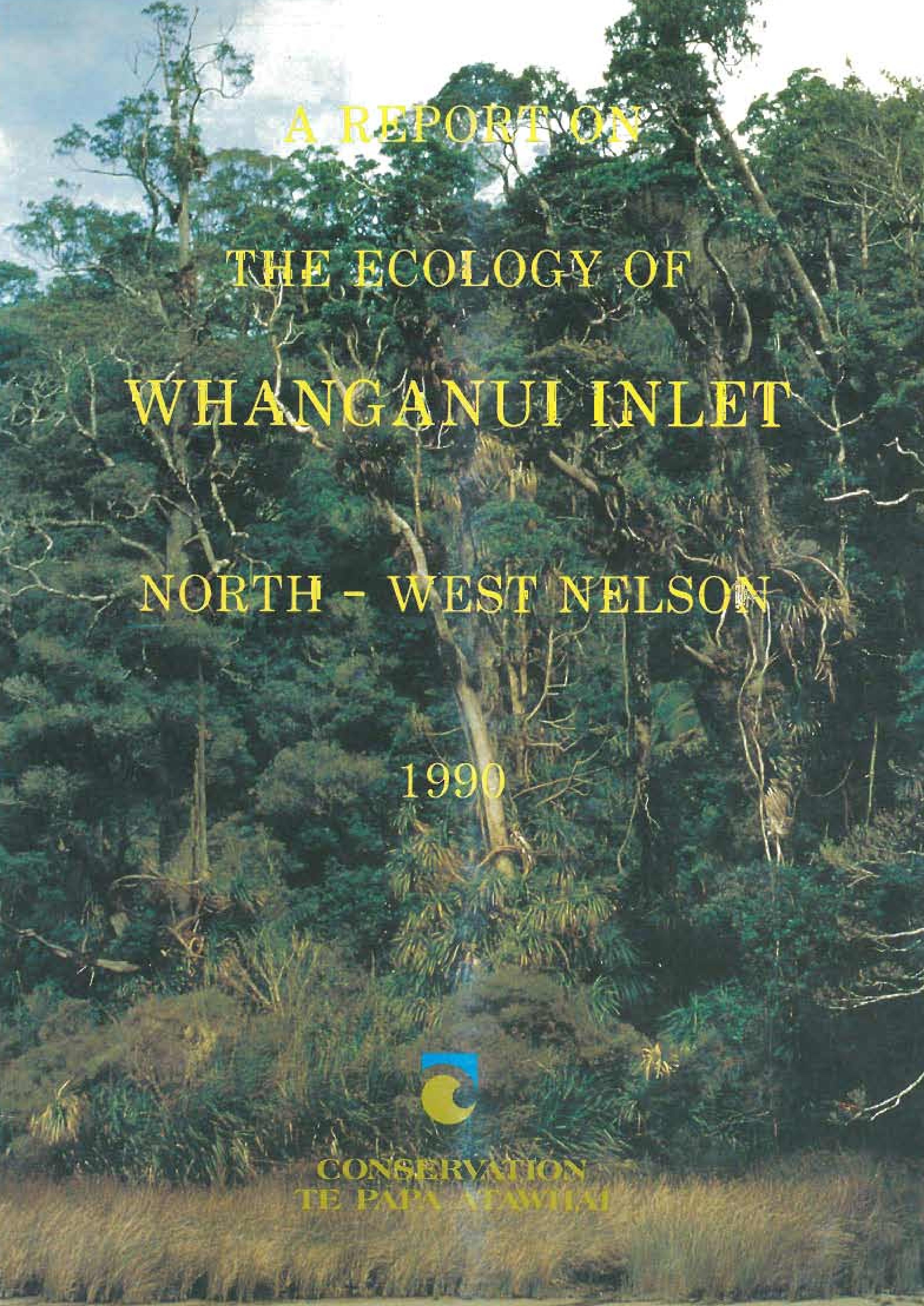

A REPORT ON THE ECOLOGY OF WHANGANUI INLET NORTH - WEST NELSON

1990

CONSERVATION
TE PAPA ATAWHAI

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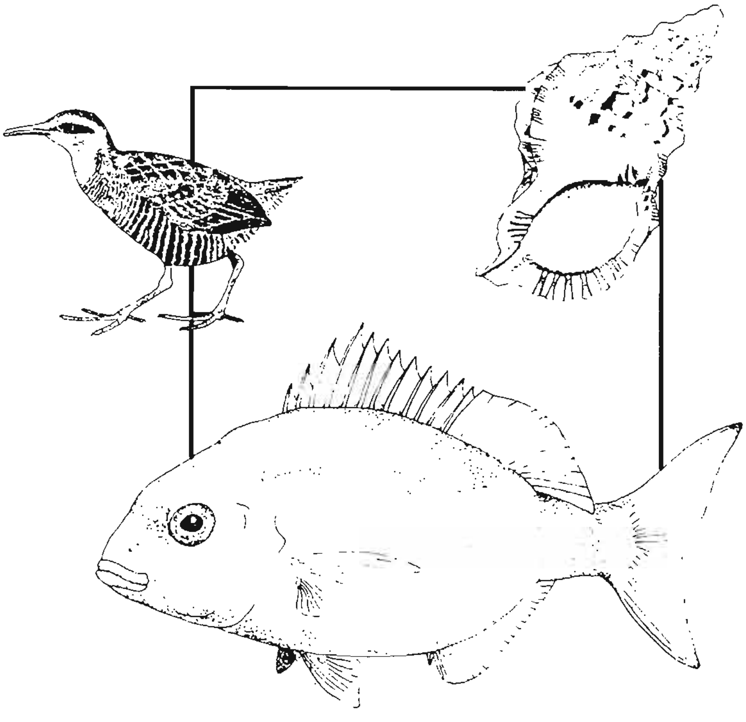
Robert J. Davidson



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Occasional Publication No 2

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Garry Holz	Plate 1,6,7,8,9,15,16,21,23
Rob Davidson	Cover and all other plates

Cover: Coastal forest, South-western Whanganui Inlet

Plate 1 Whanganui Inlet at high tide

PREFACE

Whanganui Inlet is one of the outstanding natural places in New Zealand. Known locally as Westhaven, it nestles into the west coast of the South Island near its northern most shore. Although one of the largest, least modified estuaries in the country, its values are not readily recognised by the casual observer. This report sets out to bring the hidden values of the area to light, and provides the evidence of its need for long term protection.

The report focuses on the extensive area that lies between the tides. Within the estuary the sand and mudflats and their associated eelgrass beds, which are daily covered and uncovered by the sea, are its productive heart. Together with the sand dunes, rocky shores, and cliffs of the estuary mouth and outer coast, they are the zone of highest interaction between land and sea. Sharing the attributes of both the terrestrial and marine environments, these areas have their own special character and characteristic inhabitants.

Estuaries are accessible environments and Whanganui and its environment are very familiar to local residents. The distance of the area from centres of population has, however, limited the number of outside visitors, and the area is not well known in the wider community. The remote location of Whanganui has also limited human impact, and while by no means pristine, the estuary and its environment are largely unmodified.

By focussing on the intertidal area the report if anything understates the full natural value of the Westhaven/Whanganui area as a whole. In a book being prepared on the coastal forests of New Zealand, Dr Geoff Park has identified the forests around Whanganui as some of the most important in the country. The ecological continuity of the estuary with the vast forest areas of North-west Nelson also contributes particular value in a national context.

The Department of Conservation recognises the value of the estuary to local people, both as part of their environment and for the provision of resources - particularly fish.

The department will continue to work, with local people and others, toward protecting these outstanding values for the benefit of present and future generations. We welcome this report as a most positive contribution and commend it to the attention of all those interested in the future of Whanganui Inlet.

Ian Black
<u>REGIONAL CONSERVATOR</u>

CONTENTS

ACKNOWLEDGEMENTS

I am grateful to the staff of the Department of Conservation, Nelson/Marlborough Conservancy. Of particular significance are the contributions made by David Butler (birds), Lianne Rich (habitat mapping), Kaye Stark (habitat mapping), Shannel Courtney (terrestrial vegetation), Rob Moffat (preliminary investigation), Andrew Baxter (diving), Peter Fullerton (diving), Joanne Northover (accommodation), Geoff Rennison (field centre support), and John Taylor (field support). Maps and figures were meticulously draughted by Doug Latham and Garry Holz.

A freshwater fisheries survey was organised and cariied out by Tony Eldon, Mace Ward, Mark Taylor, Jullian Sykes and Bob McDowall (Freshwater Fisheries, Nelson Acclimatisation Society). The survey was an excellent joint effort between these organisations.

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I would especially like to thank Jacqui Davidson for assistance with field survey work and photography in her own time and support throughout the project.

ABSTRACT

An ecological investigation of Whanganui Inlet (Westhaven), entrance and adjacent outer coast was carried out between October 1988 and October 1989 by Department of Conservation staff.

Whanganui Inlet is the second largest estuary in the South Island (2744 ha) behind Waimea Inlet, Nelson (3455 ha).

The coast of the inlet has been selectively logged, flax milled, and mined for coal and gold, but most of the inlet has largely escaped permanent ecological damage from industrialisation, reclamation and land clearance.

Seventeen main habitat types were recognised in the estuary, entrance and outer-coast. A characteristic invertebrate community was recognised for each habitat. Particular invertebrate communities were often common to more than one habitat type.

The distribution and location of each habitat and vegetation type are displayed on ten marine habitat maps.

Terrestrial vegetation types for the surrounding landscape are mapped on three A3 half-tones.

The most common estuarine habitat was eelgrass (859 ha) followed by fine sand (384 ha) and mobile sand (269 ha). Most eelgrass was located in the northern half of the inlet (92%).

Invertebrates were collected from 50 sites in Whanganui Inlet. One hundred and sixty three invertebrate species were recorded from intertidal and subtidal sites in the entrance and estuary. This is the highest number of species recorded for any South Island estuary. The highest density of benthic invertebrates was 4830 individuals per square metre. Mollusca were represented by 72 species, Crustacea by 45 species, Polychaeta by 26 species, Echinodermata by 5, Anthozoa 4, Porifera by numerous species, Insecta 3 species, Nemertina 1, Turbellaria 1, Hydroid 1 and Sipunculida 2 species. Three new species of amphipoda were recorded from Whanganui Inlet.

Thirty-eight marine and 12 freshwater fish species were recorded from Whanganui Inlet and freshwater catchments.

Fourty-two species of waterbird were recorded from the inlet. The most common bird species were South Island pied oyster catcher, bar-tailed godwit, knot and banded dotterel. Whanganui Inlet is the only location on the West Coast of the South Island where the nationally important banded rail is present.

Based on conservation criteria developed for the evaluation of estuaries, Whanganui Inlet was compared with three other South Island estuaries: Waimea Inlet, Avon-Heathcote and Parapara Inlet. Whanganui Inlet was ranked highest of these estuarine areas.

Productivity estimates are the highest per unit area for any estuary in the South Island to date.

Human impacts in Whanganui Inlet are outlined.

Recommendations for the management of Whanganui Inlet, entrance area and outer coast conclude the report.

1. INTRODUCTION

The most vulnerable and modified marine areas in the world are estuaries and tidal inlets. A long history of human misuse and neglect (infilling, stopbanking, drainage, subdivision, industrial development, pollution) have left few estuaries in New Zealand relatively unmodified. This is unfortunate, as estuaries are one of the most productive environments in the world, supporting complex food chains vital to fish and bird populations. Estuaries are also important spawning and juvenile areas for many commercial, traditional and recreational fisheries. Pollution, industrialisation, drainage and rubbish dumping in estuaries and associated wetlands have contributed to the low public opinion of these areas. It is important, therefore, that estuarine environments in New Zealand be protected.

Whanganui Inlet, know locally as Westhaven, has largely escaped permanent human impact and remains one of New Zealand's most significant and pristine estuarine systems. The Department of Conservation believes that the natural values of Whanganui Inlet should be recognised and protected possibly as a marine reserve. This report describes the ecology of the inlet and adjacent outer coast and the potential for marine reserve status.

2. WHANGANUI INLET

The sea entrance to Whanganui Inlet is located 19 km southwest of Farewell Spit on the west coast of the South Island (Fig.1). The inlet is a, barrier enclosed, drowned river valley 13 km long and between 2 and 3 km wide. Whanganui Inlet is the second largest estuary (2744 ha) in the South Island after Waimea Inlet, Nelson (3455 ha).

The exposed outer coastline either side of the entrance is predominantly rock reef, cliff and boulder and sand beach. Sand beaches along the north head are associated with an extensive dune system created by persistent gales and moving sands. Inside the entrance, the inlet is sheltered from ocean swells, but not the wind, which often produces choppy water conditions.

As the tide pushes into Whanganui Inlet it is divided into north-east and south-west channels. As soon as these main channels are filled by the tide, water spills onto expansive intertidal flats which dominate the inlet. Much of these flat areas are covered by a carpet of eelgrass *(Zostera muelleri)*, an important component of the estuarine food chain. The tidal flats often finish abruptly at cliff, boulder, rock and limestone platforms which may rise directly out of the tidal flats or main channels. In some areas the transition between tidal flat and the terrestrial environment is more gradual. In these areas, salt marsh vegetation forms a narrow strip between estuary and coastal forest. Pukatea, kahikatea, northern rata, beech and nikau palm forests dominate many of the catchments surrounding the inlet.

Maori occupation of the inlet at the time of the arrival of Europeans was relatively low. This may be due to invasions in the 1820-30's of forces lead by Te Niho and later Te Puohu. Three pas were known to exist on the inlet in the 1830's, the best known was at Pa Point and was likely called Onaira noa (Rushton, 1987).

Many of the natural qualities of Whanganui Inlet are intact, however, the inlet was recognised early as a source of many raw materials (Rushton, 1987). Since 1840 when Captain Moore extracted 55 tonnes of coal onto his ship the Jewess, the bulk of activity in the inlet has come from mining of gold and coal, the harvest of trees and flax and the establishment of farms (Plate 2). In 1908, the small township of Rakopi was established opposite the entrance. The town boasted a telegraph office, sawmill, wharf, school and houses. A combination of declining resources, an economic downturn and the dangerous passage for ships through the entrance saw the end of port development at Whanganui Inlet (Plate 3). Many of the farmers remained and large farms on the northern and southern promontories attest to the fertility of the soil. Much of the land surrounding the inlet has changed ownership over time. The bulk of private land is located on the northern and southern promontory and around the Wairoa River, with the remaining land designated as conservation, crown, road reserve or legal road (Fig.2).

Today, human impact in the area is relatively light. Recreational use of the inlet is primarily marine recreational fishing, whitebaiting, water-fowl shooting and sight-seeing. Commercial fishing interests within the inlet are limited to harbour facilities with relatively little commercial fishing on the outer coast adjacent to the entrance due to the weather, access and shifting sands.

Conservationists and scientists agree that Whanganui Inlet is an important area. The inlet represents a relatively unmodified estuarine environment with numerous freshwater and terrestrial systems in close proximity. Despite the fact that Whanganui Inlet represents a rare chance to study organisms in a close to natural system, little scientific work has been undertaken.

The present study establishes a platform from which further investigation will hopefully be generated.

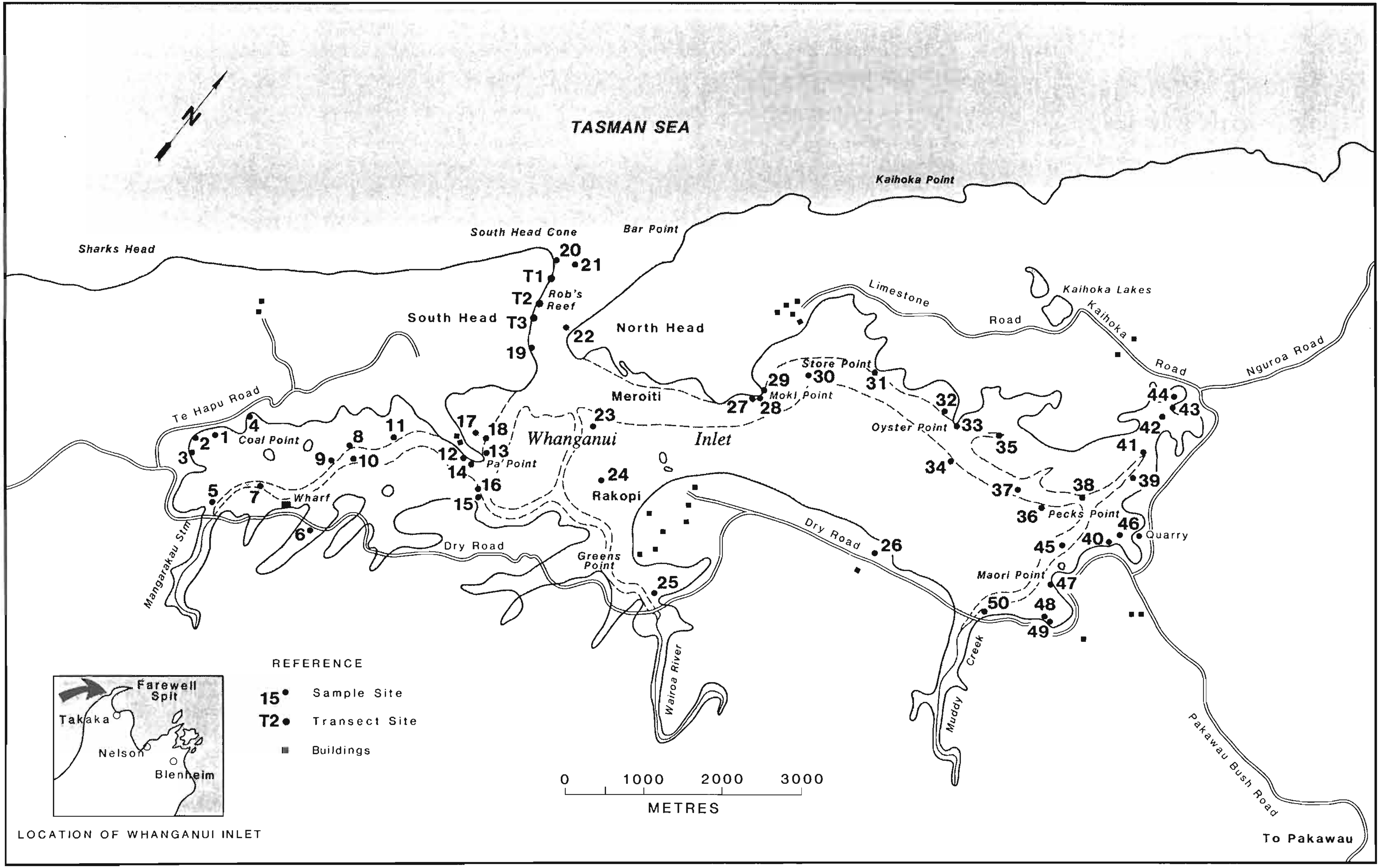


Fig. 1 WHANGANUI INLET & SAMPLE SITES

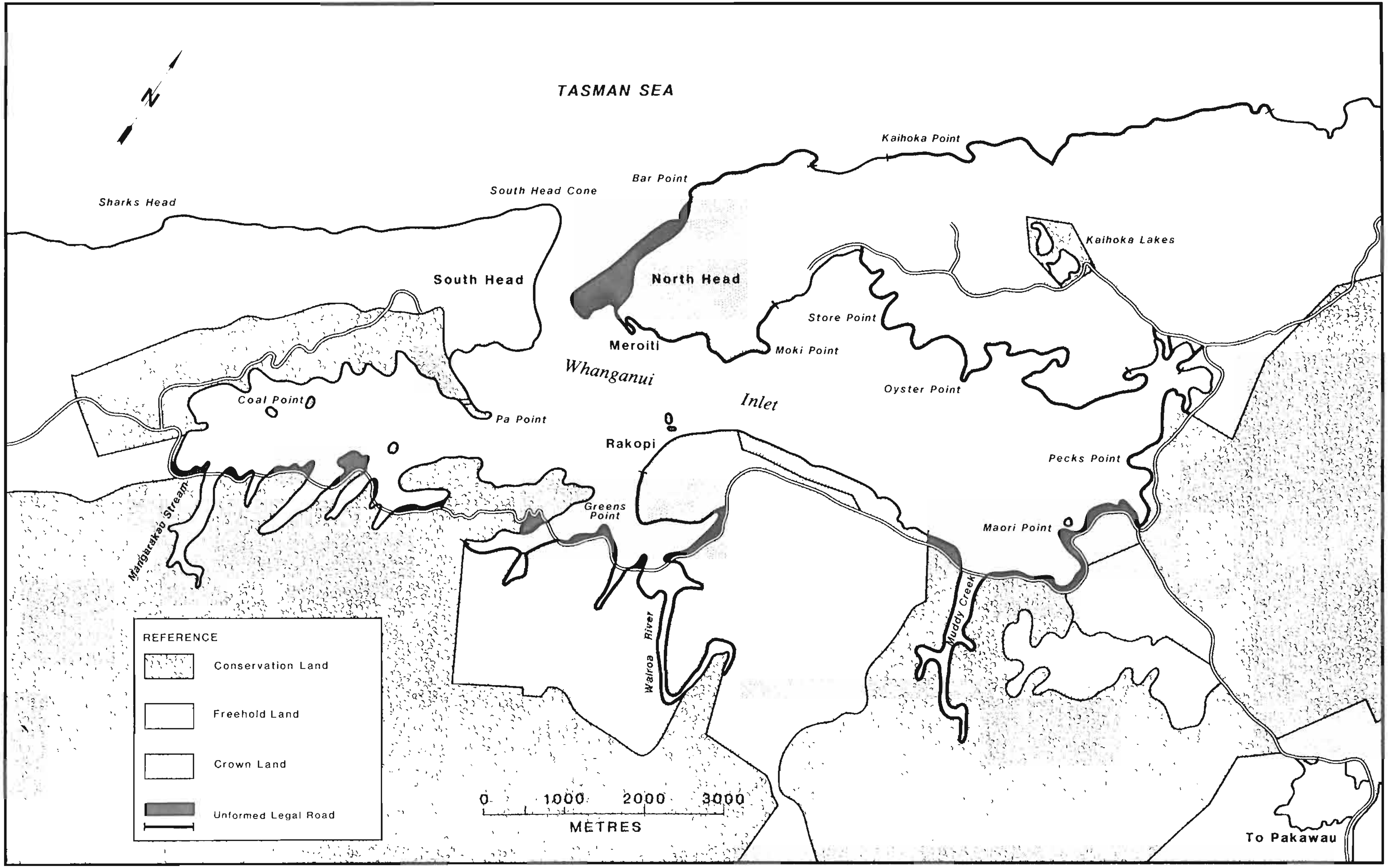


Fig. 2 LAND TENURE

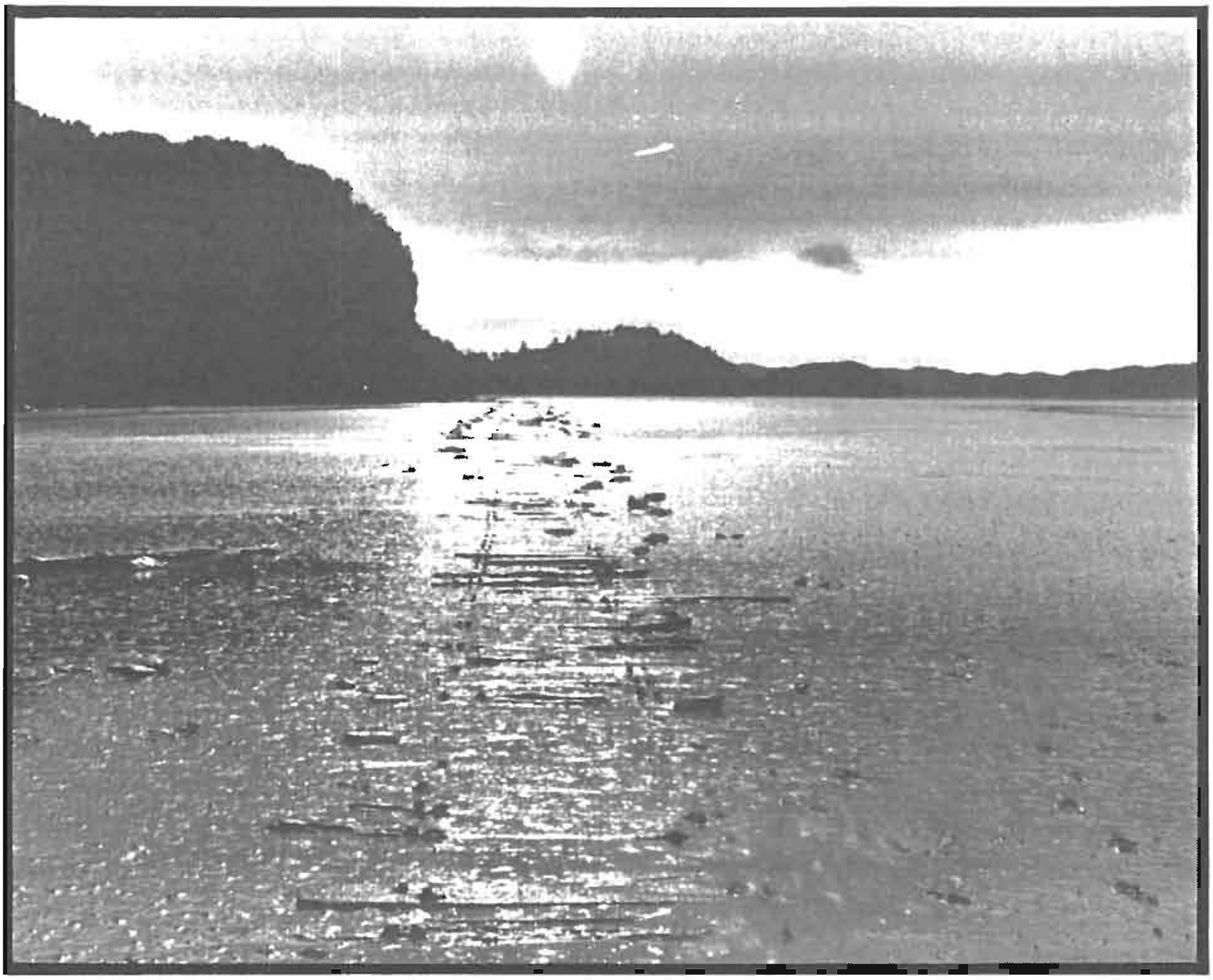


Plate 2 Tramway across tidal flat

Plate 3 Pa Point wharf

3. HABITATS AND HABITAT MAPPING

A total of 17 main habitat types were recognised in Whanganui Inlet and the adjacent outer coast. The definition of these habitats was based on a combination of physical features (substrate, tidal height, topography) and biological features (plant cover, animal community). This chapter introduces these habitats and displays their distribution on habitat maps.

3.1 ESTUARINE AND COASTAL HABITAT TYPES

Rock Platforms
Rock platforms are located on many headlands around Whanganui Inlet and along the outer coast (Plate 4). Platforms are level or almost level areas of rock often located adjacent to the main channels in the inlet (eg. Moki, Pa, and Oyster Points). Large areas of intertidal rock platform are located along the outer coast, south of the entrance (eg, South Head Cone, north of Sharks Head) (Plates 7,8).

Cliffs
Cliffs rise vertically out of intertidal and subtidal areas of Whanganui Inlet (Plate 5). Most cliff habitat is located along the western margins and remain in shade for most of the day. Freshwater seepage often keeps this habitat permanently wet and is ideal for the growth of freshwater and marine algae. The cliff habitat is also located on the outer coast (Plates 6,8).

Boulders
Cliff and headland erosion have often resulted in the deposition of boulders in the intertidal zone of Whanganui Inlet and outer coast (Plates 9,10). These boulders range in size from 0.5 to 2 m in diameter in the inlet and up to 10 m in diameter along the outer coast. Road causeways have created an artificial boulder habitat along the eastern edge of the inlet.

Pebble/Cobble
Pebbles and cobbles range in size from 4-456 mm in diameter. This habitat is relatively uncommon in Whanganui Inlet (Plate 11). Small pebble/cobble areas are located predominantly around headlands in the north-eastern inlet.

Mobile Sand
Mobile sand is most common around the entrance to Whanganui Inlet. Strong tidal currents, wind driven waves and open coastal swells shift this sediment forming bars and beaches. Wind and waves have formed small beaches at various locations within the inlet (eg. Rakopi, Maori Point). Where mobile sand has been built into dunes, introduced and native grasses have been quick to colonise (eg. marram, *Ammophila arenaria*).

Fine Sand
Fine sand flats are similar in appearance to mudflats, however, they are distinguished by their granular texture and ability to support the weight of an adult. Significant areas of fine sand are located in the south-western inlet and around Rakopi where moderately strong tidal currents carry away silts and clays.

Very Fine Sand
Very fine sand will not support the weight of an adult and is similar in appearance to mud, however, very fine sand is granular, testifying to the presence of a significant sand fraction. Both very fine sand and fine sand dominate the intertidal areas of the south-western inlet.

River Sand
The largest areas of the river sand habitat are located in the Wairoa River and Muddy Creek systems above the causeways. This substrate is presumably carried into the estuary by the associated rivers and is deposited as current velocities decline (Plate 12). River sand is hard packed and retains little moisture once the tide has receded.

Mud
Mud is a combination of silts and clays <0.063 mm in diameter. This habitat is easily recognised by a glutinous appearance and black anaerobic layer close to the surface. Mudflat areas in Whanganui Inlet are often restricted to particular embayments cut off by causeways in the north-eastern inlet.

Highshore
Areas above mean high water dominated by hard-packed clay sediments are termed "highshore". The combination of clay substrates, short duration of tidal coverage and warm weather causes these areas to dry out and harden. Highshore areas are limited to the south-western corner of the inlet and small pockets in the north-eastern inlet.

Zostera (Eelgrass)
Zostera covers most intertidal flats in the north-eastern inlet and smaller areas in the south-western inlet (Plate 14). *Zostera* grows on a variety of substrates including mud, very fine sand and fine sand. The most luxuriant beds grow on mud substrata north-east of Oyster Point (Plate 15).

Gracilaria (Agar Weed)
Significant *Gracilaria* beds grow on mudflats adjacent to Moki Point and Pa Point. This alga attaches to living and dead shell material, especially cockles, and is one of the algal species used in some areas of the world in the production of agar. This agar weed is recognised by a deep brown colour and stringy form.

Native Rushes, Sedge and Herb Field
Two rush species *(Juncus maritimus, Leptocarpus similis)* and one sedge *(Schoenoplectus pungens)* dominate the salt marsh community in Whanganui Inlet. In most areas, the two rush species grow in mixed stands, however, the jointed wire rush (*Leptocarpus*) is more common higher on the shore than the sea rush (*Juncus*) (Plate 13). The native sedge *S. pungens* was most often recorded in a thin band (less than 1 m in width), below the rushes.

Turf or herb field estuarine plants including the sea primrose (*Samolus repens*), remuremu (*Selliera radicans*) and glasswort (*Sarcocornia quinqueflora*) were often recorded growing between the native rush and sedge species.

The largest area of salt marsh in the inlet is located between Rakopi and Muddy Creek. Most salt marsh in Whanganui Inlet is represented by a relatively narrow strip around the margins. In many areas cliffs rise from the mid-tide level, presenting little opportunity for salt marsh plants to establish.

Subtidal (Sand, Shell Fragments)
A subtidal channel stretches from Pecks Point in the north-eastern inlet to Coal Creek in the south. Both the northern and southern channels meet inside the entrance before passing under the south head cliffs and out into the Tasman Sea. Water depths at high tide range from approximately 9 m at the entrance to 0.3 m in numerous minor channels throughout the inlet. Mobile sand is pushed into 1 m high sand waves and dominate the benthos in the entrance channel, while shell fragments are the most common sediment around Pa and Moki Points. The remaining channel area is lined with sand and numerous dead shell material.

Subtidal (Rock Substrate)
Subtidal reefs, cliffs, platforms and boulders are located at various points from the entrance area to Oyster Point in the north and Pa Point in the south. The subtidal outer coast and South Head are dominated by rock substrata.

Rock Splash Zone
This habitat is characterised by bare rock with no significant plant or animal colonisers (Plate 6). The rock splash zone is situated above high water and often extends some 10-20m landward. This habitat was represented on the outer coast where large seas and strong winds combine to keep these rocks essentially bare of plants and animals. The landward boundary of the rock splash zone is marked by diverse salt tolerant coastal herbfield communities dominated by the Westhaven button (*Leptinella calcarea*), remuremu (*Selliera radicans*), pennywort (*Hydrocotyle novaezelandiae*) and coastal daphne (*Pimelea urvilleana*).

Plate 4 Rock platform and fine sand flat, Wairoa River

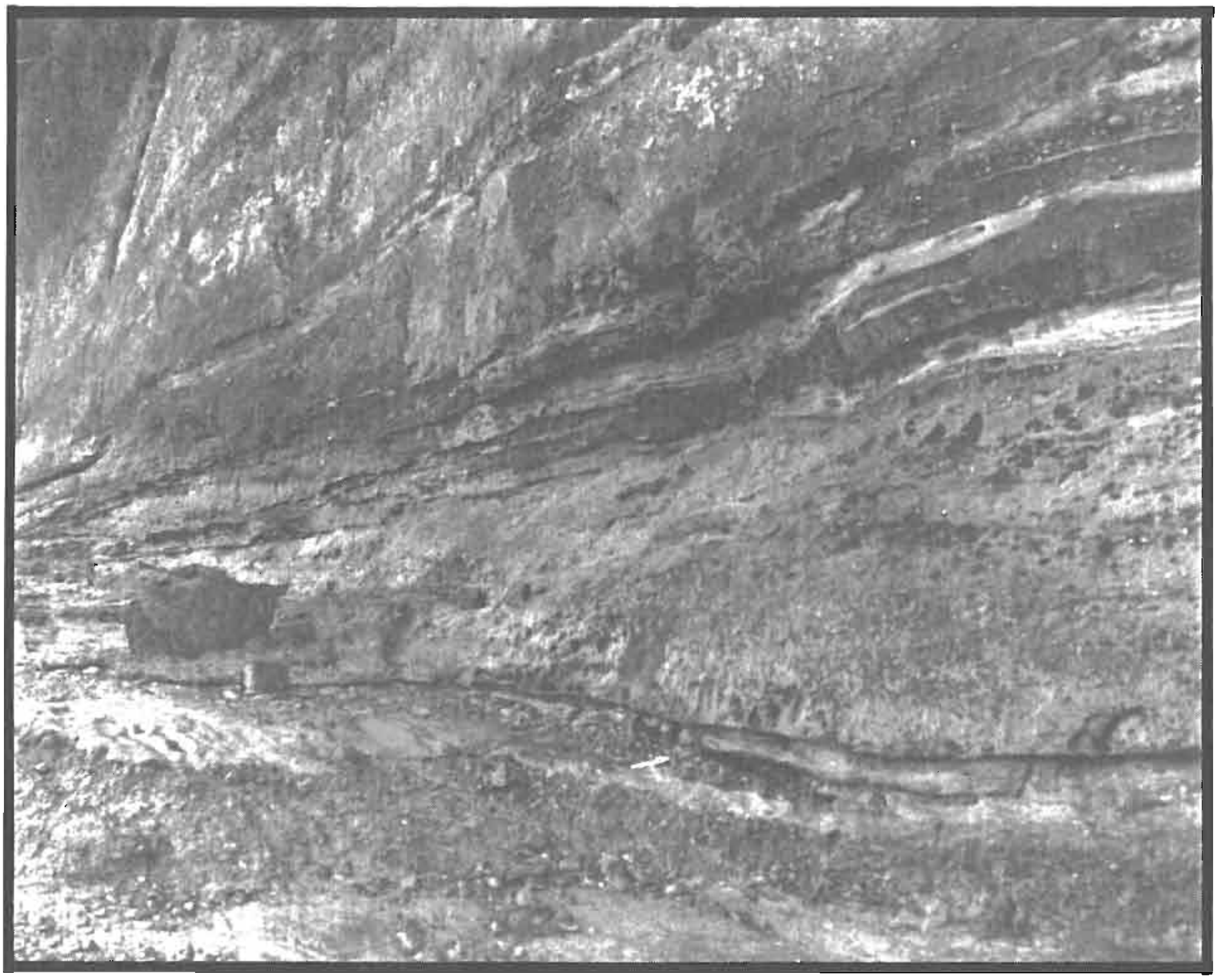


Plate 5 Cliff habitat

Plate 6 Outer coast north of Sharks Head

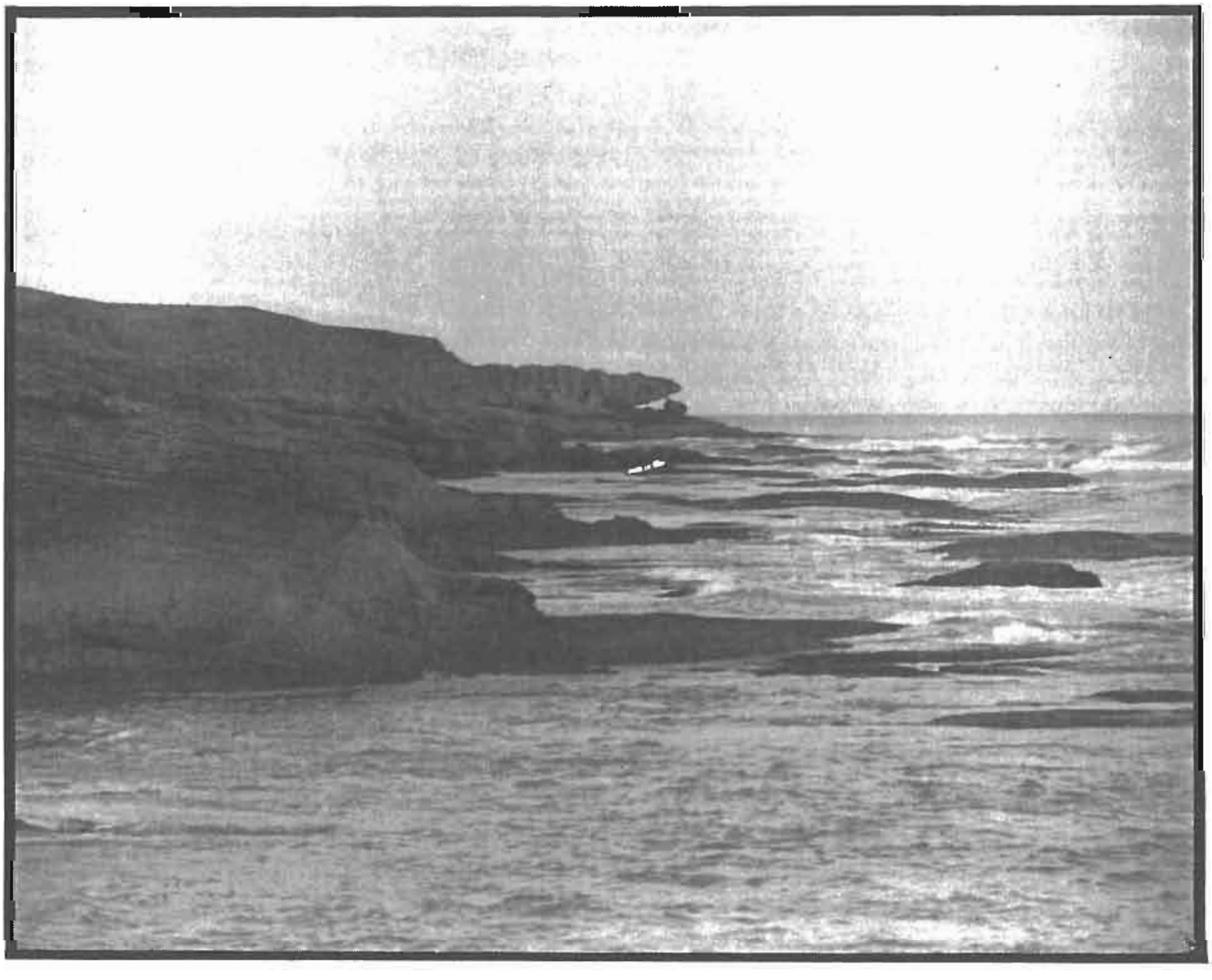


Plate 7 Sharks Head

Plate 8 Outer coast platform, cliff and beach areas

Plate 9 Outer coast boulder beach

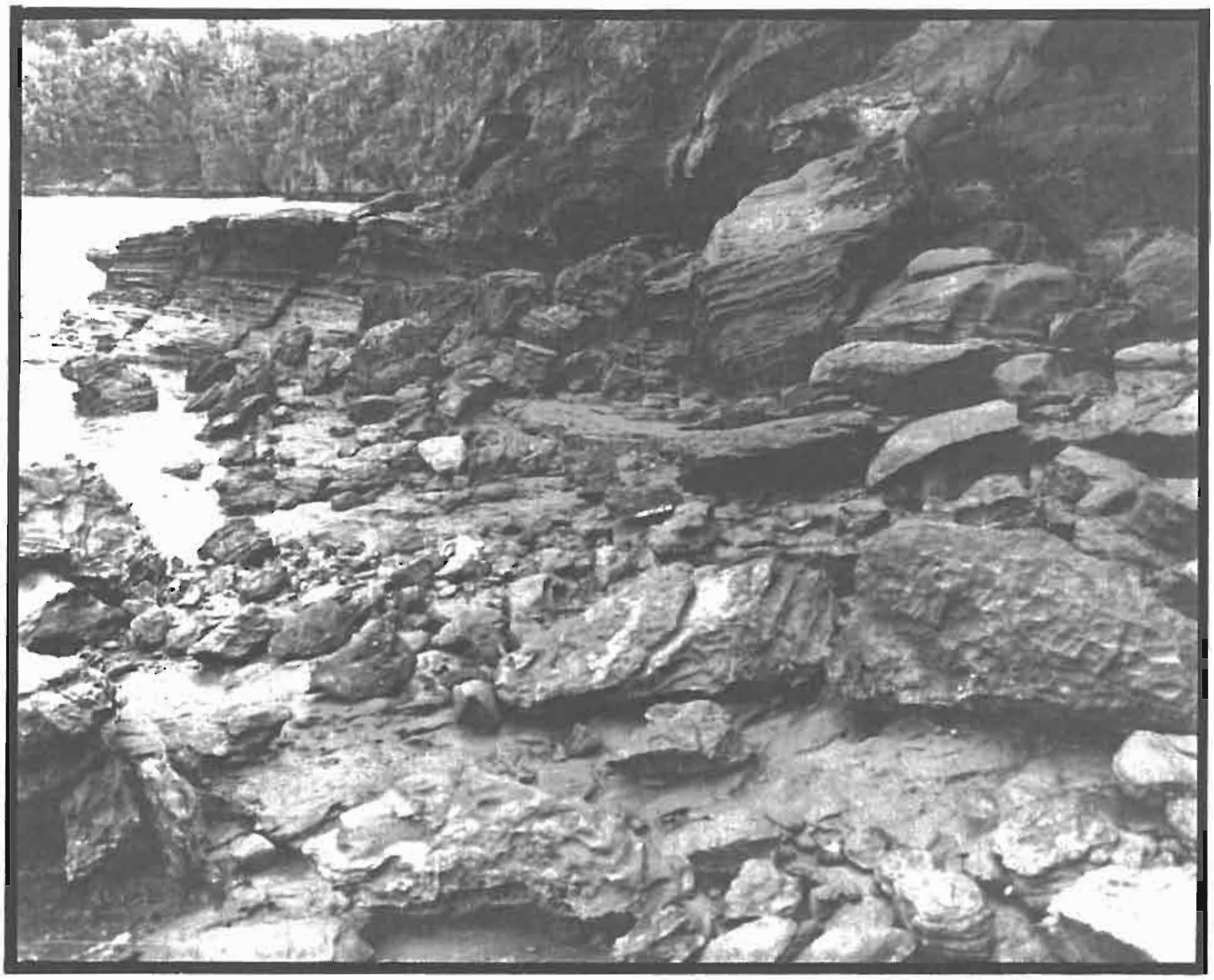


Plate 10 Boulders, Pa Point

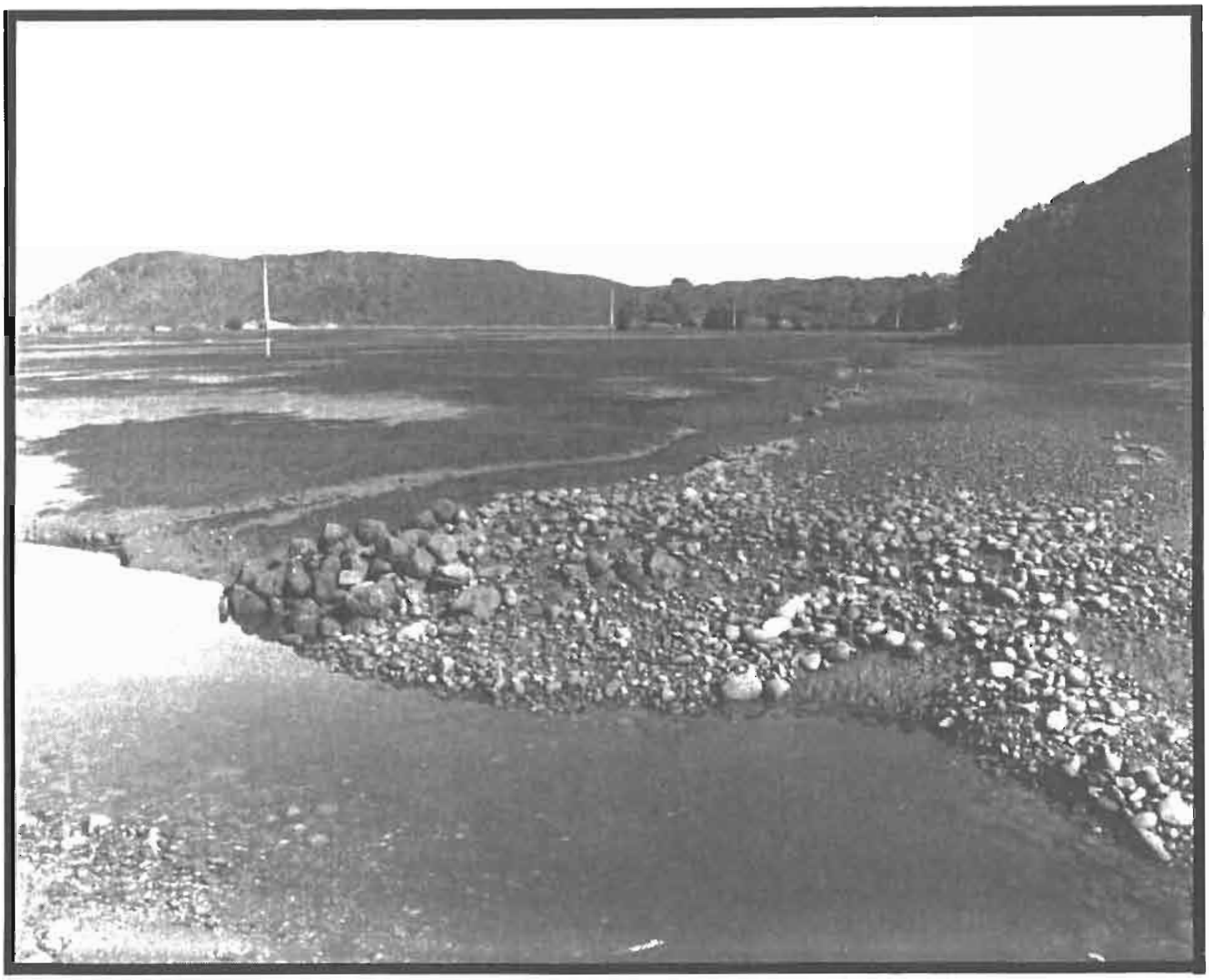


Plate 11 Pebble/cobble habitat formed by old tidal road

Plate 12 River sand, Wairoa River

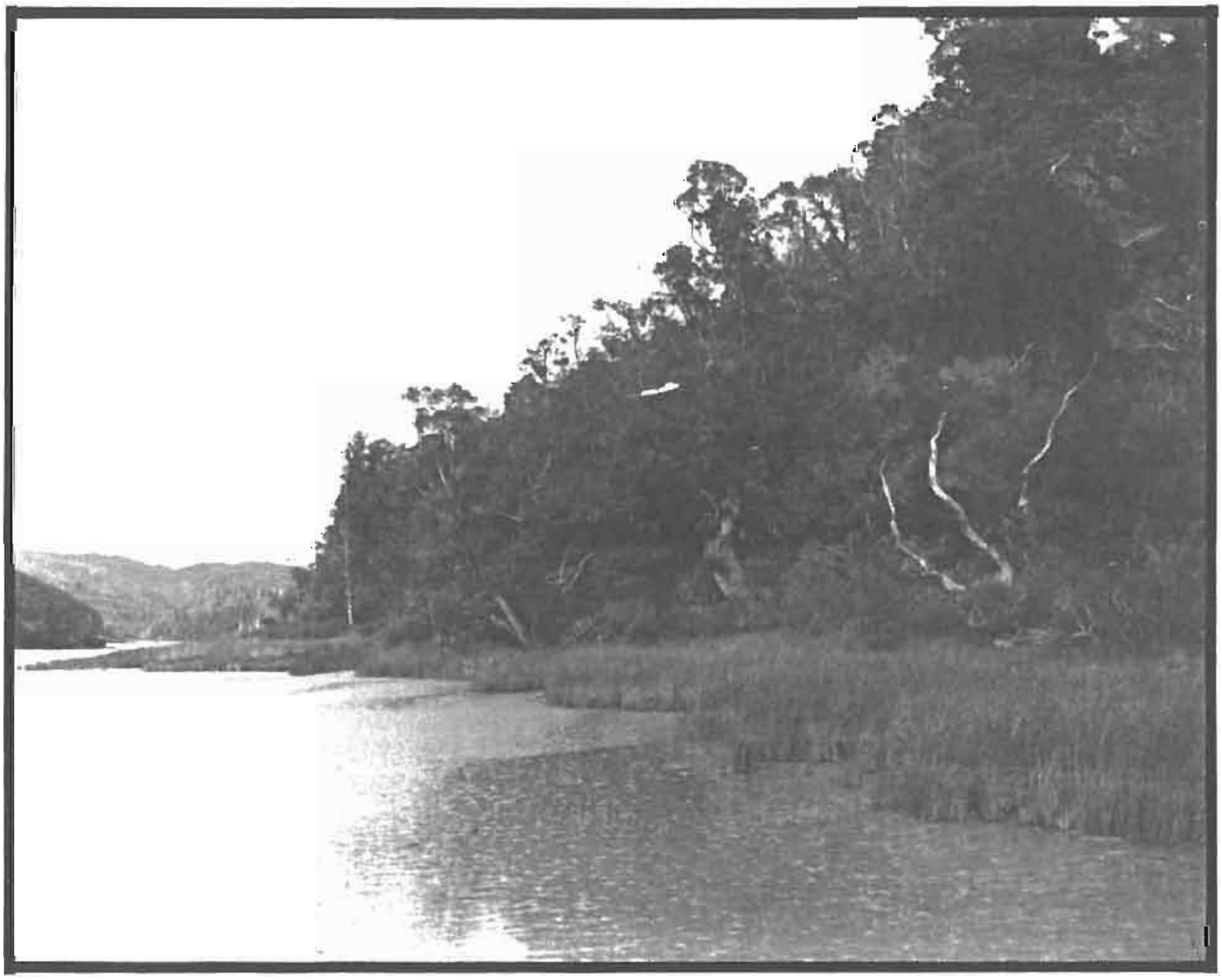


Plate 13 High shore, salt marsh and adjacent coastal forest

Plate 14 Eelgrass *(Zostera)* north-eastern inlet

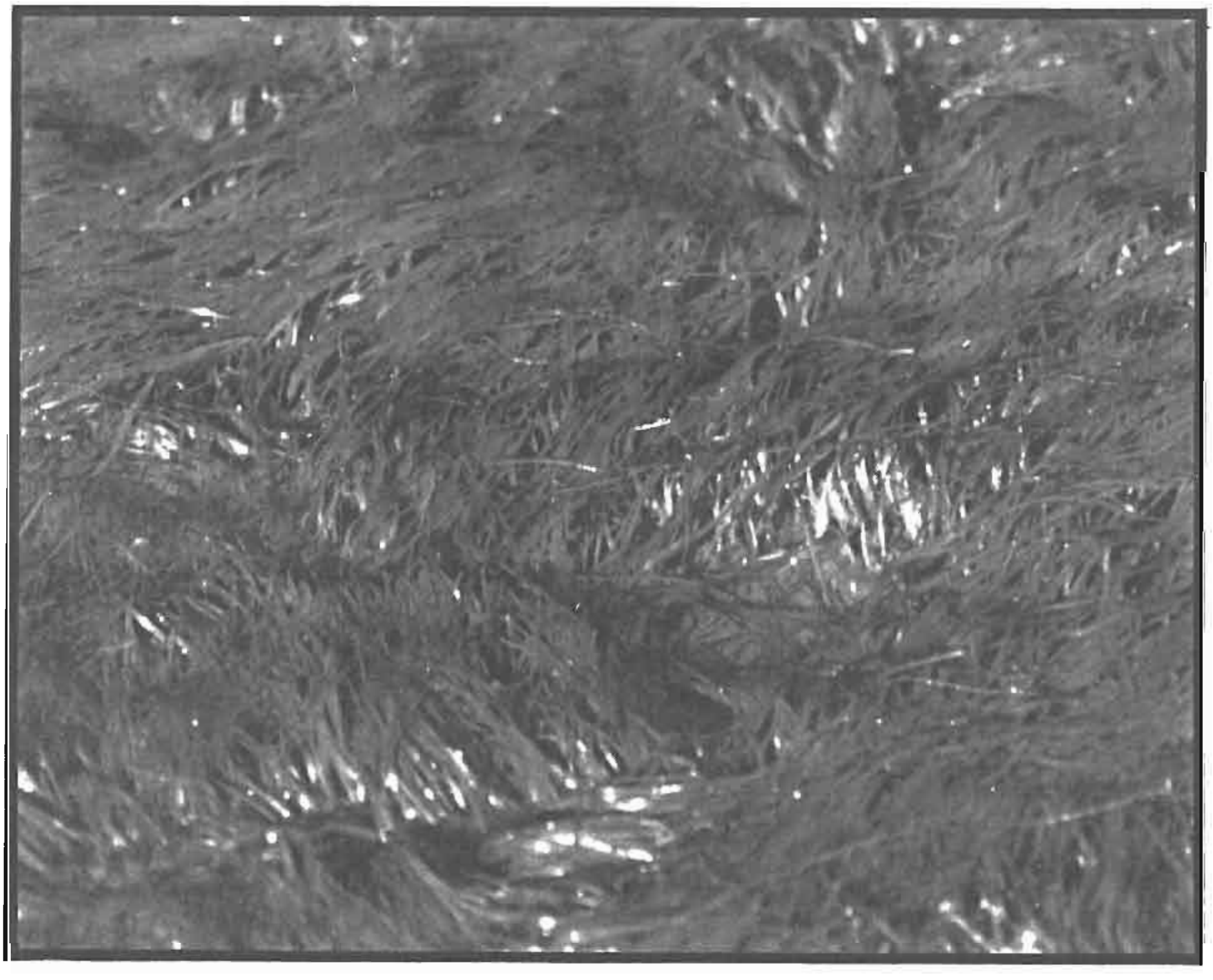


Plate 15 Eelgrass *(Zostera)*

Tidal Freshwater Wetland

Tidal freshwater wetlands are dominated by the influence of freshwater (salinity below 5ppt), however, these areas are subject to ocean-derived lunar tides (Odum, 1988). Tidal freshwater wetlands have a relatively high diversity of vascular plants compared with salt marsh communities and are dominated in Whanganui Inlet by raupo (*Typha orientalis*), flax (*Phormium tenax*) and kanuka (*Leptospermum*). The largest area of freshwater tidal wetland in the inlet is located adjacent to Rakopi in a continuum with the salt marsh which extends from Muddy Creek to Rakopi. Numerous tidal freshwater wetlands are located around the inlet at the heads of embayments.

3.2 TERRESTRIAL VEGETATION TYPES

Six structural classes of terrestrial vegetation were recognised for the area surrounding Whanganui Inlet.

Forest

Woody vegetation in which the cover of trees in the canopy is more than 80%. Trees are woody plants greater than 10cm dbh (diameter at breast height).

Scrub

Woody vegetation in which the cover of shrubs and trees in the canopy is over 80% and in which shrub cover exceeds that of trees. Shrubs are woody plants less than 10cm dbh.

Wetland Scrub

Shrubs growing on permanently wet or boggy substrate.

Wetland

Non-woody vegetation (eg. raupo, flax, sedges) growing on very wet or permanently water-logged substrate. These sites often receive salt water during the larger tides (see tidal freshwater wetlands).

Pasture

Farmland dominated by introduced grasses.

Exotic Trees

Introduced trees, usually planted or self seeded from plantations.

Combinations of these terrestrial vegetation types are forest and scrub, forest and pasture, and scrub and pasture.

3.3 HABITAT MAPPING

The major estuarine and coastal habitats from Whanganui Inlet are displayed on eight A3 and two A4 sheets (maps 1-10, Fig 3). These maps also depict structures, human use, settlements and roading. Terrestrial vegetation classes are shown on three A3 half-tone sheets (terrestrial maps 1-3).

3.4 HABITAT AREA

Area of each marine habitat was determined using a planimeter and dot-grids on the ten 1:10000 habitat maps (Table 1).

The most common habitat type recorded from the estuary was eelgrass (859 ha) followed by fine sand flats (384 ha) and mobile sand flats (260 ha). Vegetation in the estuary was dominated by eelgrass (859 ha) followed by mixtures of sea rush *Juncus maritimus* and the jointed wire rush *Leptocarpus similis* (100 ha). The estuarine area covered by vegetation was 980.7 ha or 35.7% of the total estuarine area (Table 1). Eelgrass was most widespread in the northern inlet (792 ha), with only 7.8% or 67 ha located in the southern inlet. On the outer coast, the most dominant habitat was intertidal rock, followed by mobile sand beaches.

TABLE 1. Area and percentage area covered by various habitats in Whanganui Inlet.

HABITAT	HECTARES	PERCENTAGE AREA *
Rock Platforms	4.8	0.17
Boulders	4.7	0.17
Pebble/cobble	17.5	0.64
Mobile sand	269.9	9.82
Fine sand	384.5	14
Very fine sand	134.6	4.89
River sand	36.8	1.34
Mud	110.3	4.01
Highshore	35.4	1.30
Vegetation		
Eelgrass	859.4	31.27
Juncus maritimus	46.4	1.69
Leptocarpus similis	5.6	0.20
Schoenoplectus pungens	1.8	0.06
Sarcocornia quinqueflora	0.9	0.003
Samolus repens	1.9	0.07
Juncus/Leptocarpus	32.5	1.18
Leptocarpus/Juncus	15.8	0.57
Rush and herbfield combinations	0.8	0.003
Gracilaria	15.6	0.57
Total Vegetation	980.7	35.7
Subtidal area	768.8	27.98
Intertidal area	1979.3	72.03
Total Estuary	2747.9	100

* Percentage of total estuary.

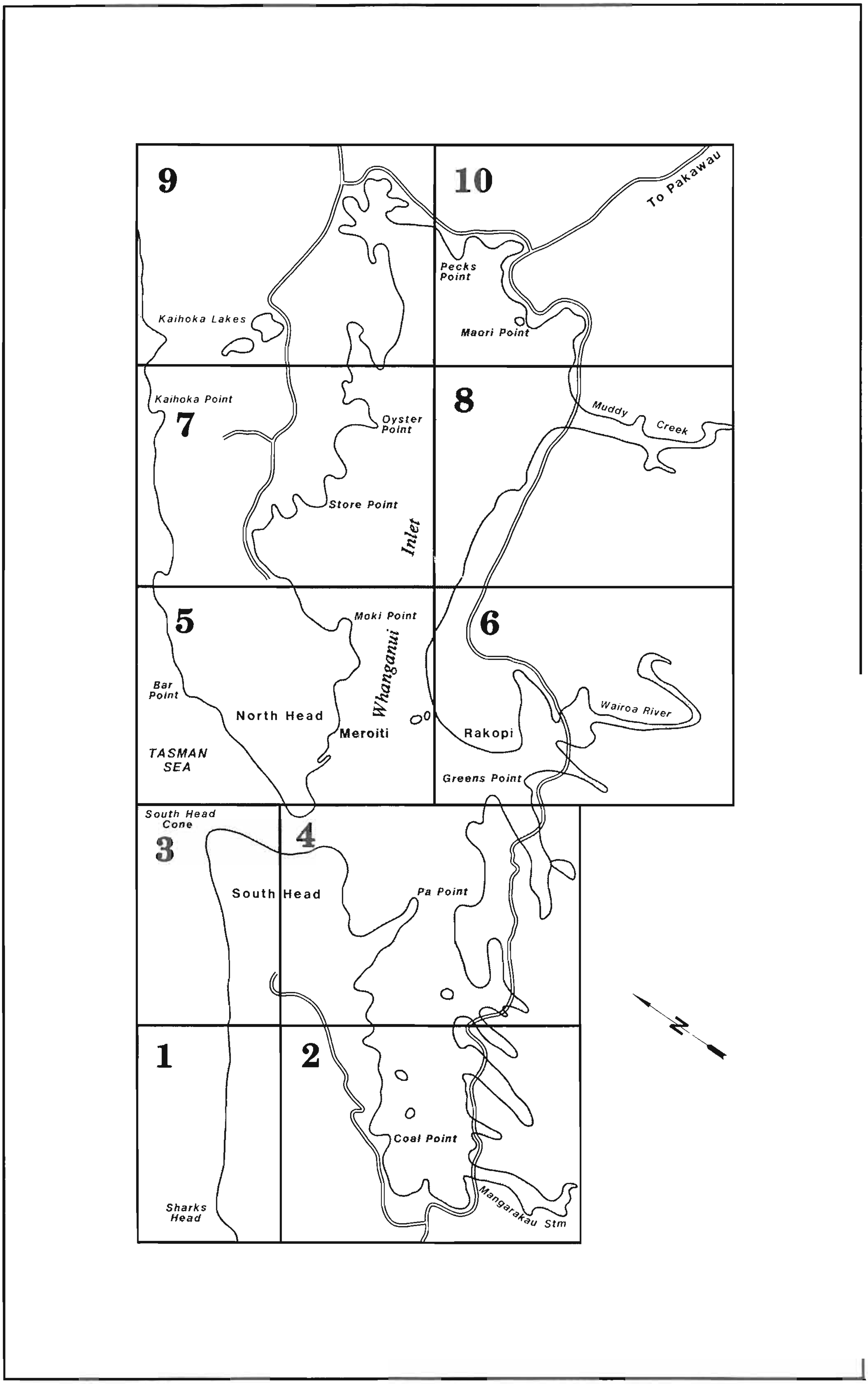


Fig. 3 MAP INDEX

HABITAT TYPES - WHANGANUI INLET

ESTUARINE SUBSTRATE

- Mobile Sand
- Fine Sand
- Very Fine Sand
- Mud
- River Sand
- Pebbles/Cobbles
- Highshore
- Boulders
- Intertidal Rock
- Subtidal, Pools & Rivers

ESTUARINE VEGETATION

Z	*Zostera muelleri*
J	*Juncus maritimus*
L	*Leptocarpus similis*
Sc	*Schoenoplectus pungens*
G	*Gracilaria sp*
S	*Sarcocornia quinqueflora*
Sm	*Samolus repens*

J/L — > 50% *Juncus*, < 50% *Leptocarpus*

L/J — > 50% *Leptocarpus*, < 50% *Juncus*

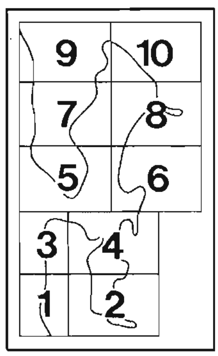
TERRESTRIAL VEGETATION

F	Forest
S	Scrub
WS	Wetland Scrub
W	Wetland
F+S	Forest & Scrub
F+P	Forest & Pasture
S+P	Scrub & Pasture
P	Pasture
Ex	Exotic Trees
Aa	Marram

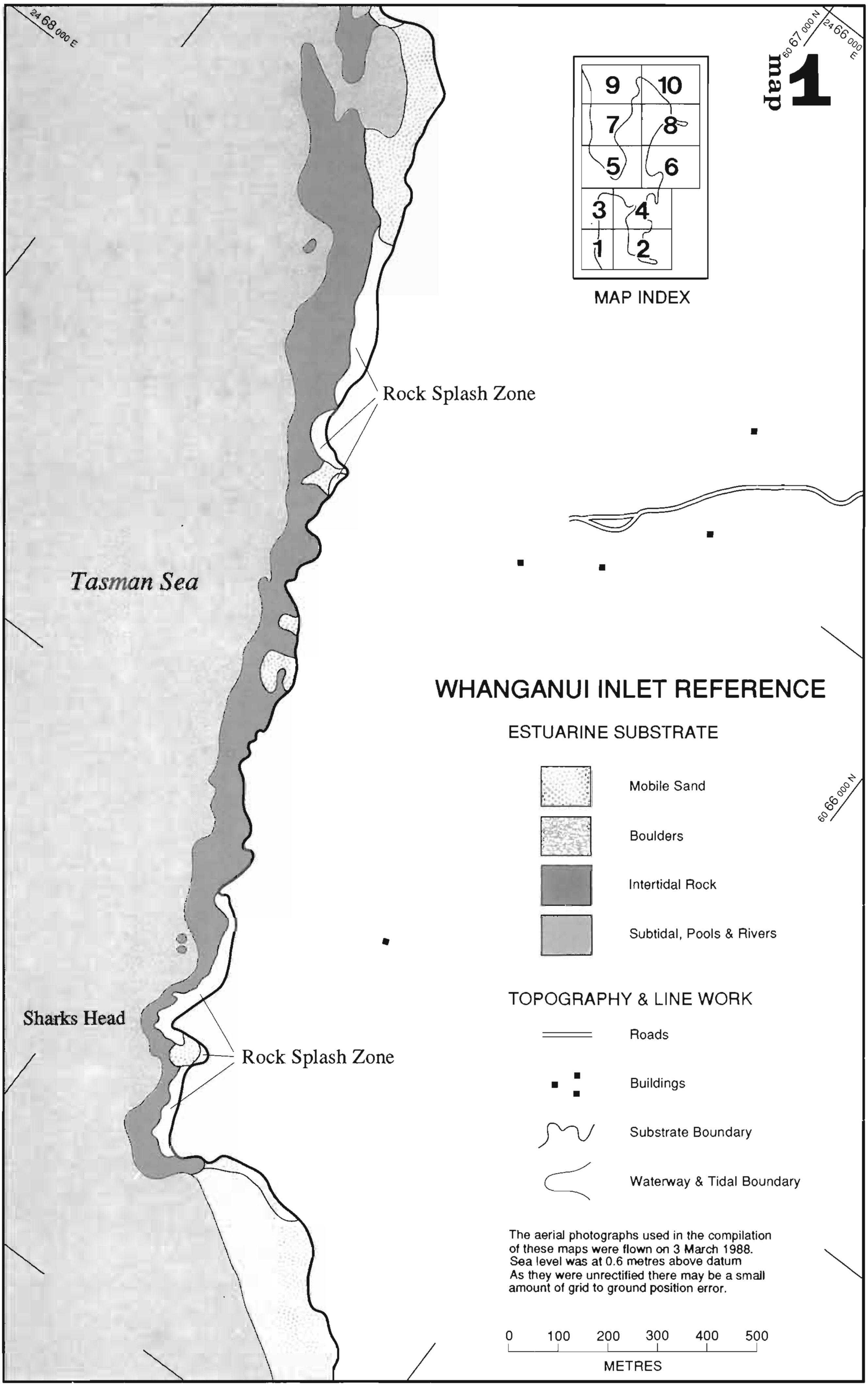
TOPOGRAPHY & LINE WORK

- Roads
- Buildings
- Cliffs
- Estuary Boundary
- Invertebrate Sample Sites (○ 10)
- Vegetation & Substrate Boundary
- Waterway & Tidal Boundary

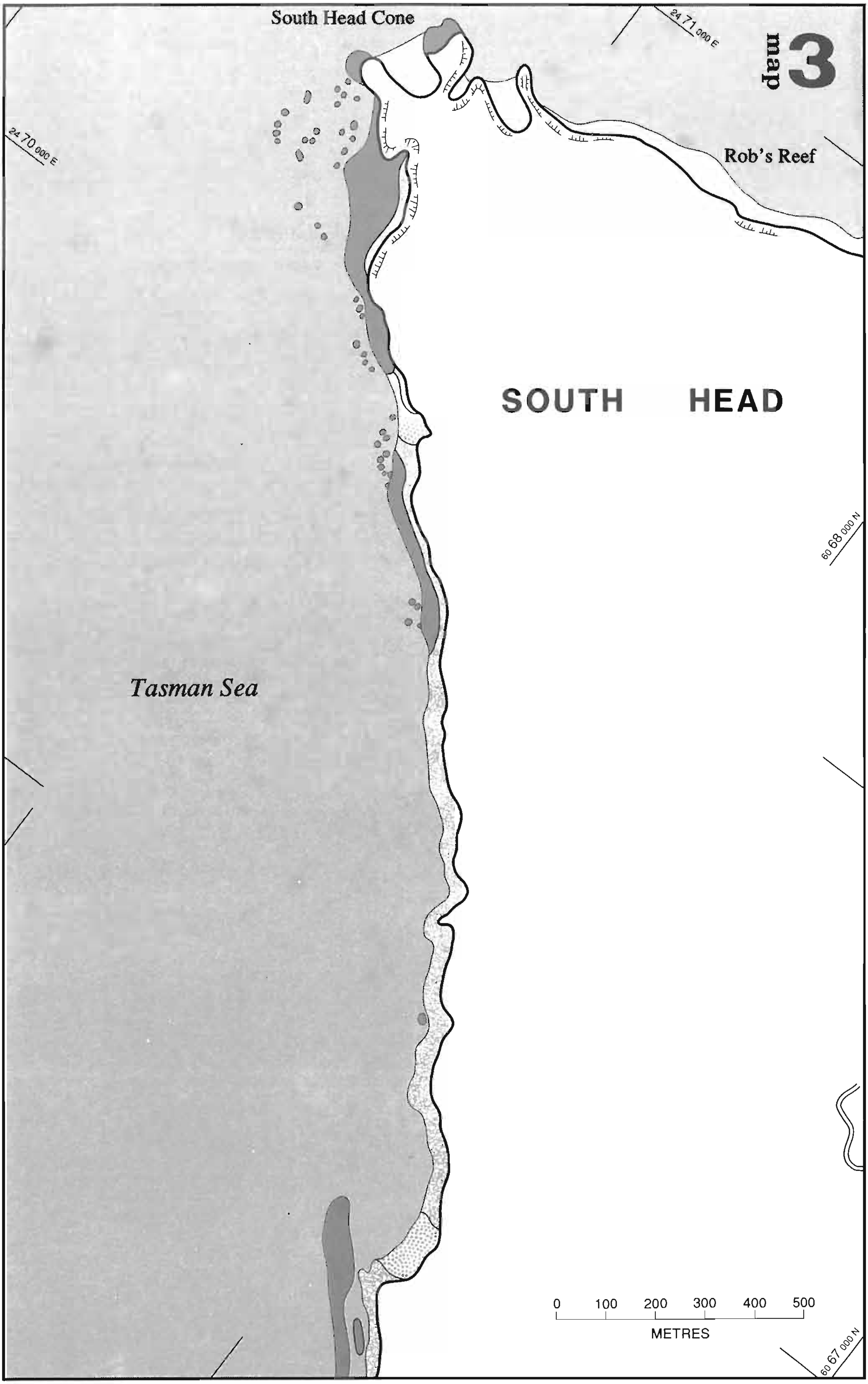
The aerial photographs used in the compilation of these maps were flown on 3 March 1988. Sea level was at 0.6 metres above datum. As they were unrectified there may be a small amount of grid to ground position error.



MAP INDEX

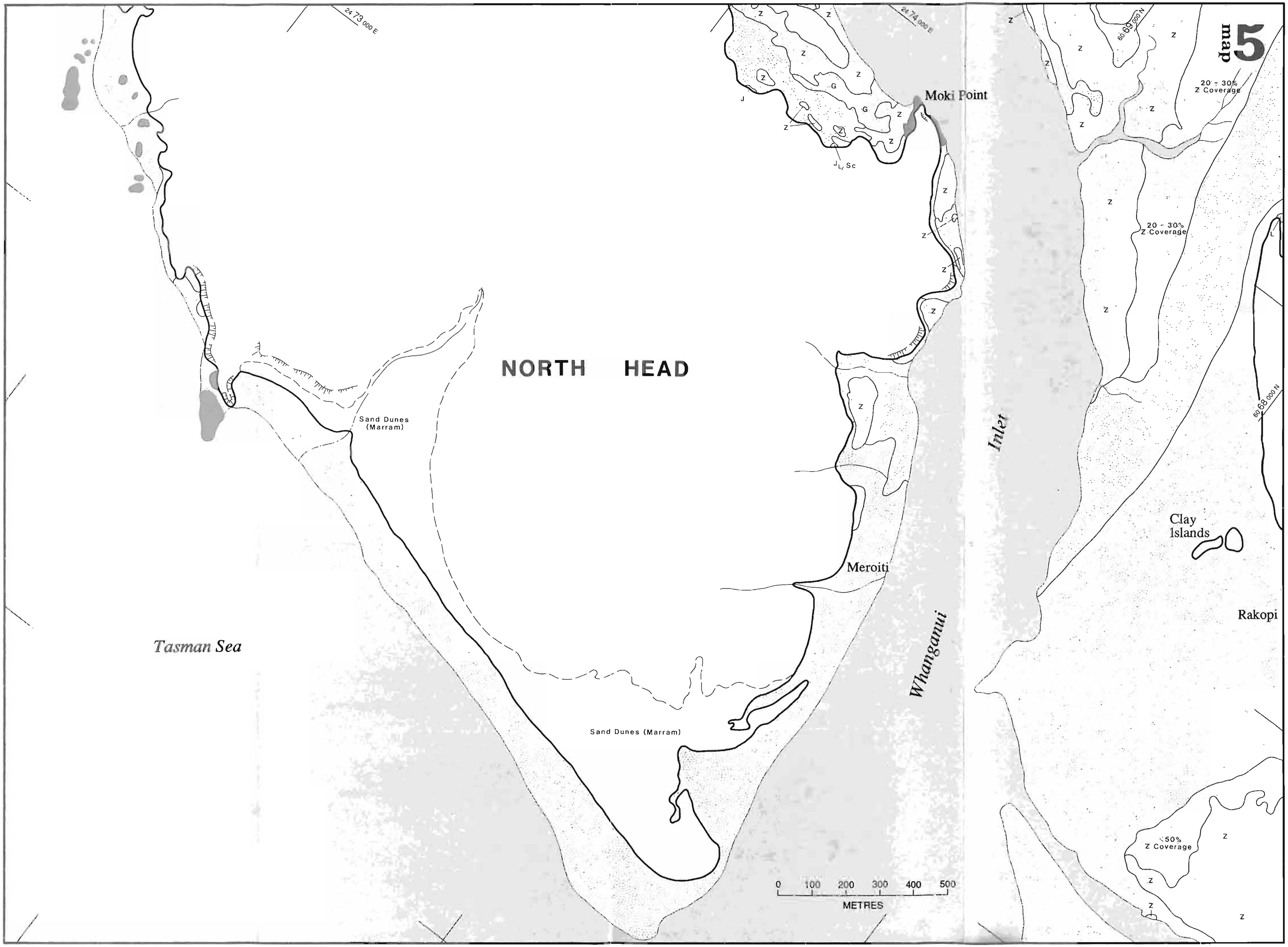

map 1
MAP INDEX
9
10
7
8
5
6
3
4
1
2
24 68 000 E
60 67 000 N
24 66 000 E
60 66 000 N
Rock Splash Zone
Tasman Sea
Sharks Head
Rock Splash Zone
WHANGANUI INLET REFERENCE
ESTUARINE SUBSTRATE
Mobile Sand
Boulders
Intertidal Rock
Subtidal, Pools & Rivers
TOPOGRAPHY & LINE WORK
Roads
Buildings
Substrate Boundary
Waterway & Tidal Boundary
The aerial photographs used in the compilation of these maps were flown on 3 March 1988. Sea level was at 0.6 metres above datum As they were unrectified there may be a small amount of grid to ground position error.
0 100 200 300 400 500
METRES

map 2
Whanganui Inlet
Island Creek
Muller Creek
Dry Road
Wharf
Te Hapu Road
Coal Point
Mangarakau Stream
Mangarakau Drain
Coal Creek
Rubbish Dump
24 70 000 E
24 71 000 E
60 64 000 N
60 63 000 N
0 100 200 300 400 500
METRES



map 3
South Head Cone
24 71 000 E
24 70 000 E
Rob's Reef
SOUTH HEAD
60 68 000 N
Tasman Sea
0 100 200 300 400 500
METRES
60 67 000 N

map 4
SOUTH HEAD
Whanganui Inlet
Pa Point
Westhaven Inlet Scenic Reserve
Dry Road
Bone Creek
Freshwater Lagoon
Banjo Creek
24 72 000 E
24 73 000 E
60 65 000 N
60 64 000 N
0 100 200 300 400 500
METRES

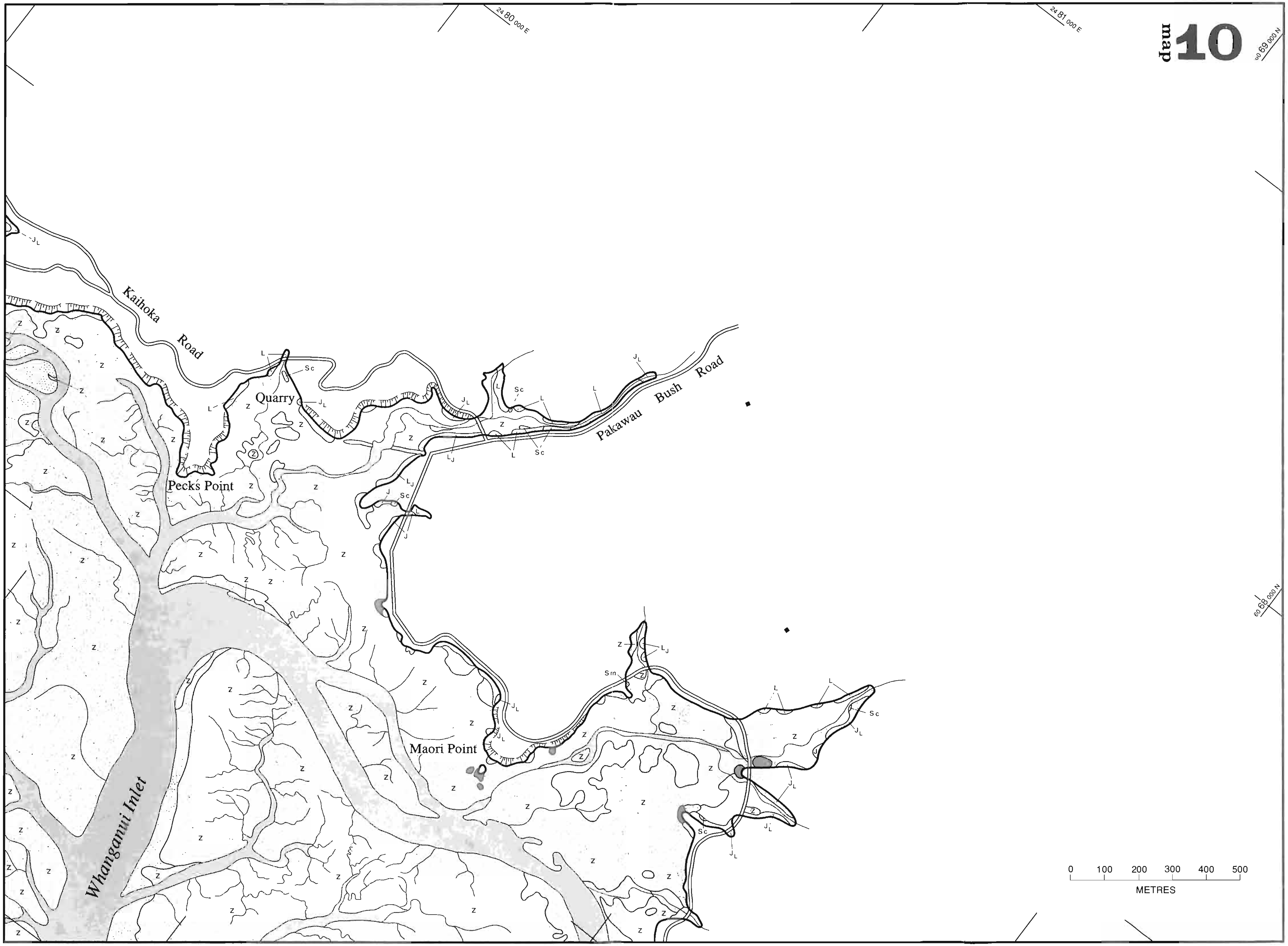

map 5
NORTH HEAD
Moki Point
Sand Dunes (Marram)
Sand Dunes (Marram)
Meroiti
Tasman Sea
Whanganui
Inlet
Clay Islands
Rakopi
20 - 30% Z Coverage
20 - 30% Z Coverage
50% Z Coverage
24 73 000 E
24 74 000 E
60 69 000 N
60 68 000 N
0 100 200 300 400 500
METRES


map 6
24 75 000 E
24 76 000 E
24 77 000 E
60 66 000 N
60 65 000 N
Tidal Wetland
Tidal Wetland
Tidal Wetland
4 WD Track
Logging Road
Rakopi
Dry Road
Private Road
Greens Point
Westhaven Inlet Scenic Reserve
Wairoa River
<50% Z Coverage
0 100 200 300 400 500
METRES


map 7
Kaihoka Point
Grey Cliff
Tasman Sea
Limestone Road
Oyster Point
Store Point
Whanganui Inlet
24 75 000 E
24 76 000 E
0 100 200 300 400 500
METRES
<50% Z Coverage
20 - 30% Z Coverage


map 8
Whanganui Inlet
Dry Road
Muddy Creek
White Pine Creek
60 - 80% Z Coverage
50% Z Coverage
20 - 30% Z Coverage
0 100 200 300 400 500
METRES


map 9
Nguroa Road
Kaihoka Road
Limestone Road
Tasman Sea
Kaihoka Lakes
24 77 000 E
24 78 000 E
24 79 000 E
60 72 000 N
60 71 000 N
0 100 200 300 400 500
METRES


map 10
24 80 000 E
24 81 000 E
60 69 000 N
60 68 000 N
Kaihoka Road
Quarry
Pecks Point
Pakawau Bush Road
Maori Point
Whanganui Inlet
0 100 200 300 400 500
METRES

TERRESTRIAL VEGETATION

TERRESTRIAL VEGETATION

TERRESTRIAL VEGETATION

HABITAT TYPES - WHANGANUI INLET

ESTUARINE SUBSTRATE

- Mobile Sand
- Fine Sand
- Very Fine Sand
- Mud
- River Sand
- Pebbles/Cobbles
- Highshore
- Boulders
- Intertidal Rock
- Subtidal, Pools & Rivers

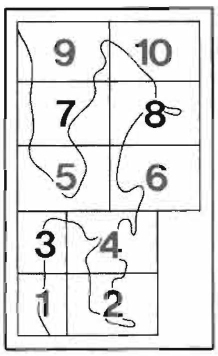
ESTUARINE VEGETATION

Z	*Zostera muelleri*
J	*Juncus maritimus*
L	*Leptocarpus similis*
Sc	*Schoenoplectus pungens*
G	*Gracilaria sp*
Sq	*Sarcocornia quinqueflora*
Sm	*Samolus repens*
J/L	> 50% *Juncus* < 50% *Leptocarpus*
L/J	> 50% *Leptocarpus* < 50% *Juncus*

TOPOGRAPHY & LINEWORK

- Roads
- Buildings
- Cliffs
- Estuary Boundary
- Invertebrate Sample Sites
- Vegetation & Substrate Boundary
- Waterway & Tidal Boundary

The aerial photographs used in the compilation of these maps were flown on 3 March 1988. Sea level was at 0.6 metres above datum As they were unrectified there may be a small amount of grid to ground position error.



MAP INDEX

4. FLORA AND FAUNA

4.1 INVERTEBRATES

Ecological estuarine studies traditionally investigate benthic invertebrate faunas (Knox, 1974; Bolton and Knox, 1977; Knox et. al., 1977; Kilner and Akroyd, 1978; Knox and Bolton, 1978; Knox et. al., 1978; Knox, 1983; Moffat, 1989; Davidson and Moffat, 1989). 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 (Knox, 1983; Rosenberg, 1978). The abundance of particular species may also suggest relatively high levels of pollution (Hicks, 1974; Rosenberg, 1976; Pearson and Rosenberg, 1978; Knox and Fenwick, 1981). Benthic invertebrates are also an important part of the food chain and a source of food to higher trophic levels including fish, birds and man.

4.1.1 SAMPLING METHODS AND ANALYSES

Intertidal Sampling
Invertebrates were sampled from 42 intertidal sites in Whanganui Inlet from 4-31 January, 1989 (Fig.1, Table 2). A minimum of two sample sites (excluding very fine sand, highshore, *Gracilaria* which were sampled at one site) were sampled in each major habitat type (Table 3).

Where possible, 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. Material remaining in the sieve was stored in 300 ml plastic pottles containing 140 mls of 80% isopropyl alcohol (IPA) for later sorting, counting and identification.

At rock platform, boulder and cliff sites, five random quadrats (250 x 250 mm) were investigated. The number of organisms living within each quadrat were recorded. Approximately 10 minutes were spent at all sites searching for rare or widely distributed invertebrates. Their presence and approximate abundance were noted.

Subtidal Sampling
Eight subtidal sites were core sampled in Whanganui Inlet (Fig.1, Table 2). Sites were sampled in the main channels (n=7) and in a secondary channel near Oyster Point (map 7). At each subtidal sample site, five 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 ensuring no water loss. Samples were sieved on the same day through 1.0 mm mesh and the material remaining in the sieve preserved in 80% IPA for later identification and counting.

Subtidal Transects
Subtidal rocky habitats were investigated in the entrance area of Whanganui Inlet using SCUBA equipment. Three transects measuring between 20 and 100 metres in length were established perpendicular from the South Head face. Substrate, depth and dominant plant and animal assemblages were recorded every five metres. All subtidal transects were recorded within one hour of low water between 10-12 January, 1989.

Cockle Sampling
Cockles, *Chione stutchburyi* collected from intertidal and subtidal benthic invertebrate core samples were counted and measured (Appendix 3).

Statistical Analyses
Statistical analyses of invertebrate data were run on a MAC microcomputer using a variety of BASIC computer programmes designed or adapted by J.D.Stark (Cawthron Institute, Nelson). Two types of data analyses were used to compare benthic invertebrate species composition for the 50 sites in Whanganui Inlet. Cluster analyses were based on programmes supplied by Professor W.Stephenson, University of Queensland, Australia. Data averaged from five replicate core samples were transformed using Log_{10} (x+1) transformation and clustered using the Bray-Curtis dissimilarity index of group average clustering strategy (Clifford and Stephenson, 1975). These analyses progressively grouped most similar species composition and abundances, and were graphically displayed in a dendrogram (Appendix 4).

A Pseudo F-test was used to determine which benthic invertebrate taxa contribute most strongly to each group, as determined by the Bray-Curtis Index. This test, although not fulfilling all the assumptions of a true F-test, allowed characteristic species for each group of sample sites to be determined. This test also determined the relative importance of each species within each group (Appendix 4).

4.1.2 RESULTS AND DISCUSSION

One hundred and sixty three invertebrate species were recorded from Whanganui Inlet (Table 4). Mollusca (shellfish, snails) dominated the fauna with 72 species followed by Crustacea (crabs, lice, sandhoppers; 45 species), Polychaeta (worms: 26 species), 5 Echnodermata (starfish, kina), 4 Anthozoa (anemones), numerous Porifera (sponges), 3 Insecta, 1 Nemertina, 1 Turbellaria (flat worm), 1 Hydroid and 2 species of Sipunculida.

Thirty three species of invertebrate were recorded only from subtidal sites (Table 4). Common subtidal species included Cook's turban *(Cookia sulcata)*, tiger shell *(Mauria tigris)*, nudibranchs (6 species), morning star *(Tawera spissa)*, brittle star *(Pectinura maculata)* and sea cucumber *(Stichopus mollis)*. Visual records of invertebrate fauna from rock habitats suggested a diverse faunal assemblage. It is probable that the fauna from subtidal rock habitats is far more diverse than these preliminary results suggest.

TABLE 2. List of Invertebrate Sample Sites.

---

1. Te Hapu Road: Highshore
2. Te Hapu Road: *Schoenoplectus* (high tide)
3. Te Hapu Road: *Leptocarpus* (high tide)
4. Te Hapu Road: *Juncus* (high tide)
5. Coal Creek: Mud (low tide)
6. Muller Creek: Mud (mid-tide)
7. Mangarakau Channal: Subtidal
8. Mangarakau: *Zostera* (low tide)
9. Mangarakau: Fine sand (low tide)
10. Island Creek Peninusla: subtidal
11. Pa Point Wharf: Fine sand (low tide)
12. Pa Point: Cliff (mid-tide)
13. Pa Point: Subtidal
14. Pa Point: Rock platform (mid-tide)
15. Reserve Peninsula: *Zostera* (low tide)
16. Reserve Peninsula: Fine sand (low tide)
17. Pa Point: Fine sand (mid-tide)
18. Pa Point: *Gracilaria* (low tide)
19. South Head: Boulders (low tide)
20. South Head: Cliff (low tide)
21. South Head: Subtidal
22. North Head: Mobile sand (mid-tide)
23. Rakopi: Mobile sand (low tide)
24. Rakopi: *Zostera* (mid-tide)
25. Wairoa River: Fine river sand (mid-tide)
26. Rakopi Salt Marsh: *Juncus* (high tide)
27. Moki Point: Boulders (mid-tide)
28. Moki Point: Cliff (mid-tide)
29. Moki Point: Rock Platform (mid-tide)
30. Moki Point: Subtidal
31. Store Point: Pebble/Cobble (mid-tide)
32. Oyster Point: *Zostera* (low tide)
33. Oyster Point: Cliff (mid-tide)
34. Oyster Point: *Zostera* (low-tide)
35. Oyster Point: Subtidal
36. Northern Channel: Fine sand (low tide)
37. Northern Channel: Subtidal
38. Northern Channel: Mudstone reef (low tide)
39. Pecks Point: *Zostera* (low tide)
40. Quarry: Pebble/cobble (mid-tide)
41. Pecks Point: Fine sand (mid-tide)
42. Nguroa Road: Mud (high tide)
43. Nguroa Road: *Leptocarpus* (high tide)
44. Nguroa Road: *Zostera* (mid-tide)
45. Muddy Creek: Subtidal
46. Pakawau Road: *Zostera* (mid-tide)
47. Maori Point: Cliff (mid-tide)
48. Ongawanga Creek: *Schoenoplectus* (high tide)
49. Ongawanga Creek: Mud (mid-tide)
50. Muddy Creek: Fine river sand (mid-tide)

T1. Southhead Cone (subtidal)
T2. Rob's Reef (subtidal)
T3. Rob's Reef (subtidal)

Table 3. Summary of invertebrate sample sites from Whanganui Inlet.

HABITAT	NUMBER	SITE NUMBER
Rock Platform	3	14, 29, 28
Cliff	5	12, 20, 28, 33, 47
Boulder	2	19, 27
Pebble/Cobble	2	31, 40
Mobile Sand	2	22, 23
Fine Sand	5	11, 16, 17, 36, 41
Very Fine Sand	1	9
River Sand	2	25, 50
Mudflat	4	5, 6, 42, 49
Highshore	1	1
Zostera (eelgrass)	8	8, 15, 24, 32, 34, 39, 44, 46
Gracilaria (Agar weed)	1	18
Native Rushes and Sedge	6	2, 3, 4, 26, 43, 48
Subtidal (sand, shell fragments)	8	7, 10, 13, 21, 30, 35, 37, 45
Subtidal (rock boulder cliff)	3	Transects 1, 2, 3

Table 4. Species List of Benthic Invertebrates From Whanganui Inlet

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

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

In the following list the feeding type is recorded:

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

Invertebrate	Common Name	Feeding Group	Habitat
Phylum Porifera (Sponges)			
Ancorina alata		Sus	Sub
Aplysilla sulfurea	Sulfur sponge	Sus	Sub
Unidentified spp.			Sub
Phylum Coelenterata (Cnidaria)			
Class Hydrozoa			
Unidentified sp.		C	Sub
Class Anthozoa (Sea Anemones)			
Actinea tenebrosa	Red waratah	C	R
Anthopleura aureoradiata	Mudflat anemone	C	P/C, M
Isoactinea olivacea	Green anemone	C	
Isocradactis magna	Sand amenone	C	
Phylum Platyhelminthes (Flatworms)			
Class Turbellaria (Free-living Flatworms)			
Notoplana sp.	Estuarine flatworm	C	R
Phylum Nemertina (Proboscis Worms)			
Unidentified sp.		C	S, M
Phylum Sipunculida (Acorn Worms)			
Unidentified sp.#1		D	S
Unidentified sp.#2		D	S

Invertebrate	Common Name	Feeding Group	Habitat
Phylum Mollusca (Molluscs)			
Class Amphineura (Chitons)			
Acanthochiton zelandica	Tufted chiton	H	M
Amaurochiton glaucus	Green chiton	H	R
Chiton pelliserpentis	Snakeskin chiton	H	R
Cryptoconchus porosus	Butterfly chiton	H	R
Eudoxochiton nobilis		H	Sub
Ischnochiton maorianus		H	R
Notoplax cuneata		H	S
Terenochitin inquinatus		H	Sub
Unidentified sp.		H	R
Class Gastropoda (Univalve Molluscs)			
Astraea heliotropium	Saw shell	H	Sub
Amphibola crenata	Mudflat snail	D	M
Austrofucus chathamensis	Whelk	C	S
Buccinulum vittatum	Lined whelk	C	R
Cantharidella tesselata	Topshell	H	Sub
Charonia capax	Trumpet shell	C	Sub
Cellana ornata	Ornate limpet	H	R
Cellana radians	Radiate limpet	H	R
Cominella adspersa	Whelk	C	R
Cominella glandiformis	Mudflat whelk	C	M
Cominella maculosa	Spotted whelk	C	M, R
Cookia sulcata	Cook's turban	H	Sub
Diloma nigerrima	Black topshell	H	R
Diloma subrostrata	Mudflat topshell	H	M,S,Z
Duplicaria tristis	Spire shell	H	S
Haliotis iris	Paua	H	R
Haminoea zelandiae	Bubble shell	D, C	Z
Haustrum haustorium	Whelk	C	R
Lepsiella scobina	Oyster borer	C	R
Littorina cincta	Brown periwinkle	H	R
Littorina unifasciata	Banded periwinkle	H	R
Maoricolpus roseus	Turret shell	H	S
Mauria tigris	Tiger shell	H	Sub
Mauria multigemmata		H	Sub
Mauria pellucida pellucida		H	Sub
Melagraphia aethiops	Spotted topshell	H	R,Z
Micrelenchus tenebrosus	Topshell	H	Z
Notoacmea helmsi	Estuarie limpet	H	Z,M
Onchidella nigricans	Shell-less snail	D	R
Ophicardellus costellaris	Snail	H, D	Veg
Potamopyrgus estuarinus	Estuarine snail	D	Veg
Risellopsis varia		H	R
Scutus breviculus	Ducksbill Limpet	H	R
Sigapatella novaezelandiae	Slipper shell	H	R
Siphonaria zelandica	Limpet	H	R
Thias orbita	White rock shell	C	R
Turbo smargdus	Cats-eye	H	R

Invertebrate	Common Name	Feeding Group	Habitat
Xenophalium pyrum	Helmit shell	C	Sub
Zeacumantus lutulentus	Spire shell	H	M,Z
Zeacumantus subcarinatus	Small spire shell	H	Z,R
Order Nudibranchia (true Sea-slugs)			
Archodoris wellingtonensis		C	Sub
Aphelodoris luctosa		C	Sub
Atagema carimata		C	Sub
Dendrodoris citrina		C	Sub
Glossodoris aureomarginata		C	Sub
Unidentified sp.		C	Sub
Class Pelecypoda (Bivalves)			
Atrina zelandica	Horse mussel	Sus	Sub
Aulacomya ater maoriana	Ribbed mussel	Sus	R
Chione stutchburyi	Cockle	Sus	S,M,Z
Gari lineolata	Pink sunset shell	D	Sub
Gari strangeri	Purple sunset shell	D	Sub
Leptomya retiaria		D	Z
Mactra ovata	Trough shell	Sus	M
Nucula hartvigiana	Nut shell	D	S,Z
Ostrea lutaria	Oyster	S	R, Sub
Paphies australis	Pipi	Sus	S,Sub
Perna canaliculus	Green lipped mussel	Sus	R
Solemya parkinsoni	Razer shell	Sus	M
Tawera spissa	Morning star	Sus	Sub
Tellina liliana	Wedge shell	D	S, M
Venerupis largillierti		Sus	Z
Xenostrobus fluviatus	Brackish mussel	Sus	Wood
Xenostrobus pulex	Little black mussel	Sus	R
Class Cephalopoda			
Octopus maorum	Octopus	C	Sub
Phylum Annelida (Segmented Worms)			
Class Polychaeta (Marine Worms)			
ERRANTIA			
Family Eunicidae			
Lumbrinereinae sp.		C	Z
Family Glyceridae		C	Z,Sub,
Glycera americana			
Glycera lamellipodia			
Family Nereidae (Rag Worms)			S,M,Z
Nereis falcaria		C	
Nicon aestuariensis		D	
Perinereis nuntia var.brevicirris		C	
Perinereis nuntia var.vallata		C	
Family Phyllodocidae (Paddle Worms)			
Eulalia microphylla		C,Sca	R

Invertebrate	Common Name	Feeding Group	Habitat
SEDENTARIA			
Family Capitellidae			
Capitella capitata		D	M
Heteromastus filiformis		D	S, M
Family Cirratulidae			
Family Maldanidae			
Asychis theodori		D	S
Axiothella quadrimaculata		D	S
Family Orbiniidae			
Haploscoloplos cylindrifer		D	S, M
Orbinia papillosa		D	S, M
Family Opheliidae			
Amandia maculata		D	S
Travisia olens		D	S
Family Oweniidae			
Owenia fusiformis		D	Z
Family Pectinariidae (Sand Mason Worms)			
Pectinaria australis		D	M,S
Family Serpulidae (Fan Worms)			
Pomatocercos caeruleus		Sus	R
Family Scalibregmidae			
Scalibregma sp.		D	Z
Family Spionidae			
Polydora polybranchia		Sus	Shell
* *Prionospio pinnata*		D	S, M
Scolecolepides sp.		D	Veg
Spirorbis sp.		Sus	Sub
Family Terebellidae			
Thelepis sp.			
Phylum Arthropoda			
Class Cirripedia (Barnacles)			
Elminius modestus	Estuarine barnacle	Sus	P/C
Epopella plicata		Sus	P/C
Class Malacostraca			
Order Mysidacea (Shrimps)			
Order Amphipoda (Sand Hoppers)			
Eorchestia sp.			S,M
Gammaropsis aff. *tawahi*			Sub
Melita festiva			Sub
Melita sp.		Sub	
Oedicerotidae sp.#1			Sub
Paramoera sp. aff. *chevreuxi*			M
Parawaldeckia thomsoni			Sub
Parawaldeckia sp.			Sub
Phoxocephalidae sp.#1			M
Phoxocephalidae sp.#2			Sub
Phoxocephalidae sp.#3			Sub

Invertebrate	Common Name	Feeding Group	Habitat
Phoxocephalidae sp.#4			Sub
Phoxocephalidae sp.#5			M,S
Waitangi chelatus			Sub
Order Isopoda (Sea Lice)		Scav,C	
Anthuridae sp.#1			Sub
Anthuridae sp.#2			Sub
Anthuridae sp.#3			Sub
Exosphaeroma planulum			Veg
Isocladus armatus		Scav	S,Sub
Ligia novaezelandica			R
Natatolana sp.#1		Para	Sub
Natatolana sp.#2		Para	Sub
Pseudaega punctata			S
Order Decapoda (Decapods)			
Callianassa filholi	Snapping shrimp	Sus	S
Cancer novaezelandiae	Pie-crust crab	C	Sub
Cyclograpsus lavauxi	Smooth-shore crab	C	R
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	R
Hemigrapsus edwardsi	Purple crab	C	R
Heterozius rotundifrons	Pebble crab	H	R
Jasus edwardsii	Crayfish	C	Sub
Leptograpsus variegatus	Shore crab	C,H	R
Macropthalmus hirtipes	Stalk-eyed crab	D	M,S
Ovalipes catharus	Paddle crab	C	Sub
Palaemon affinus	Estuarine prawn	D	Sub
Pagurus spinulimanus	Hermit crab	D	Sub
Paratya curvirostris	Freshwater shrimp		Sub
Petrolisthes elongatus	Half crab	Sus	R
Plagusia chabrus	Reef crab	H	Sub
Pinnotheres novizelandiae	Pea crab	Parasitic	
Upogebia hirtifrons	Burrowing shrimp	Sus	M
Class Insecta			
Dipteran larvae sp.#1	Larval fly	D	M
Dipteran larvae sp.#2	Larval fly	D	Veg
Philanisus plebejus	Marine caddis larvae	H	Veg
Phylum Echinodermata			
Patiriella regularis	Starfish	C	S,Sub
Coscinasterias calimara	11 arm starfish	C	Sub
Evichinus chloraticus	Kina	H	Sub
Pectinura maculata	Brittle star	D	Sub
Stichopus mollis	Sea cucumber	D	Sub

4.1.3 INVERTEBRATE COMMUNITIES

Fourteen major habitats were sampled in Whanganui Inlet (chapter 3). Within each habitat, a characteristic group of invertebrates were recognised using the Bray-Curtis Dissimilarity Index (Appendix 4). Each group often contained more than one habitat type. This suggests that different habitat types often contained similar faunal communities. In the following section, invertebrate communities associated with single or multiple estuarine habitat types are discussed.

Rock, Cliff and Boulder

These habitat types are rare in the estuaries of the Nelson/Marlborough Region. In Whanganui Inlet, rock platforms, cliffs and boulders form a dominant part of the landscape. Most of these habitats are located in the entrance area: Pa, Moki, Oyster, Store, Pecks, and Maori Points, and along Westhaven Scenic Reserve. Cliffs often rise directly out of the estuary, while in some locations time and weather has broken down cliffs forming boulder areas. At many of the headland areas in Whanganui Inlet rock platforms have formed. The largest rock platforms are located at Moki, Pa and Oyster Points.

A total of 60 species of invertebrate were recorded from intertidal rock, cliff and boulder habitats (Table 5). This was the most for any habitat in Whanganui Inlet.

The fauna was dominated by Mollusca (33 species), followed by Crustacea (9 species), Polychaeta (3 species), 3 species of anemone, a sipunculid and 2 species of echinoderm, *Evichinus chloraticus* (kina) and *Patiriella regularis* (cushion star) (Appendix 5). The dominance of Mollusca was primarily due to the presence of 13 coastal invertebrate species. The highest number of invertebrate species were recorded from sites in the entrance (27 species) and Pa and Moki Points. Number of species declined as distance from the entrance increased (Appendix 5). Species of invertebrate characteristic of rock platform, cliff and boulder habitats include the dark rock shell *Haustrum haustorium*, blue and ribbed mussel *Mytilus edulis aoteanus* and *Aulacomya ater maoriana*, oyster *Ostrea lutaria* and band periwinkle *Littorina unifasciata* (Table 6). Only the cats-eye, *Turbo smaragdus* was recorded from all rock, cliff and boulder sample sites. The combined number of invertebrates from the rock, cliff and boulder habitats ranged from 902-4820 per m^2.

Pebble and Cobble

In Whanganui Inlet, pebble and cobble areas are uncommon with most situated above mid-tide. The invertebrate fauna associated with the pebble and cobble habitat was relatively poor (20 species) (Table 5, Appendix 6). Invertebrate densities were between 1142 and 1945 individuals per m^2. Invertebrates characteristic of the pebble/cobble habitat included the mud crab *Helice crassa*, estuarine limpet *Notoacmea helmsi* and the spotted topshell *Melagraphia aethiops* (Table 6).

Mobile Sand

Large areas of mobile sand are located on the north head of the entrance and along the Rakopi sand flats. Few invertebrates were found on these expansive sand flats. Of the two sites sampled, only one had any invertebrates, these totalled 7 species and 134 individuals per m^2 (Table 5, Appendix 7). These invertebrates were the cockle *Chione stutchburyi*, paddle worm nereidae, 3 species of amphipod and sea lice *Isocladus armatus* and *Waitangi chelatus*.

Mobile sandflats in Whanganui 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 and Fenwick, 1986).

Fine Sand, Very Fine Sand, *Gracilaria* and Eelgrass

Eelgrass beds dominate the tidal flats in the northern inlet, while eelgrass, fine sand and very fine sand flats dominate the tidal flats in the southern inlet.

Small patches of *Gracilaria* (agar weed) are located near Moki Point and Pa Point. In Whanganui Inlet, eelgrass *(Zostera muelleri)* grows on fine sand and mud substrates and often grows right to the edge of the native rush and sedge habitat. *Zostera* grows best where salinities are relatively high and towards the low tide level.

The invertebrate fauna associated with eelgrass, agar weed, fine sand and very fine sand flats were grouped together by the Bray-Curtis Dissimilarity Index (Appendix 4). The index suggested that the majority of benthic invertebrates recorded from *Zostera* were also present in similar densities in fine and very fine sandflats. These areas in Whanganui Inlet, although mapped separately had very similar benthic invertebrate communities and are therefore discussed together in this section.

Forty two species of invertebrate were recorded from *Zostera*, *Gracilaria*, fine and very fine sandflats in Whanganui Inlet (Table 5, Appendix 8). The benthos was dominated by Mollusca (17 species), followed by Polychaeta (12 species), Crustacea (10 species) and a sipunculid, anemone and cushion star. Invertebrates characteristic of these habitats included the cockle *Chione* (68-2524 per m^2), mudflat whelk *Cominella glandiformis* (1-181 per m^2), minute clam *Kellia cycladiformis* (23-758 per m^2), nut shell *Nucula hartvigiana* (0-1958 per m^2), hymenosomatid crabs (0-68 per m^2) and various polychaete species (0-475 per m^2) (Table 6). Invertebrates unique to these habitats in Whanganui Inlet included *Micrelenchus tenebrosus*, *Paramoera* sp. and *Natatolana* spp.

The mean number of species recorded for these habitats was the highest for any habitat group in Whanganui Inlet (20.3 species) (Table 5). This figure is nearly six times higher than the lowest average recorded from the mobile sand habitat. Results suggest that eelgrass, agar weed, fine sand and very fine sandflats support a diverse assemblage of invertebrates in high densities (1289-4830 per m^2). These communities are dominated by detritivores and herbivores, with only three species of predators *(Cominella glandiformis, C. adspersa, Patiriella regularis)*. Predatory fishes (snapper, flatfish, kahawai) and birds (godwit, oystercatcher, knots, pied stilt) may represent the most significant predatory influence in these areas.

River Sand

Based on invertebrate community differences river sand was distinguished from the fine sand habitat (Bray-Curtis Dissimilarity Index). The Wairoa River and Muddy Creek above their respective causeways, represent the two largest areas of this habitat. The invertebrate community recorded from river sand sites was characterised by few species (4-5 species) in relatively low densities (396-431 per m^2) (Table 5, Appendix 9). A sipunculid, maldanid worm *(Axiothella quadrimaculata)*, cockle (*Chione*) and mudflat crab *(Helice crassa)*, were recorded from all river sand sites. Although these species were also recorded from fine sand flat sites, 37 species recorded from sandflats in Whanganui Inlet were absent from river sand sites. The reasons for the lack of invertebrate species from river sand sites appear to be related to salinity and substrate.

Mudflat and High Tide Eelgrass

Mud is composed of silts and clays and is recognised by its glutinous nature and an underlying black anaerobic layer. In Whanganui Inlet, large areas of mud are covered by eelgrass and are therefore discussed under the eelgrass group. The remaining mudflats in the inlet are located in many of the embayments cut off by roading causeways in the south-western inlet (Maps 2,4).

Eelgrass in Whanganui Inlet often grows to the edge of salt marsh vegetation. The fauna associated with this high tide eelgrass was grouped with the mud habitat by the Bray-Curtis Dissimilarity Index (Appendix 4). High tide eelgrass and mud habitats are therefore discussed under the one heading in this section.

The fauna associated with high tide eelgrass and mud habitats was characterised by the mud crab *Helice* (17-57 per m^2), the polychaetes *Scolecolepides* and nereidae (34-555 per m^2), the minute clam *Kellia cycladiformis* (57-928 per m^2) and the mudflat snail *Amphibola crenata* (0-91 per m^2).

A total of 23 invertebrate species were recorded from both habitats, however, 7 species recorded from eelgrass were not found in mud substrates (Table 5, Appendix 10). Total invertebrate densities from these habitats were between 408-2406 per m^2. The invertebrate community from these sites were dominated by grazers and detritivores.

Native Rushes and Sedge

Two rush species *(Juncus maritimus, Leptocarpus similis)* and the sedge *Schoenoplectus pungens* stands were sampled in Whanganui Inlet. *Bolboschoenus caldwellii* another sedge species recorded from estuaries in the Tasman Bay area by Davidson and Moffat (1990) was not recorded from Whanganui Inlet in this present study. The introduced cord grass *Spartina anglica* was recorded from the inlet (Muddy Creek), however, this infestation was small and has now been eradicated.

Sixteen invertebrate species were recorded from the rush and sedge habitat in Whanganui Inlet (Table 5, Appendix 11). Gastropod snails were the most abundant group, represented by 7 species, followed by 6 species of detritus feeding crustaceans. Only 2 species of polychaete were present in rush and sedge sites. No recognisable differences in the abundance or presence of invertebrates between rush and sedge species were recorded.

Species of benthic invertebrate characteristic of this habitat were the mud crab *Helice crassa*, polychaetes *Scolecolepides*, nereidae, amphipods *Eorchestia* sp., larval fly, estuarine snail *Potamopyrgus estuarinus* and the mudflat snail *Amphibola crenata* (Table 6).

Subtidal (Sand and shell)

Two large subtidal channels stretching the entire length of Whanganui Inlet meet at the entrance before flowing into the Tasman Sea. Forty two invertebrates were recorded in these channels (Table 5, Appendix 12). Crustaceans dominated the benthos (15 species) followed by molluscs (14 species), polychaetes (9 species) and others (4 species). Many of the 42 species of invertebrate recorded from the subtidal habitat were not found intertidally in Whanganui Inlet. These truly subtidal species included the paddle crab *Ovalipes catharus*, pie-crust crab *Cancer novaezelandiae*, hermit crab *Pagurus spinulimanus*, clam *Tawera spissa*, chiton *Terenochiton inquinatus* and numerous amphipod species.

Between 4 and 16 species of invertebrate were present at each subtidal site in Whanganui Inlet. Number of species were lowest near the entrance where strong currents continually shift the benthic substrates making life difficult for most invertebrates (Davidson, 1989). At these sites mobile amphipods dominated the benthos.

Invertebrates characteristic of most subtidal sites in Whanganui Inlet include the chiton *Terenochiton inquinatus* (33-192 per m^2), polychaete *Spirorbis* (0-5795 per m^2), bivalves *Tawera spissa* (0-45 per m^2), pipi *Paphies australis* (0-815 per m^2), nutshell *Nucula hartvigiana* (0-498 per m^2) and sea lice, *Natatolana* sp. (0-68 per m^2) and *Isocladus armatus* (0-85 per m^2) (Table 6).

Samples from soft bottom environments in Whanganui Inlet produced the second highest number of species from any one habitat.

Subtidal (Rock)

Four subtidal rock habitats were recognised from the entrance area (including Rob's Reef) in Whanganui Inlet. Rock platform dominated shallow areas on the southern side of the entrance. Rock platforms were colonised with a variety of algal species (*Ulva, Lessonia, Carpophyllum*, numerous red algae)(Fig.4). Smooth sandstone-like substrate was recorded from transect 3 where relatively few animal and plant species were recorded. Red algae (eg. *Gigartina, Ceramium*), *Ulva* and coraline paint were the most common algae in this area. Boulder habitat was located at the foot of the south head cliffs (transect 1 and 2). Smaller substrates (sands, pebbles) have accumulated around the base of these boulders which are covered in numerous species of algae (up to 80% cover). Large numbers of kina (*Evichinus chloroticus*) were recorded on the tops of particular rock outcrops (Fig.4). Rock outcrops or ridges without kina were also covered with a dense cover of algae (Fig.4). In transects 1 and 2, rock walls and overhangs were colonised by sponges (eg. *Ancorina alata, Aplysilla sulfurea*), ascidians and numerous other encrusting organisms.

Table 5. Major taxonomic groups from each habitat in Whanganui Inlet.

Habitat	Number of Sites	Mean No. of Species		Crustacea	Mollusca	Polychaeta	Others	Total
Rock, Cliff, Boulder	10	18.5	(6.0)	9	3	3	6	60
Pebble/Cobble	2	15.5	(0.5)	3	9	8	0	20
Mobile Sand	2	3.5	(3.5)	5	1	1	0	7
Fine Sand, Very Fine Sand, Eelgrass and agar weed	13	20.3	(2.4)	10	17	12	3	42
River Sand	2	4.5	(0.5)	2	1	1	1	5
Mud and High Tide Eelgrass	6	11.2	(2.3)	6	8	7	2	23
Native Rushes and Sedge	7	6.7	(3.1)	5	7	2	2	16
Subtidal	8	10.4	(4.6)	15	14	9	4	42

Values in brackets represent standard deviations.

Table 6. Characteristic invertebrate fauna from each habitat group. Statistics based on Pseudo F-Test with a significance level of 5.0.

Habitat	Characteristic Species	Pseudo F-Test Significance Level	Number per m^2	Mean Number per m^2
Rock, Cliff, Boulder	*Haustrum haustorium* (dark rock shell)	0.64	0-6	1.5
	Mytilus edulis aoteanus (blue mussel)	1.57	0-1	0.4
	Ostrea lutaria (oyster)	1.57	0-1	0.4
	Aulacomya ater maoriana (ribbed mussel)	1.57	0-1	0.4
	Littorina unifasciata (banded periwinkle)	1.57	1-141	34.2
Native Rush and Sedge	*Helice crassa* (mud crab)	<0.01	23-71	47.8
	Scolecolepides sp. (polychaete)	<0.01	0-283	102.8
	(amphipod)	0.18	0-464	175.3
	Nereidae (ragworm)	0.21	0-136	30.2
	Dipteran larvae (fly)	0.35	0-23	7.5
	Potamopyrgus estuarinus (estuarine snail)	0.80	1-3656	1176.7
	Amphibola crenata (mudflat snail)	1.71	11-215	68.0
Fine Sand, Very Fine Sand and *Zostera* and *Gracilaria*	*Chione stutchburyi* (cockle)	<0.01	68-2524	1112.2
	Glycerid (polychaete)	<0.01	0-45	20.0
	Cominella glandiformis (mudflat whelk)	0.1	1-181	55.0
	Kellia cycladiformis (minute clam)	0.12	23-758	184.5
	Nereidea spp. (ragworm)	0.21	0-441	91.5
	Prionospio pinnata (polychaete)	0.21	11-475	161.2
	Phoxocephalidea spp. (amphipod)	0.22	0-136	40.1
	Nucula hartvigiana (nut shell)	1.99	0-1958	520.2
	Hymenosomatid (spider crab)	4.28	0-68	23.6

Cont/d ...

Table 6. (Cont.) Characteristic invertebrate fauna from each habitat group. Statistics based on Pseudo F-Test with a significance level of 5.0.

Habitat	Characteristic Species	Pseudo F-Test Significance Level	Number per m²	Mean Number per m²
Mudflat and Mid-High Tide *Zostera*	*Helice crassa* (mud crab)	<0.01	0-68	18.7
	Scolecolepides sp. (polychaete)	<0.01	34-543	275.3
	Kellia cycladiformis (minute clam)	0.12	57-928	415.0
	Nereidae (ragworm)	0.21	34-555	234.0
	Phoxocephalid (amphipod)	0.22	23-204	85.0
	Amphibola crenata (mudflat snail)	1.71	0-91	52.7
Pebble/Cobble	*Helice crassa* (mud crab)	<0.01	17-57	37.0
	Glycerid spp. (polychaete)	<0.01	11-37	24.0
	Notoacmea helmsi (estuarine limpet)	<0.01	74-79	76.5
	Melagraphia aethiops (spotted topshell)	0.02	11-373	192.0
	Nereidae (ragworm)	0.21	226-441	124.5
River Fine Sand Flats	*Helice crassa* (mud crab)	<0.01	23-57	40.0
	Sipunculid (acorn worm)	<0.01	45-113	79.0
Mobile Sand	None	-	-	-
Highshore	*Helice crassa* (mud crab)	-	34-	34
Subtidal	*Terenochiton inquinatus* (chiton)	<0.01	33-192	94.5
	Spirorbis sp. (spiral polychaete)	<0.01	0-5795	290.5
	Parawaldeckia thomsoni (amphipod)	0.07	0-96	41.0
	Tawera spissa (zigzag cockle)	0.21	0-45	18.3
	Natatolana spp. (isopod)	0.85	0-68	22.8
	Paphies australis (pipi)	1.36	0-815	209.5
	Nucula hartvigiana (nut shell)	1.99	0-498	209.5
	Isocladus armatus (isopod)	4.36	0-85	25.5

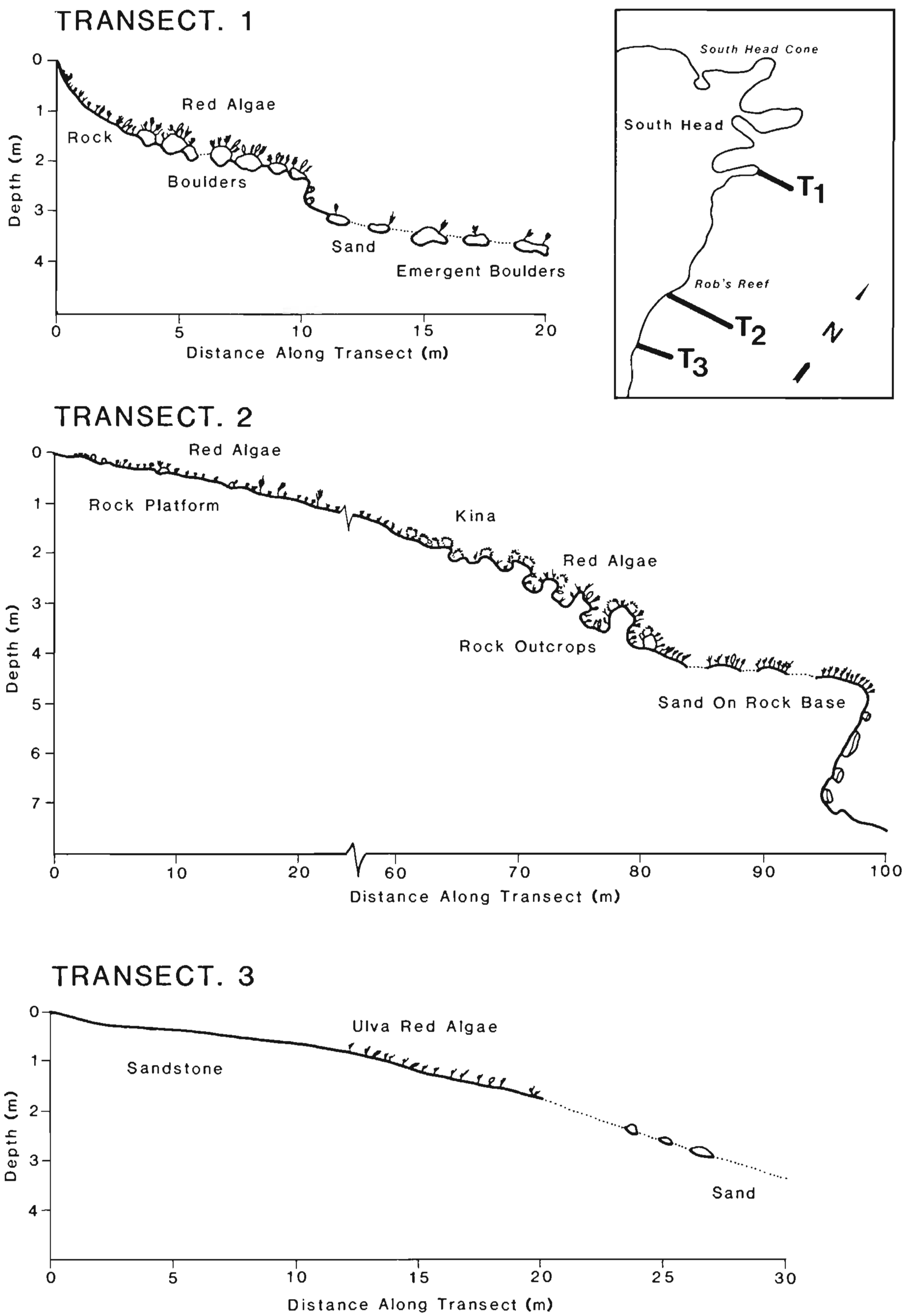


Fig. 4 SUBTIDAL TRANSECTS

Only brief visual reconnaissance of subtidal rock habitats was possible, therefore, it is probable that many subtidal invertebrate species remain unrecorded.

4.1.4 INVERTEBRATES OF PARTICULAR INTEREST

Crustacea

Leptograpsus variegatus (Large Shore Crab)

Leptograpsus is a large active crab, common in the upper intertidal area amongst boulders or in cracks in rock along the outer coast . Within the inlet, *Leptograpsus* was recorded from mid to upper tidal levels at Pa Point, Oyster Point, Maori Point and the Mangarakau Wharf. *Leptograpsus* has a wide distribution in the southern Pacific Ocean from Australia to South America. Its southern limit on the west coast of New Zealand is the Westport area (McLay, 1988).

Plagusia chabrus (Red Rock Crab)

P. Chabrus lives subtidally on rock habitat in the entrance and outer coast of Whanganui inlet. The red rock crab often shares rock crevices with crayfish *Jasus edwardsii*, however, few crayfish were recorded from the outer coast directly adjacent to Whanganui Inlet. *Plagusia* is confined to the Indo-Pacific from South Africa to Chile, and in New Zealand southwards to Canterbury.

Jasus edwardsii (Crayfish)

Numerous small crayfish were observed from one crevice in the entrance adjacent to the South Head Cone. Crayfish were uncommon on the outer coast immediately adjacent to the entrance area.

Cancer novaezelandiae (Pie-crust Crab)

The pie-crust or cancer crab is endemic to New Zealand and is strictly a subtidal species. One live specimen was recorded in the northern channel 10km from the entrance, while moulted shells were recorded from around Pa Point. Their diet is primarily composed of shellfish which are broken by the crabs large chelipeds.

Ovalipes catharus (Paddle crab)

Paddle crabs were recorded along the outer coast, in the entrance to Whanganui Inlet and in the northern channel 10 km from the entrance. Paddle crabs feed on a variety of prey including bivalves, fish, small crustaceans and polychaetes (Davidson, 1986, 1987). It is probable that paddle crabs enter Whanganui Inlet to feed on the intertidal flats and remain in the permanent channels between tides.

Isopoda (sea lice)

Eight species of isopod were recorded from Whanganui Inlet. Isopod species included the fish lice *Natatolana* sp. recorded from subtidal areas and *Exosphaeroma planulum* recorded from salt marsh in Whanganui Inlet and recorded elsewhere only from the Avon-Heathcote Estuary, Christchurch.

Amphipods

Amphipoda (sand hoppers)

Fourteen species of amphipoda were recognised from Whanganui Inlet (Hurley, 1989). Two species are new (*Parawalkeckia* sp."A", *Eorchestia* sp.) and one regarded as a probable new species *Melita* sp."A" *Eorchestia* is a new genus for estuarine and salt marsh talitrids with representatives recorded from South Africa, Victoria, Tasmania and New Zealand (Hurley 1989). In Whanganui Inlet, *Eorchestia* sp. was recorded from most salt-marsh sites in large densities (up to 464 per m^2). *Parawaldeckia* sp."A" and *Melita* sp."A"were both recorded subtidally from Whanganui Inlet. The most represented family of amphipod in the inlet was Phoxocephalidae (6 species) including the most common species *Waitangi chelatus*.

Echinodermata

Evichinus chloraticus (Kina)

Kina or sea urchin were recorded in the entrance to Whanganui Inlet on rock substrata from areas where rock substrate is swept by strong tidal currents (densities of up to 86 per m^2). Kina graze on algae growing on the substrate surface. Red moki, snapper, and blue cod are particularly fond of young urchins which, if they reach adulthood, can expect a life-span of 7-8 years (Gunson, 1983).

Coscinasterias calamaria (Eleven Arm Starfish)
Coscinasterias is a large pale yellow-orange starfish with up to 12 arms. *Coscinasterias* is most common in the North Island of New Zealand, however, is found in large numbers under mussel farms in the Marlborough Sounds. One specimen was recorded 7 km from the entrance to Whanganui Inlet in a minor channel near Oyster Point. This individual starfish was recorded lying on the bottom of predominantly mud and dead shell material.

Stichopus mollis (Common Sea Cucumber)
The common sea cucumber has a grey-brown body which reaches 200 mm in length. *Stichopus* was recorded immediately below low tide from rock substrata in the entrance and at Pa Point in low densities Sea cucumbers use their oral tube feet to pass nutritive deposits to their mouth. *Stichopus* is the most common of the 49 species of sea cucumber in New Zealand.

Polychaeta
Scolecolepides sp. (Green-headed Worm)
Scolecolepides live in U-shaped burrows and feed on the surface layer of mud. In Whanganui Inlet, these worms were most commonly recorded from mud and *Zostera* habitats in densities as high as 543 per m^2. *Scolecolepides* was recorded from all tidal heights, however, this species was restricted to the northern and southern ends of Whanganui Inlet. It is probable that *Scolecolepides* penetrates several kilometres above road causeways across the Wairoa River, Muddy, Banjo, Coal and Muller Creeks.

Nereidae (Ragworms)
Four species of ragworms were recorded from a wide variety of habitats (rush and sedge, fine sand, *Zostera*, mud and pebble/cobble) making them the most widely distributed organism in the inlet. A maximum density of 555 per m^2 was recorded from a mud site adjacent to Coal Creek in the southern inlet. Ragworms usually occupy burrows which they leave to feed or reproduce.

Glyceridae
Glycerid worms are slender, long-bodied polychaetes which either construct semi-permanent burrows in soft sediments or are free-living under rocks. Most species are carnivorous having four jaws at the tip of an extremely long proboscis. Two species of glycerid were recorded from Whanganui Inlet (*Glycera americana, G. lamellipoda*) from fine sand, *Zostera* and pebble/cobble habitats. Highest density of Glycerid worms were recorded from a *Zostera* bed at Oyster Point (45 per m^2).

Polydora polybranchia
Polydora are small tube dwelling worms recognised by a modified fifth segment and a pair of palps. *Polydora* may bore into calcareous rock, sand stone and stiff clay. They also bore into living shell, especially cockle shells. *Polydora* were most common from subtidal channels, fine sand, *Zostera* and pebble/cobble habitats in densities as high as 36 per m^2.

Porifera (Sponges)
Ancorina alata
Ancorina, like all sponges is a multicellular animal supported by a skeletal network of spicules. *Ancorina* is a grey sponge which may cover an area of over 1 m^2. In Whanganui Inlet, large *A. alata* are common on subtidal rock faces and overhangs in the entrance.

Aplysilla sulfurea (Sulfur Sponge)
The sulfur sponge forms a bright yellow layer over rocks in the entrance to Whanganui Inlet. Most specimens were recorded from underneath rock overhangs or in crevices.

Mollusca (Gastropoda)
Potamopyrgus estuarinus (Estuarine Snail)
Potamopyrgus is a small brown snail (< 6 mm length), abundant in the upper-tidal salt marsh areas of Whanganui Inlet. Densities of up to 3,656 per m^2 were recorded from jointed wire rush stands (*Leptocarpus similis*) in the south-western inlet.

Zeacumantus lutulentus, Z. subcarinatus
These species occupy the *Zostera* and some rock habitats in Whanganui Inlet. Densities of up to 260 per m^2 for *Z. subcarinatus* were recorded. These snails feed predominantly on macro-algae ((*Ulva, Enteromorpha*) and micro-algae growing on eelgrass and rock surface layers.

Mollusca: Amphineura (Chitons)
Nine species of chiton were recorded from Whanganui Inlet. Most of these species were recorded from rock substrata in the entrance, however, *Acanthochiton zelandica, Amaurochiton glaucus* and *Chiton pelliseripentis* were recorded throughout the inlet and from a variety of substrates. *Terenochiton inquinatus* was recorded from subtidal sites throughout the inlet.

Nudibranchia (True Sea-slugs)
Dendrodoris citrina
Six species of nudibranch were recorded from Whanganui Inlet. Like all Nudibranchia, *Dendrodoris citrina* has a soft bodied slug-like appearance. *D. citrina* displays a wide variety of colours between deep chrome to lemon yellow to almost white. One pale yellow-white specimen covered with pale spots was recorded from the shallow subtidal zone in the entrance to Whanganui Inlet. *D citrina* is endemic to New Zealand and is found throughout the North and South Islands.

Mollusca (Bivalves)
Tawera spissa (Morning Star)
Tawera spissa is common throughout New Zealand on clean swept tidal channels (Powell, 1979). The morning star is cockle shaped and marked with red-brown zig zag lines or bands. In Whanganui Inlet, the morning star was restricted to extreme low water and in subtidal channels. Densities ranged from 11-45 individuals per m^2.

Order Mytiloida (Mussels)
Seven of the 12 New Zealand species of mussel were recorded from Whanganui Inlet. Most species were restricted to the intertidal areas adjacent to the main channels and on rock substrate in the entrance. *Xenostrobus securis* was recorded from two sites upstream from the causeways on the Wairoa River and Muddy Creek. *Xenostrobus pulex* had the largest distribution of all these species reaching well into the estuary. All other species of mussel were restricted to the entrance area.

Nucula hartvigiana (nut-shell)
In Whanganui Inlet, the nut-shell was recorded from fine sand, agar weed, eelgrass, very fine sand and mud habitats. The highest densities were recorded from an eelgrass bed adjacent to Oyster Point (1958 per m^2). *Nucula* is intolerant to organic enrichment (Pearson and Rosenberg, 1978; Knox and Fenwick, 1981). The abundance and wide distribution of the nut-shell and the virtual absence of pollution indicating species (*Capitella capitata, Hetermastides filiformis*) in Whanganui Inlet suggests that the inlet is not significantly enriched.

Chione stutchburyi (cockle)
Chione was the most abundant mollusc in the estuary. Highest cockle densities were recorded from fine sand flats near Pa Point (up to 2524 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 oyster catcher (*Haematopus ostralegus fingchi*) (Jones, 1983). Like most suspension feeders, the cockle is one of the first species to show signs of pollution or reduced water quality (Stephenson, 1980, 1981).

4.1.5 COCKLE DISTRIBUTION, ABUNDANCE AND SIZE

The cockle (*Chione stutchburyi*) is an important member of the estuarine community. In recent times the cockle has been used as an indicator of environmental pressure (Knox 1983, Davidson and Moffat 1989). Most importantly, the cockle is representative of a niche common to most estuarine systems and its importance in the food chain has been stressed many times (Larcombe, 1971; Stephenson, 1980, 1981).

In Whanganui Inlet, some characteristics of the cockle population are unusual. Of the 14 habitats sampled, cockles were recorded as expected from all but the rushes and sedge and rock, cliff and boulder habitats. The mean size of cockles from habitats with cockles, however, was extremely low (Table 7). Further more, the percentage of cockles in the edible size range (>30 mm maximum length) from each habitat was between 0-4.8%. Cockles in this larger size range were recorded from only three sites in Whanganui Inlet. The cockle population was dominated by the middle size range of 10-20 mm (17-93.5%). The maximum number of cockles in the inlet was recorded from a *Gracilaria* bed adjacent to the entrance (2320 per m^2), while the lowest value for a cockle bearing site was 5.7 cockles per m^2. Most values for mean cockle density were below 800 per m^2.

Distribution and approximate density of cockles are presented in Figure 5. Highest densities of cockles (greater than 800 per m^2) were recorded adjacent to the major channels in fine sand substrates (Fig 5). These channel areas are swept by tidal currents ensuring cockles are not clogged by fine sediments and receive suspended food material. Relatively high densities of cockles were recorded throughout Whanganui Inlet. It appears that the environmental conditions required for cockle survival (tidal height < mean high water neap, mud <47.5%, mean diameter of sand >0.25 mm) are met in most of the inlet. Reasons why the *Chione* population in Whanganui is dominated by old individuals <30 mm length is probably related to environmental influences. It is unclear at this stage which environmental factor is limiting cockle growth, however, cockle populations in Ohiwa Harbour in northern New Zealand are also dominated by small old individuals (A.Kilner, pers. comm.).

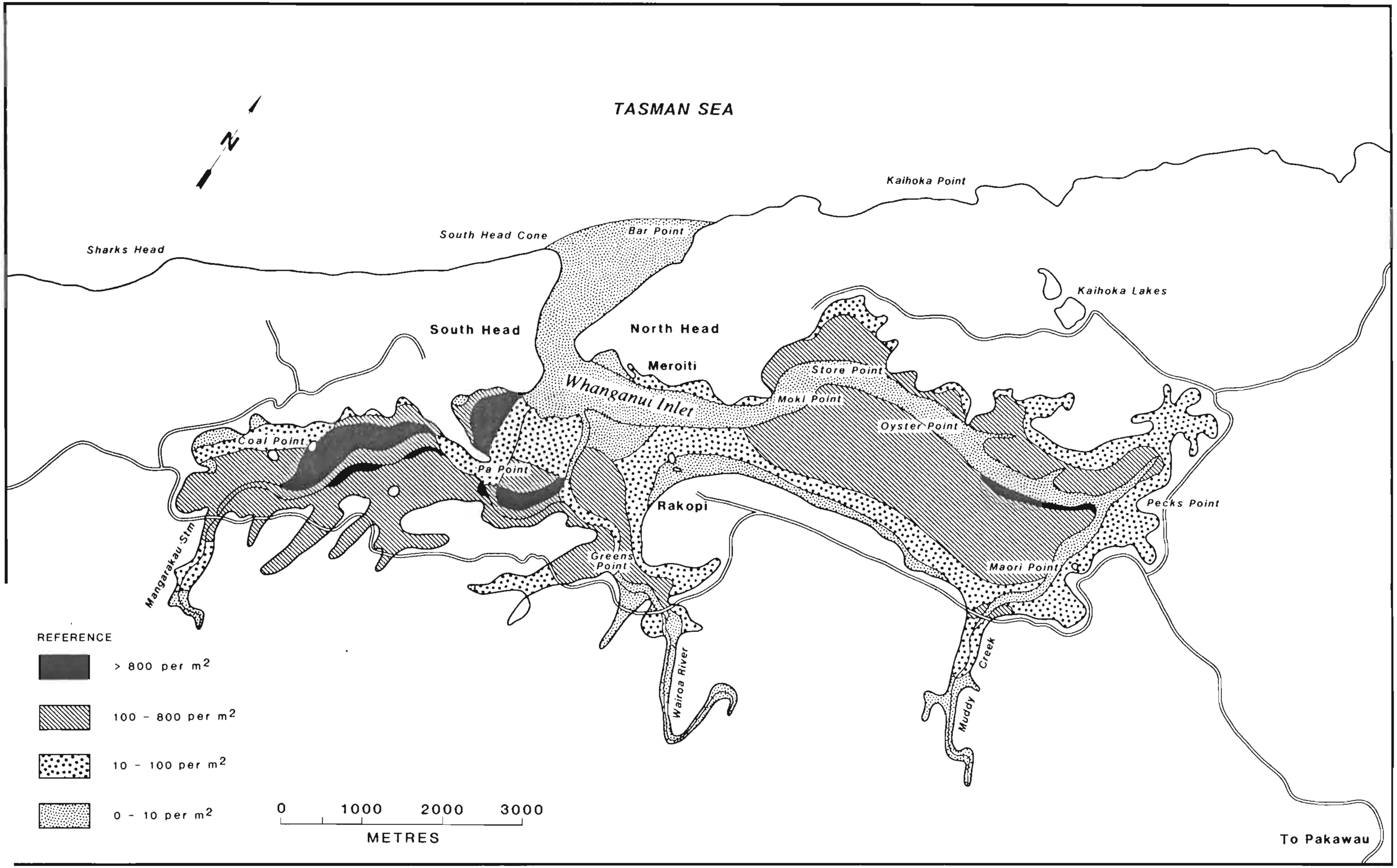


Fig. 5 COCKLE DISTRIBUTION

Table 7. Density and size of cockles from Whanganui Inlet.

Habitat	Mean No. per m^2	Mean Size (mm)	Percent <10 mm	Percent 10-30 mm	Percent >30 mm
Rock, Cliff, Boulder	0	-	-	-	-
Pebble/Cobble	57	10.7	83.3	16.7	0
Mobile Sand	5.7	4.0	100	0	0
Fine Sand	1564	16.6	15.4	84.4	0.2
Very Fine Sand	837	14.9	27.3	72.7	0
River Sand	249	14.5	13.0	87.0	0
Mud	170	11.9	31.6	68.4	0
Eelgrass	671	16.9	14.0	86.0	0
Gracilaria sp.	2320	23.6	2.7	93.5	4.8
Native Rushes and Sedge	0	-	-	-	-
Subtidal	67	16.1	35.1	62.2	2.7

4.1.6 FACTORS INFLUENCING INVERTEBRATE DISTRIBUTION

Physical factors have the greatest influence on the distribution of the invertebrate fauna within an estuary. The most important of these are salinity, substrate type and tidal height and exposure (Voller, 1973; Knox, 1983b).

Salinity

Estuaries are areas where freshwater from rivers and streams mixes with saltwater from the ocean. In Whanganui Inlet, freshwater enters from 31 rivers, streams, culverts and drains and uncountable drainage and seepage flows. Salt water enters the inlet from one source termed the "entrance" which is situated centrally (Fig.1).

Salinity readings taken at various locations around Whanganui Inlet are displayed in Table 8. Readings were taken from 20-22 June 1989, a full three days after any significant rain. Readings were taken from the surface layer and immediately above bottom sediments to assess the level of stratification. Sites were sampled at high and low tide between 6.30 am and 6.00 pm.

Results suggest that during periods of low rainfall, salinities at both low and high tide throughout Whanganui Inlet are high (Table 8). At all sites in the main channels salinity values were above 21.2ppt (parts per thousand) at low tide and 31.2ppt at high tide. Lowest salinity values at low tide were recorded in pools adjacent to causeways crossing the Wairoa River, and Muller and Muddy Creeks (Table 8). Some degree of stratification were also recorded at these sites, with fresh water overlying more saline water. At high tide stratification was not observed at any site in Whanganui Inlet suggesting good mixing of fresh and salt water.

High salinity values have often been recorded for estuaries on the incoming tide, however, salinities rapidly decline on the outgoing tide (Knox and Kilner 1973, Knox 1983). In Whanganui Inlet, salinity in most of the inlet remains relatively constant over the entire tidal cycle (29-33.6ppt). Although no records of salinity were taken following heavy rain, river and stream flow rates in Whanganui Inlet do not appear to increase dramatically (pers.obs.). Following heavy rain, the water colour in Whanganui Inlet often becomes brown which suggests flushing of dissolved organic carbon from freshwater catchments (Collier, 1987a, b; Collier and Winterbourn, 1987; Winterbourn et. al., 1988). This material may represent a significant source of detritus to the estuary (Knox, 1986).

The influence of high salinity on the distribution of invertebrates in Whanganui Inlet is immediately obvious. Typically, estuaries have relatively low invertebrate diversities compared with open coastal environments. This is largely due to the inability of freshwater species to inhabit more saline media and marine species to withstand dilute media (Barnes, 1984). Very few freshwater species survive salinities in excess of 5ppt and very few marine species are found in salinities less than 18ppt. In Whanganui Inlet, 67 species or 42% of all recorded invertebrates were coastal species. These species included the paua *Haliotis iris*, trumpet shell *Charonia capax*, ducksbill limpet *Scutus breviculus*, six species of nudibranch, horse mussel *Atrina zelandica*, pie-crust crab *Cancer novaezelandiae*, sea cucumber *Stichopus mollis* and kina *Evichinus chloraticus*. Some coastal species such as the cats-eye *Turbo smaragdus*, shore crab *Leptograpsus variegatus* and the dark rock shell *Haustrum haustorium* were recorded from both ends of the inlet (Maori Point, Mangarakau River causeway), however, the majority of coastal species were recorded from the entrance and into the inlet to Pa and Moki Points.

The remaining 58% or 94 invertebrate species recorded from Whanganui Inlet can be considered true estuarine inhabitants. These invertebrates were distributed over the bulk of the inlet and included the mud crab *Helice crassa*, mudflat snail *Amphibola crenata*, mudflat anemone *Anthopleura aureoradiata*, and mudflat whelk *Cominella glandiformis*.

Tidal Height and Exposure

Tidal height and air and wave exposure have an important role in determining the distribution of many invertebrates (Morton and Miller, 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 1983).

In Whanganui Inlet, typical rocky shore zonation patterns from periwinkles *(Littorina unifasciata, L. cincta)* at high tide to barnacles *(Elminius modestus)* at mid-tide down to mussels *(Xenostrobus pulex)* around mid-low tidal levels were recorded in the entrance. The majority of the mid-tidal levels in Whanganui Inlet are dominated by fine sand and eelgrass beds. Some invertebrates from eelgrass and fine sand flats were recorded from all tidal heights, however, abundance and species diversity often decreased towards the upper tidal levels. Many species disappeared closer to the higher tidal levels.

Substrate

Sedimentation rates are unknown for Whanganui Inlet. It is expected that sedimentation rates for the inlet are relatively low due to the forest cover in most of the larger catchments. Any sediment that enters the inlet in rivers and streams tends to flocculate and settle-out onto existing flats, in back-waters or amongst eelgrass or saltmarsh vegetation. A significant proportion of eelgrass in the inlet is growing on mud (up to 1 m deep). As eelgrass does not establish on mud it is probable that this mud has built up over long periods. Areas along the edges of channels and adjacent to the entrance are dominated by coarser sediments especially mobile sand. Fine silts and clays are transported away from these intertidal flats by relatively strong tidal currents.

Many estuarine invertebrates are substrate specific. In Whanganui Inlet, a wide variety of substrate types are available to organisms including mud, very fine sand, fine sand, mobile sand, pebbles, cobbles, boulders and rock. The availability of a wide variety of substrate types undoubtedly contributes to the high diversity of invertebrates recorded from Whanganui Inlet.

Table 8. Salinity values at various locations in Whanganui Inlet from 20-22 June 1989.

Station	Depth	Low Tide Temp(°C)	Low Tide Salinity (PPT)	High Tide Temp (°C)	High Tide Salinity (PPT)
Mangarakau Causeway	Surface	9.9	21.2	10.8	30.2
	Bottom	-	24.6	-	30.6
Mangarakau Wharf	Surface	9.8	29	12.8	31.9
	Bottom	-	29	13.0	33.6
Muller Creek	Surface	6	12.8	11	31.2
	Bottom	-	22	-	31.2
Wairoa River	Surface	7	3	10.8	30.0
	Bottom	-	5.5	-	30.6
Muddy Creek	Surface	7	3.5	10	28.6
	Bottom	-	8.3	-	28.6
Entrance	Surface	11.4	32	14	33.6
	Bottom	-	32	-	33.0
Pa Point	Surface	10	29.9	-	-
	Bottom	-	30.8	-	-

4.2 FISHES

A number of workers have shown associations between estuaries and fisheries (Moore et. al., 1970; Oviatt and Nixon, 1973; Turner, 1976; Day et. al., 1982; Knox, 1986). Reasons for this association are based on the availability of food for fish, areas for juvenile development and 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, 1982). Of these, about 20 species are either commercial, recreational or traditional fisheries (Kilner and Ackroyd, 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. In Waimea Inlet (Nelson), Davidson and Moffat (1989) recorded 31 commercial species of marine fish which entered the inlet at some stage of their life history. The extent and importance of Whanganui Inlet to fish populations 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 Whanganui Inlet.

4.2.1 METHODS

Much of the information on marine fishes was gathered through liaison with local recreational fishermen, however, some stomach analyses were undertaken to assess the importance of invertebrates in the diet of fish. Most field work involved visual verification of fish species using SCUBA equipment.

Freshwater fish inhabiting the tidal reaches of selected streams and wetlands around the inlet were sampled from 9-16 October 1989 using traps, nets and electric fishing equipment. Relevant details on the location of capture, tidal extremity, sediment, flow regime and relative numbers of each fish were also recorded. These results are presented in appendix 0, "Freshwater fishes in the catchments of the Whanganui Inlet, Northwest Nelson" by G.A.Eldon and M.Ward.

4.2.2 MARINE FISH

In Whanganui Inlet, 38 species of marine fish were recorded, 13 of which are regarded as commercial species (Table 9). No commercial fishing in the inlet is undertaken on a regular basis, but schools of kahawai which congregate in the entrance and immediately offshore have been the target of some commercial activity (B. Ferguson, pers.comm.). According to MAFFisheries staff relatively little fin-fish is landed which originates from the inshore waters along the outer coast of Whanganui Inlet.

Fifteen of the marine fish recorded from Whanganui Inlet are coastal species (eg. copper moki, *Latridopsis forsteri*; blue cod, *Parapercis colias*; red moki, *Cheilodactylus auratus*). These coastal species penetrate the inlet to varying degrees depending on their salinity tolerance. Local recreational fishers believe most of these species leave the inlet following periods of heavy rainfall, presumably in response to increased freshwater input into the inlet. This claim is substantiated by the absence of fish captured in nets during such periods.

Some species of marine fish remain in the inlet for much of their life history (eg. rockfish *Acanthoclinus fuscus*, estuarine triplefin Tripterygiidae, clingfish, *Modicus minimus*). Juvenile flatfish, snapper, mullet and some triplefin species gain sanctuary within the shallow waters of the inlet. Preliminary observations suggest Whanganui Inlet is an important nursery ground for flat fish and snapper.

Table 9. Marine fish recorded from Whanganui Inlet.

	Blue shark	*Prionace glauca*
	Eagle ray	*Myliobatis tenuicaudatis*
*	Rig	*Mustelus lenticulatus*
	Conger eel	*Conger verreauxi*
	Sprat	*Sprattus antipodum*
*	Pilchard	*Sardinops neopilchardus*
*	Anchovey	*Engraulis australis*
	Garfish	*Reporhamphus ihi*
	Clingfish	*Modicus minimus*
	Sea horse	*Hippocampus abdominalis*
	Rockfish	*Acanthoclinus fuscus*
*	Trevally	*Pseudocaranx dentex*
*	Kingfish	*Scriola grandis*
*	Kahawai	*Arripis trutta*
*	Snapper	*Chrysophrys auratus*
	Sweep	*Scorpis lineolatus*
	Kelpfish	*Chironemus marmoratus*
	Marble fish	*Aplodactylus arctidens*
*	Tarakihi	*Nemadactylus macropterus*
	Red moki	*Cheilodactylus spectabilis*
	Copper moki	*Latridopsis forsteri*
*	Blue moki	*Latridopsis ciliaris*
*	Grey mullet	*Mugil cephalus*
	Yellow-eyed mullet	*Aldrichetta forsteri*
	Spotty	*Pseudolabrus celidotus*
	Banded wrasse	*Notolabrus fucicola*
	Scarlet wrasse	*Pseudolabrus miles*
*	Butterfish	*Odax pullus*
*	Blue cod	*Parapercis colias*
*	Stargazer	Leptoscopidae
	Common triplefin	*Forsterygion* sp.
	Estuarine triplefin	Tripterygiidae sp.
	Blue-eyed triplefin	*Notoclinops segmentatus*
	Variable triplefin	*Forsterygion varium*
*	Yellow bellied flounder	*Rhombosolea leporina*
*	Sand flounder	*Rhobosolea plebeia*
*	Common sole	*Peltorhamhus novaezealandiae*
*	Leather jacket	*Parika scaber*

* Commercial Species

Some of the most notable marine fish in Whanganui Inlet are:

Flatfish
The young of many adult flatfish species are strongly dependent on estuarine areas (Webb, 1968). In Whanganui Inlet, many juvenile flatfish inhabit the small channels at low tide and are preyed on by Kahawai.

Flatfish depend on benthic invertebrates as a food source. Flatfish diet comprises mainly of small crabs, worms and small crustaceans (Webb, 1967; Davidson and Moffat, 1989). Flatfish are fast growing and are a relatively dependable fishery from year to year. In Whanganui Inlet, adult flatfish concentrations vary throughout the year and at times are caught using spears, setnets and dragnets, particularly in the Wairoa River and Rakopi area.

Snapper (*Chrysophrys auratus*)
Snapper are known to spawn in Tasman and Golden Bays, however, little is known about breeding activity along the West Coast of the South Island. Large numbers of juvenile snapper inhabit Whanganui Inlet with large individuals being occasionally caught on handlines (J. Taylor, pers. comm.). Snapper represent an important part of the recreational fishery in Whanganui Inlet.

Kahawai (*Arripis trutta*)
Although kahawai spend most of their time at sea, they regularly enter Whanganui Inlet to feed on small fish. Kahawai were regularly observed herding small fish into the shallows or chasing flatfish in small channels at low tide. Large schools of kahawai have been regularly sighted feeding in the entrance area.

Blue Cod (*Parapercis colias*)
Blue cod enter Whanganui Inlet and are caught on handlines up to 6 km from the entrance (B. Climo, pers. comm.). Blue cod are a coastal species and are not caught following periods of heavy rain and increased freshwater input.

Sweep (*Scorpis lineolatus*)
Sweep are small oval fish (<35 cm in length) with a small head and blue-grey colouration. Sweep are common in the north, however, are rarely recorded south of Cook Straight. Sweep have occasionally been recorded from Cable Bay, Nelson and the Marlborough Sounds (C.Duffy, pers.comm.). One specimen was recorded in the entrance area of Whanganui Inlet where their preferred habitat is located.

Red Moki (*Cheilodactylus spectabilis*)
Red moki are most abundant in the North Island, however, are observed regularly from the outer Marlborough Sounds and the entrance and outer coast of Whanganui Inlet. Red moki are home ranging, often occupying the same area for several years (Francis, 1988). Juveniles are relatively quick growing, however, growth soon slows and adults up to 70 cm may be 60 years old. Red moki have disappeared from many areas where they were once common. They are easily speared and are vulnerable to set netting.

Butterfish (*Odax pullus*)
Butterfish are found throughout New Zealand on rocky reefs often exposed to strong wave activity. In Whanganui Inlet, butterfish were recorded in the entrance area feeding on *Codium adhaerens* growing on rocks and boulders. Butterfish were relatively common on the outercoast where they occupied high energy surf zones adjacent to algae stands. Butterfish begin their lives as females and change sex after 1 or 2 seasons of growth (Francis, 1988).

4.2.3 THE IMPORTANCE OF WHANGANUI INLET TO MARINE FISH

Whanganui Inlet serves as a nursery for young fishes (eg. flat-fish, snapper, yellow-eyed mullet and rig), breeding area for rig and a feeding area for all the other species of marine fish which enter the inlet. The inlet represents the only significant enclosed environment along the North-west Nelson coastline and is therefore extremely important to fish which depend on estuaries at some stage of their life history.

The most important habitats to marine fish in Whanganui Inlet are the minor and major channels, eelgrass beds and intertidal pools.

4.2.4 FRESHWATER FISH

In New Zealand, 63% or 17 species of freshwater fish migrate between fresh and salt water at some stage of their life history (McDowall, 1976a). 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 the lives of most freshwater fishes, they are an essential link in the life histories that must not be interfered with (McDowall, 1976a). Pollution, culverts and habitat modification must be kept to a minimum to ensure migration routes are kept open.

Survey

During October 1989, a team of freshwater scientists from the Freshwater Fisheries Centre surveyed 31 sites in 24 waters of 16 catchments in Whanganui Inlet (Table 9b). Results from this investigation suggest that the comparatively unmodified nature of streams flowing into the inlet is an important feature of the freshwater fisheries values (Eldon and Ward, in prep). The fish fauna comprised 11 or 12 indigenous species. Only four species - banded kokopu (*Galaxias fasciatus*), inanga (*Galaxias maculatus*), redfinned bully (*Gobiomorphus huttoni*) and lonfinned eel (*Anguilla dieffenbachii*) were common. No non-diadromus fish were recorded, but koura (*Paranephrops planifrons*) were present. The absence of exotic fish species was significant.

The unmodified nature of the freshwater environment was reflected in the fish fauna. Very high densities of banded kokopu in this study is most probably due to the proximity to the sea, good intact habitat, few obstructions to migrating juveniles, clean water and the absence of exotic predators. The 42% occurrence of redfinned bullies in the Whanganui catchments indicated a stable environment, a reflection of unexploited land (Eldon and Ward, in prep).

The authors concluded that the catchments include virgin lowland areas of great rarity but the small size of streams render them very vulnerable. Virtually any development would put their ecology at risk. This small scale also renders their whitebait extremely vulnerable to fishing pressure, especially upstream of the main tidal arms. Fortunately these sites are mostly far from roads, and are not easily reached by foot. This is a distinct benefit to the fauna. The streams provide habitats for a small endemic fauna which, while not totally endangered, has considerably contracted its range and numbers in recent times. The authors also stated that these streams deserve protection, in common with the associated marine and forest environments.

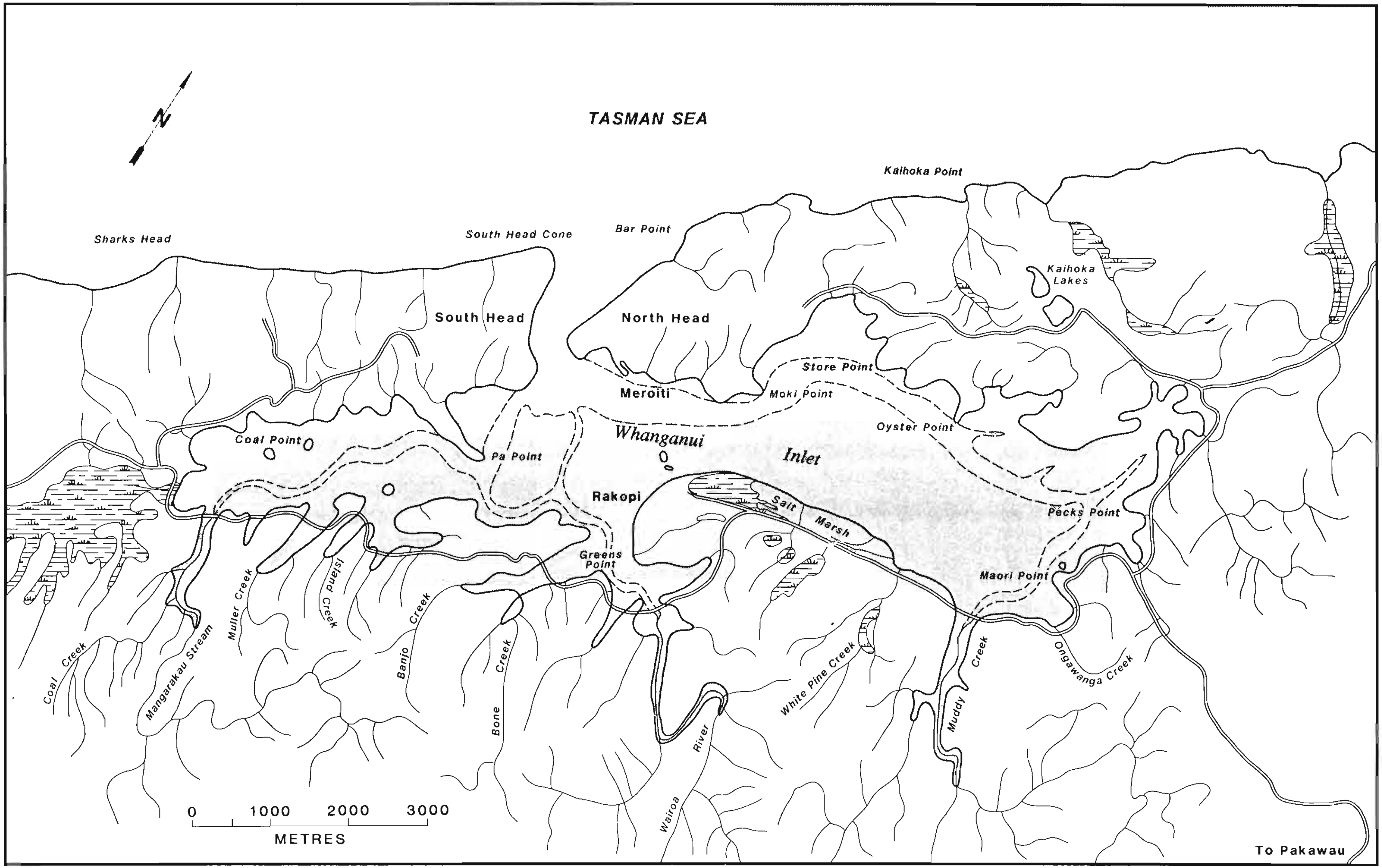


Fig. 6 LARGE WETLAND AREAS & FRESH WATER STREAMS & RIVERS

TABLE 9b Waters fished and mainstem lengths, with sampling site details, Whanganui catchments, October 1989. Catchments are listed in clockwise order from North Head to South Head.

Site No.	Catchment	Length (km) of main stem*	Site fished	Alt (m)*	Average width (m)	Average depth (m)	Max. depth (m)	number of EFM sweeps	Site Length (m)	Site Area (m^2)
1	North Head unnamed stream to inlet	0.6	mainstem	<10	0.5	0.3	0.8	PN	-	20
2	North Head unnamed stream to inlet	0.6	right fork	<20	0.4	0.15	0.4	3	35	12
3	North Head unnamed stream to open sea	1.2	mainstem	40	1.0	0.2	0.7	1	65	65
4	North Head second unnamed stream to open sea	2.3	headwater tributary	40	0.4	0.15	0.45	3	31	12
5	North Head second unnamed stream to open sea	2.3	headwater tributary	40	0.5	0.2	0.45	1	19	9
6	Kaihoka Lakes (landlocked)	-	eastern lake	55	-	-	-	T(8)	500	-
7	North end unnamed stream to inlet	1.0	left fork	<10	0.4	0.3	0.53	3	4	4
8	Muddy Creek	5.5	tributary	30	7.0	0.4	1.5	SF	1000	-
9	Muddy Creek	5.5	sub-tributary	>30	1.0	0.2	-	SF	75	-
10	White Pine Creek	2.2	estuary	0	5.0	0.4	0.7	PN	-	50
11	White Pine Creek	2.2	left fork	3	2.5	1.0	1.2	1	40	100
12	White Pine Creek	2.2	left fork tributary	3	1.5	0.25	-	1	25	38
13	White Pine Creek	2.2	left fork tributary	3	1.5	0.25	-	1	25	38
14	White Pine Creek	2.2	right fork	>20	1.0	0.15	0.3	2	45	45
15	Wetland	<2.0	drain	3	1.5	0.8	1.2	T(2)	20	-
16	Second wetland	<2.0	open pond	10	-	-	-	T(4)	75	-
17	Wairoa River	7.0	South branch	<20	9.0	0.2	-	1	20	180
18	Wairoa River	7.0	South branch	<20	6.0	0.7	1.2	1	10	60
19	Wairoa River	7.0	South branch tributary	<20	1.5	0.25	0.7	SF	-	-
20	Wairoa River	7.0	tributary	<10	4.2	0.4	1.0	1	60	252
21	Wairoa River	7.0	tributary	10	4.0	0.5	1.0	SF	200	-
22	Bone Creek	2.5	mainstem	120	1.5	0.35	1.2	2	57	86
23	Bone Creek	2.5	mainstem	<20	1.3	0.25	-	2	28	36
24	Bone Creek	2.5	lagoon	< 5	100.0	0.8	1.5	T(2)	-	-
25	Banjo Creek	2.0	mainstem	10	4.0	0.3	1.0	3	31	124
26	Banjo Creek	2.0	mainstem	35	4.0	0.3	1.0	SF	800	-
27	Coal Creek	3.0	headwater tributary	100	3.5	0.3	0.7	1	10	35
28	Coal Creek	3.0	headwater tributary	100	0.5	0.2	0.5	1	6	3
29	Mangarakau Swamp drain	2.3	drain outlet	1	4.0	-	-	PN	-	-
30	South Head unnamed stream to inlet	0.9	mainstem	<20	0.5	0.3	0.7	2	55	30
31	South Head second unnamed stream to inlet	0.5	mainstem	<20	1.2	0.25	0.7	1	80	96

* = estimated from N.Z. Map Series 260, sheets M24 and M25.
EFM = electric fishing machine.
PN = pole net.
SF = spot fishing.
T = traps (no. in parenthesis).
\- = no data.

4.3 BIRDS

4.3.1 INTRODUCTION AND METHODS

Whanganui Inlet was rated as a coastal wetland of 'high' value by the Wildlife Service (Walker, 1987), partly as a result of its variety of birdlife. Its large expanses of intertidal mudflat offer feeding areas for many wading birds, and its unmodified sections of fringe vegetation support characteristic species that are becoming increasingly rare.

The results presented here are derived from one survey in January 1989 (4th -13th, 23rd-31st) (referred to as "this survey" in section 4.3.2.), casual observations made during June 1989, and the records of the Nelson Branch of the Ornithological Society of New Zealand (OSNZ). Wader counts have been carried out by OSNZ each June and November since June 1984 (Table 11), typically by one or two observers walking at high tide from Rakopi to White Pine Creek. The present survey, which covered several high tides, showed that, in addition to using this stretch of shoreline, birds also roosted in farmland inland of Rakopi (not visible from the road), and on one occasion somewhere on the ocean beach beyond the mouth of the inlet.

The relative isolation of the inlet has meant that it has not been visited by ornithologists as frequently as other estuaries in the region. Its species list is likely to be less complete as a result, particularly in terms of wading birds.

Birds recorded at the inlet are listed in section 4.3.2. in the order of Kinsky (1970) (as amended in Kinsky (1980)). Those found in the surrounding scrub and forest are listed separately at the end of the section.

Most areas of estuarine fringe with unmodified vegetation (i.e. extending from *Juncus* and or *Leptocarpus* through to raupo, manuka and other shrubs), have been surveyed at least once, either during this study or the banded rail survey conducted by G.P. Elliott in 1982 (Elliott, 1983). Information has been extrapolated from these sites to indicate others not visited that may support rails or crakes (Figure 7).

4.3.2 BIRDS RECORDED FROM WHANGANUI INLET

Cook Strait Blue Penguin (*Eudyptula minor variabilis*)
Penguins are present along the coast and probably use the inlet occasionally. Nesting may occur within Whanganui Inlet, but this has not been recorded.

Petrel Spp. (*Pterodroma Spp.*)
Two unidentified seabirds sitting in the inlet were reported during the survey. Their size (larger than a red-billed gull), colour (dark grey/black) and beak shape and colour (short, dark petrel-like) suggest they were grey-faced petrels *(Pterodroma macroptera)*. This is an oceanic species and the pair may have been sheltering in Whanganui Inlet.

Australian Gannet (*Sula bassana serrator*)
Individuals were seen in the inlet on two occasions during the survey. Gannets will be continually moving up and down the coast and probably regularly visit the inlet to take surface-shoaling fish or to shelter from rough weather.

Black Shag (*Phalacrocorax carbo*)
Several black shags were seen during the survey using the rivers and major creeks as well as the body of the inlet itself.

Little Black Shag (*Phalacrocorax sulcirostris*)
Two little black shags were seen during the survey.

Little Shag (*Phalacrocorax melanoleucos*)
Little shags are the most abundant shag at Whanganui Inlet, making particular use of the lower reaches of the creeks and rivers. Birds are often seen flying to and fro from roost and nest sites in trees high on the sides of the river gorges. The population using Whanganui Inlet would be in the order of 30-50 birds. Owen (1980) noted a major roost at Banjo Creek, supporting over 30 little shags.

White-faced Heron (*Ardea novaehollandiae*)
White-faced heron are present at Whanganui Inlet all year and probably nest in the gorges of the major creeks and rivers. Herons have occasionally been included in counts of waders made at roosts in the Rakopi area, ie. 64 in June 1985, 31 in November 1987. During the survey the largest number seen in a group at high tide was 30 birds, but this probably represents less than half the birds present in the inlet as a whole. As the counts indicate, the highest number of herons occurs in winter. Feeding is concentrated in river and tidal channels including those in the smaller embayments cut off by road causeways.

White Heron (*Egretta alba*)
White herons appear to visit Whanganui Inlet occasionally, one being recorded in January 1984, two in June 1988, and one in June 1989 at White Pine Creek.

Reef Heron (*Egretta sacra*)
A single reef heron was seen flying in the inlet during the main survey and two near the entrance in June 1989. A single bird was observed resting in a rock crevice at Pa Point during September, 1989. This species is associated with rocky shores on sea coasts and establishes well-defined breeding territories. This isolated sighting suggests birds may not be resident in the inlet, but may visit to feed on exposed platforms and pebble beaches.

Australasian Bittern (*Botaurus stellaris*)
A single bittern was flushed from a channel in the centre of the major swamp east of Rakopi during the survey. A local resident reported that in the past booming was heard regularly from this area in spring. Three bitterns were recorded at the inlet during the November 1988 wader count. Few of the areas of estuarine fringe vegetation support sufficient areas of raupo to support breeding bitterns and no other birds were found during a brief survey playing tapes of their calls. Extensive freshwater wetlands behind the inlet at the north-eastern end, south of Rakopi, and at the western end leading to Mangarakau swamp probably represent the strongholds for this species in the area.

Royal Spoonbill (*Platalea leucorodia*)
Three spoonbill were observed at Whanganui Inlet during the June 1987 wader count (OSNZ) and this species is likely to be an occasional visitor to the inlet.

Black Swan (*Cygnus atratus*)
Black swan are present at Whanganui Inlet all year, but peak numbers are expected during the moult, between November and March. The following counts have been made at the inlet: 1300 on 25 March 1980, 510 in January 1989. A few pairs breed.

Canada Goose (*Branta canadensis*)
Four Canada geese were seen at nearby Kaihoka Lakes in November 1981, and 19 recorded in the 10,000yd grid square that includes the inlet in March 1979, though their exact location is not known.

Paradise Shelduck (*Tadorna variegata*)
A few paradise shelduck were noted on farmland surrounding the inlet during the survey. Small flocks are likely to be present during the moult.

Mallard (*Anas platyrhynchos*) Grey Duck (*Anas superciliosa*)
Small groups of duck were encountered regularly around the inlet during the survey, the largest being of c15 birds in Island Creek. Many groups included both species, but grey duck alone were found near the limit of the intertidal reaches of Wairoa River and several of the creeks.

Australasian Harrier (*Circus approximans*)
Harriers were frequently seen quartering the marshes and farmland adjoining the inlet and occasionally hunting over the mudflats themselves at low tide.

California Quail (*Lophortyx californica*)
Quail were frequently encountered in small family groups on the roads surrounding the inlet during the survey, but make no use of estuarine areas.

Banded Rail (*Rallus philippensis*)
Banded rail footprints were only located at one site at the western end of the inlet during the survey. This was the same site that Elliott located the species in 1982 and he also found birds at a site at the eastern end (Fig.7). The 1989 survey involved only single visits to sites. More visits would have been needed to be certain that banded rails were not present outside these two areas. In particular, the large coastal strip east of Rakopi appears to offer ideal habitat and one bird flushed from there could have been a rail.

Western Weka (*Gallirallus australis*)
Weka were not encountered during the main survey, but were heard in June 1989 and are known to be present in the forests and scrub surrounding the inlet. They would be expected to forage on the edge of the intertidal area on occasions.

Marsh Crake (*Porzana pusilla*)
The playing of calls of spotless crake elicited responses believed to be marsh crake from two sites (Fig.7) (marsh crake have been found to respond to spotless calls by many observes). The birds were not seen, but footprints found at one site were consistent with marsh crake. One bird was flushed from the coastal wetland east of Rakopi, but was seen too briefly to determine whether it was a rail or crake. Two of the sites not visited appear suitable for marsh crake.

Spotless Crake (*Porzana tabuensis*)
Elliott (1983) concluded during his banded rail survey that there was no resident population of spotless crake in the Nelson/Marlborough regions. There is one record of spotless crake in the 10,000 yard grid square that includes Whanganui Inlet (K Owen, March 1980) (OSNZ Atlas), but the exact location is unrecorded.

Pukeko (*Porphyrio porphyrio*)
Pukeko are fairly common in the farmland adjoining the estuary and make some use of the coastal wetlands, eg. at Rakopi.

South Island Pied Oystercatcher (*Haematopus ostralegus finschi*)
The twice-yearly wader counts of OSNZ indicate that pied oystercatcher (SIPO) numbers vary greatly from count to count with little seasonal pattern. However, the roosting behaviour of the species at Whanganui Inlet (see Section 4.3.3) suggests that birds may well be missed during a brief count.

Variable Oystercatcher (*Haematopus unicolor*)
Counts (Table 11) show that small numbers of variable oystercatcher are present at the inlet both summer and winter, as expected from this largely non-migratory species.

Spur-winged Plover (*Vanellus miles*)
One or two pairs of spur-winged plover have been recorded using the upper intertidal areas and the surrounding farmland at Whanganui Inlet (Table 11).

Least Golden Plover (*Pluvialis fulva*)
There is a single record of this summer visitor at Whanganui Inlet of nine birds during the November 1987 wader count. Twenty golden plover have once been recorded at Farewell Spit, but generally less than ten visit the entire Nelson region.

Banded Dotterel *(Charadrius bicinctus)*
Counts indicate that up to 150 banded dotterel winter at Whanganui Inlet and that birds are absent in the breeding season in November (Table 11). The January count may represent the arrival of overwintering birds after breeding. One colour-banded bird from the Cass River, Canterbury, was seen at Whanganui Inlet in June 1985.

Wrybill *(Anarhynchus frontalis)*
A single wrybill was recorded in the 10,000 yard square that includes Whanganui Inlet (sq. no. 6091) on 2 March 1971 (OSNZ Atlas). This bird would have either been at Whanganui Inlet or at Pakawau Inlet.

Far-eastern Curlew *(Numenius madagascariensis)*
A few curlew visit the Nelson region in summer, the majority (maximum 9) being found on Farewell Spit. Single birds have been recorded at Whanganui Inlet on two occasions including one during this survey (Table 11).

Eastern Bar-tailed Godwit *(Limosa lapponica baueri)*
Godwits are the most numerous wader found at Whanganui Inlet in summer and a few birds overwinter (Table 11). The summer population at Whanganui Inlet (mean 1,645, November counts 1985-88) is approximately one tenth of that visiting Farewell Spit (mean 15,856, same counts) (OSNZ counts).

Wandering Tattler *(Tringa incana)*
A single bird was seen in grid square no.6091 in March 1980 (see wrybill above for explanation).

Common Sandpiper *(Tringa hypoleucos)*
Common sandpipers are rare summer visitors to New Zealand and have been recorded at Wairoa River, Whanganui Inlet, one apparently staying from March to November 1981 (the first South Island record of the species) and the other in January 1983 (second South Island record) - perhaps the same bird.

Terek Sandpiper *(Xenus cinereus)*
A single bird of this uncommon visitor to New Zealand (rarely more than six a year) was reported at Whanganui Inlet in April 1980.

Knot *(Calidris canutus)*
Knot have been recorded visiting Whanganui Inlet in the summer when numbers are second only to godwits, but do not apparently overwinter. The count during this survey (850 birds) is significantly higher than any November totals (Table 11), indicating either that numbers do not reach their peak until after the November counts or that birds may.be missed during these counts.

Sharp-tailed Sandpiper *(Calidris acuminata)*
Up to 200 individuals visit New Zealand annually (Heather & Braithwaite, 1985) though they are very rarely recorded in the Nelson region. One bird was seen at Whanganui Inlet during the November 1987 wader count.

Pied Stilt *(Himantopus leucocephalus)*
Small numbers of pied stilt are present at Whanganui Inlet all year round and they may breed on farmland fringing the inlet.

Black Stilt *(Himantopus novaezealandiae)*
There are two records of black stilt at Whanganui Inlet, one by KL Owen in March 1980 and the other by a local farmer (B. Ferguson, date uncertain). This species is very rarely recorded on migration in the Nelson region.

Southern black-backed Gull *(Larus dominicanus)*
This is the most numerous gull species at Whanganui Inlet, but most of the birds are seen as individuals or small groups foraging along beaches or exposed tidal flats. During the survey no more than fifty would have been present and no nesting colonies were found.

Table 10. Summer counts of godwit and knot, winter counts of sipo and banded dotterel Nelson Region (OSNZ counts).

Date	Whanganui	Farewell Spit	Golden Bay*	Motueka Estuary*	Waimea Inlet	Nelson Haven	Total Region
GODWIT:							
NOV 1983	NC	8130	485	1200	1400	810	12025 (16.8)
NOV 1984	72	16080	913	2500	1550	768	21883
NOV 1985	1100	11075	500	1500	2930	550	17655 (21.3)
NOV 1986	1100	11920	535	1100	1200	581	16436
NOV 1987	1702	12752	1133	2000	2800	750	21137
NOV 1988	2680	14776	1790	2270	1510	750	23776
JAN 1989	1980	NC	484**	NC	NC	NC	-
KNOT:							
NOV 1983	NC	16500	0	20	6	0	16526 (35.3)
NOV 1984	40	24227	0	15	210	2	24494
NOV 1985	320	11335	0	30	170	0	11855 (24.1)
NOV 1986	230	15734	0	30	100	0	16094
NOV 1987	371	18409	0	100	750	0	19630
NOV 1988	746	17347	7	100	70	1	18271
JAN 1989	850	NC	5**	NC	NC	NC	-
SIPO SITE							
JUNE 1984	153	7071	3851	2080	3065	597/240	17057
JUNE 1985	128	7746	4380	2116	2341	318/200	17229
JUNE 1986	250	5689	3851	2791	838	720/195	14334
JUNE 1987	442	5788	3751	1990	1975	780/187	14913
JUNE 1988	131	8042	3541	1571	1840	573/134	16675*
BANDED DOTTEREL							
JUNE 1984	0	990	100	53	84	30/10	1267
JUNE 1985	150	1322	155	18	30	60/6	1741
JUNE 1986	204	1169	95	21	47	50/0	1586
JUNE 1987	91	1275	128	2	25	40/11	1572
JUNE 1988	107	1442	118	1	0	103/2	1773

*Golden Bay = coast from Puponga inlet to Wainui Inlet.
NC = no count.

Motueka = the following 3 intertidal areas: Moutere Inlet (713 hectares), Motueka River Mouth (900 hectares) and Motueka Sandspit (170 hectares). Counts were made at the sandspit, the high-tide roost for the vast majority of birds using all these areas.

** Pakawau roost only.

( ) % of national total.

* incl. 843 at Marahau.

Table 11. Counts of waders at Whanganui Inlet, 1984-9.

Species	1984 June	1984 Nov	1985 June	1985 Nov	1986 June	1986 Nov	1987 June	1987 Nov	1988 June	1988 Nov	1989 Jan
S.I. pied oystercatcher	153	207	128	300	250	54	442	97	131	11	365
Variable oystercatcher	2	8		5	19	19	42	8	27	8	18
Spur-winged plover			4		7						5
Least golden plover								9			
Banded dotterel			150		204		91		107		79
Far-eastern curlew								1			1
Whimbrel sp.						1					
Bar-tailed godwit	170	72	61	1100	78	1100	51	1702	65	2680	1980
Knot		40		320		230		371		746	850
Sharp-tailed sandpiper								1			
Pied stilt	47		2	5	33		22	5		12	
TOTAL	372	327	345	1730	591	1404	648	2189	335	3445	3310
Source	Wader counts of OSNZ										This survey

Red-billed Gull *(Larus novaehollandiae)*
Small groups of red-billed gull have been recorded at the inlet on most visits (March and September, OSNZ Atlas results; January, this study) and they are probably present all year. The largest flock seen during the survey was of eight birds. The nearest nesting colonies are thought to be on Farewell Spit.

Black-billed Gull *(Larus bulleri)*
One small flock of black-billed gulls was seen at Whanganui Inlet during the survey. This species is expected to visit the inlet occasionally in autumn/winter, but breeds inland.

Black-fronted Tern *(Sterna albostriata)*
There was an unconfirmed report of this species at Whanganui Inlet during the survey. It is expected to visit the inlet only rarely for it breeds inland.

Caspian Tern *(Hydroprogne caspia)*
A few caspian terns were seen during the survey as single birds either roosting or hunting over the inlet for surface-shoaling fish and 11 were recorded in one group at Rakopi in July 1989. The nearest breeding colony is at Farewell Spit and birds are expected to visit Whanganui Inlet at all times of year.

White-fronted Tern *(Sterna striata)*
Small numbers of white-fronted tern were seen most days of the survey. Up to fifty have been recorded at other times of year.

New Zealand Kingfisher *(Halcyon sancta vagans)*
One or two kingfishers were seen in the upper parts of the intertidal area during the survey. The species will be present in much greater numbers in winter.

South Island Fernbird (*Bowdleria punctata punctata*)
Fernbird were recorded at six sites at Whanganui during this survey (Fig.7). Tape-recordings of their calls were played at other sites where there was suitable habitat of rushes and scrub on the edges of the inlet, but no responses were obtained. This does not prove that fernbird were absent from these areas, for birds do not respond well to calls in January, particularly if the weather is hot. A better time to survey specifically for this species would be October, the start of the breeding season.

The following species are not dependent on any parts of the marine system. However, welcome swallows do cover the mudflat areas in their aerial hunt for insects, blackbirds, thrushes and starlings will sometimes forage on beaches and some of the finches may take the seeds of plants of the saltmarsh fringe. For information the following species have been recorded in areas adjacent to the inlet:-

New Zealand Pigeon *(Hemiphaga novaeseelandiae)*
Shining Cuckoo *(Chrysococcyx lucidus)*
Morepork *(Ninox novaeseelandiae)*
Broad-billed Roller *(Eurystomus orientalis)* (1 on 8 March 1983, OSNZ)
Skylark *(Alauda arvensis)*
Welcome Swallow *(Hirundo tahitica neoxena)*
New Zealand Pipit *(Anthus novaeseelandiae)*
Hedgesparrow *(Prunella modularis)*
Grey Warbler *(Gerygone igata)*
South Island Fantail *(Rhipidura fuliginosa fuliginosa)*
Yellow-breasted Tit *(Petroica macrocephala macrocephala)*
Song Thrush *(Turdus philomelos)*
Blackbird *(Turdus merula)*
Silvereye *(Zosterops lateralis)*
Bellbird *(Anthornis melanura)*
Tui *(Prosthemadera novaeseelandiae)*
Yellowhammer *(Emberiza citrinella)*
Chaffinch *(Fringilla coelebs)*

Goldfinch *(Carduelis carduelis)*
Redpoll *(Carduelis flammea)*
House Sparrow *(Passer domesticus)*
Starling *(Sturnus vulgaris)*

4.3.3 PATTERNS OF USE

The patterns of use described here are largely based on the survey of January 1989 and cannot be assumed to apply at other times of year.

Waders
Feeding and roosting patterns of waders were observed over a few tidal cycles during the survey. Figure 8 indicates the movements associated with incoming tides in January. The two major roosts were at Rakopi and east of there towards White Pine Creek (exact location varies), sites that are used throughout the year (OSNZ). Birds assembled in three areas of the eastern inlet as the tide moved them from feeding grounds, two pre-roost gatherings and the major roost, before all joining this roost. During spring tides combined with north-westerly winds, these roosts were inundated and most godwits and knot flew out the mouth of the inlet (probably to roost there) while South Island pied oystercatchers and a few godwit and knot went to the fields near Rakopi.

In terms of feeding, the waders can be divided into three groups: the oystercatchers (pied and variable), the godwits and knot (and curlew), and the dotterel. The former fed in a variety of habitats including mobile sand and cockle beds, whereas the latter were concentrated in fine sand and mud, most of which was covered in *Zostera*.

The dotterel fed high on the beach in the medium sand zone extending east from Rakopi. The feeding patterns around the high tide were consistent. The last species to stop feeding and roost and the first to start feeding again was the knot, moving across the sand zone at the edge of the tide. Next to start was the godwit as areas of fine sand and mud with *Zostera* were exposed and finally the oystercatchers. The dotterel roosted separately from the other species near the Clay Islands or in the fields and could feed soon after the tide began to fall.

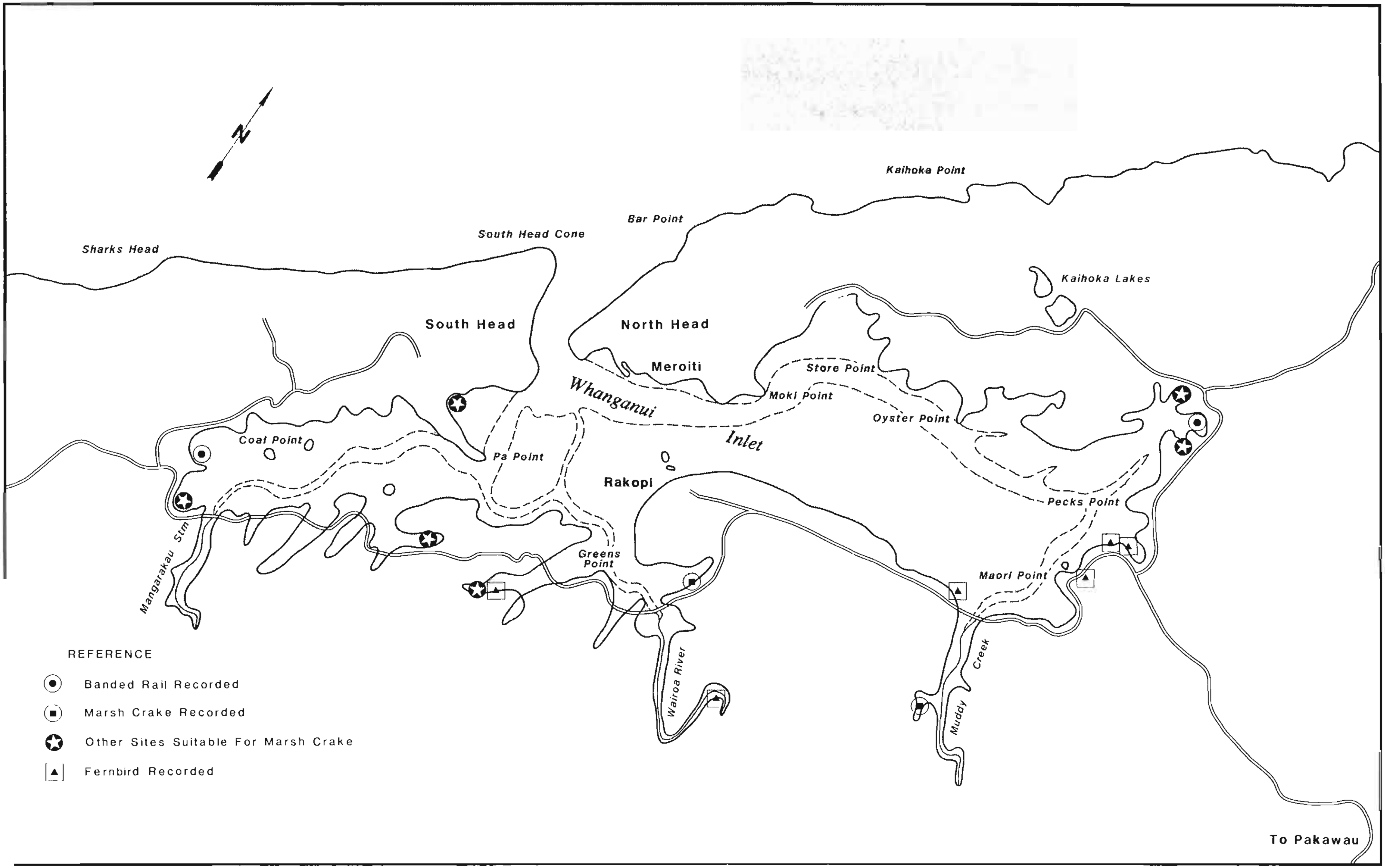
Few birds fed in the western inlet (west of Pa Point) and small flocks of knot, godwit and oystercatchers moved from there as the tide rose to join the Rakopi roost. Waders were very rarely seen upstream of any of the bridges or causeways except for occasional oystercatchers. Most were thus concentrated in the large, *Zostera*-covered expanses of the northern inlet.

Shags and Herons
Little shags fed throughout the inlet and the river channels during most of the tidal cycle, but moved to roost high up in the river gorges over the low tide. White-faced herons were also frequently seen flying to and fro from night roosts in these locations, though they spent most of the day in the inlet roosting during the high tide on sandbars or logs.

Black Swan
Swans, like godwits and knot, were concentrated on the *Zostera* beds in the north-eastern part of the inlet. At high tides when these were covered, a few birds rested on the northern shore, but the majority gathered off the area around White Pine Creek.

4.3.4 SITES OF SPECIAL BIOLOGICAL INTEREST TO BIRDS

Rakopi Salt marsh
This is the largest salt marsh at Whanganui Inlet and contains a large diversity of habitats, including raupo, standing water and extensive areas of *Juncus* and *Leptocarpus*. Bittern and crakes or rails are present in addition to ducks and probably fernbird. The main wader roost for the inlet is on the seaward edge of this salt marsh.



ig. 7 LOCATION OF FERNBIRD, BANDED RAIL & MARSH CRAKE

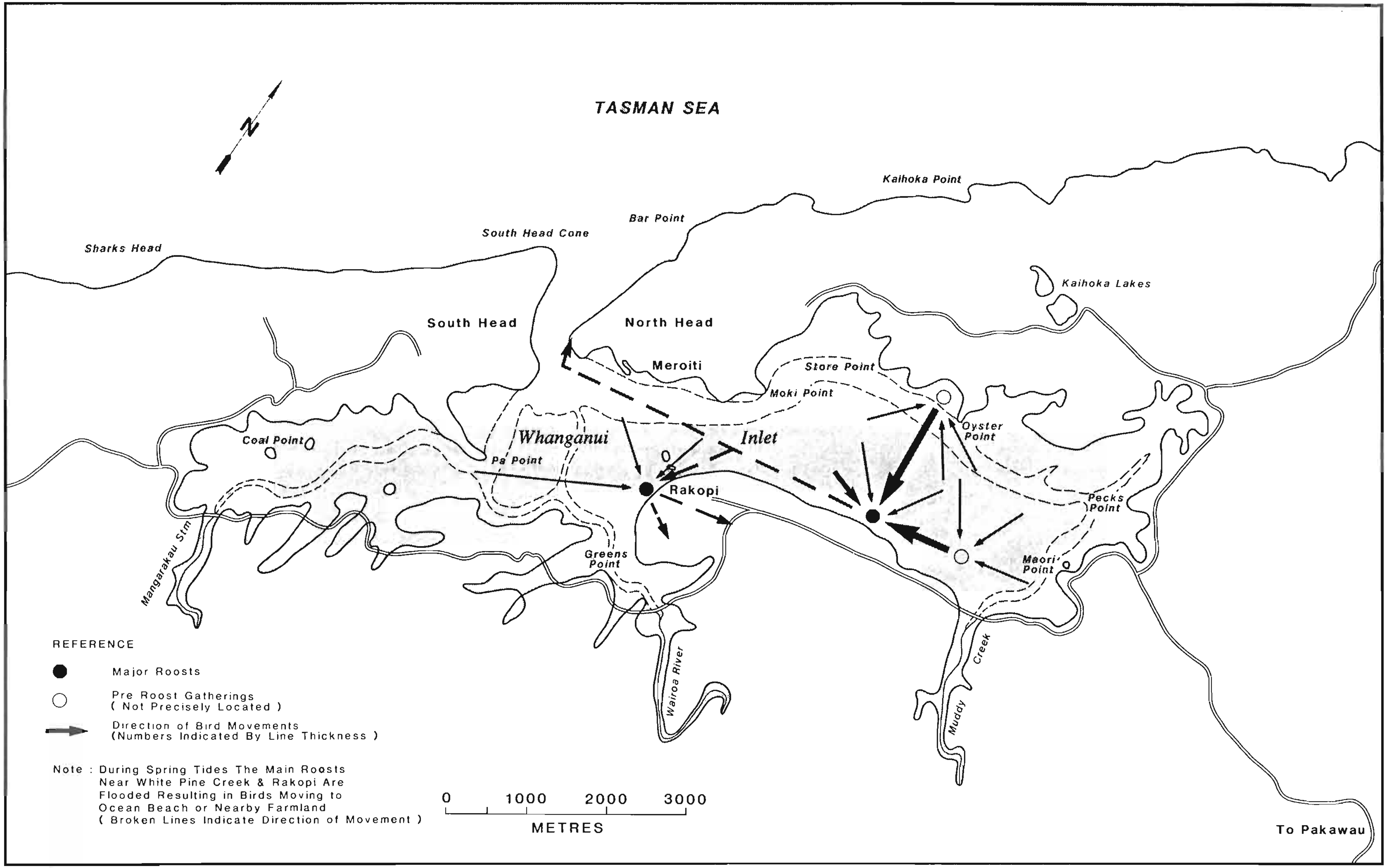


Fig. 8 WADER MOVEMENTS ON INCOMING TIDES,- JANUARY 1989

Banded Rail Salt marshes

These marshes are significant as the only two confirmed to hold banded rail at Whanganui Inlet. The vegetation fringe provides an intact succession from *Juncus* to scrub.

Muddy Creek Salt marsh

This area on the true left of Muddy Creek contains an extensive area of marsh in three areas bisected by major channels. Marsh crake are present and fernbird and bittern may occur.

Northern Inlet

The eastern third of the inlet is the most significant feeding area for northern hemisphere waders and black swan at Whanganui Inlet.

4.4 ESTUARINE VEGETATION

Whanganui Inlet represents the only large estuarine environment in the Nelson/Marlborough region with almost all of its intertidal vegetation intact. Most estuaries in New Zealand have been significantly modified, especially around their margins where most estuarine vegetation grows. Intertidal vegetation is extremely important in the estuarine food chain, buffers erosion, reduces nutrient flows and supplies habitat to many species of animal.

Numerous species of algae were noted from Whanganui Inlet. The greatest diversity of algal species was observed subtidally from the entrance, while the largest quantities of algae were recorded from intertidal Whanganui Inlet *(Gracilaria)*. Outside the inlet on the South Head reef, large quantities of *Ulva* sp. covered intertidal rock platforms.

The most common vascular plants in the inlet were eelgrass *Zostera muelleri*, sea rush *Juncus maritimus*, jointed rush *Leptocarpus similis* and three square *Schoenoplectus pungens*.

Eelgrass grows over the intertidal flats, while the two species of rush and one sedge grow around the margins of Whanganui Inlet. Whanganui Inlet may represent the largest combined area of *Schoenoplectus pungens* in any estuary in the Nelson/Marlborough region.

5. COMPARISON WITH OTHER ESTUARIES

5.1 INVERTEBRATES

The number of invertebrate species recorded from Whanganui Inlet are compared with other New Zealand estuaries in Table 13. Whanganui Inlet is represented by the highest number of species, followed by the Avon-Heathcote Estuary (Christchurch) and Waimea Estuary (Nelson). Lowest values were recorded from the Wairau River Estuary (Blenheim) and Ahuriri Estuary (Napier).

Densities of common benthic invertebrates from various New Zealand estuaries are compared in Table 14. In Whanganui Inlet, maximum densities of most species are in the mid-range, however, some species are in relatively low densities (pipi, *Paphies australis*; capitellid polychaetes; stalk-eyed crab, *Macropthalmus hirtipes*; mud crab, *Helice crassa*; hairy-handed crab, *Hemigrapsus crenulatus*). Densities of the nut shell, *Nucula hartvigiana* (1958 per m^2) recorded from eelgrass beds in Whanganui Inlet is the highest recorded for any New Zealand estuary to date.

Whanganui and Waimea Inlets have the highest recorded number of species of invertebrate at the highest densities for an estuary in the Nelson/Marlborough region. Davidson and Moffat (1989) suggested estuary size, sampling intensity and habitat diversity contributed to the large number and densities of invertebrates in Waimea Inlet. Whanganui Inlet can be characterised by having even more habitat types than Waimea Inlet, and this combined with unusually high salinity values helps account for the high diversity of invertebrates. High salinities recorded over most of the inlet at both high and low tide allows many coastal species to enter (see 4.1.6). This phenomenon is particularly apparent in the entrance area where subtidal and intertidal rock and sand habitats combined with high salinity dominate the environment. It is expected that numerous species have yet to be recorded from this area.

All of the major feeding types are represented in Whanganui Inlet. As expected for estuaries, detritivores (deposit feeders) dominated the invertebrate fauna with 47 species. Detrivore numbers were closely followed by carnivores (41 species), herbivores (40 species), suspension feeders (21 species) and others (10 species) mostly parasites and scavengers. The number of herbivores recorded in Whanganui Inlet is relatively high, probably due to the presence of eelgrass and rock substrata, both of which are covered in a layer of algae. The dominance by detritivores in Whanganui Inlet and probably most estuaries in New Zealand emphasises the importance of the detrital food chain (see Chapter 6).

Most detrital material in an estuary is derived from river input and fringe vegetation (Knox and Kilner, 1973; Gillespie and MacKenzie, 1981; Gillespie, 1983; MacKenzie, 1983; Barnes 1984; Knox 1986).

5.2 FISH

Fish species recorded from Whanganui Inlet are compared with selected New Zealand estuaries in Table 15. The highest number of marine species of fish recorded from an estuary are recorded from Whanganui Inlet (37 species), closely followed by Porirua and Pauatahanui Inlets (36 species) and Waimea Inlet (31 species).

The number of freshwater fish species living in the catchments of the inlet is relatively high (Table 15). Eldon and Ward (1990) suggested that the high density of some fish, particularly the banded kokopu, was due to the relative proximity of adult waters to the sea. This combined with the clean waters, the unmodified nature of the area, lack of barriers and absence of trout make the inlet and associated catchments an important area for native freshwater fish (appendix 0).

The variety of fish entering, living and/or feeding in Whanganui Inlet suggests that the inlet is an important fishery area. The inlet is the only significant sheltered body of water along the North-west Nelson coastline. This factor is also reflected in the importance recreational fishers place on the inlet.

Table 13. Number of macroinvertebrate species recorded from Whanganui Inlet and other estuaries in New Zealand.

	Crustacea	Mollusca	Polychaeta	Others	Total
Whanganui Inlet (North-west Nelson)	45	71	26	20	159
Waimea Inlet (Nelson) [2]	27	36	36	12	111
Nelson Haven (Nelson) [3]	5	11	17	3	36
Parapara Inlet (Nelson) [4]	4	21	24	5	54
Moutere Inlet (Motueka) [5]	11	27	16	5	59
Wairau River Estuary (Blenheim) [6]	10	3	7	0	20
Brooklands Lagoon (Canterbury) [7]	13	8	10	9	40
Avon-Heathcote Estuary (Canterbury) [8]	30	49	27	29	134
Okarito Lagoon (Westland) [9]	15	7	3	17	42
Ahuriri Estuary (Napier) [10]	6	11	14	2	33
Upper Waitemata Harbour (Auckland) [11]	21	31	25	10	87

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

Table 14. Maximum densities (per m^2) of selected species from Whanganui Inlet and other New Zealand estuaries.

	Whanganui Inlet	Waimea Inlet	Moutere Inlet	Parapara Inlet	Wairau River Estuary	Avon-Heathcote Estuary	Ahuriri Estuary
Bivalves							
Chione stutchburyi	2524	3168	1347	1426	1340	3050	7270
Paphies australis	815	3530+	4494	-	452	2547*	present
Tellina liliana	283	815	419	230	-	1337*	730
Nucula hartvigiana	1958	1268	226	present	-	-	NA
Gastropods							
Amphibola crenata	215	532	68	230	129	977*	580
Diloma subrostrata	127	170	79	63	-	1146*	360
Potamopyrgus estuarinus	3656	23450	present	present	10449	884000	2500
Zeacumantus lutulentus	260	147	226	150	-	-	740
Zeacumantus subcarinatus	962	-	11	-	-	18000*	NA
Polychaetes							
Capitellidae	45	4674	691	50	12040	36584*	present
Nereidae	555	509	464	230	602	1350*	present
Decapods							
Helice crassa	71	328	430	180	516	250*	420
Hemigrapsus crenulatus	57	566	260	present	-	255*	present
Macropthalmus hirtipes	23	102	215	-	516	250*	present

* Jones, 1983

\+ Subtidal

5.3 BIRDS

Waders

The estuaries of the Nelson region rank alongside those of the Auckland region in their importance to wading birds. This is particularly so in summer when the November counts of OSNZ show Nelson sites holding 20.5-30.8% of the national total of waders; c.f. winter (June) 14.5-18.1% (years 1983-6, 'OSNZ NEWS'). Farewell Spit alone holds 15-25% of the summer total and shares with Manukau Harbour the position as the most important site in terms of numbers each year. Whanganui Inlet is one of about twenty sites in New Zealand that hold 1000 waders or more in summer, ranking c17th in its totals in 1985 and 1986 (OSNZ).

A large proportion of the summer wader population in the Nelson region is made up of two Northern hemisphere species, the eastern bar-tailed godwit and the knot (Table 17) (counts of OSNZ).

Summer numbers of godwit at Whanganui Inlet, 1000-2000 birds (Nov 1984 count assumed to have missed most birds as will occur on some tides - see methods), represent 5-10% of those in the Nelson region. Whanganui Inlet holds a smaller percentage of the regional total of knot, but typically ranks second behind Farewell Spit.

In winter the Nelson region is particularly important for two species, South Island pied oystercatcher, though it holds fewer than the Auckland harbours, and banded dotterel for which Farewell Spit and Lake Ellesmere are the major sites. Whanganui Inlet holds few South Island pied oystercatchers (Table 17), but its dotterel population is of more relevance representing a significant proportion of the regional total.

Table 17 compares the four major estuaries of the Nelson region with the three major estuaries in the Auckland region. In terms of wader density (waders/intertidal hectare), Whanganui Inlet does not appear to rank highly, but it stands out along with Farewell Spit for the markedly different densities in summer and winter. This pattern is largely explained by the relatively low numbers of South Island pied oystercatchers overwintering at these two sites.

The similarity of seasonal patterns at Whanganui Inlet and Farewell Spit raises the question of whether the two sites are linked, birds moving the 11 kilometres from one to the other. OSNZ observers have suspected such movements, but they are difficult to confirm. During the very high tides of the January survey most godwit and knot flew out the mouth of Whanganui Inlet, to roost, it was assumed, on the ocean beach. However, these bird could have moved up the coast to the Spit. In a previous summer, a pre-roost gathering of 900 godwit was observed at the very northern end of the inlet, an area where no roost site would be available at the top of the tide (J M Hawkins, pers. comm.). These birds too could have been on their way to the Spit.

Whanganui Inlet ranks second in the Nelson region for the number of wader species recorded, yet it is visited very rarely by birdwatchers compared to the other sites of Table 4. Examination of the species recorded at the inlet shows that they represent most wader 'types', i.e.

1. *Tringa* sandpipers - common sandpiper, wandering tattler.
2. *Calidris* sandpipers - knot, sharp-tailed sandpiper.
3. *Numenius* spp - far-eastern curlew.
4. Plovers and dotterels - golden plover, banded dotterel.

More frequent surveys of Whanganui Inlet would be expected to record occasional visits by the other species in these wader groupings that regularly visit the region (e.g. whimbrel, red-necked stint, NZ dotterel etc).

Marsh Birds

This group includes the species that occupy the zone of estuarine fringe, from *Juncus/Leptocarpus/Schoenoplectus* through raupo and flax to manuka and shrub species.

The most significant species to occupy this habitat at Whanganui Inlet is the banded rail, recorded at two sites at each end of the inlet. Unlike the other species in this group, it is now only found in marshes with a marine influence (salt marshes) in the South Island, not in freshwater sites. Whanganui Inlet represents the only site for the species on the west coast of the South Island, while a few are present on Stewart Island (Bull et al, 1985). The location of banded rail in the same marsh at the western end of the inlet in 1982 and 1989, and not in neighbouring marshes, suggests stability of the population.

Bitterns require densely vegetated wetlands, particularly those with standing water (Williams, 1985). One was flushed from a site west of Rakopi that offered this combination with water in channels and ponds at all tidal levels. Tapes of booming calls were played at this and other sites with no response, though it was rather later in the season than ideal for such a survey. Bittern are known from two nearby freshwater sites, Rakopi wetland and Mangarakau swamp.

Crakes are notoriously difficult to census. This brief survey indicated that marsh crake were resident in two or three sites, areas with a fairly broad fringe including scattered raupo. Extrapolating from these sites (Fig.7) it is considered that there are six other sites suitable for crakes, two of which have never been surveyed and four that have been covered, but no birds found. The presence of single birds at Muddy Creek and east of Rakopi is assumed to indicate the presence of breeding pairs there. Extending this assumption to the other sites the best estimate of the marsh crake population of the inlet is between two and nine pairs. Another assumption which is borne out by this brief survey and the very much more extensive one of Elliott (1983) is that banded rail and marsh crake will not occupy the same saltmarsh.

The survey was too brief to state categorically that there is no resident population of spotless crake at Whanganui Inlet, but this seems likely, particularly after the findings of Elliott (1983) referred to earlier. The species was recorded at relatively few sites in New Zealand during the 1969-76 bird mapping scheme of OSNZ (Bull et al, 1985) and at none round the coast from the Takaka area to Hokitika. Whanganui Inlet is thus a new location for the species, but recent work is showing marsh crake to be more common that once thought (eg. birds located near Westport in 1985).

Fernbirds were located at six sites during the survey. This is considered to be a very incomplete picture of their distribution, for birds do not respond very readily to tapes at the time of year the survey was made. Suitable habitat exists round most of the larger saltmarshes at Whanganui Inlet.

Both the banded rail and bittern are considered as "threatened" species and the fernbird as "regionally threatened" (Bell, 1986). This largely results from habitat destruction through wetland drainage, infilling, burning etc. The numbers of these species occurring at Whanganui Inlet are not large, but they are significant because of this destruction which continues in many areas. The only major coastal wetlands with formal protection in the region are those at Farewell Spit and in Abel Tasman National Park. Protection of the sites at Whanganui Inlet would be an important contribution to the safeguarding of marsh birds within the region.

Herons, Egrets and Spoonbills

Whanganui Inlet supports large numbers of the widespread white-faced heron, but apparently is only visited by occasional individuals of the other rarer species within this group. Both white herons and royal spoonbills have small populations in New Zealand, 100-120 and 50-100 birds respectively, and have been recorded once or twice at Whanganui Inlet. Cattle egret visit New Zealand in winter in much larger numbers and have only been recorded once at Whanganui Inlet. However, the inlet's location may make it one of the arrival points for Nelson region's cattle egret - the first records each winter usually come from nearby Pakawau (JM Hawkins, pers. comm.).

Seabirds

Whanganui Inlet did not support large numbers of seabirds during the survey though more gulls may occur in winter. Gannets, caspian and white-fronted terns and red-billed gulls that breed on Farewell Spit may regularly feed there and the inlet may provide shelter for other seabirds during storms on the West Coast. Little shags and black-backed gulls would be the most numerous of the resident species, but Whanganui Inlet does not hold significant numbers of either.

Table 15. Number of fish species recorded living, visiting or migrating into Whanganui Inlet and other estuaries in New Zealand.

ESTUARY	MARINE SPECIES	FRESHWATER SPECIES	COMMERCIAL SPECIES	TOTAL SPECIES
Whanganui Inlet [1]	38	12	17	50
Waimea Inlet [2]	31	10	20	41
Ahuriri Estuary [3]	21	8	18	29
Avon-Heathcote [4]	24	10	19	34
Porirua, Pauatahanui [5]	36	7	14	43
* Wairau River Estuary [6]	13	9	7	22
Upper Waitemata Harbour [7]	20	1	10	21

* includes Vernon Lagoons

1. Present Study
2. Davidson and Moffat, 1989
3. Kilner and Akroyd, 1978
4. Knox and Kilner, 1973
5. Jones and Hadfield, 1985
6. Knox, 1984
7. Biggs, 1980

Table 16. Number of waterbird species from Waimea Inlet and other New Zealand estuaries

ESTUARY	NUMBER	SOURCE
Whanganui Inlet	42	Present Study
Waimea Inlet	50	Davidson and Moffat, 1989
Wairau (Vernon Lagoons)	56	Knox, 1983
Avon-Heathcote	53	Holdaway, 1983
Kaipara Harbour	42	Veitch, 1979
Pauatahanui	30	Healy, 1980

Table 17. 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:

Whanganui 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.9). 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).

Primary autochthonous production in estuaries is from macro-algae (eg. *Ulva*, *Enteromorpha*, *Gracilaria*.), salt marsh vegetation (eg.*Juncus*, *Leptocarpus*, *Schoenoplectus*), eelgrass (*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 Whanganui Inlet, 47 species of invertebrate deposit feeder were recorded. The most abundant invertebrate was the mudflat snail (*Amphibola*), wedge shell (*Tellina*), nutshell (*Nucula*), estuarine snail (*Potamopyrgus*), stalk-eyed crab (*Macropthalmus*), and mud crab (*Helice*). Deposit feeding fishes were also recorded in the inlet (eg. yellow-eyed mullet, grey mullet).

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 Whanganui Inlet. The rich source of suspended detritus supports large populations of cockles (*Chione*) and barnacles (*Elminius*).

Both deposit feeders and suspension feeders are potential prey for higher trophic levels (Fig. 9). A large diversity of invertebrate predators, especially gastropods, was recorded from Whanganui 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.

6.1 PRIMARY PRODUCTIVITY IN WHANGANUI INLET

Evidence of high estuarine productivity has been based on estuaries with mangroves or extensive salt marshes (McCarthy et.al., 1974; Correll, 1978; Southwick and Pine, 1975; Orth, 1977; Knox, 1986). Estuaries in the South Island of New Zealand are dominated by mud and sand flats with salt marsh communities often restricted to the margins. Productivity values for this type of estuary has been shown to be far lower than overseas estuaries or mangrove estuaries in New Zealand (MacKenzie, 1983; Davidson and Moffat, 1990).

Although no calculations of plant productivity exist for Whanganui Inlet, an approximation of estuarine productivity for the inlet is calculated using values calculated for Delaware Inlet (Gillespie and MacKenzie, 1981; MacKenzie, 1983) and Kaituna Marsh, Pelorus Sound (Odum et.al., 1983). The approximation of productivity for Whanganui Inlet using these figures is shown in Table 18.

Eelgrass (Zostera) covers 859 ha or 31% of the total estuary and contribute an estimated 75% of the total yearly primary production. Salt marsh species *Juncus, Leptocarpus* and *Shoenoplectus* cover 122 ha or 4.4% of the total estuary and contribute approximately 13% of the primary production (Table 18).

Epibenthic microalgae consist mainly of diatoms and euglenoids and colonise the entire surface area of rocks, plants, mud and sand flats. In practice this represents a far larger area than is used in calculations in Table 18, therefore the figure of 7.2% of primary productivity may be conservative.

The other main sources of primary productivity in Whanganui Inlet are from phytoplankton and macroalgae (*Ulva, Gracilaria*). Values of primary production for these producers is difficult to accurately estimate due to large fluctuations throughout the year.

An approximation of the total tonnes of carbon produced in the inlet per year (4006 tonnes) was used to calculate the primary production for the whole estuary (Table 18). The value of 146 g.C.m^2/year is low compared with many overseas estuaries, however, is high compared with other South Island estuaries. Mean primary production for Delaware Inlet (109.5 g.C.m^2/year) and Waimea Inlet (49.4 g.C.m^2/year) are both considerably lower than the mean primary productivity for Whanganui Inlet. This difference is due to the large areas of eelgrass present on much of the intertidal flats in Whanganui Inlet.

It is stressed that these figures are an approximation of primary productivity in Whanganui Inlet. It is certain that environmental factors (nutrients, climate, sediments) operating in this area will be different than those operating in the estuaries where productivity values were obtained. Primary production in the inlet is operating largely without significant artificial enrichment. The inlet therefore represents one of a small number of estuaries in New Zealand which operate in a relatively natural way.

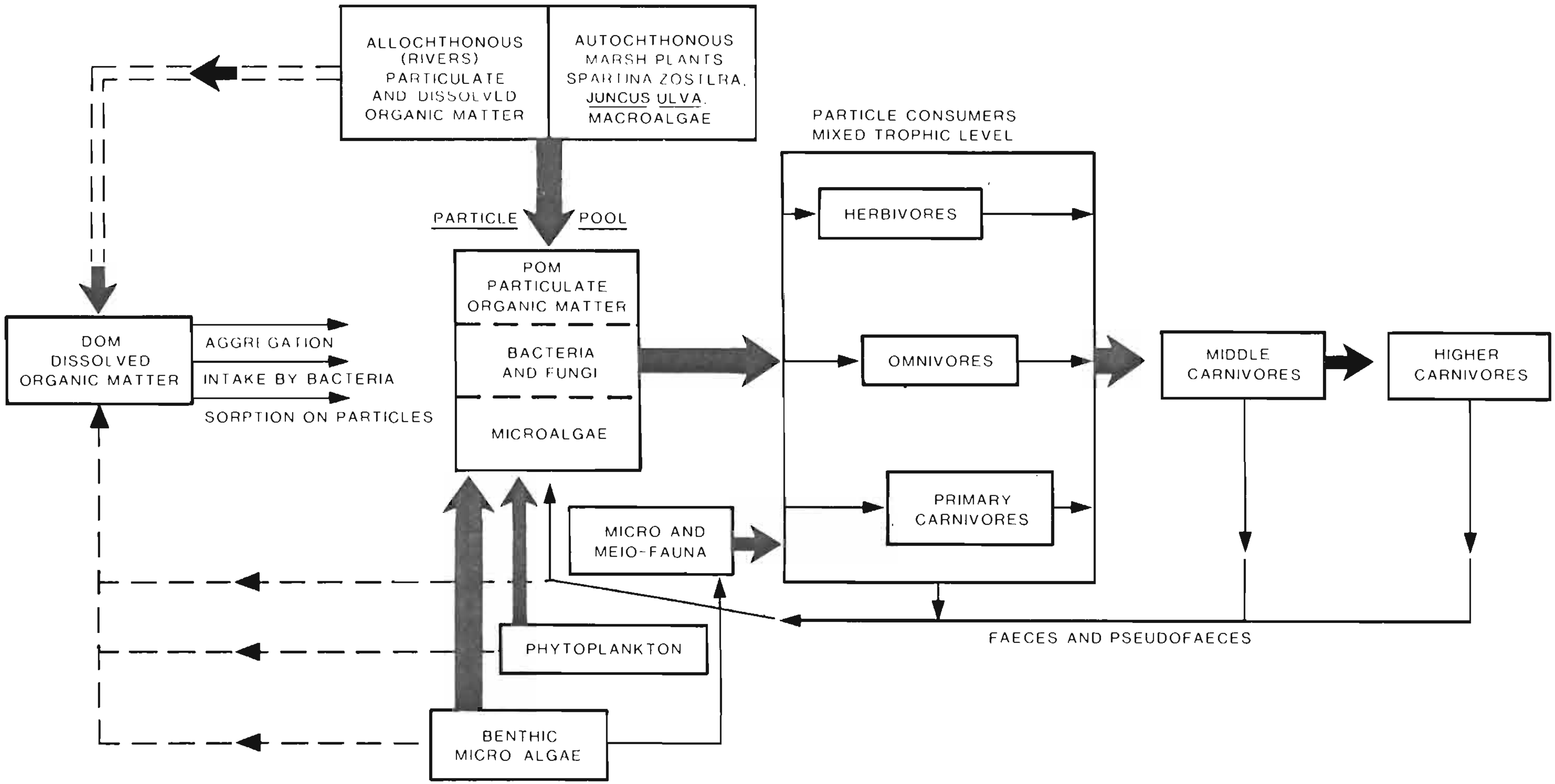


Fig. 9 A conceptual model of a salt marsh-fringed estuary showing the most important energy flows as broad arrows, less important food chains as narrow arrows, and the pathway of dissolved organic matter as dotted lines.

Table 18. Approximation of primary productivity in Whanganui 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 $_1$	122	4.4	534	13%
Zostera muelleri	350 $_2$	859	31.3	3007	75%
Macroalgae	475 $_1$	15.6	0.57	74	1.8%
Epibenthic Microalgae	14.6 $_1$	1979	71.9	289	7.2%
Phytoplankton	3.7 $_1$	2748	100	102	2.5%
Total	145.8	2748		4006	

1. Mackenzie, 1983; 2. Thayer et. al., 1975.

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

7. HUMAN IMPACTS

Estuarine areas have changed dramatically due to human activity and this has often had significant impacts on the ecology of these areas. For example, eelgrass has disappeared from many intertidal areas of the world (Thayer et. al., 1975; Orth 1976). Overseas studies have linked the loss of eelgrass to a major decline of fish numbers (Milne and Milne, 1951), fish density and diversity (Briggs and O'Connor, 1971), major reduction in the number of invertebrates (Flemer et. al., 1967), and a major reduction in productivity entering the system (Knox, 1986). Taylor and Saloman (1968) estimated that the destruction of 1,100 tonnes of eelgrass resulted in the immediate loss of approximately 1,800 tonnes of infauna. They also estimated that at least 73 tonnes of fishery products and 1,100 tonnes of macro-invertebrate fauna were lost annually as a result of eelgrass death due to dredging. Loss of eelgrass has been related to a range of factors, most of which are related to human impact (eg. increased sedimentation, dredging, trawling).

The primary reasons for the high intensity of activities around estuaries are related to their association with fertile alluvial plains, navigable water ways and cheap land gained by infilling. Today, estuaries are still being modified by industrialisation, urbanisation, aquaculture, dumping of rubbish, pollution, agriculture and roading. The high ecological values of Whanganui Inlet remain largely intact, however, the impact of human activity in the past has been significant.

7.1 POLLUTION AND NUTRIENT INPUT

Estuaries are extremely vulnerable to concentration of pollutants and nutrients (Barnes, 1984; Knox, 1986; Franko, 1987). Fine sediment particles have been shown to concentrate pollutants from petroleum by-products, persistent pesticides and heavy metals (Odum et. al., 1969; Stephenson, 1980; Knox, 1986). The impact of pollution in Whanganui Inlet is potentially serious. At present, there exist relatively few point sources of pollution and the inlet is in a relatively natural state. This could be quickly altered by an increase in the loading of nutrients or pollutants.

Probably the largest source of unnatural nutrient enrichment is from farm run-off. Any impact on the inlet is not recognisable within the scope of this study. This may be because many of the streams and gullies draining farmland are covered with scrub and remnant forest and bordered by salt marsh, thereby filtering out much of the nutrients. It is important that these buffer strips be maintained. Invertebrate communities recorded from the inlet were poorly represented by the pollution indicating organisms (eg. *Capitella capitata, Heteromastides filiformis*) and pollution sensitive organisms such as the nut shell (*Nucula hartvigiana*) were abundant and widely distributed in the inlet.

Whanganui Inlet presents a unique opportunity whereby an estuarine system can be studied in a near natural stage. Most studies on nutrient cycling in New Zealand estuaries have been undertaken in systems where effluent, sewage or land run-off have significant impacts (Knox and Kilner, 1973; Gillespie, 1983; Knox 1986).

7.2 REFUSE DISPOSAL

A small rubbish dump is located in the south-east corner of Whanganui Inlet on land managed by the Department of Conservation (Map 1; Plate 16). The tip is well above mean high water, but is undesirable for the following reasons:
(a) it is aesthetically unacceptable;
(b) it is possible leachate of toxic substances into inlet; and
(c) it is a food source for rats.

The apparent absence of rails or crakes from this site is likely caused by a local increase in predators in the form of rats and cats.

Before this illegal dump is removed, an alternative solution or site is required. Some people have been observed dumping bottles directly into the main channels flowing under causeways.

7.3 CAUSEWAYS AND ROADING

A total of 18 causeways cross embayments in Whanganui Inlet. Fourteen of these causeways are located along the eastern side of the inlet and connect Mangarakau settlement with the road to Collingwood. The remaining four causeways are located along the north-eastern end of the inlet and link the north-head farms to the main road.

Causeways upset the natural ecology of the embayment area by interrupting water currents, salinity regimes, sedimentation patterns and flushing. No data is available on the impact of causeways in Whanganui Inlet. Observations of embayments cut off by causeways in the estuaries of Tasman Bay suggest that the size and tidal height of the culvert has a significant impact on the enclosed area. In Parapara Inlet, construction of a road causeway cut off a large embayment. Modification of the catchment and gold sluicing activities resulted in increased sedimentation rates altering the ecology of the area (Knox et. al., 1977). In Whanganui Inlet, all of the large eastern embayments are bisected by road causeways. The impact of these causeways in the inlet appears minimal. All of the pipes or bridges which allow the interchange of water are constructed in a way that allow all water within the embayment to flow away at low tide. Only an embayment at Bone Creek retains a layer of trapped water at low tide.

Causeways restrict water flows, creating eclosed areas of relatively still water. Sediments settle out more readily under such conditions. Causeways, therefore, trap sediments that would otherwise be dispersed over a much wider area. Hense thay accentuate any ecological problems caused by sediment run-off from surrounding catchments.

Most embayments show little sign of high sedimentation rates. Nearly all catchments in Whanganui Inlet are covered in bush thereby reducing sediment run-off. Signs of increased sedimentation in the Mangarakau embayment is probably due to relatively recent logging of the area and the influence of the causeway.

Much of the inlet is bordered by unformed legal road which is clad in coastal forest. Establishment of roads around the estuary can cause loss of salt marsh, increased sedimentation, blocking of freshwater flows and loss of coastal forest (Plates 19,20).

7.4 TRANSMISSION LINES

Transmission lines cross the inlet at various points. There are two types of line in the inlet. The first is the traditional wooden pole placed over the intertidal flats while the second type consists of poles places on hill tops and peninsulas with overhead wires spanning the inlet. Although these power poles do not have a detrimental impact on the ecology of the estuary, they have a visual impact, particularly the wooden poles on the intertidal flats. Prior to installation or replacement of powerlines, consideration should be given to the location and type of structure to be used. Underground cables would provided a more suitable long-term solution.

Disused lines and poles are located at various points along the south-eastern edge of Whanganui Inlet. The lines have fallen from the poles and lie across the estuary flats.

7.5 LIVESTOCK GRAZING

Grazing by livestock (cattle, sheep, goats) in intertidal and dune areas was recorded from the Rakopi salt marsh, along the margins of the northern peninsula and once from the south-west corner of the inlet. Grazing also occurs in privately owned remnant coastal forests on the north and south peninsulas and on the extensive dune system on the north head (road reserve). Grazing by livestock has a detrimental impact on the diversity and continued survival of the ecology of these areas, however, many are privately owned and managed as such.

7.6 LOGGING OF FOREST

Significant areas around the margins and in the catchments of Whanganui Inlet are forested. The forest is one of the inlet's assets which sets it aside from most estuaries in New Zealand. The forest has an important role in maintaining the sound ecology of the estuary through nutrient input, reducing sediment run-off and providing habitat for estuarine birds. Therefore, loss of any of the forest surrounding the inlet or in the catchments of the estuary would have a serious influence on the inlet's ecology. Large quantities of sediment brought down the rivers following logging could cover the eelgrass beds, smother feeding appendages of many invertebrates, and change the entire sediment regime of the inlet. A sedimentation study of the deposition into the Upper Waitemata Harbour, (Hume and McGlone, 1986) suggested that pre-Polynesian sedimentation rates were 1.5 mm/year. Following forest clearance, rates of sediment deposition into the estuary increased to 3 mm/year. Sedimentation rates would be significantly higher behind causeways.

7.7 INFILLING OF ESTUARY AND WETLAND DRAINAGE

Infilling of salt marsh areas, as has occurred recently during road construction adjacent to Wairoa River, clearly renders sites unsuitable for wetland birds and permanently destroys estuarine habitat (Plates 19,20).

Drainage of wetland areas located on private land around the inlet is threatening valuable habitat (Plate 18). The area of major concern is in the White Pine Creek catchment.

7.8 INTRODUCTION OF EXOTICS

Following the introduction and subsequent establishment of the cord grass *Spartina anglica*, an eradication program was carried out by the Wildlife Service. One small remnant clump of *Spartina* was recorded in the present study and has since been removed.

Introduction of other exotics in the estuary is a continual threat. Marram grass for example, has virtually excluded the native sand binding species, while the ice plant *Carpobrotus edulis* is at the early stages of establishment in a localised area on the north head. Attempts by local land owners to introduce the Pacific Oyster *Crassostrea gigas* have failed. Establishment of this oyster in Whanganui Inlet is unlikely to occur natuarally due to the west coast currents, however, artificial introduction and the possible establishment may result in the dominance of much of the rocky intertidal areas by this oyster. This may result in the exclusion of many intertidal species and make the traditional movement of stock around the estuary edges difficult.

Plate 16 Illegal rubbish dump

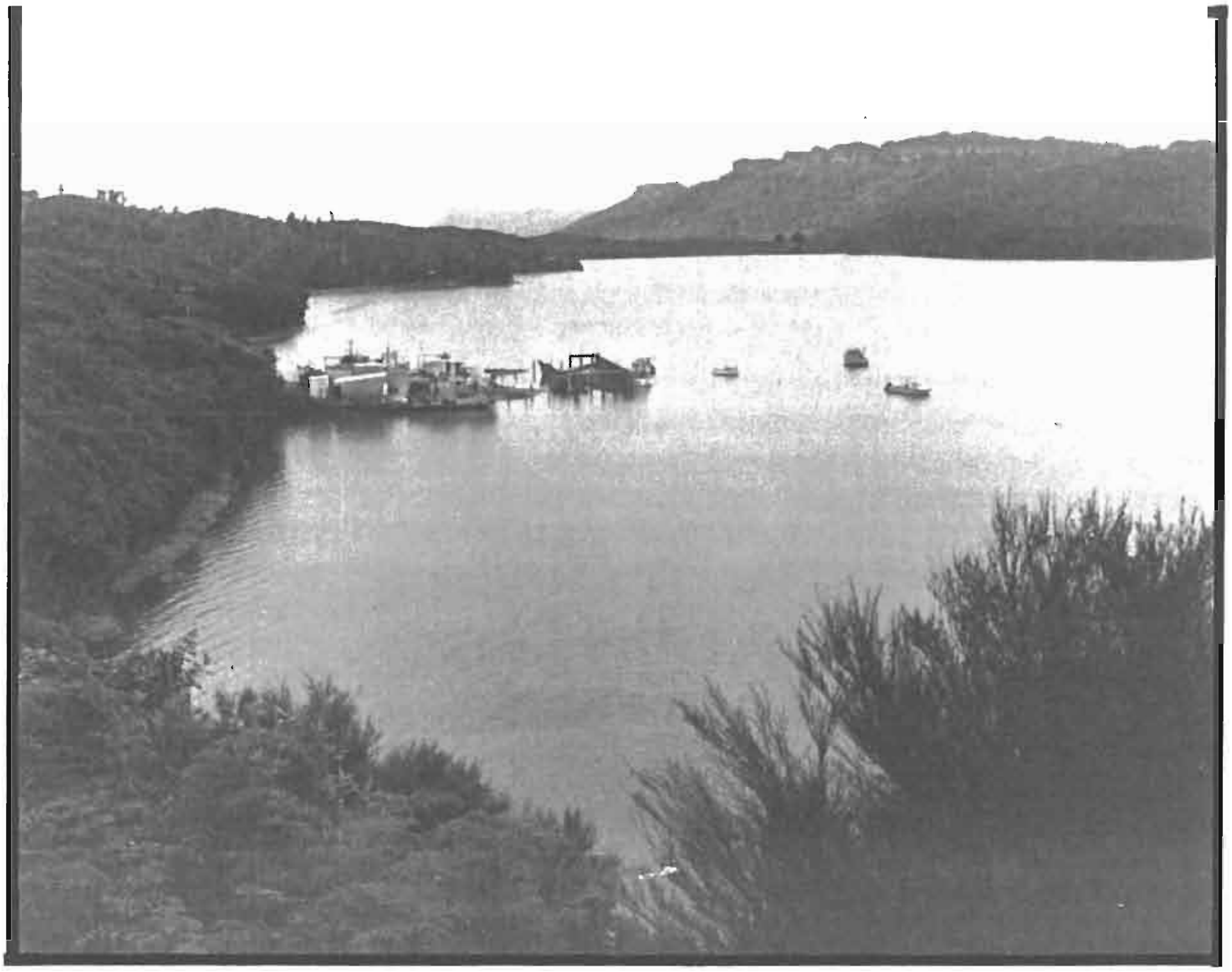


Plate 17 Mangarakau wharf

Plate 18 Drainage of wetland forest

Plate 19 Impact of roading, Wairoa River

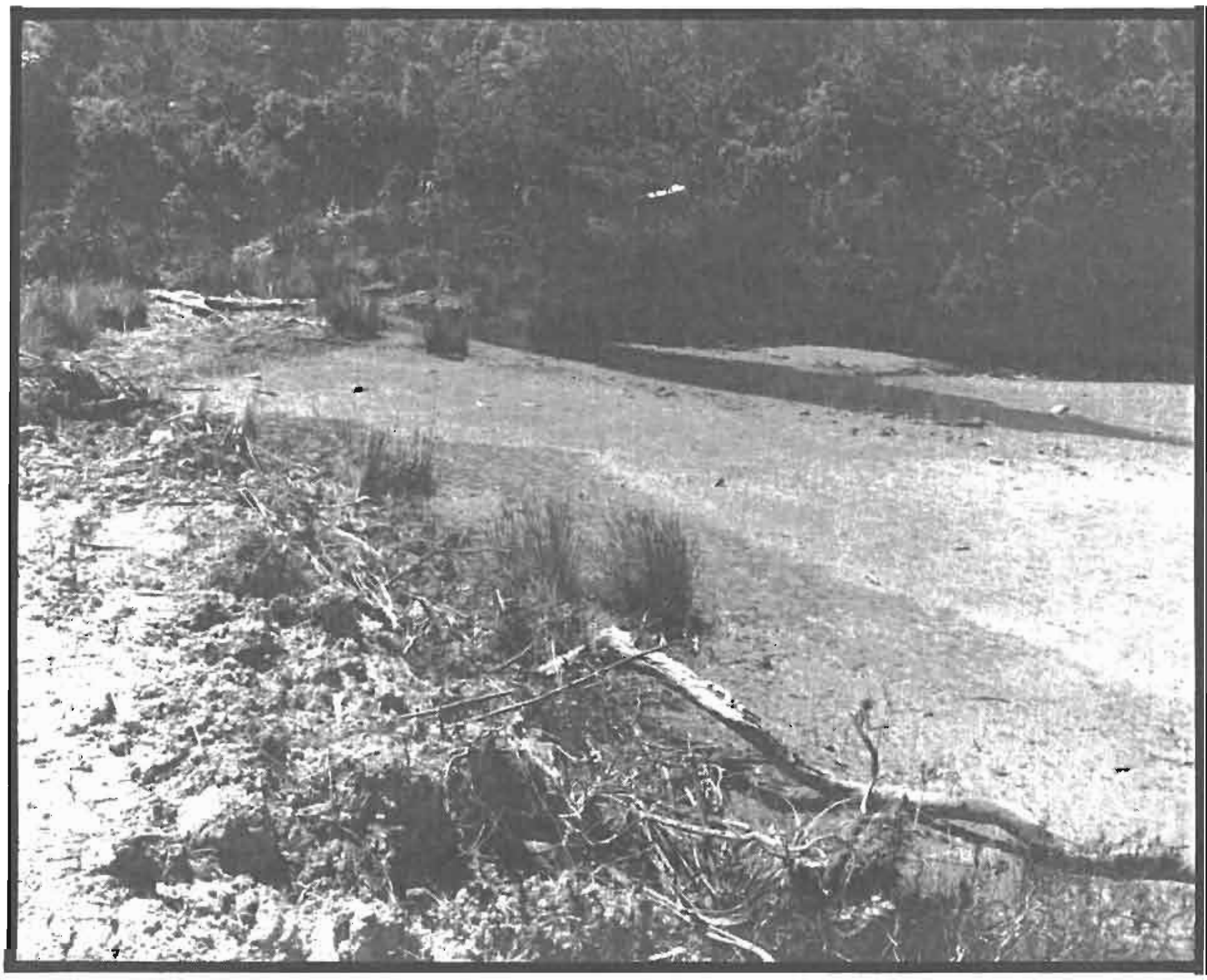


Plate 20 Loss of salt marsh through roading

8. REPRESENTATIVE AREAS OF BIOLOGICAL IMPORTANCE

To assign areas of biological importance on a national scale would effectively encompass the entire inlet and outer coast. This chapter focuses below this level and deals with the best representative sites of biological importance within the inlet, the entrance area and along the adjacent outer coastline (Fig.10).

8.1 OUTER COAST

The outer coast is characterised by a rugged, exposed and scenic seascape. A variety of exposed coastal habitats are represented within a relatively short distance from the inlet mouth.

Beach/Dune/Coastal Forest (Area A)
The outer coast zone from Sharks Head to Kaihoka Point has numerous sand beaches, however, most are entirely intertidal and have little or no associated dunes. The beach situated on the northern side of the entrance to Whanganui Inlet is approximately 2 kilometres in length and fronts an extensive area of marram covered dunes with one recorded site of pingau (approximately 6 plants) (Fig.10; Plate 21). At the northern end, the dunes grade into coastal forest dominated by nikau palms. This is the only site along the west coast of the Nelson region where uninterrupted coastal forest through dunes to sandy beach remain. The beach and dune system is zoned road reserve, and is currently grazed by the north-head land owners. Although grazing appears to have little impact on the stability of the dunes, the understory of the privately owned forest is threatened.

Intertidal Rock (Area B)
The outer coast is dominated by rock, subtidally, intertidally, and in the splash and salt-spray zone. Significant areas of intertidal rock platform are located immediately south of South Head Cone and north of Sharks Head. These extensive rock platforms are subject to fierce wave action, testified by the presence of bull kelp *(Durvillea antarctica)* on the seaward faces. Most rock platform is covered by a dense carpet of encrusting algae (eg. *Corallina, Gigrartina, Ulva*)(Plate 22). Landward of the rock platforms at the South Head are either cliffs or boulders, while north of Sharks Head, a series of pancake rocks, caves and coastal forest remnants border the intertidal zone (plate 6).

Subtidal Reef (Area C)
Extensive subtidal reef areas are located along the outer coast and at the entrance (Rob's Reef). Large seas make investigation of subtidal areas on the outer coast difficult. Of the areas investigated, the subtidal rock reef on the southern side of the entrance represents the best subtidal site recorded in the inlet to date (Fig.10). Local reports suggest that the outer coast adjacent to the entrance is swept by large quantities of moving sand which often buries rock habitats.

The subtidal area in the entrance supports a rich flora and fauna and is a habitat found nowhere else in the estuaries of the Nelson/Marlborough region. The Rob's Reef area is dominated by coastal species of fish, invertebrate and algae and is the only area in the vicinity where visual subtidal work can be carried out on a relatively regular basis.

8.2 ESTUARY

Sequence from Forest to Estuary (Area G)
The uninterupted sequence of natural vegetation from forest through to an estuarine environment is rare in the Nelson/Marlborough region. The only other estuaries in the region with forest to estuary sequences are found in the Abel Tasman National Park, Big River Estuary and selected tidal areas in the Marlborough Sounds. In Whanganui Inlet, this sequence stretches from snow capped mountains in the North-west Nelson Forest Park down to the estuary (Plate 23).

Salt Marsh (Area D,E)
Salt marsh grows above mean high water mark around the margins of estuarine areas. In Tasman and Golden Bays significant salt marsh areas have been lost especially around the margins of Waimea, Moutere, and Ruataniwha Inlets. In Whanganui Inlet, most salt marsh has remained intact and forms a relatively thin band around the estuarine margins.

Two areas of salt marsh in Whanganui Inlet can be regarded as exceptional cases (Fig.10). Approximately 6 km above the Wairoa River Causeway is a 0.4ha area of *Leptocarpus similis* (jointed wire rush) salt marsh (Plate 24). This salt marsh has established in an 3.2 ha embayment deposited by the Wairoa River. The salt marsh is bordered by mature beech forest which is privately owned. The second salt marsh in the inlet of special biological importance is the Rakopi salt marsh. The Rakopi salt marsh begins at Muddy Creek and stretches 4 km towards Rakopi before grading into a 24 ha tidal wetland (Fig.10,11; Plate 25). The Rakopi salt marsh is approximately 1 km wide and encompasses an area of 56 ha. The most abundant species of plant is the sea rush *Juncus maritimus*. Significant areas of jointed wire rush *(Leptocarpus)*, sea primrose *(Samolus repens)* and numerous other ground dwelling estuarine plants also occur.

Zostera (Eelgrass) (Area F)
In Whanganui Inlet, 859 ha or 43% of the intertidal area is covered by eelgrass *(Zostera muelleri)*. Most eelgrass grows on mud substrate and is luxuriant, however, around Rakopi significant areas of eelgrass grows on fine sand and are sparsely distributed. The single largest area of eelgrass in the inlet is located centrally in the northern arm (Fig.10; Plate 26). This 792 ha area in the northern inlet is covered with a complex network of minor channels which drain the eelgrass beds. Only 8% of all the eelgrass in the inlet is located outside the northern end of Whanganui Inlet.

8.3 FRESHWATER CATCHMENTS AND WETLANDS

Mangarakau Wetland (Area H)
Mangarakau wetland is the largest freshwater wetland in the Nelson/Marlborough region (Davidson et.al., 1990). The wetland drains southward into the Patarau River and to the north through an artificial drain into Whanganui Inlet. The wetland is an important area for many wetland birds (bittern, fernbird) and freshwater fish. Banded kokopu whitebait have been recorded moving into the wetland from the inlet via a small waterfall.

Freshwater Catchments
The eastern catchments of the inlet are forested, while most of the western side is farmed. The eastern catchments are characterised by steeply sided valleys covered in bush with low gradient estuarine and river flats below. The extent of tidal flow into these arms of the inlet is often many kilometers. Most notable freshwater catchments are Muddy Creek, Wairoa River, Banjo Creek and Bone Creek.

The catchments on the western side of the inlet are smaller, stable streams which often drain fertile pastures or lowland coastal forest. The size and nature of these small streams makes them vulnerable to human activity such as land clearance and grazing (Eldon and Ward, 1990; appendix 0).

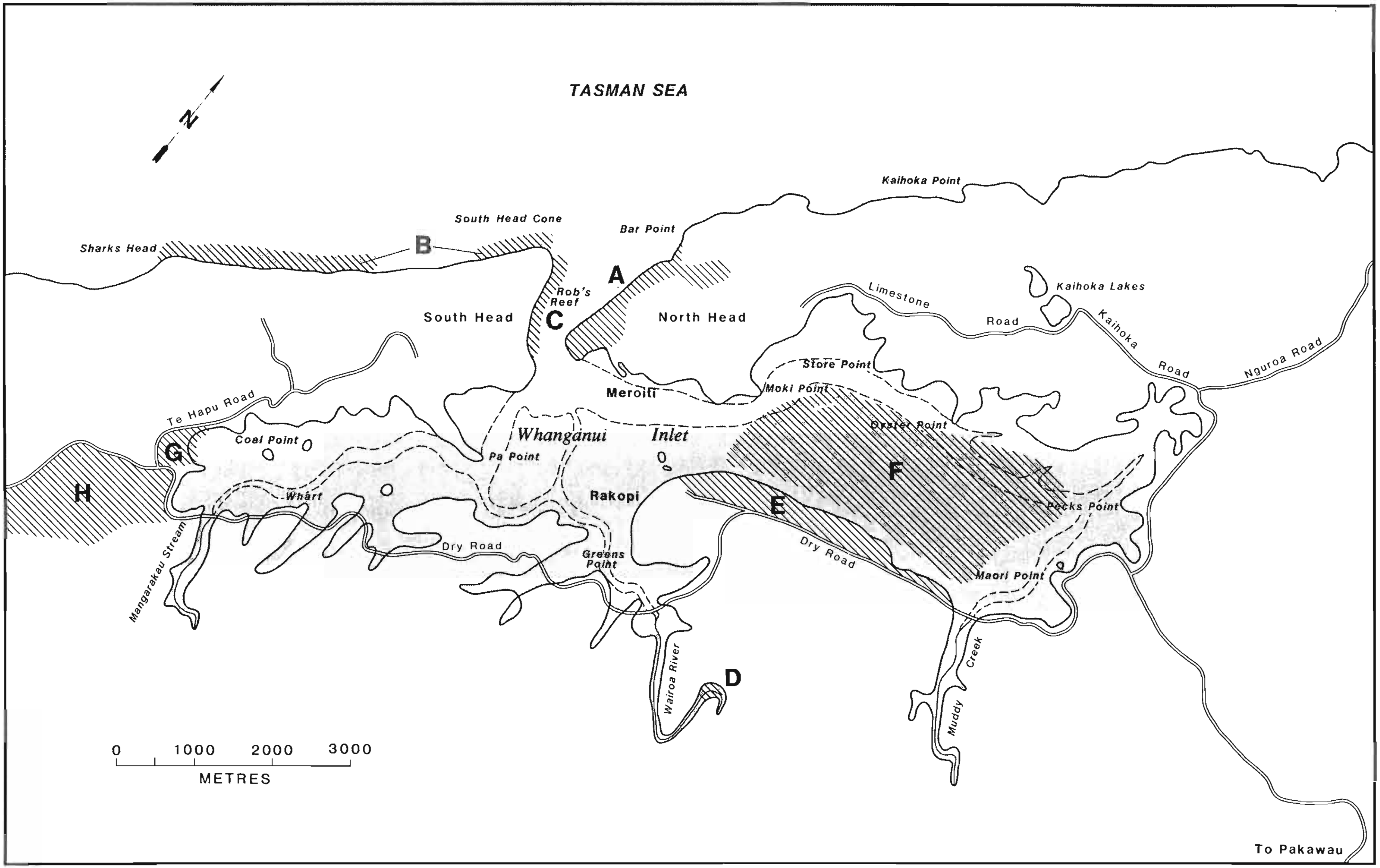


Fig. 10 REPRESENTATIVE AREAS OF BIOLOGICAL IMPORTANCE

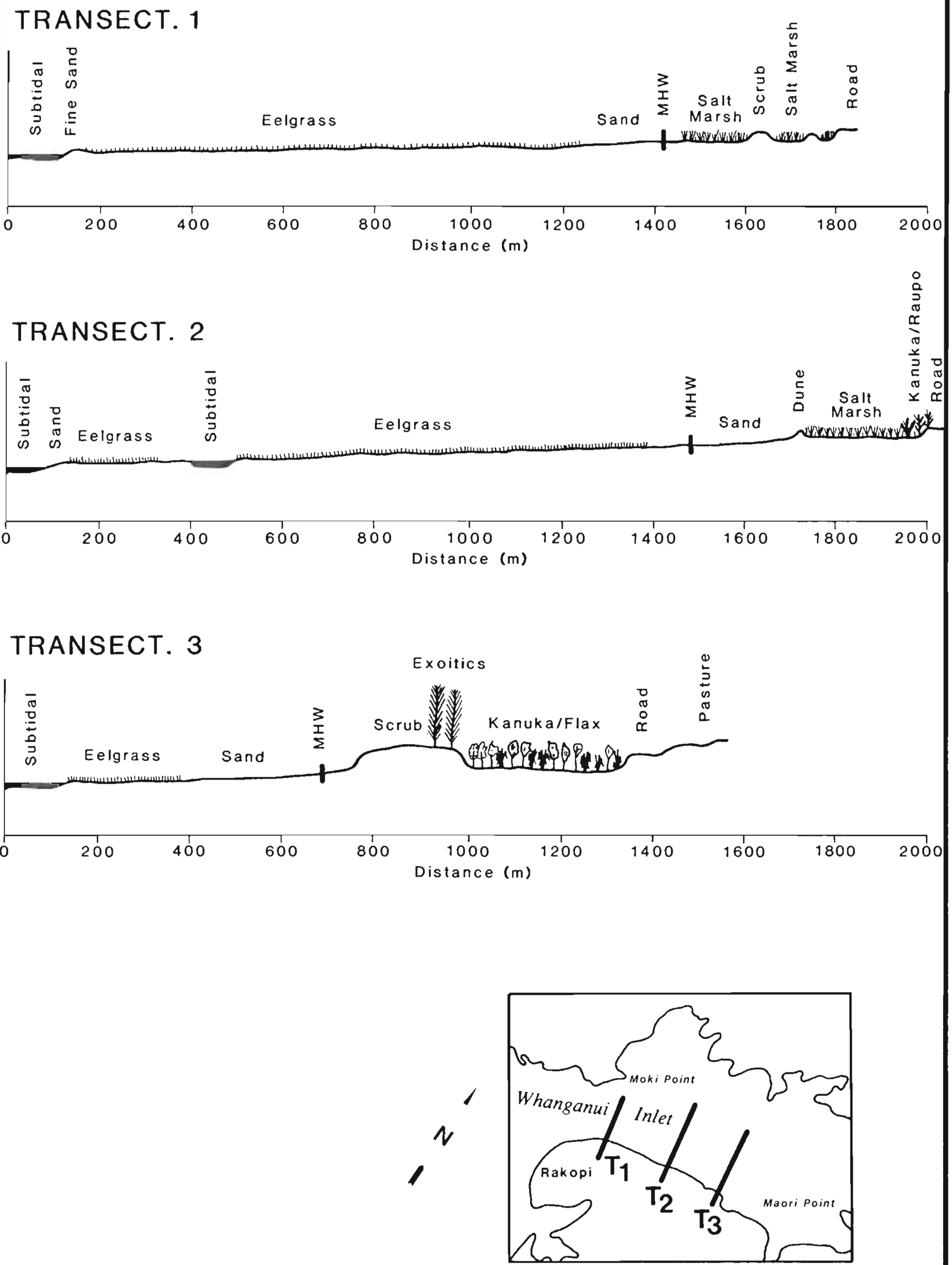


Fig.11 INTERTIDAL TRANSECTS

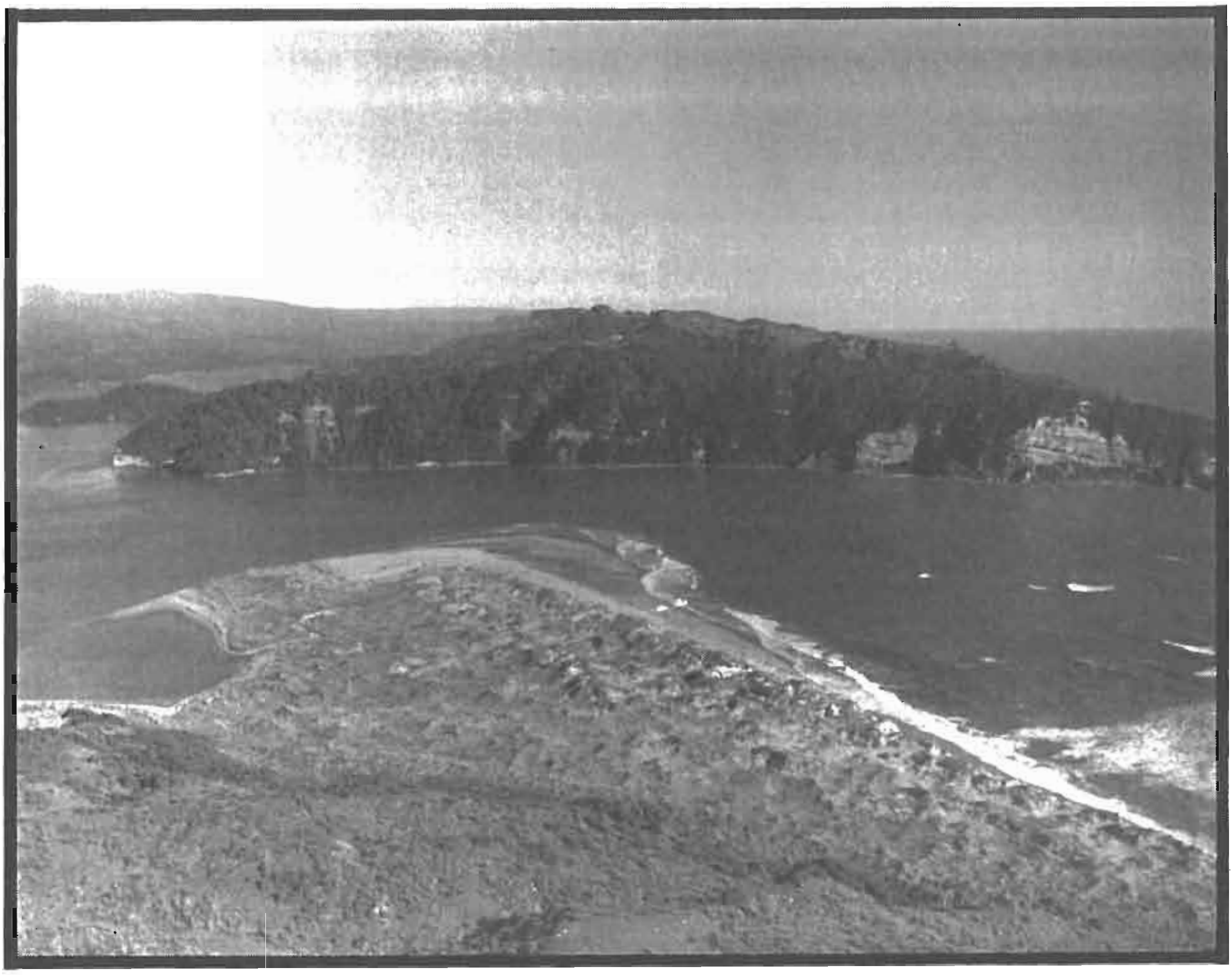


Plate 21 Dune system, North Head

Plate 22 Rock platforms, South Head

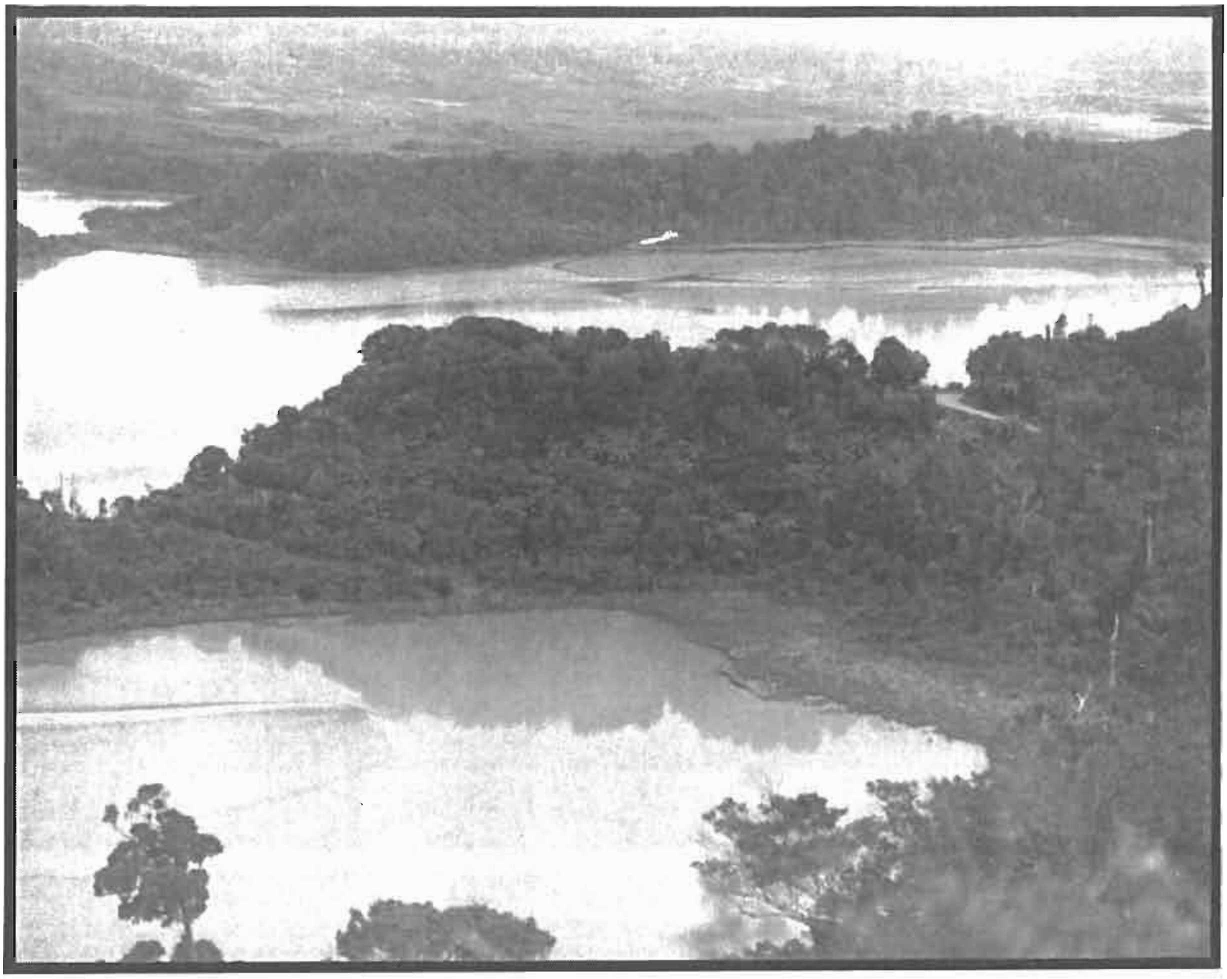


Plate 23 Coastal forest, southern inlet

Plate 24 Salt marsh, Wairoa River

Plate 25   Rakopi salt marsh

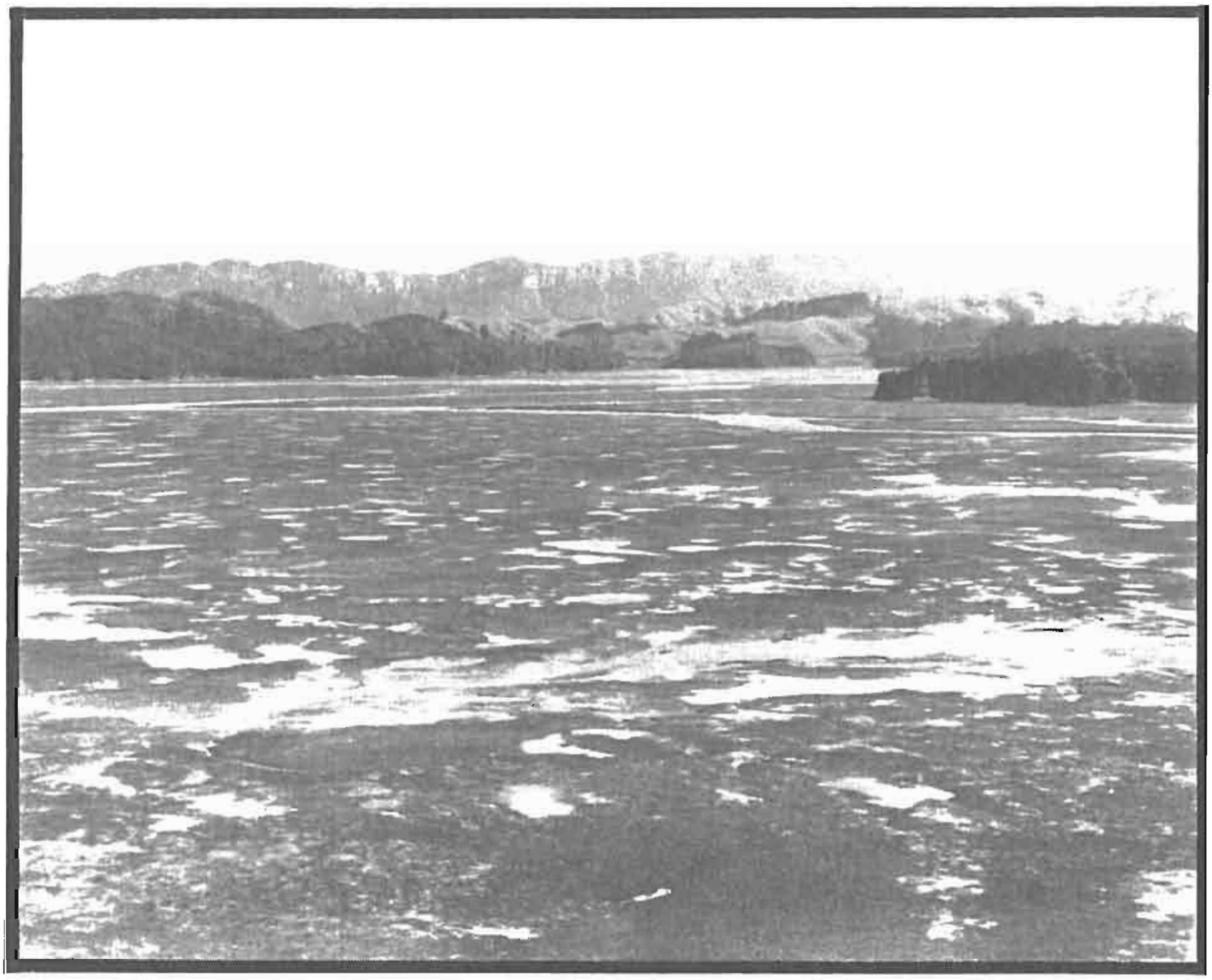


Plate 26   Eelgrass *(Zostera)*, northern inlet

9. EVALUATION OF WHANGANUI INLET

The conservation value of Whanganui Inlet is compared with three other South Island estuaries in Table 19. This evaluation process used criteria developed by Davidson and Moffat (1989) for Waimea Inlet (Appendix 13). Parapara, Waimea and the Avon-Heathcote estuaries have each been the subject of relatively in depth studies (Knox and Kilner, 1973; Knox et. al., 1977; Davidson and Moffat, 1990).

On conservation grounds, Whanganui Inlet clearly ranks highest of the four estuaries. Whanganui Inlet received the highest possible scores in representativeness, pollution status, salt marsh vegetation, size, and invertebrate and fish diversity criteria (Table 19). For all other criteria, Whanganui Inlet received the second highest possible score. Waimea and Avon-Heathcote estuaries scored poorly in some areas due to human impacts of a permanent nature (eg. infilling, industrial development). Most human modification in Whanganui Inlet has been minor in comparison and has largely recovered over time (eg. selective logging, grazing, flax milling). Parapara Inlet has had relatively low levels of human impact below the road causeway, but is typical of small inlets in the Golden Bay area where species diversity is generally low.

Table 19. Evaluation of Whanganui Inlet and three other South Island estuaries (see appendix 13).

Criteria	Whanganui Inlet	Waimea Inlet	Parapara Inlet	Avon-Heatcote
(1) Representativeness in region	80	80	27	80
(2) State of estuary	60	40	40	40
(3) Pollution status	60	30	45	15
(4) State of terrestrial vegetation	45	15	30	15
(5) State of salt marsh vegetation	60	45	45	30
(6) Size of intertidal and subtidal areas	60	60	24	36
(7) Number of invertebrate species	40	32	16	32
(8) Number of waterbird species	24	24	8	32
(9) Number of fish species	40	40	30	40
(10) Maximum cockle density	32	40	24	40
(11) Number of intertidal vascular plant species	10	20	15	20
Total	511	426	304	380
Percent	91%	76%	54%	68%

10. MANAGEMENT RECOMMENDATIONS

This chapter outlines management recommendations based on conservation values in Whanganui Inlet and the adjacent outer coast.

10.1 A CASE FOR PROTECTION

Human activity in and around most New Zealand estuaries has had severe and lasting impacts. Whanganui Inlet and its surrounding land has also been modified through logging, mining, flax milling, roading and land clearance (chapter 7). These activities have undoubtedly affected the estuary in the past, but through time many of the scars have disappeared. Whanganui Inlet is now one of the best examples of a natural estuarine environment in New Zealand. It embodies many of the elements that charactered estuaries of the Nelson/Marlborough region prior to human arrival. It is important, therefore, that Whanganui Inlet and associated freshwater and terrestrial areas be protected before these last areas are lost or seriously modified.

The high natural and human values associated with Whanganui Inlet are largely attributable to isolation and harsh weather conditions. These factors may not in the future, ensure that the values of the inlet are retained. Present threats to the natural values include: roading, deforestation, over-fishing, marine farming and grazing of estuarine vegetation. Threats unforseen at present, may develop in the future. In the past, standard statutory procedures have failed to adequately protect New Zealand estuaries. Loss of salt marshes, sewage disposal, port development, contamination of shell fish, over fishing, whitebait habitat destruction, marine farming and industrial development have made many estuaries true waste-lands. The values of Whanganui Inlet should be preserved using legislation that offers an adequate level of protection.

10.2 DEFINITION OF THE ECOLOGICAL AREA

An estuarine environment cannot be regarded separately from the adjacent land and the surrounding inshore coastal waters. In Whanganui Inlet, the estuary, catchments, entrance and adjacent outer coastline are one integrated ecological system. Each area can be influenced by the others. For example, clearance of forests may increase sediment and freshwater runoff. These would smother eelgrass beds and upset salinity regimes which would in turn severely reduce the food available to fish entering the inlet from the outer coast. Protection and management of the estuarine area as an isolated unit will not succeed.

Based on ecological grounds, the Whanganui Inlet ecological area includes the whole inlet to the upper limit of tidal influence, particular freshwater streams and wetlands which receive seawater on the large tides, the entrance area and the adjacent outer coast. The catchments, although out of the scope of this study, are also an integral part of the inlet's ecology.

10.3 NATURAL VALUES

The natural values of Whanganui Inlet ecological area inlude:

(1) the inlet, entrance and adjacent outer coast have been recognised as an internationally important ecological area (Davidson, et.al.,1990);
(2) the intertidal area of the inlet and outer coast represent an area with low present day human impact or modification;
(3) the types of habitat represented within the area are very diverse;
(4) the intertidal fauna associated with these habitats is diverse;
(5) salinity regimes within the inlet are unlike most other estuaries in New Zealand;
(6) the inlet is important to bird species including marsh crake, fernbird, godwit, and oystercatcher;
(7) the inlet is the only site on the west coast of the South Island where the threatened banded rail is recorded;

(8) the inlet is an important area for juvenile flatfish and snapper;
(9) the freshwater catchments are an important spawning and adult habitat for native fish species;
(10) the catchments are devoid of introduced trout species;
(11) the inlet contains the largest single salt marsh in the Nelson/Marlborough region;
(12) the estuarine fringe of salt marsh is largely intact;
(13) the area is no longer infested with the cord grass *Spartina anglica*;
(14) the inlet has the largest beds of eelgrass for an estuary in the Nelson/Marlborough region;
(15) most catchments are covered in regenerating native forest;
(16) areas of nationally important coastal forest are located directly adjacent to the inlet;
(17) threatened species of plant are located on the outer coast;
(18) the inlet and outer coast has high sea-scape values;
(19) a wide variety of exposed west coast features (rock platform, reef, cliff, boulder and beach habitats) are located on the adjacent outer coast;
(20) the entrance represents a unique estuarine habitat in the Nelson/Marlborough region;
(21) the area has a rich history with numerous archaeological sites; and
(22) the area has a potential for scientific study as an estuary operating in a natural state.

10.4 RECOMMENDED APPROACH TO PROTECTION

This report establishes Whanganui Inlet as an area of outstanding natural value. It is also an area of particular value to the people who live there and to the Maori people who are tangata whenua of the area.

Whanganui Inlet is an important area for recreational fishing, traditional food gathering, waterfowl hunting, and for stock movement. There are no other estuarine environments along the west coast accessible to Golden Bay residents where they can fish in an enclosed estuary in relative safety.

Whanganui Inlet is of particular significance to Maori as a source of kaimoana and because of sacred sites and occupation reserves around its shores.

Recommendations on the principles for action by the Department of Conservation and specific management principles for all agencies are set out below. It is intended that these principles are adopted by the Department in its actions and advocacy for protection of the inlet.

General Principles

It is recommended that the Department of Conservation:

(1) recognises Whanganui Inlet as an internationally important area with outstanding natural values;
(2) seeks full protection for the natural values of Whanganui Inlet and its environs;
(3) recognises customary uses of the inlet and, to the extent compatible with protection of ecological values, seeks to preserve those uses;
(4) uses its powers under the Marine Reserves Act 1971 to establish a marine sanctuary in a substantial portion of the inlet; and
(5) recognise that the estuarine environment is influenced by the adjacent terrestrial environment.

Specific Management Recommendations

It is recommended that the following princples are adopted by all those using and administering the inlet and its environs:

(6) that the inlet, entrance and adjacent outer coast area regarded as one ecological system;
(7) that the fundamental goal of management be the maintenance and improvement of the natural values of the inlet;

(8) that indiscriminate bulk fishing methods, such as set nets, and commercial fishing not be permitted in the inlet (this does not include whitebait fishing);
(9) that modification of the estuary by marine farming not be permitted;
(10) that particular reef species are fully protected (e.g. red moki, sea weeds, encrusting organisms and benthic invertebrates);
(11) that waterfowl shooting be restricted to black swan, mallard, grey and paradise ducks;
(12) that construction in the intertidal zone be minimised, and that in particular permanent maimais and whitebait jetties not be permitted;
(13) that local land owners be encouraged to retain scrub and forest vegetation in gullies and land adjacent to the estuary;
(14) the use of underground transmission lines be encouraged and the gradual replacement of existing aerial lines also be encouraged (chapter 7.4);
(15) disused lines and poles be removed from the inlet and estuary margins;
(16) the introduced iceplant *Carpobrotus edulis* be eradicated from the estuary;
(17) discharge of any effluent or disposal of rubbish within or adjacent to the inlet be prohibited;
(18) fences be constructed in appropriate situations where livestock are grazing on estuarine and boundary vegetation;
(19) departmental activities in the area such as interpretation, use or signposting, not compromise or detract from the natural and wilderness values of the area; and
(20) establishment of a regular monitoring program within and outside the proposed boundaries, should a marine protected area be established.

Marine Sanctuary

In New Zealand, no fully protected marine area exists which incorporates an estuary and an open coastal environment. The result of such a marine protected area is largely unknown. It is probable, however, that adults of fish such as snapper and moki and adult invertebrates such as crayfish and paua will set up residences in parts of the sanctuary and thereby be an important part of the reproductive effort for adjacent waters. An estuarine sanctuary would facilitate scientific study into the importance of estuaries to flora and fauna, especially fisheries.

It is recommended that a marine sanctuary is established in Whanganui Inlet with the following characteristics:

(21) no taking and minimal disturbance of plants and animals;
(22) it should include a substantial portion of the estuary (approximately half) to be ecologically viable in the long term;
(23) it must include large areas of the plant communities which provide the primary productive base for all life in the estuary;
(24) the sanctuary should include a full range of the habitats found in the estuary and adjacent open coast;
(25) the sanctuary should secure undisturbed passage for mobile species such as fish between the estuary and the sea;
(26) human activity should be restricted to passive pursuits, allowing free navigation for vessels and for people to enjoy the environment without damaging it.

10.5 BUFFER STRIP

The benefits of buffer strips have been documented for streams and rivers (Graynoth, 1979; Newbold, et. al., 1980), estuaries (Knox, 1980) and coastal areas generally (Bascom, 1980). Buffer strips or strips of land which boarder a marine area, will, if managed properly, minimise the impacts of land based activities (eg. nutrient runoff, flooding, sediment load) and also protect the land from coastal erosion. Much of the privately owned land adjacent to the inlet is bordered by unformed legal road (Fig.2). These strips of land around the estuary edge, if managed in conjunction with a marine protected area, would effectively create a buffer zone around most of the inlet.

10.5 EDUCATION

Education about estuarine systems is an important part of estuarine management (Norriss and Davidson, 1989). The realisation that estuaries are important coastal ecosystems is relatively new in the scientific community and is not widely understood by the public. Whanganui Inlet is therefore an important educational resource as the inlet represents a rare opportunity for students and the public to study and observe an estuary in a natural state. Such education should be encouraged.

REFERENCES

Allen, J.R.L. 1987. Desiccation of mud in the temperate intertidal zone: studies from the Severn Estuary and Eastern England. *Phil. Trans. R. Soc. Lond.*, Vol.315, pp. 127-156.

Angel. J. and R. Hayes. 1983. Coastal wetlands in New South Wales: a guide to their planning and protection. Total Environment Centre, Sydney.

Baker, A.J. 1969. The comparative biology of New Zealand oystercatchers. Unpub. MSc. Thesis, Dept. of Zoology, University of Canterbury.

Baker, A.J. 1973. Distribution and numbers of New Zealand oystercatchers. *Notornis* 20(2), pp. 128-144.

Barnes, R.S.K. 1984. Estuarine Biology. Studies in Biology No.49, 76pp.

Bell, B.D. 1985. The conservation status of New Zealand wildlife. NZ Wildl. Service, Occas. Publ. No.12, Wellington.

Barnes, R.S.K. 1989. The coastal lagoons of Britain: an overview and conservation appraisal. Biological Conservation, Vol. 49, pp. 295-313.

Bascom, W. 1980. Waves and beaches. Anchor Books. N.Y.

Bolton, L.A., and G.A.Knox. 1977. The ecology of selected sites near Mapua, Waimea Inlet. University of Canterbury, Estuarine Research Unit Report No. 10, 30 pp.

Bradstock, M. 1985. Between the tides. Reed Methuen Publishers. 158 pp.

Bull, P.C., P.D. Gaze & C.J.R. Robertson. 1985. Provisional atlas of the birds of New Zealand. Ornithological Society of New Zealand, Wellington.

Butler, DJ, 1989. 'Birdlife' pps - in: 'A report on the ecology of Waimea Inlet, Nelson. R Davidson & R Moffat, Department of Conservation, Nelson.

Briggs, P.T. and J.S. O'Connor. 1971. Comparison of shore-zone fishes over naturally vegetated and sand-filled bottoms in Great South Bay. *N.Y. Fish Game.* Vol. 18 (1), pp. 15-41.

Clark, J. 1967. Fish and man. Conflict in the Atlantic estuaries. American Littoral Society, Special Publication, No. 5, 78 pp.

Clark, J. 1974. Coastal Ecosystems. Ecological Considerations for management of the coastal zone. The Conservation Foundation, Washington, D.C.

Collier. K.J. 1987a. Spectral properties of some West Coast waters and their relationship with dissolved organic carbon. *Maori Ora*, Vol. 14, pp. 25-32.

Collier, K.J.. 1987b. Spectrophotometric determination of dissolved organic carbon in some South Island streams and rivers (Note). *NZ Journ. Mar. Freshw. Res.* Vol 21, pp. 349-351.

Collier, K.J., and M.J. Winterbourn. 1987. Faunal and chemical dynamics of some acid and alkaline New Zealand streams. *Freshwater Biology* Vol. 18, pp. 227-240.

Correll, D.L. 1978. Estuarine Productivity, *Bioscience.* Vol. 28 (10), pp. 646.

Cramp, W. **1985.** Handbook of the birds of the western Palearctic. Vol., 2. Oxford University Press. Oxford.

Darnell, R.M. 1961. Trophic spectrum of an estuarine community based on studies of Lake Pontchartrain. *Ecology* Vol. 42, pp. 553.

Darnell, R.M. 1967. Organic detritus in relation to the estuarine system. In *Estuaries*, Publ. No. 83, Lauff, American Association for the Advancement of Science, Washington D.C.

Davidson, R.J. 1986. Mussel selection by the paddle crab *Ovalipes catharus* (White): evidence of flexible foraging behaviour. *J.Exp. Mar. Biol. Ecol.*, Vol. 102, pp. 281-299.

Davidson, R.J. 1987. Natural food and predatory activity of the paddle crab, Ovalipes catharus: a flexible forager. M.Sc. Thesis, University of Canterbury. 110 pp.

Davidson, R.J. 1989. The bottom fauna from three subtidal locations around Banks Peninsula, Canterbury, New Zealand. *New Zealand Natural Sciences*, Vol. 16, pp. 87-95.

Davidson, R.J. and C.R. Moffat. 1989. A report on the ecology of Waimea Inlet, Nelson. Department of Conservation, Nelson/Marlborough Conservancy Occasional Publication No.1, 165pp.

Davidson, R.J., **Rich, L., Brown, D., Stark. K., Cash, B., Preece, J., Waghorn, E., and G. Rennison. 1990.** First order coastal resource inventory. Nelson/Marlborough Conservancy.

Day, J.W., Hopkinson, C.S., and W.H. Conner. 1982. An analysis of environmental factors regulating community metabolism and fisheries production in a Louisianna estuary. In: Estuarine Comparisons, Acedemic Press, New York. 121 pp.

Eldon. G.A. and M. Ward. 1990. Freshwater fisheries in the catchments of the Whanganui Inlet, Northwest Nelson. New Zealand Freshwater Fisheries Report.

Elliott, G.P. 1983. The distribution and habitat requirements of the banded rail *(Rallus philippensis)* in Nelson and Marlborough. Unpubl. MSc. Thesis, Victoria University, Wellington.

Heather, B.D & D.H Braithwaite, 1985. 'Sharp-tailed sandpiper, p. 206 in Reader's Digest book of New Zealand Birds. Robertson, CJR (Ed.) Reader's Digest, Sydney.

Fenchel, T. **1970.** Studies on the decomposition of organic detritus derived from the turtle grass. *Thalassia testudium. Limnol. oceanogr.*, Vol. 15, pp. 14.

Flemer, D.A., Dovel, C., Pfitzenmeyer., and D.E. Ritchie, Jnr. 1967.
Spoil disposal in upper Chesapeake Bay. II. Preliminary analysis of biological effects. In. P.L. McCarty and R. and R. Kennedy, *Proc. Nat. Symp. on Estuarine Pollution.* Stanford Calif., Univ. Press.

Francis, M. 1988. Coastal fishes of New Zealand, a diver's identification guide. Heinemann Reed. 63 pp.

Franko, G.D. 1987. Environmental impact assessment of the use of amitrole/dalaphon herbicide sprays to control *Spartina* grass in Waimea Inlet, Nelson. Cawthron Institute Report, 81 pp.

Franko, G.D. 1988. A guide to Delaware Inlet. D.S.I.R. Publishing, 42 pp.

Gillespie, P.A., and A.L. MacKenzie. 1981. Autotrophic and heterotrophic processes on an intertidal mud-sand flat, Delaware Inlet, *New Zealand. Bull. Mar. Sci.* Vol. 31(3), pp. 648-657.

Gillespie, P.A. 1983. Tidal nutrient exchange in Delaware Inlet. *Water and Soil Misc. Publ.*, No. 60, pp. 4-6.

Graynoth, E. 1979. Effects of logging on stream environments and faunas in Nelson. *NZ. Journ. Mar. Freshw. Res.*, Vol. 13(1), pp. 79-109.

Gunson, D. 1983. Collins guide to the New Zealand Sea Shore. William Collins Publishers Ltd, 240 pp.

Healy. W.B. 1980. Pauatahanui Inlet-an environmental study. NZ.D.S.I.R. Information Series 141. 198 pp.

Heath, R.A. 1976. Broad classification of New Zealand inlets with emphasis on residence times. *N.Z. J. Mar. Freshw. Res.*, Vol. 10 (3). pp. 429-44.

Heather, B.D. 1978. The cattle egret in New Zealand in 1977. *Notornis* 25, pp. 218-234.

Heather, B.D. 1982. The cattle egret in New Zealand, 1978-1980. *Notornis*, 29, pp. 241-268.

Heather, B.D. 1984. Cattle Egret Survey. *OSNZ News* 1984, p6. Ornithological Society of New Zealand, Wellington.

Hicks, F.J. 1974. The biological effects of fish processing wastes on receiving waters. Seminar on fish processing plant effluent treatment on guidelines.

Holdaway, R. 1983. Birds. In: Animals of the Estuary Shore. M.B.Jones. Univ. of Canterbury Publ. No. 32, Christchurch. pp.103-148.

Hume T.H., and M.S. McGlone. 1986. Sedimentation patterns and catchment use change recorded in the sediments of a shallow tidal creek, Lucas Creek, Upper Waitemata Harbour, New Zealand. NZ. Journ. Mar. Freshw. Res., Vol. 20, pp. 677-687.

Hurley, D.E. 1989. Amphipoda, Isopoda, and Mollusca from Whanganui Inlet, Nelson. D.S.I.R. report, 7 pp.

Imboden, C. 1978. An evaluation of wildlife habitats. In Wildlife, A Review (Ed.) P. Morrison. NZ. Wildlife Service. pp. 54-58.

Johnston, M.R. 1979. Geology of the Nelson Urban Area. D.S.I.R. Report. 52 pp.

Jones, M.B. 1983. Animals of the estuary shore: Illustrated Guide and Ecology. University of Canterbury Publication No. 32. 162 pp.

Jones, J.B. and J.D. Hadfield. 1985. Fishes from Porirua and Pauatahanui Inlets: occurrence in gill nets. *N.Z. J. Mar. Freshw. Res.*, Vol.19, pp. 477-484.

Ketchum, B.H. 1969. Eutrophication of estuaries. In: National Academy of Science and National Research Council, Eutrophication, causes, consequences and correctives, Washington, D.C., pp 197-200

Kilner, A.R. and J.M. Akroyd. 1978. Fish and invertebrate macrofauna of Ahuriri Estuary, Napier. Fisheries Technical Report No. 153. 79 pp.

Kinsky, F.C (Ed), 1970. Annotated checklist of the birds of New Zealand. A.H. & A.W. Reed for Ornithological Society of New Zealand, Wellington. 96pp.

Kinsky, F.C. 1980. Ammendments and additions to the 1970 Annotated Checklist of the birds of New Zealand. Notornis 27 (Suppl.). 23pp

Knox, G.A. 1974. Report on an investigation of Blaketown Lagoon, Greymouth. University of Canterbury, Estuarine Research Unit Report. 33 pp.

Knox, G.A. 1979b. Ahuriri Estuary: An environmental study. Technical Committee, Napier City Council. 84 pp.

Knox, G.A. 1980. The estuarine zone. *Soil and Water*, Vol. 16(2), pp 13-17.

Knox, G.A. 1980a. Resource evaluation as a basis for the zoning of coastal areas. Coastal Zone Management Seminar. Vol. 1, 8pp.

Knox, G.A. 1983a. The ecology of Kaituna Marsh, Pelorus Sound, with special reference to the introduction cord grass, *Spartina*, In. Nutrient Processing and Biomass Production in NZ Estuaries, *Water and Soil Misc. Publ.* No. 60, pp 32.

Knox, G.A. 1983b. An ecological survey of Wairau River Estuary. University of Canterbury, Estuarine Research Unit Report No. 27. 141 pp.

Knox, G.A. 1986. Estuarine Ecosystems: A systems approach. CRC Press Inc, Florida. Vol. I and II.

Knox, G.A., L.A. Bolton. and K. Hackwell. 1977. Report on the ecology of the Parapara Inlet, Golden Bay. University of Canterbury, Estuarine Research Unit Report No. 11. 66 pp.

Knox, G.A. and L.A. Bolton. 1978. The ecology of the benthic macrofauna and fauna of Brooklands Lagoon, Waimakariri River Estuary. Estuarine Research Unit, Zoology Department, University of Canterbury, Report No. 16. 128 pp.

Knox, G.A. and L.A. Bolton. 1979. An ecological survey of Shakespeare Bay Queen Charlotte Sound. University of Canterbury, Estuarine Research Unit Report No. 18. 143 pp.

Knox, G.A., L.A. Bolton and P. Sagar. 1978. The ecology of Westshore Lagoon Ahuriri Estuary, Hawke Bay. University of Canterbury, Estuarine Research Unit Report No. 15. 89 pp.

Knox, G.A., and A.R. Kilner. 1973. The ecology of the Avon-Heathcote Estuary, University of Canterbury, Estuarine Research Unit Report No. 1, 358 pp.

Knox, G.A. and G.D. Fenwick, 1981. Zonation of benthos off a sewage outfall in Hawkes Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research.* Vol. 15, pp. 417-435.

Lands and Survey, 1983. Farewell Spit nature reserve draft management plan, Dept. Lands and Survey, Nelson.

Larcombe, M.F. 1971. The ecology, population dynamics, and energetics of some soft shore molluscs. University of Auckland, Ph.D. Thesis. 250 pp.

MacKenzie, A.L. 1983. Primary production in Delaware Inlet. In: Nutrient Processing and Production in N.Z. Estuaries. *Water and Soil Misc. Pub.* No. 60, pp. 16-19.

Mann, K.H. 1972. Macrophyte production and detritus food chains in coastal waters, *in Detritus and its Role in Aquatic Ecosystems,* Melchorri - Santalini Eds., Memoir Inst. Italiano Idriobiol., (suppl. 29).

Marsden, I.D., and G.D. Fenwick. 1986. Port Underwood - Marlborough intertidal survey. University of Canterbury. Estuarine Research Unit Report No. 29, 72 pp.

Marshal, N. 1970. Food transfer through the lower trophic levels of the benthic environment. In: Marine Food Chains, Steele J.H. Ed. Oliver and Boyd, Edinburgh, pp. 52.

McDowall, R.M. 1976a. The role of estuaries in the life cycles of fishes in New Zealand. *N.Z. Ecol. Soc. Proc.* Vol. 23, pp. 27-32.

McDowall, R.M. 1976b. The New Zealand whitebait book. A.H. and A.W. Reed Ltd, 210 pp.

McDowall, R.M., and G.A. Eldon. 1980. The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). Fisheries Research Bulletin No. 20, 172 pp.

McHugh, J.L. 1966. Management of estuarine fisheries. In: A Symposium on Estuarine Fisheries. American Fisheries Society Publication No. 3. pp. 133-154.

McHugh, J.L. 1976. Estuarine fisheries: are they doomed? In: Wiley, M. (ed.), Estuarine Processes. 1. uses, stresses, and adaptation to the Estuary, Academic Press, New York. pp. 15-27.

McLay, C.L. 1976. An inventory of the status and origin of New Zealand estuarine systems. *Proc. N.Z. Ecol. Soc.*, Vol. 23, pp. 8-26.

McLay, C.L. 1988. Crabs of New Zealand. Leigh Laboratory Bulletin, No. 22, 463 pp.

Milne, L.J. and M.J. Milne. 1951. The eelgrass catastrophe. *Sci. amer.* Vol. 184 (1). pp. 52-55.

Moffat, C.R. 1984. Aspects of the special segregation in adult koaro (Galaxias brevipinnis) and juvenile trout (*Salmo gairdnerii* and *S. truta*) in the Ryton River. BSc. Hons. Project. University of Canterbury.

Moffat,C.R. 1989. Preliminary assessment of the ecological state of Moutere Inlet, Motueka. Dept. of Conservation Report, Nelson/Marlborough Region. 26pp.

Moore, D., Basher, H.A., and L. Trent. 1970. Relative abundance, seasonal distribution and species composition of demersal fishes off Louisianna and Texas, 1962-1964. *Contrib. Mar. Sci. Univ. Tex.*, Vol. 15, 45 pp.

Morgan, N.C. 1982. An ecological survey of standing waters of North-west Africa: II site descriptions for Tunisia and Algeria. *Biol. Conserv.*, Vol. 24, pp. 83-113.

Morton, J. and M. Miller. 1968. The New Zealand sea shore. William Collins and Sons Ltd. 652 pp.

Myers, S.C., G.N. Park, and F.B. Overmars. 1987. A guidebook for the rapid ecological survey of natural areas. N.Z. Biological Resources Centre Publication No. 6. 113 pp.

Newbold, J.D., Erman, D.C. and K.B. Roby. 1980. Effects of logging on macroinvertebrates in streams with and without buffer strips. *Can J. Fish. Aquato Sci.*, Vol. 37, pp. 1076-1085.

Norriss, E. and R.J. Davidson. 1989. Waimea Inlet study. Nelson Education Office and Dept. of Conservation Publication.

Odum, E.P., and de la Cruz. 1967. Particular organic detritus in a Georgia Saltmarsh ecosystem, In: Estuaries. Publ. No. 83. Am. Assoc. Adv. Sci. Washington. 383 pp.

Odum, E.P., and M.E. Fanning. 1973. Comparison of the productivity of *Spartina alterniflora* and *Spartina cynosuroides* in Georgia coastal marshes. *Bull. G. Acad. Sci.* Vol. 31, pg. 1.

Odum, E.P., Knox, G.A., and D.E. Campbell. 1983. Organisation of a new ecosystem, exotic *Spartina* salt marsh in New Zealand. Rep. Natl. Sci. Found. Exchange Prog. N.Z.-U.S., Centre for Wetlands, University of Florida, 106 pp.

Odum, E.P., Woodwell, G.M., and C.F. Wurster. 1969. DDT residue absorbed from organic detritus by fiddler crabs. *Science*. Vol. 164, pp. 576.

Odum, W.E. 1988. Comparative ecology of tidal freshwater and salt marshes. *Ann, Rev. Ecol. Syst.*, Vol. 19, pp 147-176.

Ogle, C.C. 1982. Wildlife and wildlife values of northland. NZ. Wildlife Service, Faunal Survey Unit Report. No. 30, 272pp.

Orth, R. 1976. The demise and recovery of eelgrass, *Zostera Marina,* in the Chesapeake Bay, Virginia. *Aquatic Botany,* Vol. 2, pp. 141-159.

Orth, R.J. 1977. The importance of sediment stability in seagrass communities. In: Ecology of Marine Benthos, University of South Carolina Press, Columbia, 281 pp.

Oviatt, C.A., and S.W. Nixon. 1973. The demersal fish of Narragansett Bay: an analysis of community structure, distribution and abundance. *Estuarine Coastal Mar.* Sci Vol. 1, pp. 361.

Owen, K.L, 1980. Summary sheet for grid square 59 x 91. Unpubl. data, Fauna Survey Unit, NZ Wildlife Service, Wellington. (Held at Department of Conservation, Nelson).

Owen, K.L., and M.G. Sell. 1985. The birds of Waimea Inlet. *Notornis,* Vol. 32, pp. 271-309.

Park, G.N., and G.Y. Walls. 1978. Inventory of tall forest stands on lowland plains and terraces in Nelson and Marlborough land districts, New Zealand. D.S.I.R. Botany Division.

Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and marine pollution, annual review,* Vol. 16, pp 229-311.

Powell, A.W.B. 1979. New Zealand Mollusca. William Collins Publishers Ltd. 500 pp.

Pressey, R.L. 1985. Some problems with wetland evaluation. *Wetlands (Australia).* Vol. 5 (1).

Ratcliffe, D.A. 1977. A nature conservation review. The selection of biological sites of national importance to nature conservation in Britain. Cambridge University Press.

Rosenberg, R. 1976. Benthic faunal dynamics during succession following pollution abatement in a Swedish estuary. *Oikos* Vol. 27, pp. 414-427.

Rushton, G.E. 1987. Proposed marine protected area: Whanganui Inlet, Central South Region. Central Fisheries Region Report No. 5. 38pp.

Ryther, J.H. 1969. Photosynthesis and fish production in the sea. *Science,* Vol. 166, pp. 72.

Scrimgeour, G.J., R.J. Davidson, and J.M. Davidson. 1988. Recovery of benthic macroinvertebrate and epilithic communities following a large flood, in an unstable, braided, New Zealand river. *N.Z. J. Mar. Freshw. Res.,* Vol. 22, pp. 337-334.

Spect, R.L., E.M. Roe., and V.H. Boughton. 1974. Conservation of major plant communities in Australia and Papua New Guinea. *Austr. J. Bot. Suppl. Ser.* No. 7.

Stephenson, R.L. 1980. Avon-Heathcote. Estuary under stress. *Water and Soil,* Vol. 16(2), pp. 22-25.

Stephenson, R.L. 1981. Aspects of the energetics of the cockle *Chione stutchburyi* in the Avon-Heathcote Estuary, Christchurch, New Zealand. University of Canterbury, Ph.D. Thesis. 155 pp.

Taylor, J.L. and C.H. Saloman. 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida, U.S. Fish. Wildl. Ses., *Fish. Bull.,* Vol. 67, pp. 213-41.

Taylor, R.H. 1966. Seasonal and altitudinal distribution of kingfisher in the Nelson district. *Notornis,* Vol. 13, pp.200-203.

Teal, J.M. 1962. Energy flow in the salt marsh system. *Ecology,* Vol. 40, pp. 614.

Veitch, C.R, 1978. Waders of the Manukau Harbour and Firth of Thames. Notornis 25: pps 1-24.

Thayer, G.W.. Wolfe, D.A., and R.B. Williams. 1975. The impact of man on seagrass systems. *Am. Sci,* Vol. 63, pp. 288.

Veitch, C.R. 1979. Kaipara Harbour - Easter 1978. *Notornis* 26, pp. 289-296.

Voller, R.W. 1973. Salinity, sediment, exposure and invertebrate macrofaunal distributions on the mudflats of the Avon-Heathcote Estuary, Christchurch, New Zealand. University of Canterbury, M. Sc. Thesis.

Walker, K. 1987. Wildlife in the Nelson Region. N.Z. Wildlife Service, Faunal Survey Report No. 42. 239 pp.

Webb, B.F. 1968. Fish populations of the Avon-Heathcote Estuary. *N.Z. J. Mar. Freshw. Res.* Vol.6 (4), pp. 570-601.

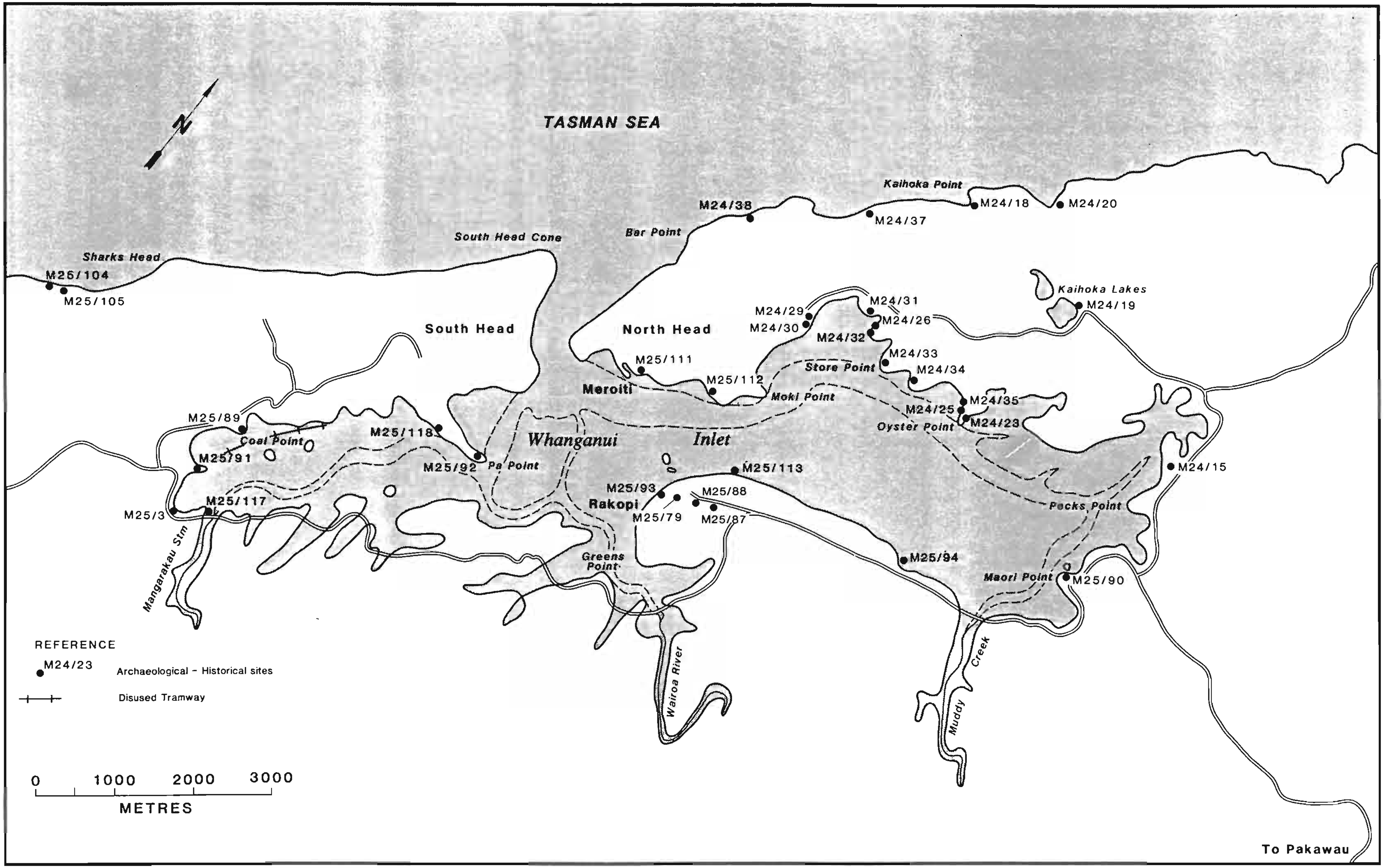
Webb, B.F. 1967. A study of the biology of the fish population in the Avon-Heathcote estuary, Christchurch. University of Canterbury, M.Sc. Thesis. 304 pp.

Winterbourn, M.J., Collier, K.J. and A.K. Graesser. 1988. Ecology of small streams on the West Coast of the South Island, New Zealand. *Verh. Internat. Verein. Limnol.* Vol. 23, pp. 1427-1431.

Williams, M. 1985. 'Australasian Bittern', p. 135 in Reader's Digest book of New Zealand Birds. Robertson CJR (Ed). Reader's Digest, Sydney.

Veitch, C.R. 1978. Waders of the Manukau Harbour and Firth of Thames. *Notornis*, Vol. 25(1), pp. 1-24.

Wright, D.F. 1977. A site evaluation scheme for use in the assessment of potential nature reserves. *Biol. Conserv.*, Vol. 11, pp. 293-306.

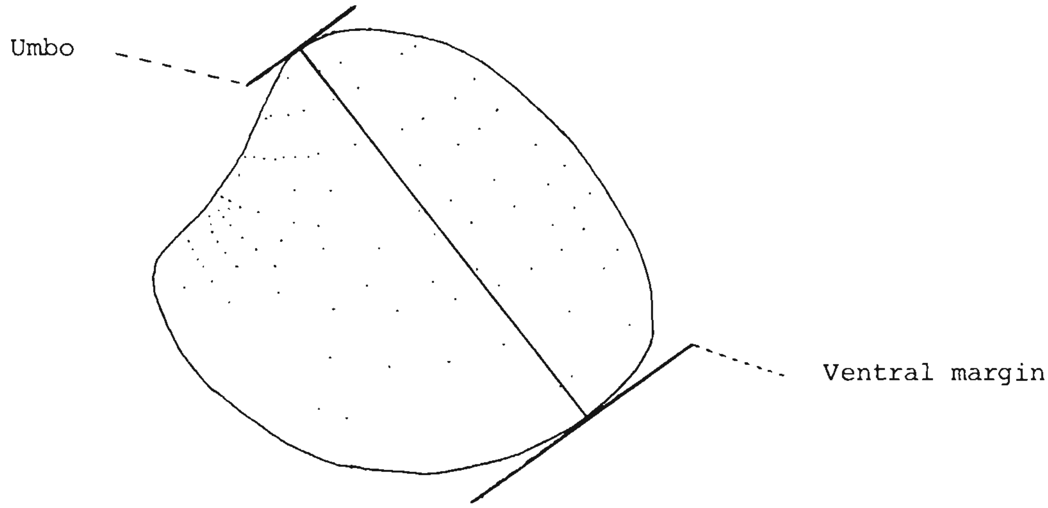


APPENDIX. 1 ARCHAEOLOGICAL - HISTORICAL SITES

Appendix 2: Recorded Archaeological Sites - Whanganui Inlet

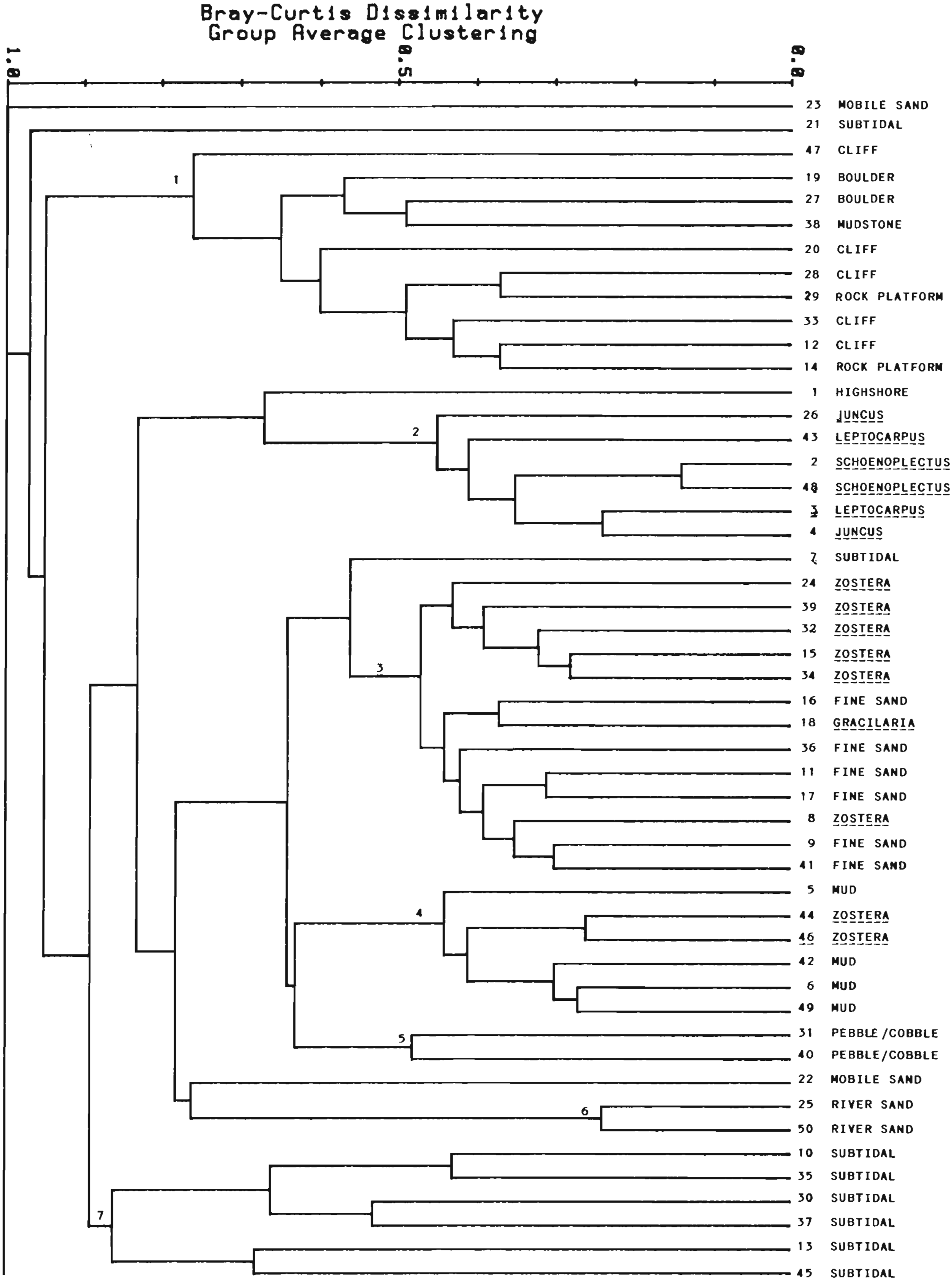
SITE NUMBER	LOCATION	SITE DESCRIPTION
M24/15	North of Pecks Point	Midden
M24/18	Kaihoka Point	Midden
M24/19	Kaihoka Lakes	Pits
M24/20	Northeast of Kaihoka Point	Rock Shelter/Midden
M24/23	Oyster Point	Midden/Flaking
M24/25	Oyster Point	Midden/Working Area
M24/26	North of Store Point	Midden
M24/29	Airstrip	Midden
M24/30	Airstrip	Find Spot
M24/31	North of Store Point	Midden/Overstones
M24/32	North of Store Point	Midden
M24/33	Store Point	Midden
M24/34	Between Store & Oyster Point	Midden/Caves
M24/35	Oyster Point	Midden
M24/37	South of Grey Cliff	Midden
M24/38	East of Bar Point	Midden
M25/3	Mangarakau	Midden
M25/79	Rakopi	Midden
M25/87	Rakopi	Midden
M25/88	Rakopi	Midden
M25/89	Coal Point	Garden Soil
M25/90	Maori Point	Ovens, Flaking
M25/91	Parkeston	Midden/20th Cent Settlement
M25/92	Pa Point	Midden
M25/93	Rakopi	Midden
M25/94	White Pine Creek	Midden
M25/104	Te Hapu	Find Spot
M25/105	Te Hapu	Middens
M25/111	Meroiti	Midden
M25/113	Rakopi	Wharf
M25/117	Mangarakau	Wharf
M25/118	Pa Point	Wharf

Appendix 3



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

APPENDIX 4



Dendrogram of benthic invertebrate sample sites based on five replicate core, transect and visual samples. The seven groups reflect differences in invertebrate communities between:- (1) Hard shore Types; (2) Rushes and Sedge; (3) Fine Sand flats and eelgrass beds; (4) mud flat and marginal eelgrass beds; (5) pebble/cobble banks; (6) river sand flats; and (7) subtidal.

Appendix 5. Invertebrate fauna (per m^2) averaged from 5 quadrats from rock (sites 14, 29, 38), cliff (sites 12, 20, 28, 33, 47) and boulder (sites 19, 27). * = Invertebrates recorded visually. NB: No counts taken at site 19 & 38.

Sites	12	14	19	20	27	28	29	33	38	47
Actinea tenebrosa	*	-	-	*	*	-	-	-	-	-
Isoactinea olivacea	-	*	-	-	-	-	-	-	-	-
Isocradactis magna	-	-	-	*	-	-	-	-	-	-
Sipunculid	-	-	*	-	-	-	-	-	-	-
Acanthochiton zelandica	-	*	*	16	26	-	*	-	*	-
Amaurochiton glaucus	-	3	*	-	-	-	-	-	*	-
Chiton pelliserpentis	166	29	*	112	*	3	*	61	*	32
Cryptoconchus porosus	-	-	*	-	*	-	-	-	-	-
Ischnochiton maorianus	-	-	*	-	-	-	-	-	-	-
Buccinulum vittatum	-	*	-	-	-	-	*	-	-	-
Cellana ornata	-	-	*	64	-	*	42	*	-	-
Cellana radians	-	-	*	*	-	-	-	-	-	-
Charonia capax	-	-	-	-	*	-	-	-	-	-
Cominella adspersa	-	-	*	-	-	-	-	-	-	-
Cominella maculosa	-	*	*	-	13	-	-	-	-	-
Diloma nigerrima	*	-	-	-	*	-	-	-	-	-
Diloma subrostrata	3	-	-	-	-	-	-	-	-	16
Haustrum haustorium	*	6	*	*	*	3	*	*	-	-
Lepsiella scobina	-	-	*	512	*	-	*	-	-	*
Littorina cincta	-	-	-	-	*	-	-	*	-	-
Littorina unifasciata	141	*	*	128	*	6	61	*	*	*
Melagraphia aethiops	32	*	*	*	3	*	-	16	*	57
Notoacmea helmsi	3	-	*	48	*	-	-	-	-	-
Onchidella nigricans	-	58	*	-	*	-	-	*	*	-
Scutus breviculus	-	-	-	*	*	-	-	-	-	-
Sigapatella novaezelandiae	*	-	-	-	-	-	*	-	-	-
Siphonaria zelandica	10	13	-	-	-	-	-	3	-	-
Thias orbita	-	-	-	*	-	-	*	-	*	-
Turbo smargdus	6	*	*	*	*	*	*	6	*	*
Zeacumantus lutulentus	-	-	-	-	-	3	-	-	-	-
Zeacumantus subcarnatus	42	42	-	-	11	-	3	*	*	880

Cont/d ...

Appendix 5. Invertebrate fauna (per m^2) averaged from 5 quadrats from rock (sites 14, 29, 38), cliff (sites 12, 20, 28, 33, 47) and boulder (sites 19, 27). * = Invertebrates recorded visually. NB: No counts taken at site 19 & 38.

Sites	**12**	**14**	**19**	**20**	**27**	**28**	**29**	**33**	**38**	**47**
Bivalves										
Aulacomya ater maoriana	*	-	*	*	-	-	-	-	*	-
Mytilus edulis aoteanus	*	-	*	*	-	-	*	-	-	-
Ostrea lutaria	*	*	*	*	-	-	-	-	-	-
Perna canaliculus	-	-	-	*	-	-	-	-	-	-
Xenostrobus pulex	19	32	-	3200	*	784	218	*	-	-
Worms										
Eulalia microphylla	*	*	*	-	-	-	-	-	-	-
Nereidae	-	-	*	-	13	*	-	-	*	-
Pomatoceros caeruleus	19	16	-	-	-	-	*	*	-	16
Crustacea										
Elminius modestus	1379	1222	*	-	480	512	4493	813	*	-
Epopella plicata	-	-	*	-	48	-	3	3	-	-
Cyclograpsus lavauxi	-	-	-	-	*	-	-	-	-	-
Helice crassa	-	*	-	-	-	-	-	-	-	-
Hemigrapsus edwardsi	-	-	-	-	*	-	-	-	-	-
Heterozius rondifrons	-	*	*	-	*	-	-	-	-	-
Leptograpsus variegatus	-	*	-	-	-	-	-	*	-	-
Petrolisthes elongatus	-	3	*	-	16	-	-	*	*	*
Upogebia hirtifrons	-	*	-	-	-	-	-	-	-	-
Echinoderms										
Evichinus chloraticus	*	-	-	*	-	-	-	-	-	-
Patiriella regularis	*	*	*	*	-	-	*	-	*	-
Number of species	21	25	27	21	25	10	17	16	14	9
Number of individuals (per m^2)	1832	1456	NA	4080	607	1311	4820	902	NA	944

Appendix 6. Invertebrate fauna (per m^2) averaged from 5 samples from pebble/cobble sites. * = Invertebrates recorded visually.

SITES	31	40
Amaurochiton glaucus	57	11
Gastropods		
Diloma subrostrata	-	11
Melagraphia aethiops	373	11
Notoacmea helmsi	74	79
Zeacumantus lutulentus	-	57
Zeacumantus subcarinatus	17	102
Bivalves		
Kellia cycladiformis	57	453
Chione stutchburyi	17	45
Paphies australis	792	-
Tellina liliana	57	-
Worms		
Glyceridae	37	11
Maldanidae	17	-
Nereidae	226	23
Polydora polybranchia	-	11
Prionospio	-	11
Scalibregmidae	17	11
Scolecolepides	-	147
Crustacea		
Elminius modestus	170	102
Helice crassa	17	57
Isocladus armatus	17	-
Number of species	15	16
Number of individuals (per m^2)	1945	1142

Appendix 7. Invertebrate fauna (per m^2) averaged from 5 samples from mobile sand.

Sites	22	23
Chione stutchburyi	11	-
Nereidae	11	-
Oedicerotidae sp A	11	-
Waitangi chelatus	56	-
Phoxocephalid species D	11	-
Pseudaega punctata	11	-
Isocladus armatus	23	-
Number of species	7	0
Number of individuals (per m^2)	134	-

Appendix 8. Invertebrate fauna (per m^2) averaged from 5 quadrats from fine sand (11, 16, 17, 36, 41), *Gracilaria* (18), eelgrass (8, 15, 24, 32, 34, 39) and very fine sand sites (9). * = Invertebrates recorded visually.

SITES	8	9	11	15	16	17	18	24	32	34	36	39	41
Anthopleura aureoradiata	-	-	-	-	68	634	11	-	-	-	-	-	34
Sipunculid	-	-	-	11	34	-	-	23	23	68	11	11	45
Acanthochiton zelandica	-	-	-	11	11	-	-	-	11	11	-	-	-
Amaurochiton glaucus	-	-	-	11	-	-	-	*	91	-	23	-	11
Gastropoda													
Cominella adspersa	-	-	-	-	-	-	11	-	-	-	11	-	-
Cominella glandiformis	120	*	68	85	57	23	11	11	181	68	23	57	28
Diloma subrostrata	-	-	-	-	11	11	*	11	-	-	11	11	-
Hamonea zelandiae	11	-	-	-	-	-	11	-	-	-	11	45	-
Melagraphia aethiops	-	-	-	-	11	-	-	-	11	*	*	11	-
Micrelenchus tenebrosus	328	-	-	11	-	11	-	11	11	-	-	-	-
Notoacmea helmsi	11	-	*	-	-	11	-	-	-	-	-	-	-
Turbo smaragdus	-	-	-	11	-	-	-	*	11	-	-	-	-
Zeacumantus lutulentus	11	*	23	85	11	-	-	45	-	91	23	125	11
Zeacumantus subcarinatus	-	*	-	809	215	11	-	136	962	328	23	-	-
Bivalves													
Kellia cycladiformis	23	34	23	255	68	68	34	23	362	758	158	139	453
Chione stutchburyi	996	838	1234	764	2524	2275	2297	622	656	396	1415	68	3730
Nucula hartvigiana	1517	23	11	809	385	79	351	192	1958	985	-	272	181
Paphies australis	-	-	-	-	23	11	-	-	11	-	11	-	-
Tellina liliana	68	34	45	11	136	45	68	57	45	-	283	23	34

Cont/d...

Appendix 8. Invertebrate fauna (per m^2) averaged from 5 quadrats from fine sand (11, 16, 17, 36, 41), *Gracilaria* (18), eelgrass (8, 15, 24, 32, 34, 39) and very fine sand sites (9). * = Invertebrates recorded visually.

SITES	8	9	11	15	16	17	18	24	32	34	36	39	41
Worms													
Capitellidae	-	34	-	11	11	11	45	-	-	-	-	-	11
Cirritulidae	238	11	-	28	-	-	-	-	-	11	11	23	170
Glyceridae	23	11	34	11	23	34	11	23	34	45	-	-	11
Haploscoloplos cylindrifer	34	34	-	-	-	204	23	11	-	-	-	-	11
Maldanidae	-	-	249	28	23	57	-	-	-	33	181	-	79
Nereidae	91	91	79	28	-	23	-	-	57	34	102	266	441
Orbina papillosa	-	-	-	-	-	-	-	-	11	-	11	-	-
Owenia fusiformis	23	23	-	-	-	-	-	-	-	57	-	-	-
Petinaria australis	-	-	11	11	-	11	34	-	-	-	-	-	-
Polydora polybranchia	-	-	-	-	34	-	136	-	-	-	113	-	34
Prionospio	215	215	192	71	351	419	475	23	192	11	68	23	11
Scalibregmidae	23	23	-	28	-	-	-	-	170	215	-	147	-
Crustacea													
Paramoera sp.	-	-	-	-	-	-	34	-	-	-	-	-	-
Elminius modestus	-	11	11	-	11	23	-	-	-	-	-	-	-
Hymenosomatid	34	11	-	11	57	-	23	*	11	34	23	68	34
Helice crassa	-	-	*	-	-	11	-	11	*	-	-	-	-
Hemigrapsus crenulatus	-	*	-	-	11	-	57	-	11	-	11	-	-
Isocladus armatus	11	11	11	11	23	34	-	-	-	-	11	-	11
Natatolana spp.	-	-	-	-	-	-	-	-	-	-	-	-	11
Macropthalmus hirtipes	11	11	*	-	-	-	-	*	11	-	-	*	*
Phoxocephalid spp.	45	136	79	-	11	23	57	11	-	-	57	-	102
Eorchestia sp.	-	-	-	-	-	-	57	-	-	-	-	-	-

Cont/d...

Appendix 8. Invertebrate fauna (per m^2) averaged from 5 quadrats from fine sand (11, 16, 17, 36, 41), *Gracilaria* (18), eelgrass (8, 15, 24, 32, 34, 39) and very fine sand sites (9). * = Invertebrates recorded visually.

SITES	8	9	11	15	16	17	18	24	32	34	36	39	41
Echinoderms													
Patiriella regularis	-	-	11	-	-	-	-	-	11	-	-	-	-
Number of species	20	21	17	23	23	22	20	18	22	17	23	16	22
Number of individuals (per m^2)	3815	1551	2070	3122	4109	4029	3746	1210	4830	3145	2591	1289	2096

Appendix 9. Invertebrate fauna (per m^2) averaged from 5 samples from river sand sites. * = Invertebrates recorded visually.

Sites	25	45
Sipunculid	113	45
Bivalves		
Chione stutchburyi	272	226
Worms		
Maldanidae	23	11
Crustacea		
Melita sp.	-	57
Helice crassa	23	57
Number of species	4	5
Number of individuals (per m^2)	431	396

Appendix 10. Invertebrate fauna (per m^2) averaged from 5 samples from mud (5, 6, 42, 49) and high tide eelgrass (44, 46) habitats. * = Invertebrates recorded visually.

SITES	5	6	42	44	46	49
Sipunculid	-	23	-	45	11	-
Gastropods						
Amphibola crenata	-	45	34	22	-	91
Cominella glandiformis	11	11	-	11	-	11
Melagraphia aethiops	-	-	-	-	57	-
Zeacumantus lutulentus	-	-	*	260	-	-
Zeacumantus subcarinatus	11	23	-	79	272	-
Bivalves						
Kellia cycladiformis	928	385	170	622	385	57
Chione stutchburyi	464	170	-	11	23	45
Nucula hartvigiana	-	-	-	-	23	-
Worms						
Cirritulidae	-	-	-	-	11	-
Haploscoloplos cylindrifer	11	23	11	-	-	-
Maldanidae	113	-	-	11	-	-
Nereidae	555	91	272	158	192	34
Polydora polybranchia	-	-	-	11	-	
Scalabregmidae	-	-	-	226	272	-
Scolecolepides	34	532	362	543	102	68
Crustacea						
Melita spp.	-	-	-	192	-	-
Elminius modestus	57	-	-	-	-	-
Helice crassa	-	34	11	11	1	68
Macropthalmus hirtipes	11	-	-	-	-	-
Phoxocephalidae	102	91	34	204	79	23
Hymenosomatid	-	-	-	-	79	-
Dipteran larvae	-	-	-	-	-	11
Number of species	11	11	8	15	13	9
Number of individuals (per m)	2297	1428	894	2406	1506	408

Appendix 11. Invertebrate fauna (per m²) averaged from 5 samples from *Juncus* (4, 26), *Leptocarpus* (3, 43), *Schoenoplectus* (2, 48) and highshore (1).

SITES	1	2	3	4	26	43	48
Sipunculid	-	-	-	-	11	-	-
Gastropods							
Amphibola crenata	11	215	11	23	11	57	215
Cominella glandiformis	-	-	-	-	-	45	-
Diloma subrostrata	-	-	-	127	-	-	-
Ophicardellus costelaris	-	-	-	-	57	-	-
Potamopyrgus estuarinus	-	1098	3656	1969	326	11	1449
Zeacumantus lutulentus	-	-	-	-	-	45	-11
Zeacumantus subcarinatus	-	-	-	-	-	79	-
Worms							
Nereidae	-	57	34	-	11	45	136
Scolecolepides sp.	-	34	158	74	-	283	79
Crustacea							
Melita sp.	-	-	79	-	-	34	-
Eorchestia sp.	-	-	464	396	124	68	-
Helice crassa	34	23	57	71	45	23	45
Exosphaeroma planulum	-	-	-	-	-	11	-
Phoxocephalid	-	-	-	-	-	57	-
Insects							
Dipteran larvae	-	-	-	-	23	23	-
Number of species	2	5	7	6	8	13	6
Number of individuals (per m²)	45	1427	4459	2660	608	781	1935

Appendix 12. Invertebrate fauna (per m^2) averaged from 5 samples from subtidal soft bottom sites. * = Invertebrates recorded visually.

SITES	7	10	13	21	30	35	37	45
Sipunculid	-	-	-	17	-	-	-	-
Encrusting Bryozoan	-	*	*	-	*	-	*	*
Terenochiton inquinatus	-	192	-	-	96	33	57	-
Gastropods								
Cominella adspersa	-	-	-	-	17	-	-	-
Hamonea zelandica	11	-	-	-	-	-	-	-
Notoacmea helmsi	-	-	-	-	-	-	11	-
Zeacumantus lutulentus	91	-	-	-	-	-	-	-
Zeacumantus subcarinatus	-	-	-	-	-	23	-	-
Bivalves								
Gari strangeri	-	-	-	-	11	-	-	-
Gari lineolata	-	-	-	-	11	-	-	-
Atrina zelandica	-	-	-	-	-	*	-	-
Kellia cycladiformis	-	11	-	-	-	-	-	-
Chione stutchburyi	226	130	96	-	-	23	-	-
Nucula hartvigiana	-	498	-	-	-	238	102	-
Tawera spissa	-	45	19	-	17	11	-	-
Paphies australis	-	23	-	-	-	-	815	28
Worms								
Cirritulidae	-	-	-	-	-	11	11	-
Glyceridae	34	-	-	-	-	11	-	-
Haploscoloplos cylindrifer	45	57	-	-	-	-	-	-
Nereidae	23	-	-	-	-	-	-	-
Orbina papillosa	-	23	19	-	-	-	-	23
Pectinaria australis	23	-	-	-	-	-	-	-

Cont/d...

Appendix 12. Invertebrate fauna (per m^2) averaged from 5 samples from subtidal soft bottom sites. * = Invertebrates recorded visually.

SITES	7	10	13	21	30	35	37	45
Polydora polybranchia	11	57	-	-	-	91	-	-
Prionospio	79	-	-	-	-	23	-	-
Spirorbis	-	-	-	-	266	5795	317	-
Crustacea								
Parawaldeckia thomsoni	-	-	-	-	96	11	68	-
Melita spp.	-	-	-	-	96	-	45	-
Oedicerotidae	-	-	-	40	-	-	-	-
Phoxocephalidae	11	-	-	17	-	-	45	-
Waitangi chelatus	-	-	-	57	-	-	-	-
Eorchestia sp.	11	-	-	-	-	-	-	-
Elminius modestus	34	-	-	-	-	-	-	-
Hymenosomatid	23	11	-	-	-	-	23	-
Anthuridae spp.	-	11	-	-	17	-	-	11
Isocladus armatus	23	-	-	-	-	-	-	-
Natatolana spp.	85	-	-	-	17	-	-	-
Macropthalmus hirtipes	23	-	-	-	-	-	-	-
Ovalipes catharus	-	-	-	*	-	-	*	-
Cancer novaezelandiae	-	-	-	-	-	-	*	-
Pagurus spinulimanus	-	-	-	-	*	-	-	-
Coscinasterias calamara	-	-	-	-	-	*	-	-
Patiriella regularis	-	11	-	-	-	11	-	-
Number of species	16	13	4	6	12	14	14	4
Number of individuals (per m^2)	753	1069	134	131	678	6281	1505	62

Appendix 13. 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 20). 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 21):

(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 21).

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 22, 23).

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 22, 23).

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 20. 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

Cont/d...

Table 20. Evaluation of an Estuary as One Unit.

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 21. 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.

Table 22. 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 23. 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

NELSON/MARLBOROUGH CONSERVANCY OCCASIONAL PUBLICATIONS

No. 1	A Report on the Ecology of Waimea Inlet, Nelson.	Davidson, RJ and CR Moffat	1990	165pp	NZ$30.00
No. 2	A Report on the Ecology of Whanganui Inlet, North-west Nelson.	Davidson, RJ	1990	133pp	NZ$32.00
No. 3	Minutes of a Workshop on the Management Issues of Stephens Island.	Walker, KJ	1990	30pp	NZ$3.00