterion. The possible score for each criterion is divided by the number of ranks in that criterion to give the difference in scores between adjacent ranks (see table below):

CRITERIA	1	2	3	4	5	6	7	8	9	10	11
Possible Score	80	80	60	60	60	40	40	40	40	40	20
No. of ranks	3	4	4	4	4	5	4	5	4	5	4
Rank (a)	80	80	60	60	60	40	40	40	40	40	20
Rank (b)	54	60	45	45	45	32	30	32	30	32	15
Rank (c)	27	40	30	30	30	24	20	24	20	24	10
Rank (d)	-	20	15	15	15	16	10	16	10	16	5
Rank (e)	-	-	-	-	-	8	-	8	-	8	-

Table 25. Scores for Conservation Status of Part of an Estuary.

Each criterion has an assigned value of 60. This value is divided by the number of ranks in each criterion to give the difference in score between adjacent ranks (see table below):

CRITERIA	1	2	3	4	5
Possible Score	60	60	60	60	60
No. of ranks	3	3	3	4	4
Rank (a)	60	60	60	60	60
Rank (b)	40	40	40	45	45
Rank (c)	20	20	20	30	30
Rank (d)	-	-	-	15	15

Statistics on Davidson and Moffat's (1990) invertebrate data from the Waimea Inlet.

	No. species	No. individuals per sq. m.
	20	1371
	14	654
	16	769
	26	2669
	23	1179
	23	3349
	25	1222
	17	1008
	13	1165
	9	746
	11	929
	18	1561
	17	1029
	15	1166
	17	1084
	13	3032
	17	2817
	17	1154
	9	497
	14	1210
	15	1525
	14	2207
	19	1006
	21	76350
	25	17997
	16	6666
	9	395
	23	39261
	22	13716
	9	2035
	14	1630
	2	136
	1	38
	2	57
	2	135
	2	2965
	6	102
	9	284
	6	577
	7	90
	9	543
	3	351
	4	23665
	6	13368
	6	17994
	4	1098
	5	2433
	6	14430
	3	4391
	5	2163
	5	2851
	4	8409
	5	871
Mean	11.75472	5440.566
sd	7.247067	12368.47
n	52	52
Max	26	76350
Min	1	38