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FISH AND INVERTEBRATE MACROFAUNA OF AHURIRI ESTUARY, NAPIER

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FISHERIES TECHNICAL REPORT

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by

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Report to the Ahuriri Estuary Steering Committee

by

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AHURIRI ESTUARY

FISH AND INVERTEBRATE MACROFAUNA

1. GENERAL INTRODUCTION

1.1 Aims and Purpose

Estuaries are recognized throughout the world as unique and important marine ecosystems. They are the most productive ecosystems on the surface of the earth (Odum, 1971). They are important to marine fisheries production. In New Zealand it has been estimated that about 30 marine species use estuaries to a large extent at some stage of their life history. About 16 species of native freshwater fish and some introduced species such as trout and salmon also use our estuaries.

The Ministry of Agriculture and Fisheries has statutory interests in marine and freshwater fisheries, and therefore recognizes the importance of estuaries to fisheries. Fisheries Management Division instigated a study of Ahuriri Estuary after certain proposals for modifying the estuary were mooted. The Division considered that a biological investigation was required to assess the effect of these proposals. When the Ahuriri Estuary Steering Committee was formed our investigation was incorporated into the Committee's programme.

A preliminary investigation of most Hawke Bay estuaries has suggested that only Ahuriri Estuary has any important contribution to marine fisheries. The relatively poor contribution to fisheries potential of most Hawke Bay estuaries stresses the danger to fisheries should Ahuriri Estuary be seriously damaged by the proposed modifications. The objectives of our investigation therefore were:-

(a) To study the fish population and its potential value.

(b) To study the invertebrate macrofauna and its value as the major food source for the fish population.

(c) To endeavour to assess the likely effects on the fish and invertebrate macrofauna of the proposed modifications to the estuary.

This preliminary report has been prepared for the Ahuriri Estuary Steering Committee to assist them in formulating plans for managing the estuary. We have endeavoured to write this report in non-technical terms so that it might be of general rather than just scientific use.

Not all of the data collected has been analysed at the date of writing. It is intended that all of the information collected will be published in the future as several scientific papers.

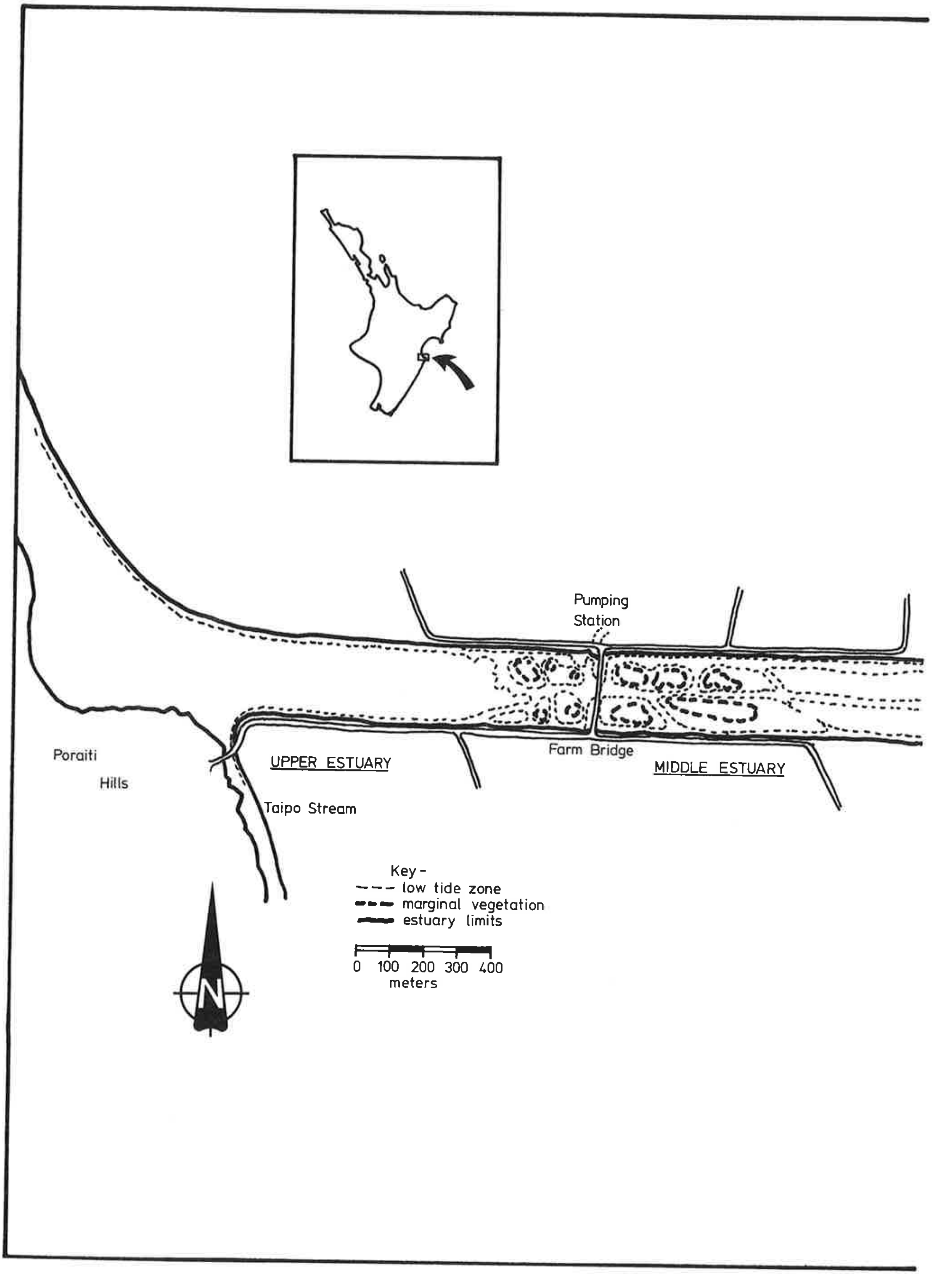
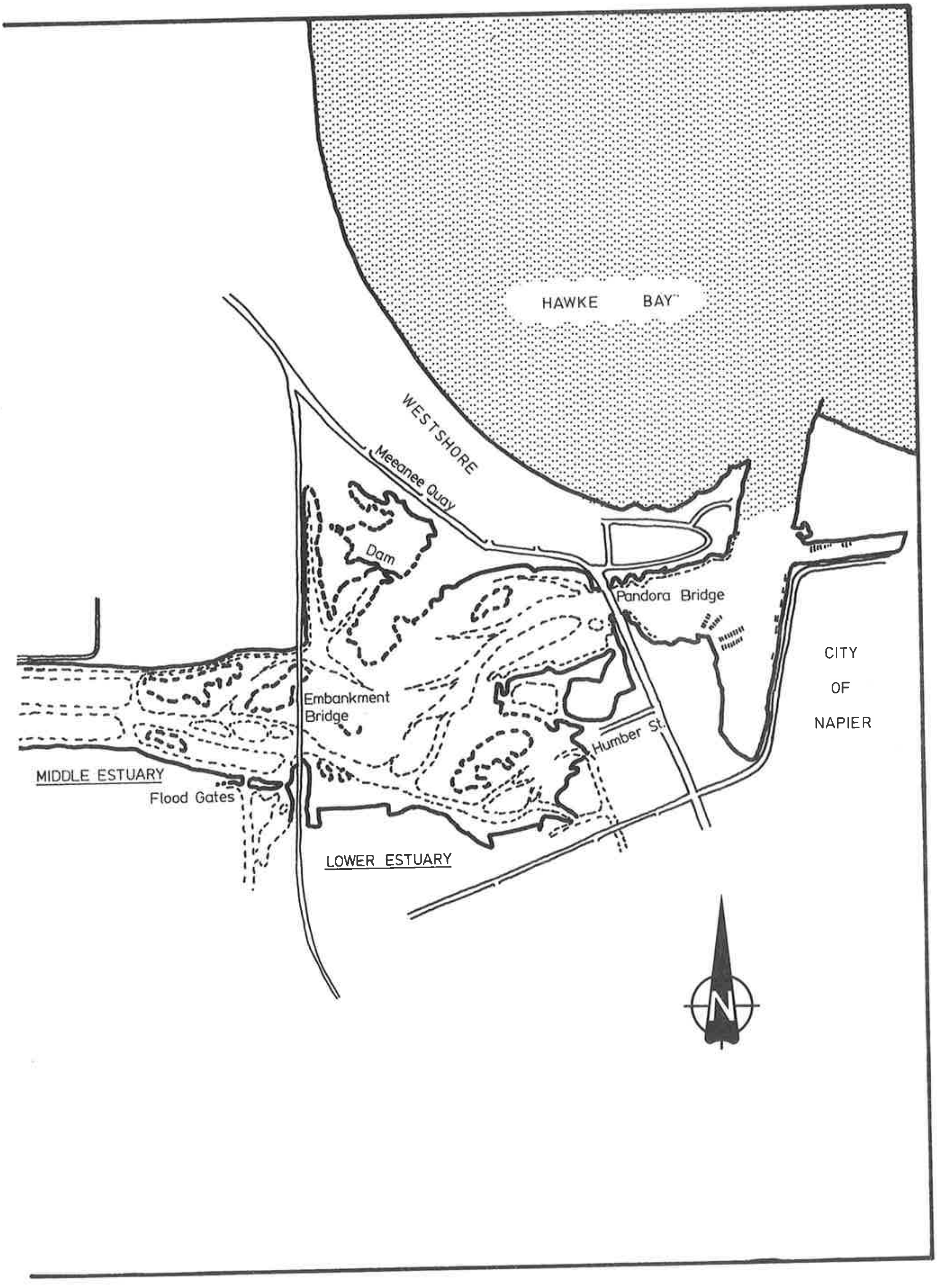


Fig. 1 : General map of Ahuriri Estuary


HAWKE BAY
WESTSHORE
Meeanee Quay
Dam
Pandora Bridge
CITY
OF
NAPIER
Embankment
Bridge
Humber St.
MIDDLE ESTUARY
Flood Gates
LOWER ESTUARY
N

1.2 Physical Description

Ahuriri Estuary was formed by the 1931 Napier Earthquake at which time the land was uplifted and the extent of the existing body of water was markedly reduced, forming approximately the present estuary.

The estuary drains from the Poraiti Hills across the plains to enter Hawke Bay just north of Bluff Hill (Fig. 1). Soon after the earthquake the area of the estuary was further reduced when stopbanks were constructed along the middle and upper parts. The surrounding land includes farmland, airport and part of Napier, and drains into the estuary via a network of draingage ditches and pumping stations. The distribution of tidal mudflats, the low tide zone and areas of marginal vegetation are shown (Fig. 1).

The areas studied have been divided into three sections:-

(i) Lower Estuary - the area enclosed between Pandora and Embankment Bridges.

(ii) Middle Estuary - the area enclosed between Embankment and Farm Bridges.

(iii) Upper Estuary - the area enclosed between Farm Bridge and just upstream of the confluence with the Taipo Stream.

1.3 Other Studies

Published research on the ecology of the invertebrate macrofauna and fish populations of Ahuriri Estuary is sparse. Hunnable and Spackman (1974) compiled an ecological report based on their uncompleted work for an Environmental Impact Report on the marina proposals for the estuary. The other significant work which contains some biological information was undertaken by Sprott and Associates (1976) for an Environmental Impact Assessment on dredging in the estuary. Recently an unpublished M.Sc. thesis has been completed by Voice (1978) on resource evaluation and management alternatives for the estuary.

Recent studies in New Zealand on invertebrate macrofauna include studies of the Avon-Heathcote Estuary (Knox and Kilner, 1973), Mapua Inlet (Bolton and Knox, 1977), Parapara Inlet, Golden Bay, (Knox, Bolton and Hackwell, 1977), Manakau Harbour (Grange, 1977; Cassie and Michael, 1968). In the overseas literature many studies have been reported especially those which describe the aggregation of species of infaunal animals in relation to sediment, depth and salinity.

Fish populations in New Zealand estuaries have received even less attention. The principal published study is contained in a series of papers on the fish population of the Avon-Heathcote Estuary (Webb 1972, 1973a, 1973b, 1973c, 1973d).

2. INVERTEBRATE MACROFAUNA

- by J.M. Akroyd

2.1 Introduction

The aim of this study is to look at the distribution and abundance of the invertebrate macrofauna of Ahuriri Estuary. The effect of some physical factors and how they may have affected the distribution of the various species was studied. An attempt was made to identify communities in the estuary by examining the distribution of species, seeing how they were grouped together and then classifying the sites by species composition.

This is a baseline study carried out before any further changes occur in the estuary. Hence the effect of future environmental disturbances or major deviations from the 'normal' can be assessed.

Only a few of New Zealand estuaries have been studied in any detail. This study will add to the knowledge of the invertebrate macrofauna of New Zealand estuaries. The information collected is compared, in terms of abundance of the invertebrate fauna, to studies conducted in other New Zealand estuaries.

Hunnable and Spackman's report (1974) described the ecology of Ahuriri Estuary in qualitative terms but made no attempt to give quantitative data or to assess the value of this area in relation to other estuarine areas.

2.2 Methods

Stations

A grid pattern with numbered intersections was placed over an aerial photograph of the estuary. Forty-three stations, chosen randomly, were surveyed and marked with numbered posts see Fig. 2a-c.

Species

Initially stations were sampled at three monthly intervals for a year. However, the first set of data was discarded as initial sampling problems would have introduced some inaccuracies into the data analysis.

At each of the 43 stations a 0.1 metre square sample was taken to a depth of 12 centimetres. All the material was collected and initial sorting carried out in the field. The smallest mesh size of the sieves used was one millimetre. All material retained in the sieves was fixed in 5% formalin and taken back to the laboratory for further sorting under a stereomicroscope. Animals were identified, counted and stored in 60-70% iso-propanol alcohol.

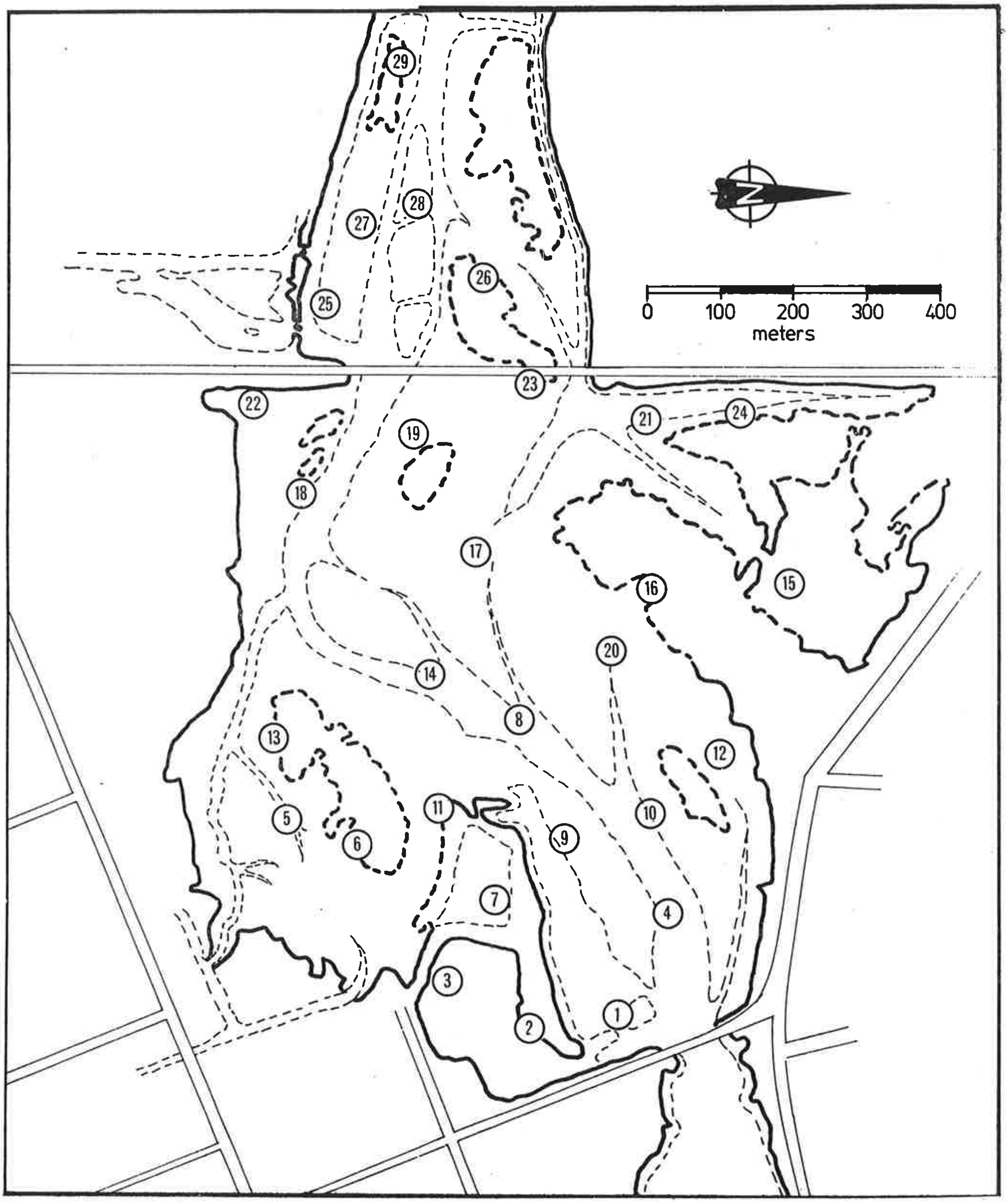


Fig.2a : Sampling stations in the lower estuary

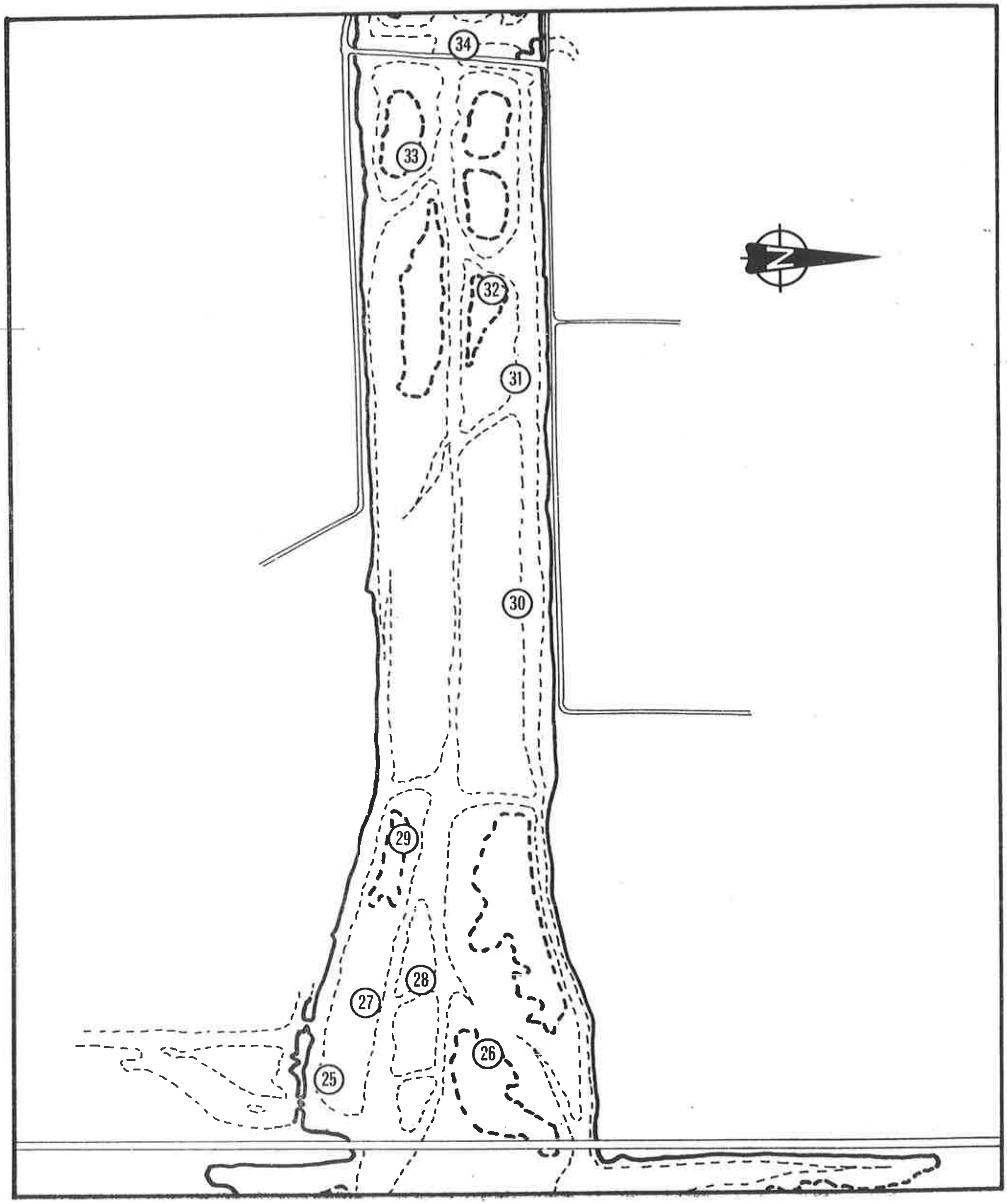


Fig.2b : Sampling stations in the middle estuary

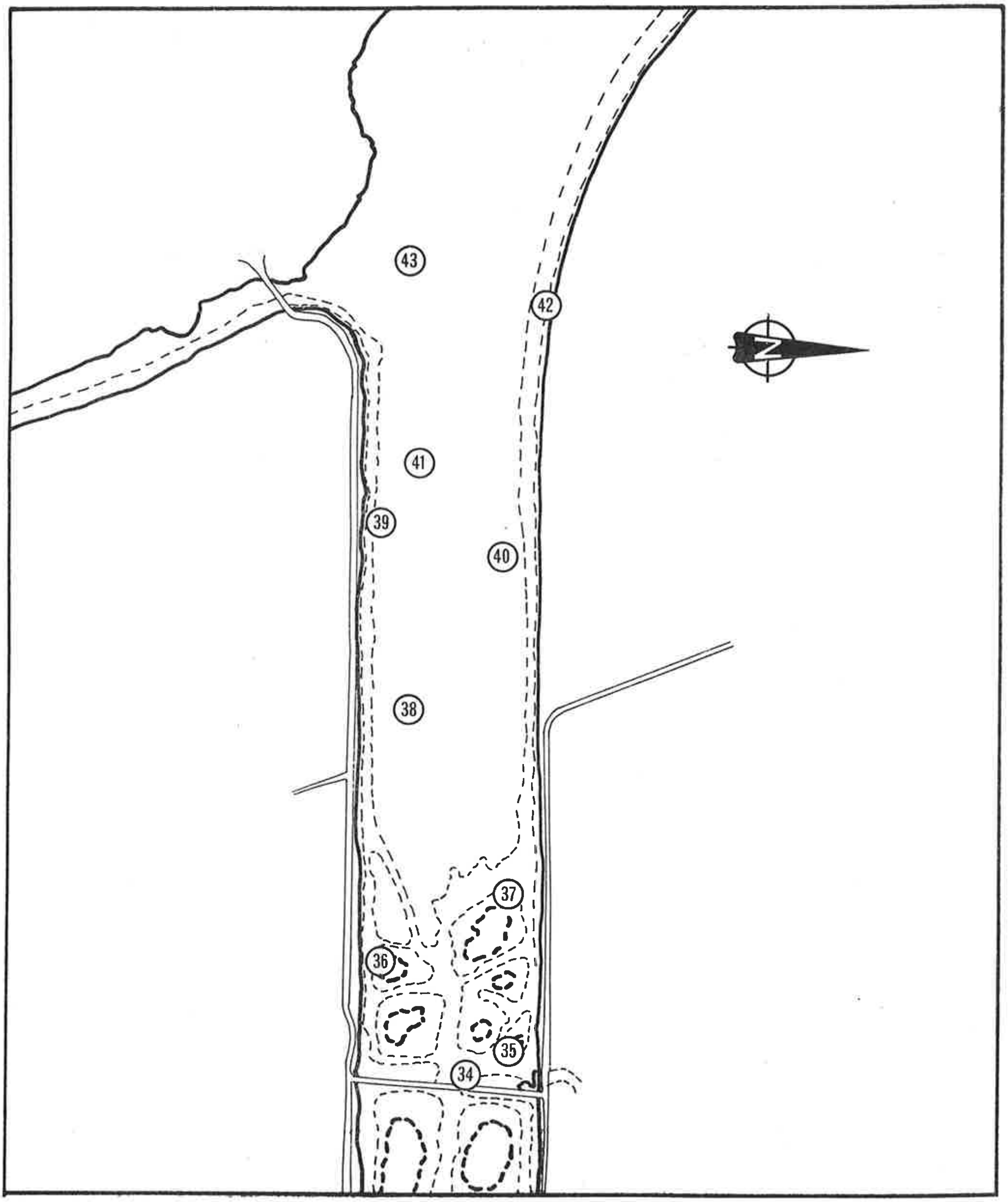


Fig.2c : Sampling stations in the upper estuary

Sediment

A core sample was taken to a depth of 12 centimetres at each of the 43 stations. A grading analysis was carried out on these samples and the percentage of gravel and shell, sand and mud (clay and silt) was determined. Where the particle size was greater than 2 mm it was described as gravel, between 0.063 mm and 2 mm as sand, and less than 0.063 mm as mud. A soil type was given to each station using a phi (Ø) classification (phi being equal to - $\log_2 d$ where d is the diameter of the grains). The soil type value at each station was calculated from the amount of gravel, sand and mud present.

Exposure and Tidal Height

Tidal posts were set up at each of the 43 stations and observed over a neap tide for a period of 12 hours. The length of time each station was exposed and the height of water covering each station was recorded.

Salinity

An unsuccessful attempt was made to determine the interstitial salinity at each station. Problems with sampling meant that this data had to be omitted. However, the salinity was measured over two complete tidal cycles (25 hrs) at each of the three bridges (Fig. 1) with an inductive salinometer. From this information salinities at each station have been estimated by interpolation, using the distances from these bridges.

2.3 Results and Discussion

Sediment

Sediment type is considered to be one of the major factors determining the distribution of invertebrate fauna. Sediment is carried into the estuary by (i) marine currents, the amount being dependent on tidal movements, wind conditions and the nature of the surrounding seabed and by (ii) river flow which is dependent on rainfall and the nature of the watershed.

Hence the sediment in the estuary is greatly dependent on the adjacent marine and terrestrial deposits. The distribution of sediments within the estuary depends on a number of factors such as current velocity, wind and wave action, tidal flushing and the distribution of marginal vegetation which traps fine sediments.

In general, the distribution of sediment in the Ahuriri Estuary is fairly typical in that there is a transition from predominantly sand at the mouth of the estuary to mud in the upper reaches. Also, there is a transition from sandy gravel in the channels to finer sediments in the quiet lateral parts of the estuary. The distribution of sediments is derived from analysis of the sediment at each station and from observations of the estuary (Fig. 3a-c).

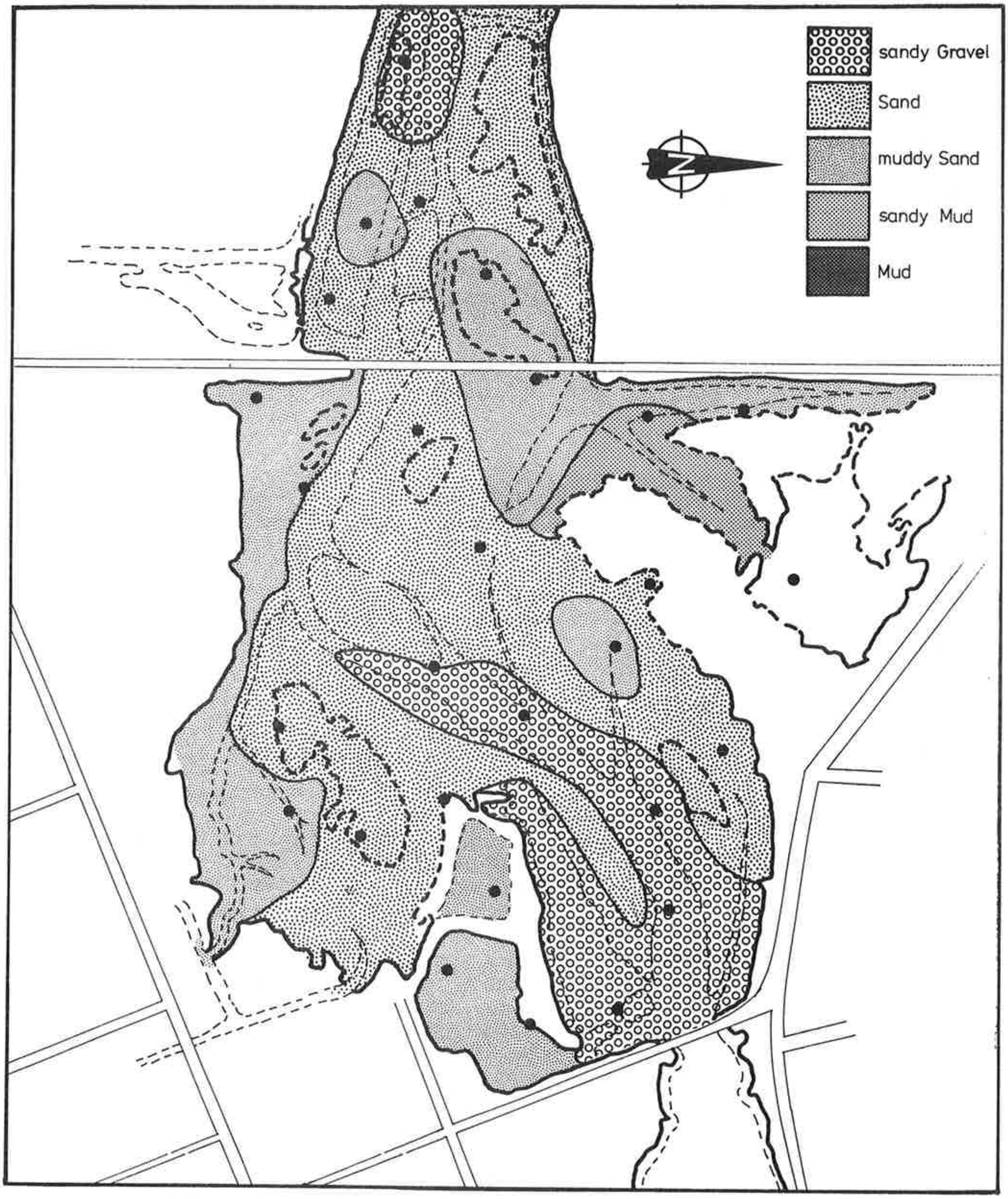


Fig.3a : Distribution of sediments in the lower estuary

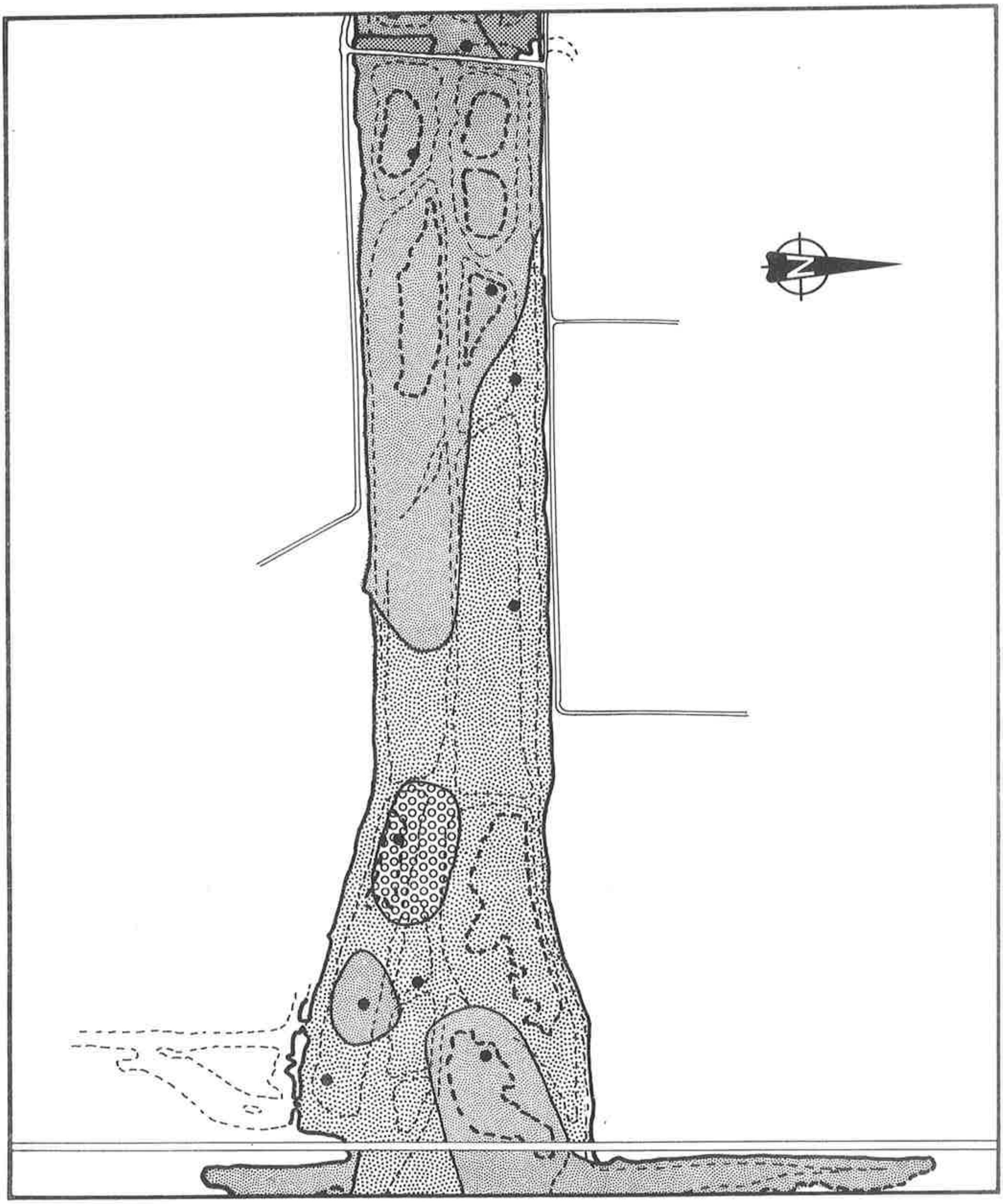


Fig.3b : Distribution of sediments in the middle estuary

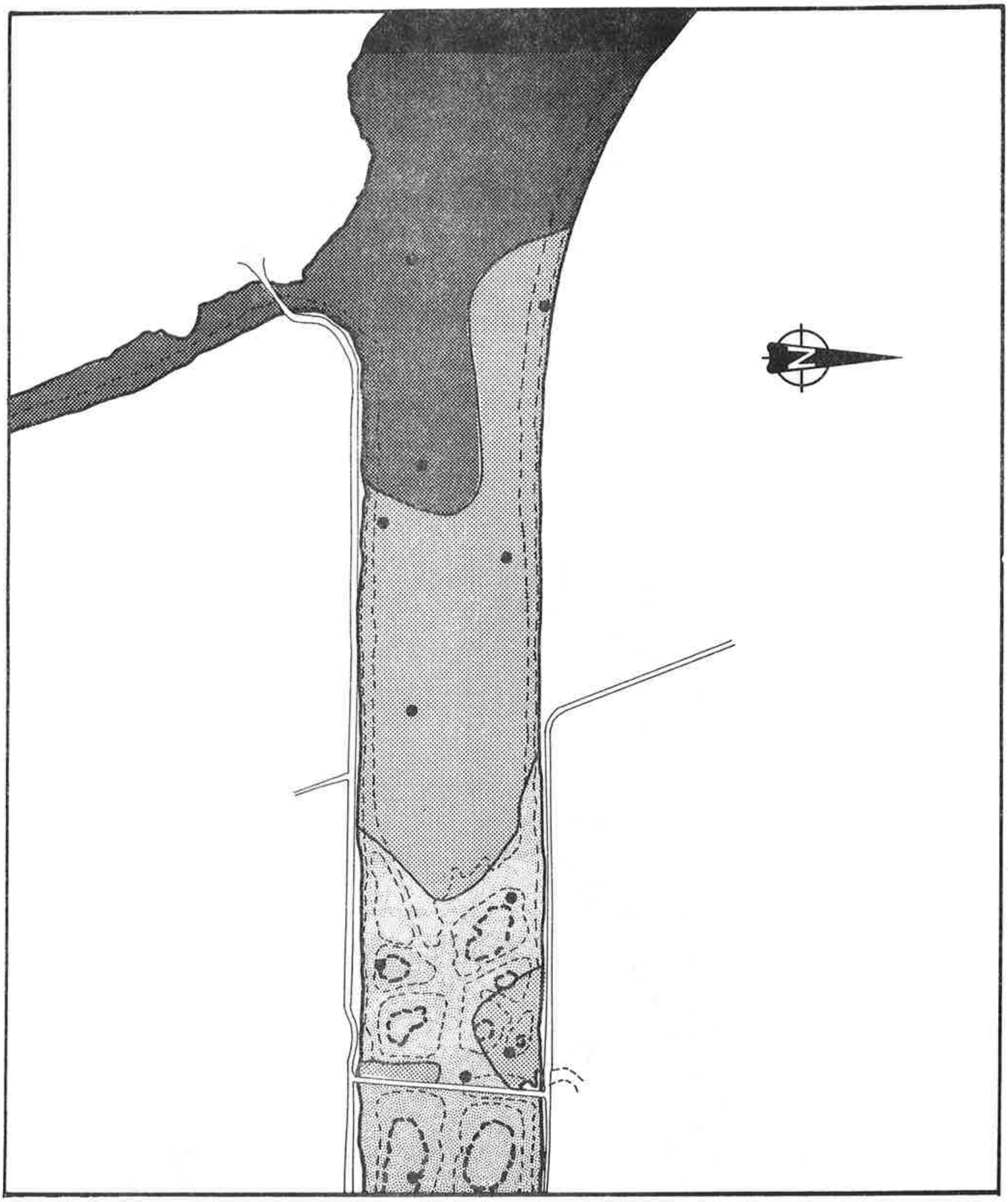


Fig 3c : Distribution of sediments in the upper estuary.

Lower Estuary

Sediments in the lower estuary originate primarily from the marine environment. In general they are sandy. The sediment analysed near the channels (Stations 4,8,10,14) had the greatest percentage of large particles as it is greatly affected by tidal currents and wave action. Further away from the channels the sediment becomes better sorted and consists mostly of sand (Stations 12, 20, 17, 22). In a quiet backwater north-east of the Embankment Bridge (Station 24) the sediment consists of much finer material. The sediment in the vicinity of marginal vegetation is generally sandy/mud. The marginal vegetation is responsible for much of the organic input into the estuary. Other areas consisted predominantly of mixtures of sand and shell fragments (Stations 9 and 19).

Middle Estuary

As expected sediment at stations in the low tidal zone consists of sand/gravel with finer sediment in areas near marginal vegetation. Towards the upper end the sediment becomes progressively finer and muddier especially in the vicinity of the Farm Bridge.

Upper Estuary

In this part of the estuary sediments are largely derived from the Taipo Stream and from run-off from the surrounding land. The sediments (Stations 41 and 43) in the upper reaches are very muddy. Much of this fine sediment is carried down the Taipo Stream and from the adjacent low-lying land and trapped in the *Zostera* beds (eel grass). The *Zostera* beds will also contribute fine organic matter to the estuary. The area in the vicinity of the pumping station is a very fine silty mud probably due to the large amount of suspended matter being pumped in from the airport and surrounding farm land drains. It has been reported that the silt in the upper estuary has increased greatly in recent years. The Farm Bridge is responsible for these fine sediments being trapped in this area and for their build-up as it severely restricts the water flow.

Other Physical Factors

All physical factors in some way influence the distribution of animals. Other physical factors looked at in this study are salinity, tidal height and exposure.

Salinity

A major feature of an estuary is the variation in the salt content of its waters. The degree of dilution of the seawater by fresh water and the variations are important in determining distribution patterns of plants and animals. Tidal flow, river flow, wind action and the shape of the estuary determine the salinity regime. Generally, salinity decreases from seawater at the mouth to almost completely fresh water at the head of the Ahuriri Estuary. Seawater being more dense than freshwater tends to move along the bottom underneath the freshwater causing the estuary waters to be stratified.

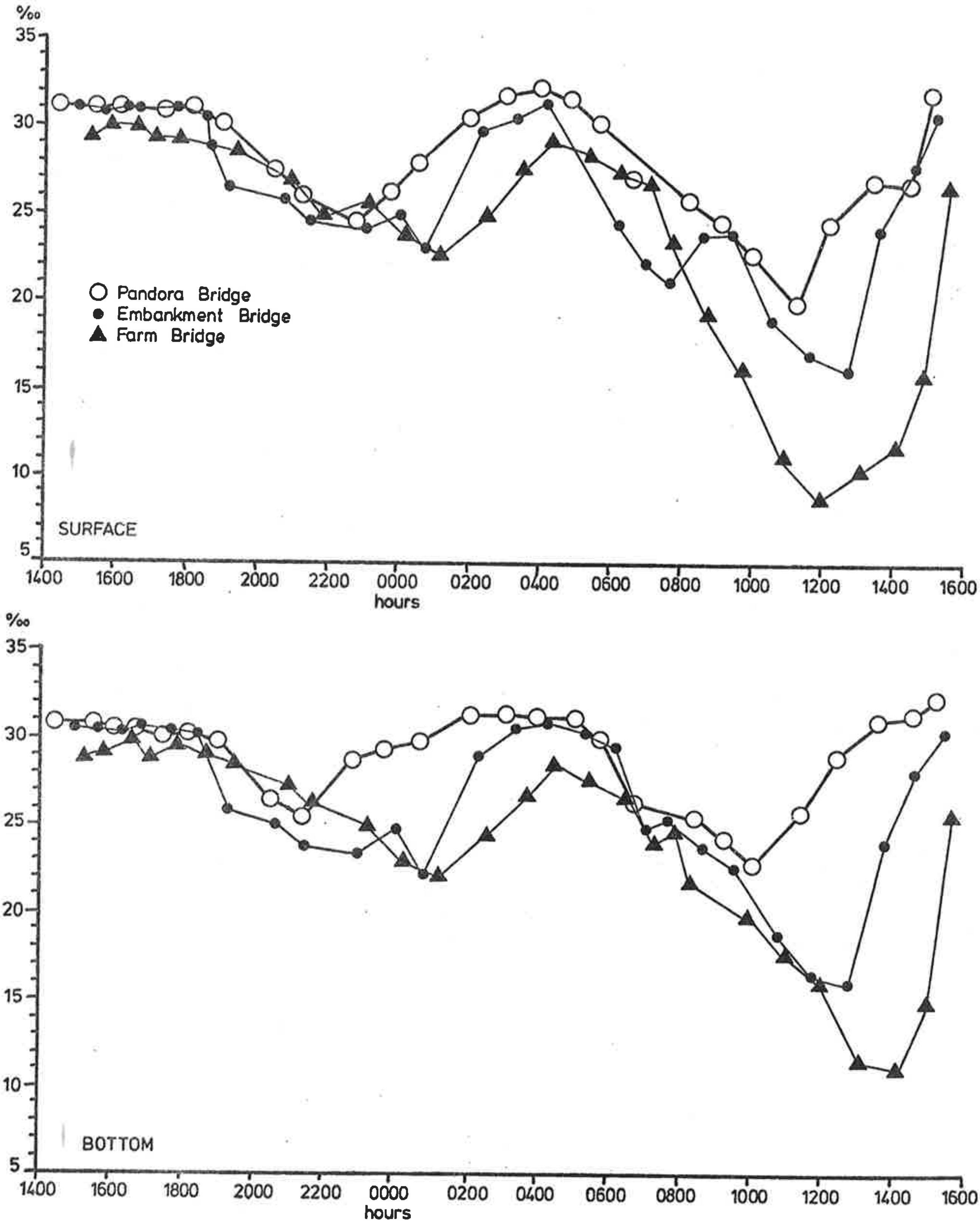


Fig. 4 : Salinity measurements taken in mid-channel over two tidal cycles at Pandora, Embankment and Farm Bridges.

Over a 24 hour sampling period the salinity at Pandora Bridge ranged from 31.8°/oo to 19.4°/oo at the surface to between 32.2°/oo to 23°/oo at the bottom (Fig. 4). Seawater is 33°/oo. The animals living at this end of the estuary were marine and estuarine animals tolerant to small changes in salinity. At the Embankment Bridge salinities ranged from 30.4°/oo to 15.2°/oo on the surface and 30.6°/oo to 15.8°/oo at the bottom. (Fig. 4). Species found in this area were slightly more tolerant to reduced salinities than those at the mouth.

Farm Bridge water salinities had a much wider range with levels between 28.5°/oo and 7.8°/oo at the surface and 28.8°/oo to 11°/oo at the bottom (Fig. 4). Here the animals must be extremely tolerant to large changes. Unfortunately, measurements were not made further up the estuary. Hunnable and Spackman (1974) recorded salinities of about 4.7°/oo at the mouth of Taipo Stream, and lower salinities further upstream in the outfall channel. The species found were freshwater animals tolerant of slight increases in salinity.

Animals living in the sediment are not so affected by changes in salinity as those living on the surface. Interstitial salinities are generally relatively constant over a tidal cycle - decreasing from mouth to head and increasing with tidal height (Knox and Kilner 1973).

Some parts of the estuary are subject to considerable changes in salinity. For example, in a wet period a much larger volume of water enters the estuary from run-off. This results in a much larger volume of freshwater entering at the pumping stations, from the airport and surrounding farmland, and also at the floodgates (Fig. 1) when these are opened after heavy rain.

Hence salinities in these areas can be markedly altered from the normal salinity cycle. Animals living permanently in these areas will be species that are able to tolerate considerable changes in salinity.

The effect of heavy rainfall on salinities recorded in the estuary can be seen in Fig. 4, where the low tide salinities are much lower in the second tidal cycle than in the first, after a period of rain occurred between these two low tides.

<u>Tidal Height</u>

The general movements of water within the estuary and the approximate length of time areas of the estuary were exposed over a 12 hr neap tidal cycle was determined by observing tidal posts at the stations (Fig. 5). Exposure has an important role in distribution of some species. Some animals are not able to survive if they are uncovered by water for any great length of time, e.g. chitons - which are found in the channels and low tidal areas of the estuary (e.g. Stations 4 and 8). Other animals prefer being exposed for most of the tidal cycle, e.g. <u>Helice crassa</u> - which is fairly mobile and at low tide is distributed all over the estuary.

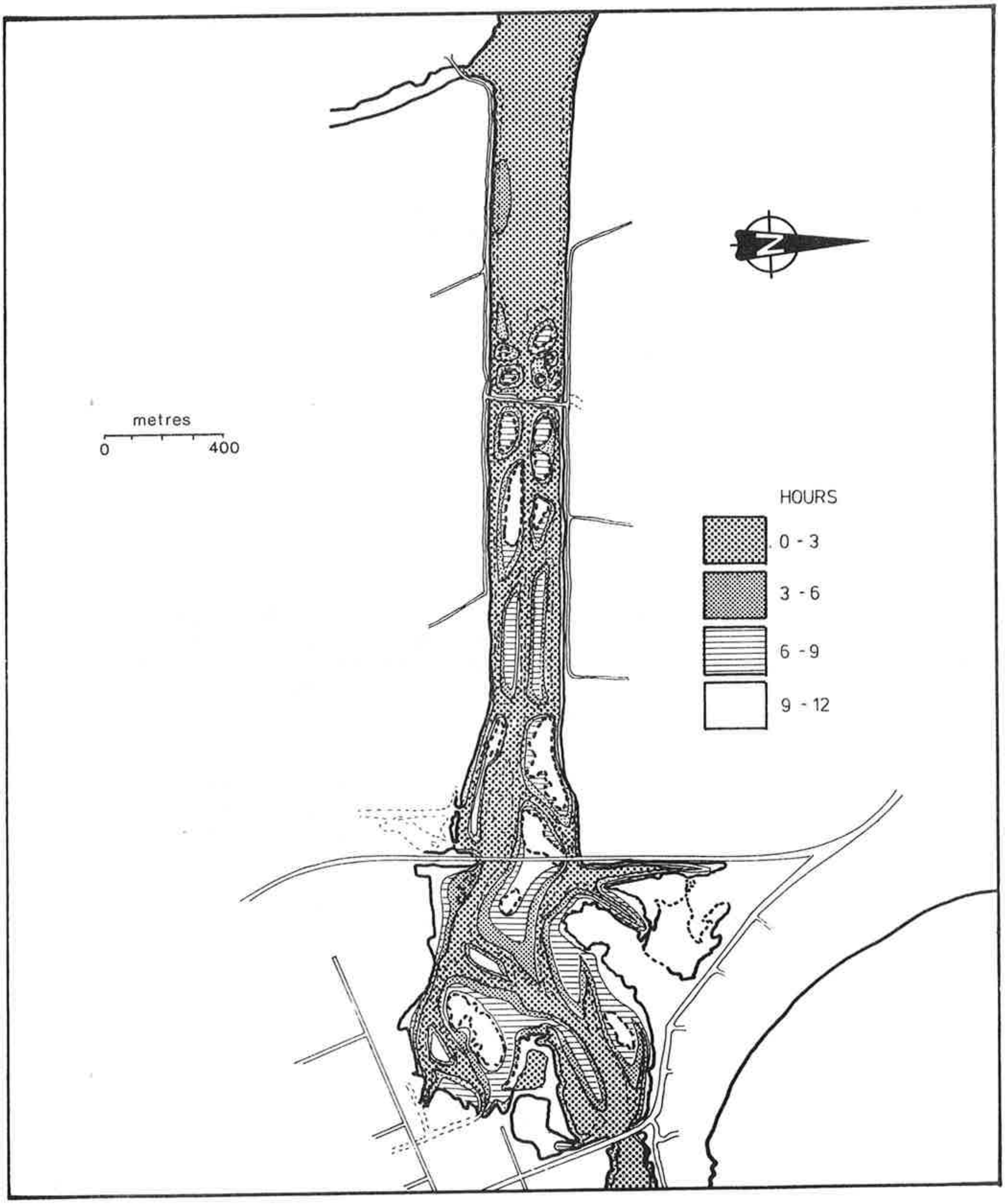


Fig. 5 : Zones of exposure time measured over a neap tidal cycle

The tidal height also affects animal distribution. Areas subject to large changes in tidal height are usually those with high current velocities, e.g. Station 4. The animals living here differ from those in other areas, such as quiet backwaters, where although water covers the surface for all or most of the tide, the water level does not change very much. Most of the tidal flats in the lower estuary are covered from 3-9 hrs by 5-60 cms of water. The upper estuary was not subject to great changes in tidal height as is the lower estuary. Most areas, excluding the marginal vegetation, were covered for more than 9 hrs of the tidal cycle but by only 5-20 cms of water. Tidal heights indirectly affect animal distribution through their effect on the interstitial salinity. In general, the greater the tidal height the higher the interstitial salinity (Knox and Kilner, 1973).

Distribution of the Invertebrate Macrofauna

The bottom living animals in the estuary are important as they are a major element in ecosystem stability as well as an important food supply for fish and birds.

In an estuary the invertebrate macrofauna is derived from both the marine and freshwater environments but it is probably more abundant than either. Distribution is determined by chemical and physical factors some of which have already been discussed. The largest numbers of animals and the greatest variety of species occurred on the tidal flats in the lower estuary. Upstream towards the freshwater influence numbers and variety declined as fewer species were able to tolerate the lowered salinities and muddier sediments.

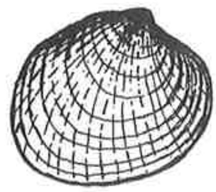
Thirty-three species of macroinvertebrates were identified in the samples collected (Table 1).

(i) Mollusca Bivalves

Three species of bivalves, the cockle Chione stutchburyi, Macomona liliana and the pipi Paphies australe were found in the estuary.

Chione stutchburyi - (cockle)

The cockle was the most numerous animal found. It is a filter feeder and was found in many parts of the estuary numbers decreasing si'nificantly toward the upper estuary (Fig. 6a-c). Chione stutchburyi tolerated a wide range of exposure times but was more abundant from the mid-tidal levels to the channel areas. Densities up to 7500/m^2 were recorded however size was generally small (mean 15 mm) over the whole estuary. Chione was tolerant of a wide range of sediment types but preferred a sandy substrate.



Chione stutchburyi

TABLE 1

Species list for invertebrate macrofauna - Ahuriri Estuary.

MOLLUSCA - Pelecypoda (bivalves)

Chione stutchburyi (cockle)
Macomona liliana (thin wedge-shell)
Paphies australe (pipi)

MOLLUSCA - Gastropoda

Amphibola crenata (mud snail)
Cominella glandiformis (whelk)
Zediloma subrostrata
Potamopyrgus estuarinus (snail)
Xymene plebius
Zeacumantus lutulentus
Zeacumantus subcarinatus

MOLLUSCA - Amphineura (chitons)

Sypharochiton pelliserpentis

ARTHROPODA - Crustacea

Elminius modestus (barnacle)
Halicarcinus whitei (crab)
Helice crassa (mud flat crab)
Hemigrapsus crenulatus (hairy crab)
Macrothalmus hirtipes (crab)
Paracorophium lucasi (amphipod)

Isopods (unidentified)

ANNELIDA - Polychaeta (worms)

Aglaophamus macroura
Aonides trifidus
Boccardia (Paraboccardia) syrtis
Capitella capitata
Cirriformia filigera
Glycera lamellipoda
Haploscoloplos cylindrifer
Heteromastus filiformis
Nicon aestuariensis
Paraprionospio pinnata
Pectinaria australis
Platynereis australis
Perinereis nuntia
Scolecolepides benhami

NEMERTINA - (Proboscis worms)

unidentified

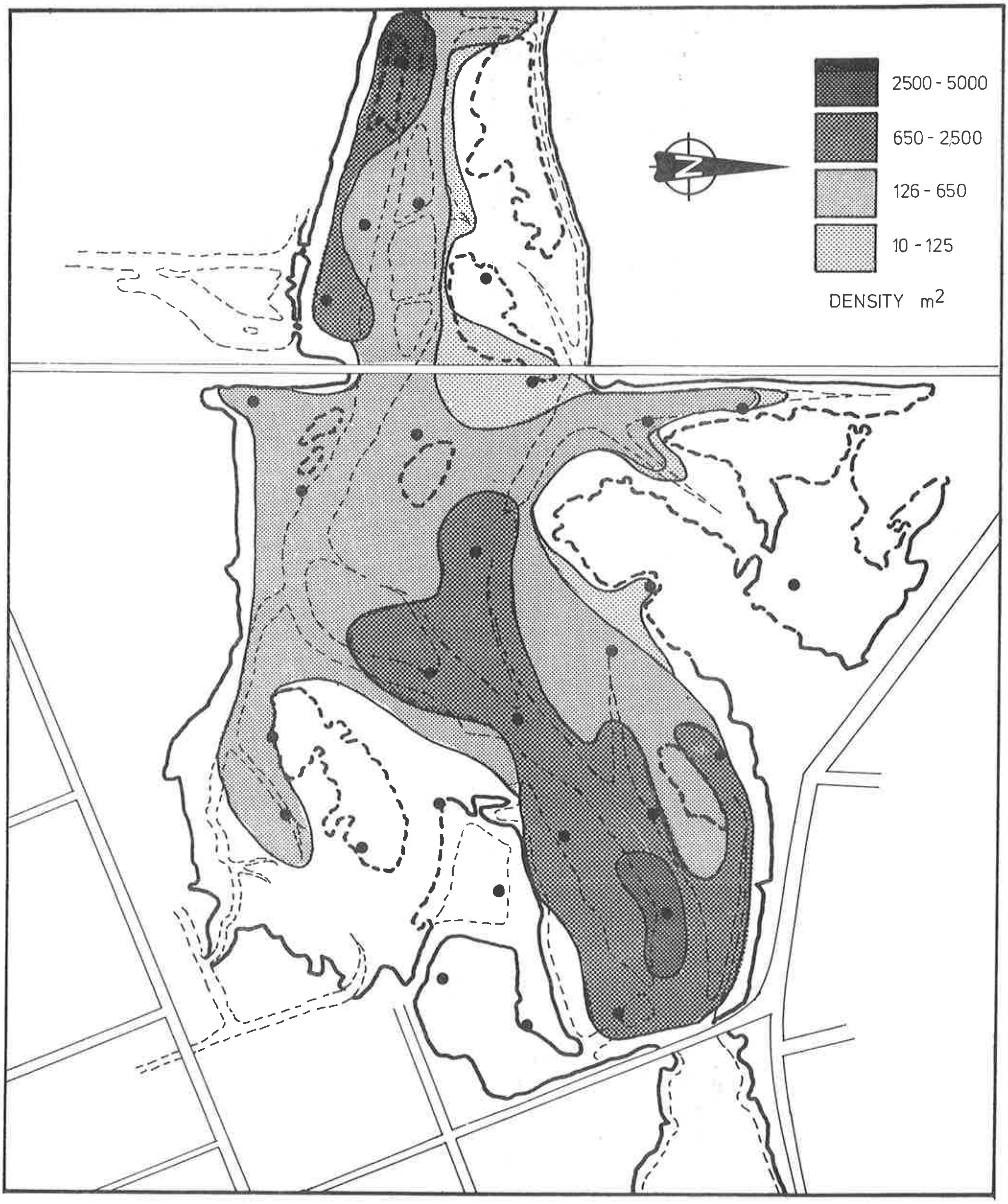


Fig.6a : Distribution of Chione stutchburyi in the lower estuary

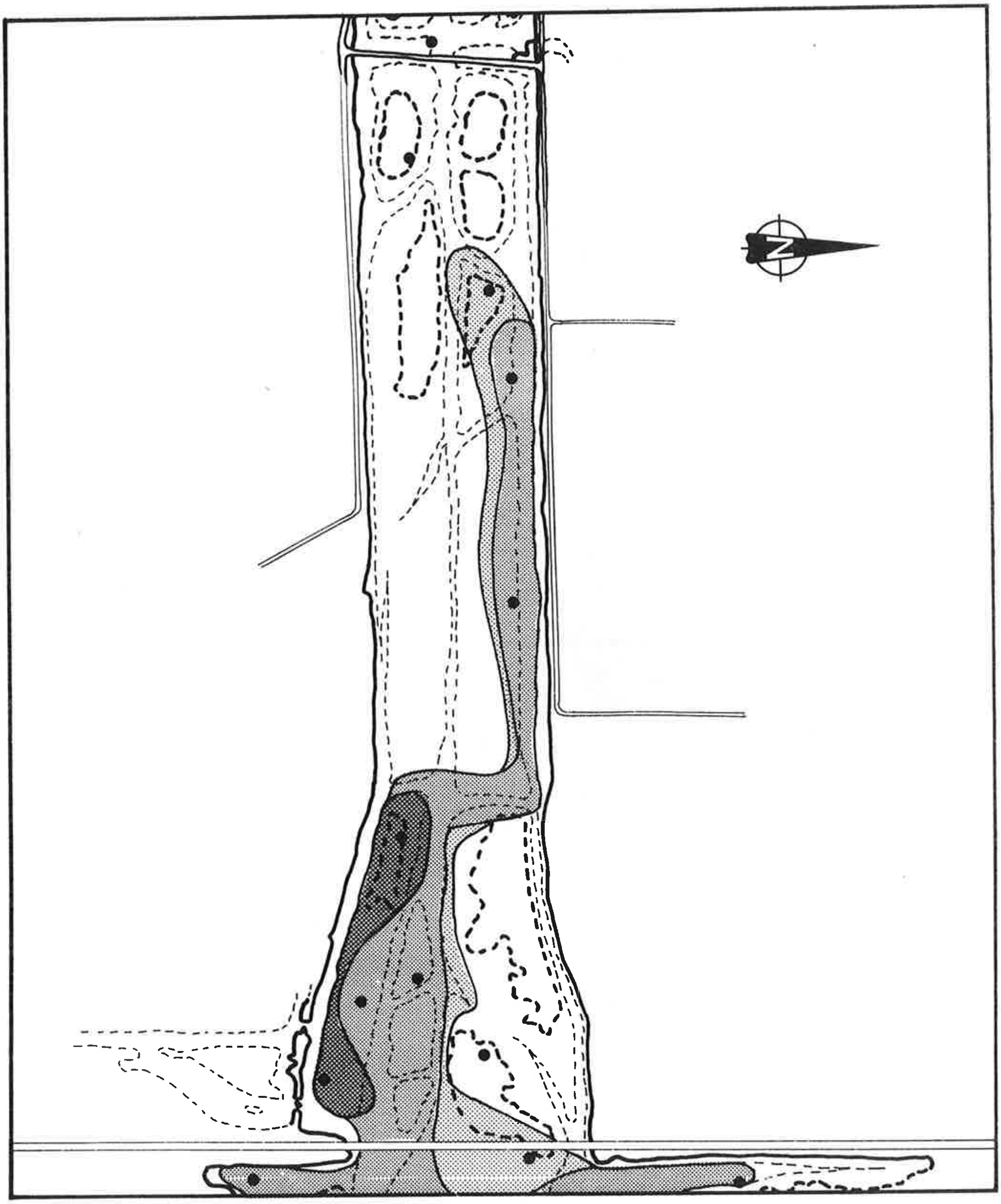


Fig.6b : Distribution of <u>Chione</u> <u>stutchburyi</u> in the middle estuary

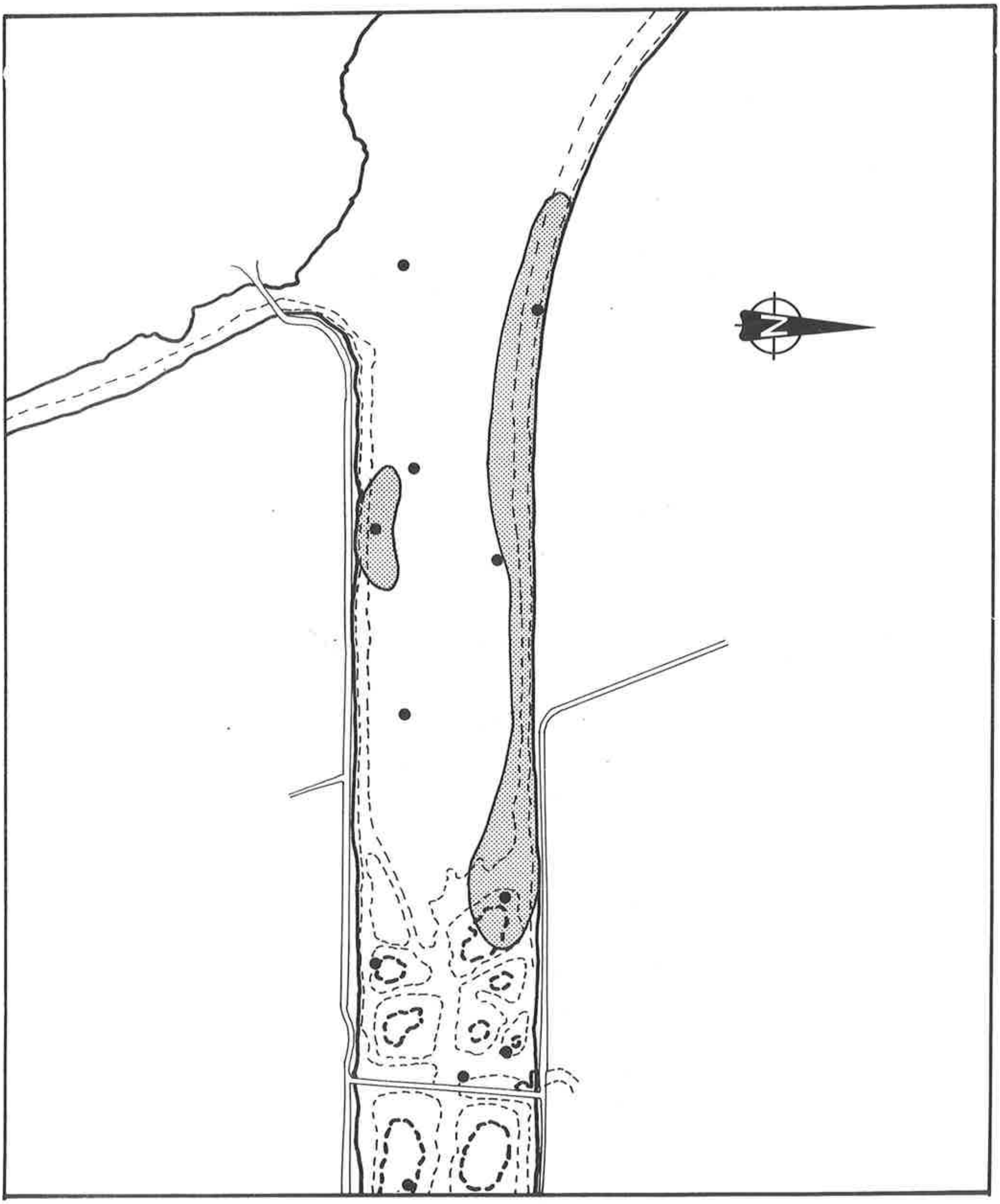
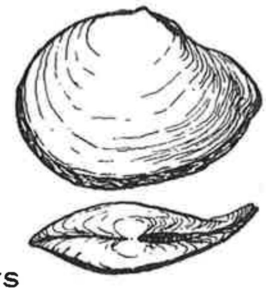


Fig.6c : Distribution of Chione stutchburyi in the upper estuary

Macomona liliana - (thin wedge-shell)

Macomona liliana



Macomona was also very abundant in the estuary occurring in numbers up to $730/m^2$. Its distribution was similar to Chione but it was not found as far up the estuary (Fig. 7). It preferred a sandy substrate and is known not to be able to tolerate living in sediment with a high percentage of mud (Knox and Kilner, 1973). This would account for its absence in the upper estuary. Macomona is a deposit feeder and burrows to 10-12 cms.

Paphies australe - (pipi)

The pipi was not very common in this estuary. Only a few small pipis were found in the high salinities of the lower estuary. Most were found in channel stations where the sediment was sandy gravel.

(ii) Mollusca - Gastropoda

Seven species of gastropods were identified. Amphibola crenata, Cominella glandiformis, Zediloma subrostrata, Potamopyrgus estuarinus, Xymene plebius, Zeacumantus lutulentus, Zeacumantus subcarinatus.

Amphibola crenata (mud snail)

This animal was most common in the upper estuary being tolerant of reduced salinities. It did not occur in any of the sandy gravel areas but preferred muddy sand. The animals found were generally small (mean size 10 mm).

Cominella glandiformis (whelk)

This animal had a similar distribution to Chione but was not as abundant. It preferred high salinities and a gravel substrate. Groups of Cominella were often seen scavenging on dead or moribund animals.

Zediloma subrostrata

This shellfish was most abundant near the mouth of the estuary preferring the higher salinities and the gravelly sand substrate. It is a herbivore.

Potamopyrgus estuarinus (snail)

Potamopyrgus estuarinus

This snail was found in very large numbers in the upper estuary up to $2500/m^2$ and only very rarely in the middle and lower estuary.

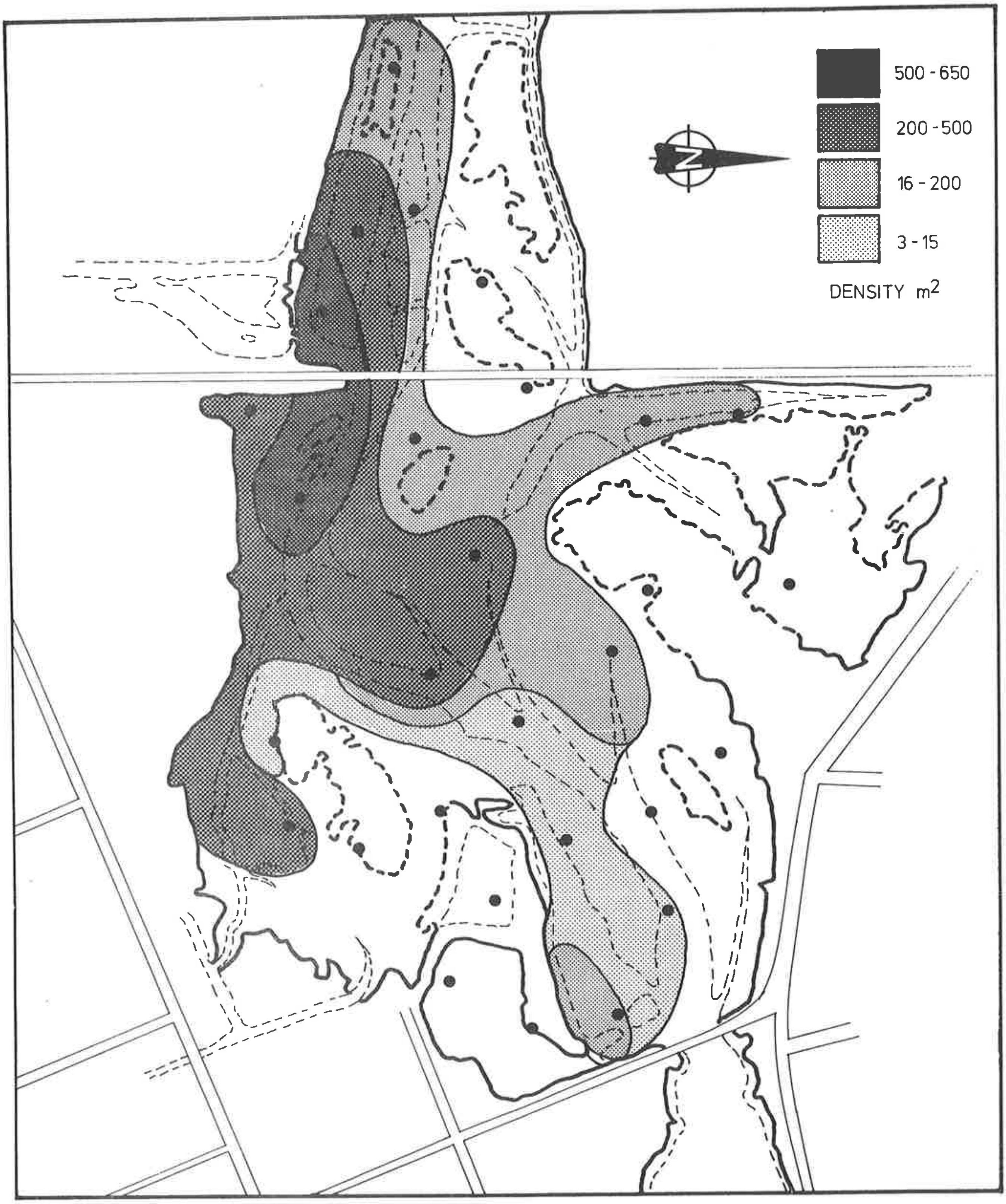


Fig. 7 : Distribution of Macomona liliana

Xymene plebius

This animal was rare in the estuary found only at Station 31.

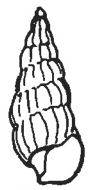
Zeacumantus lutulentus

This gastropod was fairly common in some parts of the estuary. It preferred a sandy substrate and was generally found on the tidal flats over a wide exposure and fairly wide salinity range.

Zeacumantus lutulentus

Zeacumantus subcarinatus

This species is generally smaller and darker in colour than the Zeacumantus lutulentus and was not nearly as common.



Zeacumantus subcarinatus

(iii) Mollusca - Amphineura (chitons)
Sypharochiton pelliserpentis

This chiton occurred attached to rocks and shellfish in the low tidal zone.

(iv) Crustacea

Seven species of crustacea were found in the estuary.

Elminius modestus

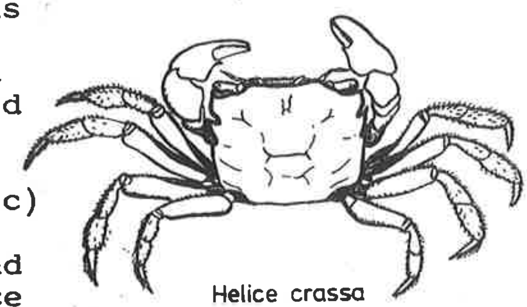
This barnacle was commonly found on pebbles in the low tidal zone.

Halicarcinus whitei

This tiny delicate crab was found only in small numbers generally in the middle and upper estuary. It preferred lowered salinities and a sandy substrate.

Helice crassa

This mud flat crab was very common and very conspicuous all over the estuary. It was particularly common on the tidal flats of the lower and middle estuary. It preferred sandy substrate. Its distribution and relative abundance is shown (Fig. 8a-c) Helice crassa was found in densities of up to $420/m^2$ and tended to be small (mean size 10 mm).



Helice crassa

Hemigrapsus crenulatus

This hairy legged large size crab was found rarely.

Macrothalmus hirtipes

This crab was only found in small numbers generally near the low tidal zone and in areas of fairly high salinity.

Paracorophium lucasi

This small delicate amphipod was found mainly in the upper estuary being able to tolerate lowered salinities. Large numbers were found at Station 34 which is affected by the discharge from the pumping station.

Isopods

Isopods were widely distributed.

The abundance and distribution of isopods and amphipods proved difficult to assess accurately as the smallest mesh collected was 1 mm. Many of these animals are smaller than this.

(v) Annelida - polychaete worms

Fourteen species were identified. In both number of individuals and number of species it was larger than any other group. The most common species found were Aonides trifidus and Scolecolepides benhami.

Aonides trifidus

This was the most abundant polychaete being found in numbers up to $5000/m^2$. It was found in the lower part of the estuary in coarse sediments and high salinities.

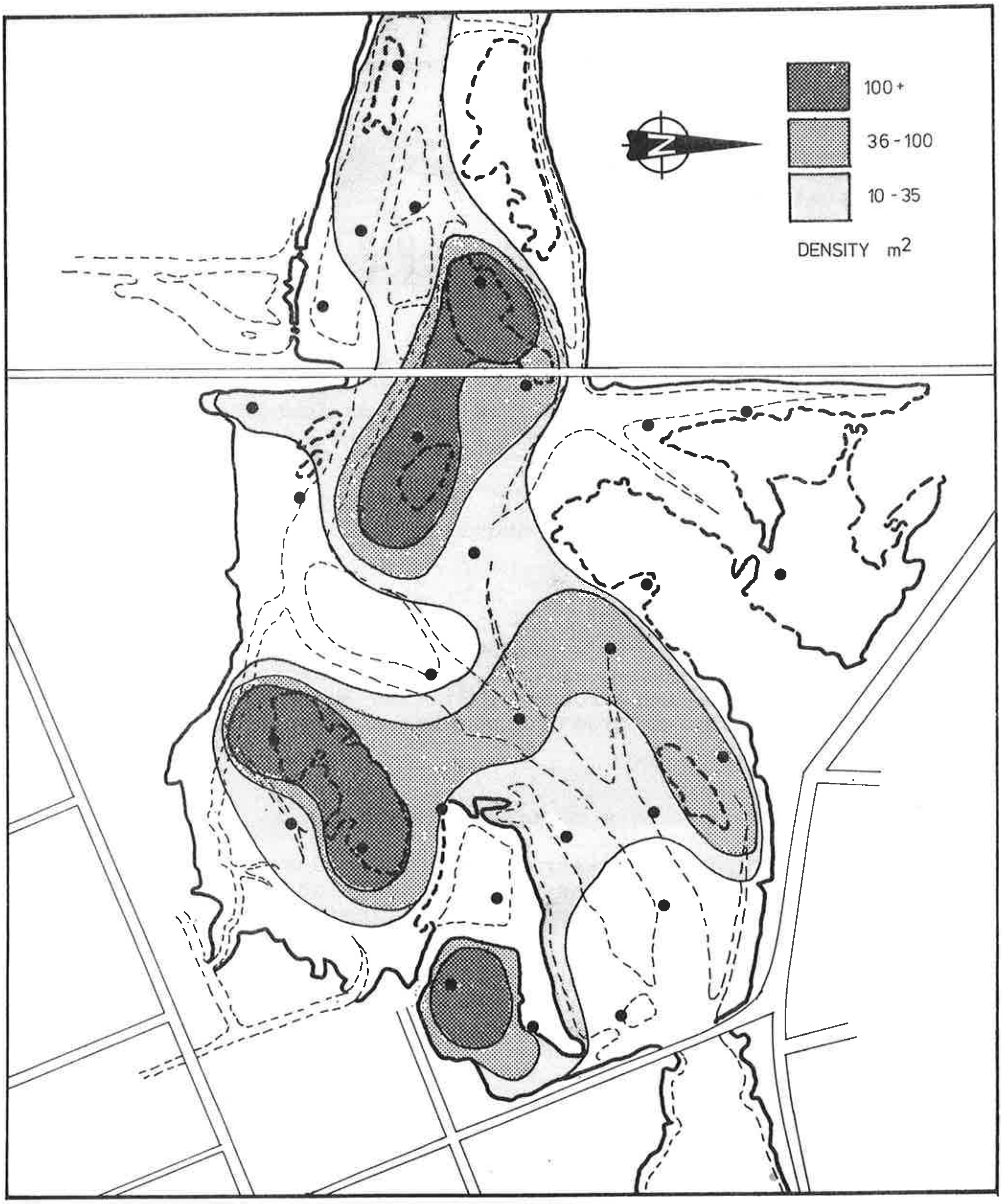


Fig.8a : Distribution of Helice crassa in the lower estuary

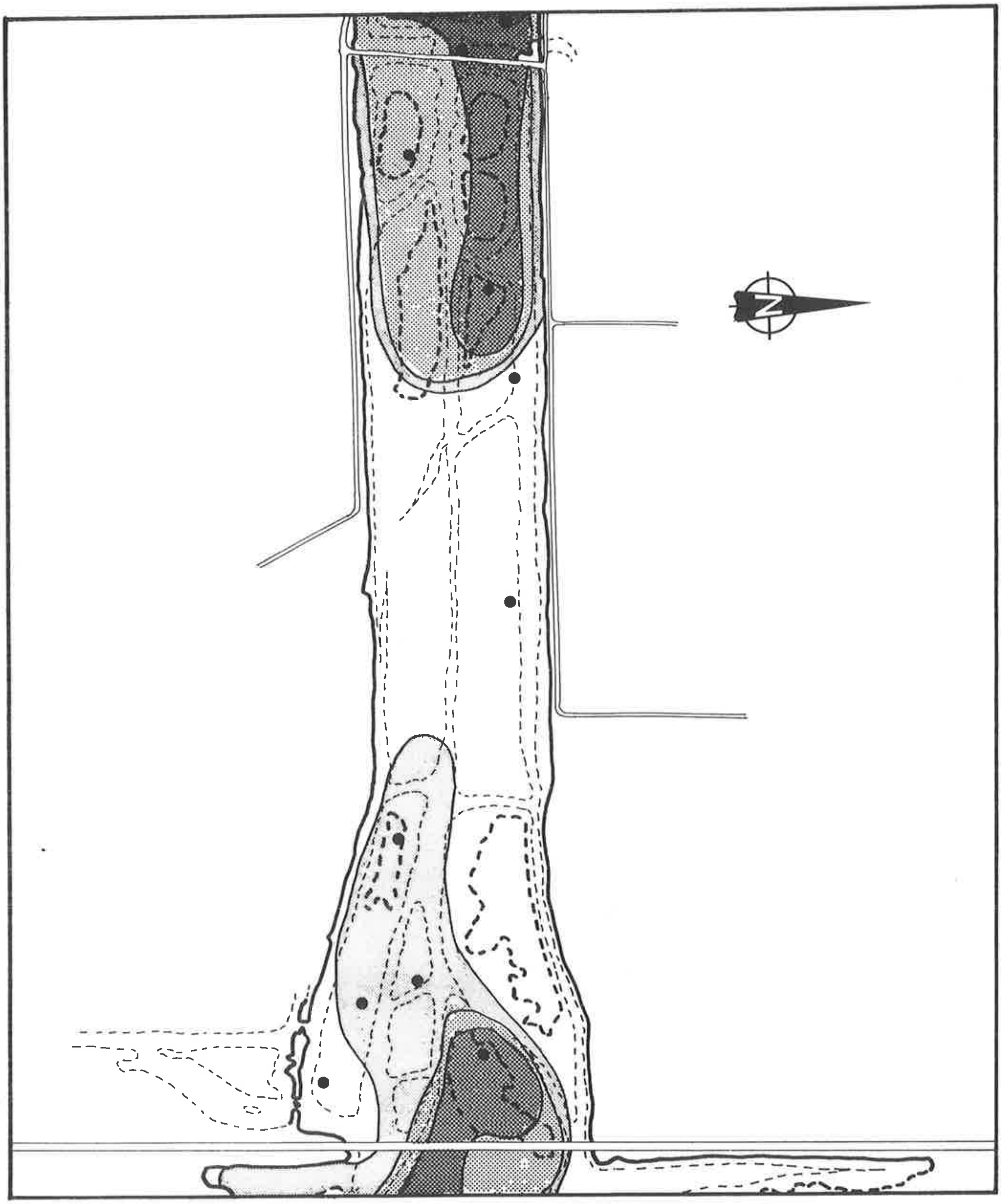


Fig.8b Distribution of Helice crassa in the middle estuary

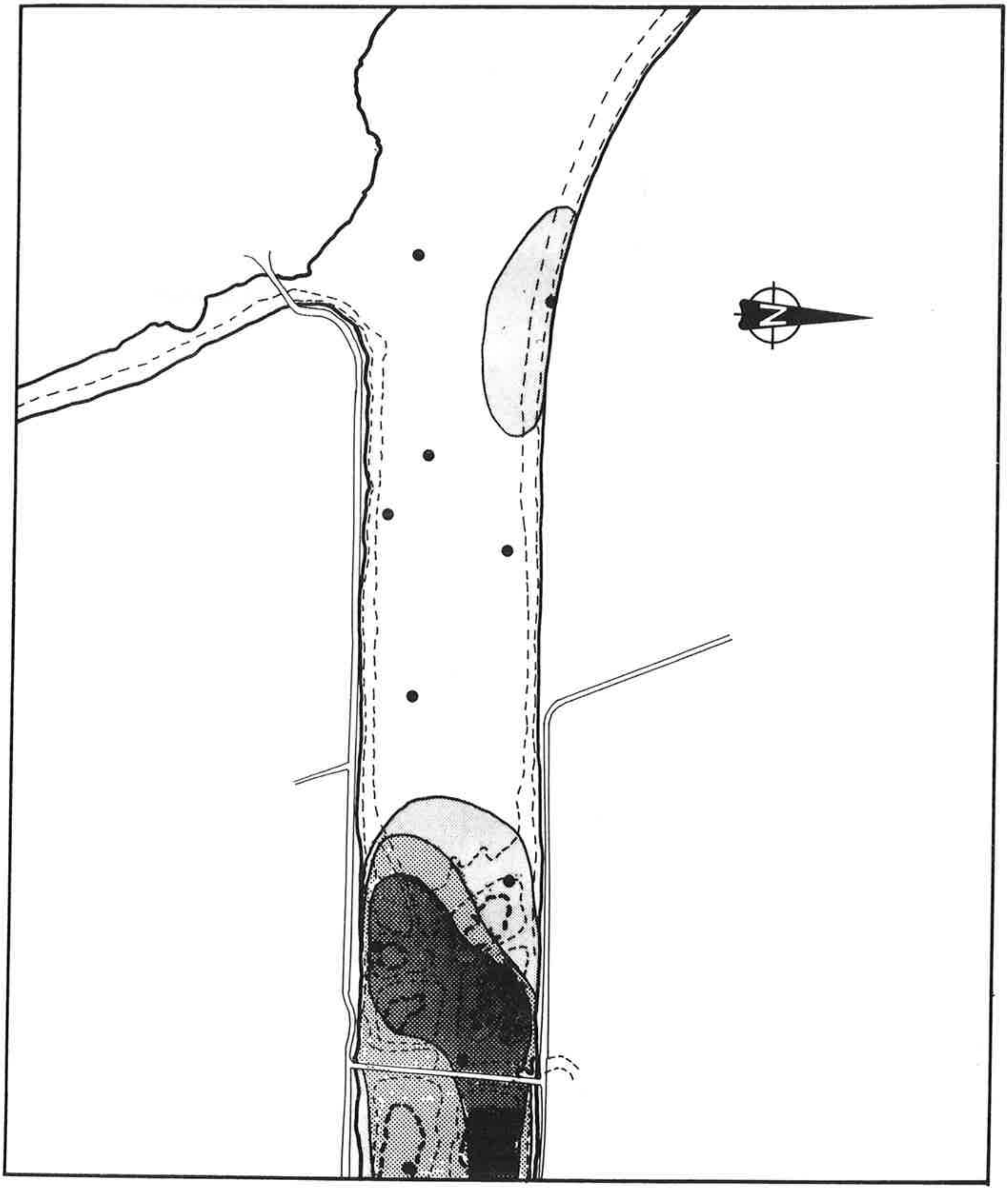


Fig.8c : Distribution of Helice crassa in the upper estuary

Scolecolepides benhami

This was most abundant in the upper reaches where salinity was low and sediments finer. Its maximum abundance was $1600/m^2$.

Three other notable species were Haploscoloplos cylindrifer occurring in the lower estuary (higher salinity and coarse sediments), and Nicon aestuariensis and Perinereis nuntia both fairly common especially in the upper reaches of the estuary. Of the other species Aglaophamus macroura, Boccardia (Paraboccardia) syrtis, Glycera lamellipoda, Paraprionospio pinnata, Pectinaria australis were found mostly in sandy regions. Capitella capitata was found only at Station 7 which at the time of sampling was a stagnating pond.

Species Groups

The distribution of all species was examined to see how the animals grouped together. A principal component analysis of the most common species was made using a correlation matrix (Cassie and Michael, 1968). The first four principal components (which explained 78% of the variation) were used. From this the species could be divided into five groups (some of these groups are very close together).

Group 1 - the major one was dominated by Chione stutchburyi and the most commonly occurring animals in it are Chione stutchburyi, Macomona liliana, Zediloma subrostrata, Cominella glandiformis, chitons and Aonides trifidus.

Group 2 was characterised by Potamopyrgus estuarinus and included:- Potamopyrgus estuarinus, Amphibola crenata, Halicarcinus whitei, Perinereis nuntia, and Scolecolepides benhami.

Group 3 was dominated by Zeacumantus lutulentus; Group 4 by Zeacumantus subcarinatus and Group 5 by Helice crassa.

Using these species groups the estuary can be divided into areas depending on what species were found there. The first division includes areas of high salinity, low exposure time and relatively coarse sediment. Stations (1, 4, 8, 10, 14, 17 and 25) in this area tended to be in the low tidal zone. The dominant animal group is Chione stutchburyi (i.e. Group 1 above).

The second division includes most of the intertidal areas of the lower and middle estuary where the sediment is sandy and the salinity not too low. There are a large number of Stations in this group (5, 9, 11, 12, 13, 16, 18, 20, 21, 22, 23, 24, 27, 28, 29, 30 and 31).

Zeacumantus lutulentus (Group 3) and the *Chione* group (Group 1) were the dominant animal groups found.

The third division includes areas with high exposure, sandy sediment, and medium salinity and often occurred near marginal vegetation. Stations 3, 6, 19, 26, 32, 33, 35 and 36 were in this area. It was characterised by the mud crab *Helice crassa*.

The fourth division is the upper estuary area where the salinity is low and the sediment fine. Stations 37, 38, 39, 40, 41, 42 and 43 occur in this area. The dominant animal group is Group 4 the *Potamopyrgus* group.

Several stations are not included in these areas. No animals were found at Stations 2 and 15. Both of these areas were dry at the time of sampling. Station 2 occurs on a reclaimed area now used as a road. Station 15 is dried up due to a dam (Fig. 1). The dam has since been semi-removed and regeneration studies are being carried out in this area.

Station 7 occurs in a stagnating pond, and could not be compared to any other area. *Capitella capitata* was the only animal found there constantly. This polychaete is known to inhabit polluted waters.

Station 34 again could not be compared easily to other stations. The animals here changed each sampling trip due to changes in organic content, volume and salinity of water flowing over it from the pumping of the adjacent airport and farmland. Only a few species were found here, in particular polychaetes and amphipods.

Comparison with Other New Zealand Estuaries

Thirty-three species of macro-invertebrates were identified in this study (Table 1). This is fewer than in either the Avon-Heathcote where 111 species were identified or the Parapara Inlet where 59 have been identified. However, in this study the smallest size sieve used had a 1 mm diameter mesh. A 0.5 mm sieve would almost certainly have allowed the identification of some of the smaller species of macro-invertebrates - in particular isopods, amphipods and polychaetes and thus increased the total number of species found.

Numbers of individuals of the major species in Ahuriri tended to be greater than in either of the other estuaries.

Molluscs in Ahuriri Estuary are more abundant than in the Avon-Heathcote or Parapara (Table 2). However, many of them are very small. For example, the size range of *Chione* was between 1 mm and 35 mm the mean size being approximately 15 mm. The reason for this is not known but could be due to general conditions in the estuary, shortage of food or predation.

The mud crab *Helice crassa* was again more abundant than the Avon-Heathcote or Parapara (Table 2). It is an important food for fish (see 3.3 and 3.4).

TABLE 2

A comparison of the maximum densities found of the common invertebrate species of Ahuriri Estuary, Napier, with those of the Avon-Heathcote Estuary, Christchurch, and the Parapara Inlet, Golden Bay.

Species	Numbers $/m^2$		
	Ahuriri	Avon-Heathcote	Parapara
MOLLUSCA			
Chione stutchburyi	7270	2560	1240
Macomona liliana	730	304	230
Zeacumantus lutulentus	740	-	150
Zediloma subrostrata	360	340	63
Amphibola crenata	580	485	230
CRUSTACEA			
Helice crassa	420	200	180
POLYCHAETA			
Aonides trifidus	5000	6000	180
Scolecolepides benhami	1660	8000	-

The invertebrate macrofauna of Ahuriri Estuary consists of abundant and diverse numbers of individuals and species typical of a New Zealand estuarine area. There is no doubt that this group of animals has a critical role in the food-chain and an essential role in the balanced network of biotic inter-relationships in this estuary.

3. FISH POPULATION

- by A.R. Kilner

3.1 Introduction

The fish population of Ahuriri Estuary has been studied to arrive at an understanding of the distribution, movement patterns, breeding and feeding of fish species in this estuary.

These studies have been carried out in order to make an assessment of the potential value of the estuary to fisheries, of its role in contributing to the fisheries of Hawke Bay, and to obtain information with which to assess the likely effects on the fish population of the proposed modifications to the estuary.

3.2 Sampling Methods

The fish population of Ahuriri Estuary was sampled over the period May 1976 to July 1977. Seven sampling trips each of 3-4 days fishing were carried out at intervals during this period.

A number of net types were used to catch different species and a range of fish sizes. The following types of static nets were used: set (gill) nets, fyke nets, and whitebait set nets. In addition, a small hand-pulled drag net and a dip net were used in suitable places. Static fishing nets were mainly used to sample the fish population because of problems in sampling the estuary. The estuary is shallow and has a large number of logs and snags which make trawl nets and beach seines ineffective. Most nets used were either partially or totally ineffective in sampling the swift currents of the deeper channels in the lower estuary.

Each set was made for at least several hours over a change of tide or were set overnight. The fish caught were measured, and the gut was opened to stop digestion. They were stored in 5% formalin for later dissection.

Set Nets

Several monofilament set nets of 10.5 cm stretched mesh were used. These nets are set across an area of water so that fish swimming into the mesh are caught by the gills. They caught only larger individuals such as parore, yellow-bellied flounder, river flounder, yellow-eyed mullet, grey mullet and kahawai. They do not catch very small fish like juvenile flatfish, bullies, whitebait or eels. These nets suffered the most from fouling by floating weeds, which often caused the net to roll up.

Fyke Nets

Fyke nets of 2 cm mesh were used; they have a narrow funnel-shaped entrance through which fish enter, but have difficulty in finding again to escape. These nets were set in pairs one facing upstream, the other downstream.

They caught mainly eels when set overnight, but also caught other small fish, such as juvenile yellow-eyed mullet, flatfish and bullies, if set during daylight.

Whitebait Set Nets

These nets covered with nylon insect netting (7 meshes per centimetre) were used in attempts to catch "whitebait", but also caught juvenile yellow-eyed mullet and flatfish.

Drag Net

A small drag net of 2 cm stretched mesh, and 5 m width was pulled by hand in the quiet shallow waters of the tidal flats and channels where they were free of snags and soft sediments did not impede progress. This small net was effective only in catching juvenile fish, and even then only those large enough not to pass through the net. When floating weeds were abundant, this net rapidly filled with weed and became ineffective.

Dip Net

A dip net covered in nylon insect netting was used to catch juvenile fish too small for the drag net, and in habitats along rocky shores and in the upper estuary where the drag net could not be used.

The effectiveness of the above nets varied with the species and habitat. Not all species would have been effectively sampled. Quantitative comparisons of abundance between different net types and different species are not possible. The abundance of different species is given on a subjective basis, based on past experience of fishing in a number of estuaries.

Gut Contents

In the laboratory the alimentary tracts of the main species captured were examined using a stereo-microscope. As far as possible stomach contents only were examined as less digestion has taken place there than in the intestines where food groups with hard exoskeletons or shells tend to persist longer and become over-represented in the data collected. The degree of fullness of complete stomachs was determined using Hynes' (1950) method as modified by Thompson (1959). Points were allotted as in Table 3.

TABLE 3

Points allotted to stomachs of varying fullness.

Number of Points	Fullness of Stomach
20	Full
15	3/4
13	2/3
10	1/2
7	1/3
5	1/4
2	trace
0	empty

Food items were separated into major categories (e.g. crustaceans, molluscs, polychaete worms, etc.) and wherever possible specific identifications of organisms were made. Food points were then allotted as in Table 3 for the relative volume of each food category. These points were summed and divided by the total potential stomach volume, thus giving the percent volume occupied by each food category including the empty volume.

The subjective allocation of points is the main limitation of the above rapid technique for examining stomach contents. No consideration of comparative sizes of stomachs was made, as it was assumed that a full stomach is just as important for a small fish as for a large fish.

Breeding

The breeding of fish in the estuary was investigated to a limited extent to allow an assessment of which species were using the estuary for breeding, feeding or both.

Fish were sexed whenever possible, and their gonads were examined under a microscope to assess gonad maturity using the criteria proposed by Bowers (1954) modified for this study as in Table 4.

Only for some species were sufficient fish captured to allow their gonads to be assigned to one of the groups in Table 4 with any degree of confidence. For the other species the gonads were simply examined to see whether they were immature or ripe and running (or near to it).

TABLE 4

Gonad maturity index

Male

I	Immature; testes small, no sperm
II	Mature; sperm extruded on cutting and squeezing
III	Ripe running; testes enlarged and lobate, milt extruded by pressure
IV	Spent; testes crinkled and shrunken, little sperm left

Female

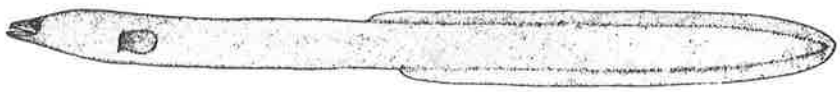
I	Immature; ovaries very small, translucent, eggs microscopic
II	Mature ripening; ovaries of moderate size, eggs visible
III	Almost ripe; ovaries large and distended, eggs clearly visible and opaque
IV	Ripe running; nearly all eggs transparent, eggs extruded by slight pressure
V	Spent; ovaries flaccid and shrunken.

3.3 Results

Eels

New Zealand has two species of freshwater eel - the short-finned eel Anguilla australis schmidtii, and the long-finned eel A. dieffenbachii. Both species were found in the estuary, short-finned eels being one of the main species found there permanently. Long-finned eels were not as common.

Long-finned eel *(Anguilla dieffenbachii).*



Short-finned eel *(Anguilla australis).*

Short-Finned Eels

The short-finned eel (shortfins) was very common and found throughout the estuary. Shortfins tended to increase in numbers upstream; they were common above Embankment Bridge and most abundant above Farm Bridge.

Shortfins were also commonly found in the drains of the farms on either side of the Outfall Channel and eels are known to pass through the pumps draining the farms and enter the estuary.

Eels feed and grow in the estuaries and rivers, and migrate as adults to breed far offshore. The juvenile eels (referred to as glass eels) return from the sea and invade the estuaries and rivers in late winter and early spring (Jellyman, 1977). Once in estuarine areas these glass eels delay further upstream migration until they have completed a behavioural change and developed dark pigmentation by which time they are known as elvers. On several occastions during spring 1976 elvers were found in samples of estuary sediment, some were caught in a dip net.

It was apparent from the data collected that there was an increase in numbers of shortfins caught in summer and a decrease in the catch in winter. The winter decrease in catches could be due to decrease in activity of fish with colder water temperatures and thereby lessening their chance of being caught by fyke nets.

Length frequency distributions for shortfins did not show marked differences between samplings (Fig. 9). Most shortfins caught in the estuary were between 30-48 cm. Thus the majority of shortfins caught were small, not yet approaching sexual maturity and the time when they migrate to sea to breed. At this size they have several years of feeding and growing in the estuary and its tributaries before migrating to sea.

Stomach contents were examined for 166 shortfins. The data obtained was not a good representation of the shortfin's diet as they were trapped overnight and held alive until the nets were emptied in the morning. Thus for eels caught in the early part of the night there would be sufficient time for digestion of food in the stomach especially of soft-bodied organisms.

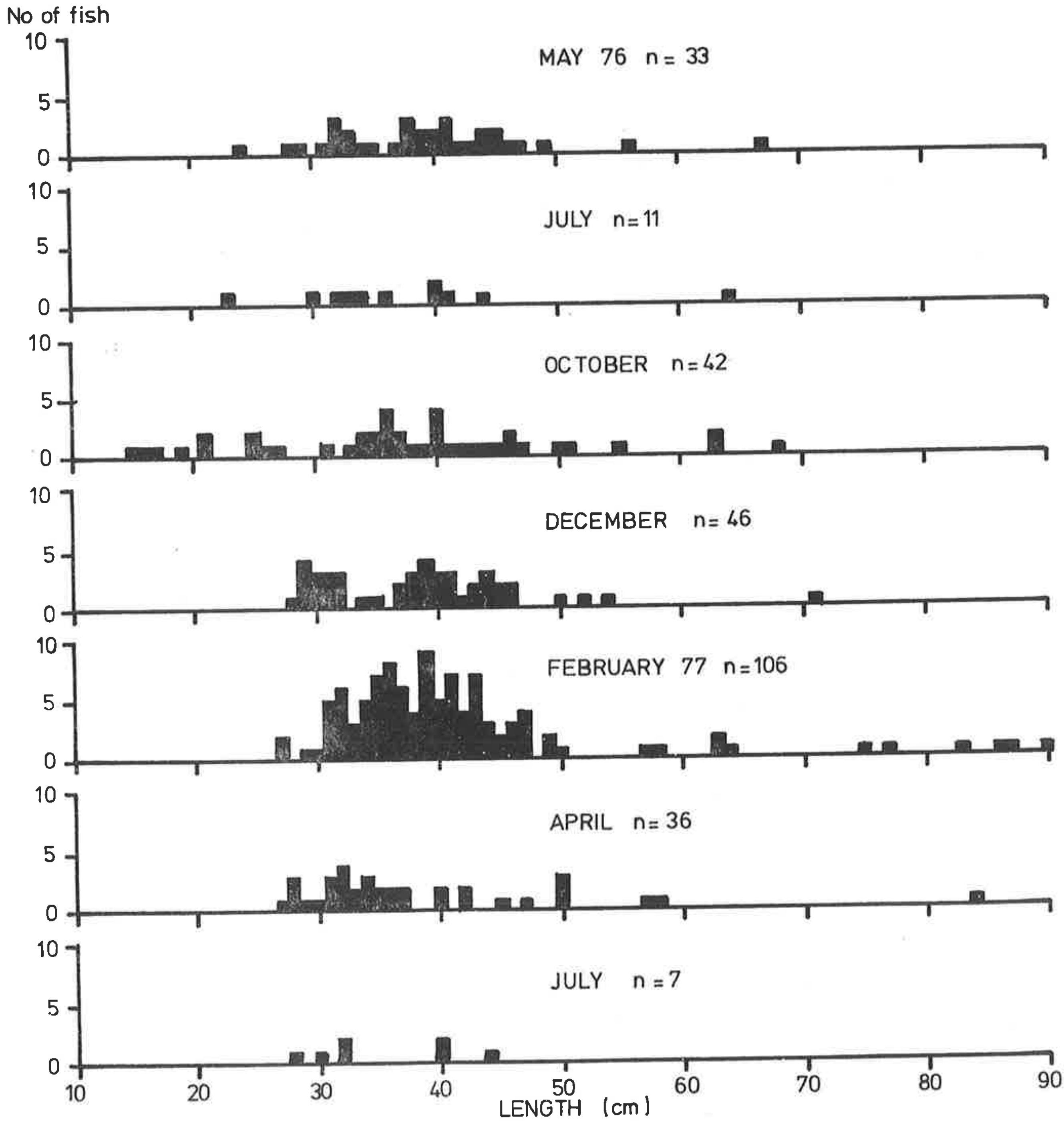


Fig. 9 : Length frequency distribution of short-finned eels

It was found that 70% of the total stomach volume of shortfins was not occupied by food (Fig. 10). The most important food items were crustacea 19.1% and fish 6.9% Crustaceans eaten were the mudflat crabs 14.9% (Helice crassa, Macrothalmus hirtipes, and Halicarcinus whitei), shrimps 2.7% (unidentified), isopods 1.4% (unidentified) and amphipods 0.1% (Paracorophium lucasi). Fish eaten were yellow-eyed mullet 2.2%, unidentifiable fish remains 3.8% (most of which was probably yellow-eyed mullet), stargazer 0.5% and small flounder 0.4%. The other food items eaten were unidentified algae 1.2%, shellfish 1.1% (mainly cockles Chione stutchburyi, snails Potamopyrgus estuarinus), and polychaete worms 1% (mainly Scolecolepides benhami).

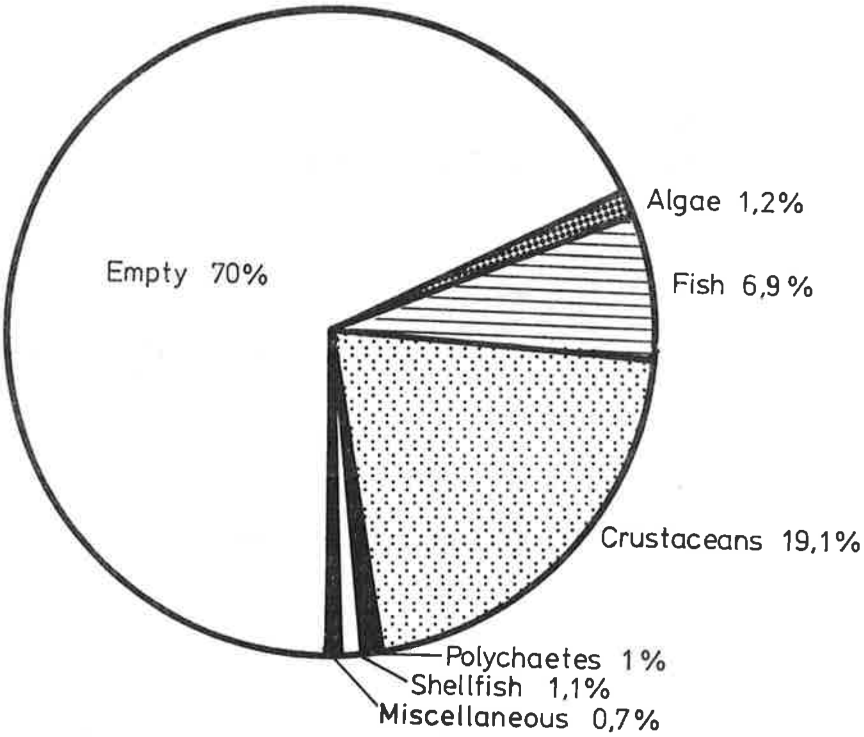


Fig. 10 : Relative occurrence of food types in stomach contents of short-finned eels.

During the year certain foods became seasonally important, notably shrimps in the October sample. Some differences in food eaten in different parts of the estuary were noted. The crab Halicarcinus and the snail Potamopyrgus were eaten in the upper estuary above Farm Bridge, and rarely found in samples from lower down the estuary.

There is commercial fishing for eels in the estuary and tributaries.

Long-finned eels

Only a few long-finned eels *Anguilla dieffenbachii*, were captured. They prefer a different habitat to shortfins and probably occur in greater numbers upstream of the area sampled.

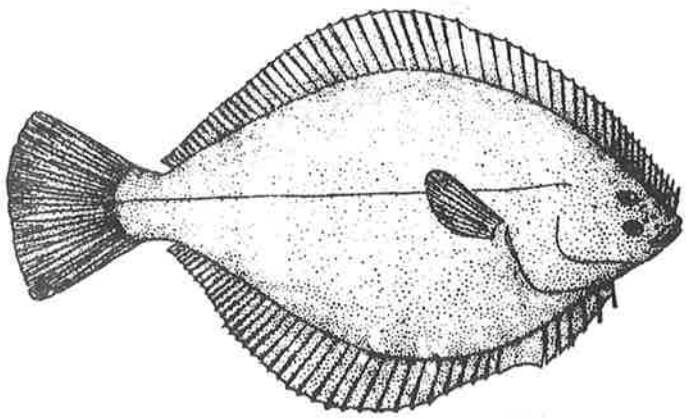
The size of the eight long-finned eels captured ranged from 35.6-42.8 cm. Five stomach contents were examined; they contained little food. Two were completely empty and the other three contained some crabs (*Helice*) and yellow-eyed mullet.

Flatfish

Four species of flatfish were captured in the estuary; yellow-bellied flounder (*Rhombosolea leporina*), sand flounder (*Rh. plebeia*), river flounder (*Rh. retiaria*) and common sole (*Peltorhamphus novaezealandie*).

Yellow-bellied flounder were the most common flatfish both as large fish and as juveniles. Sand flounder were almost solely caught as juveniles. River flounder were less common, all sizes being captured and were usually found further upstream than the other species. Common sole were caught only infrequently, even as juveniles.

Yellow-bellied Flounder



Yellow-bellied flounder, *Rhombosolea leporina*, were the predominant flatfish in the estuary.

Larger yellow-bellied flounder were found in the channels of the lower estuary at low tide. With the onset of flood tide these fish move upstream and out onto the tidal flats to feed. There is an exchange of fish between the estuary and the sea, adult fish moving into feed, and juveniles moving out to sea as they grow to sufficient size to move freely. The length frequency distribution shows that a major proportion of the yellow-bellied flounder captured were juvenile fish (less than 12 cm length) in their first year of life (Fig. 11). The numbers and size of adult fish varied from sampling to sampling as they moved in and out of the estuary to feed.

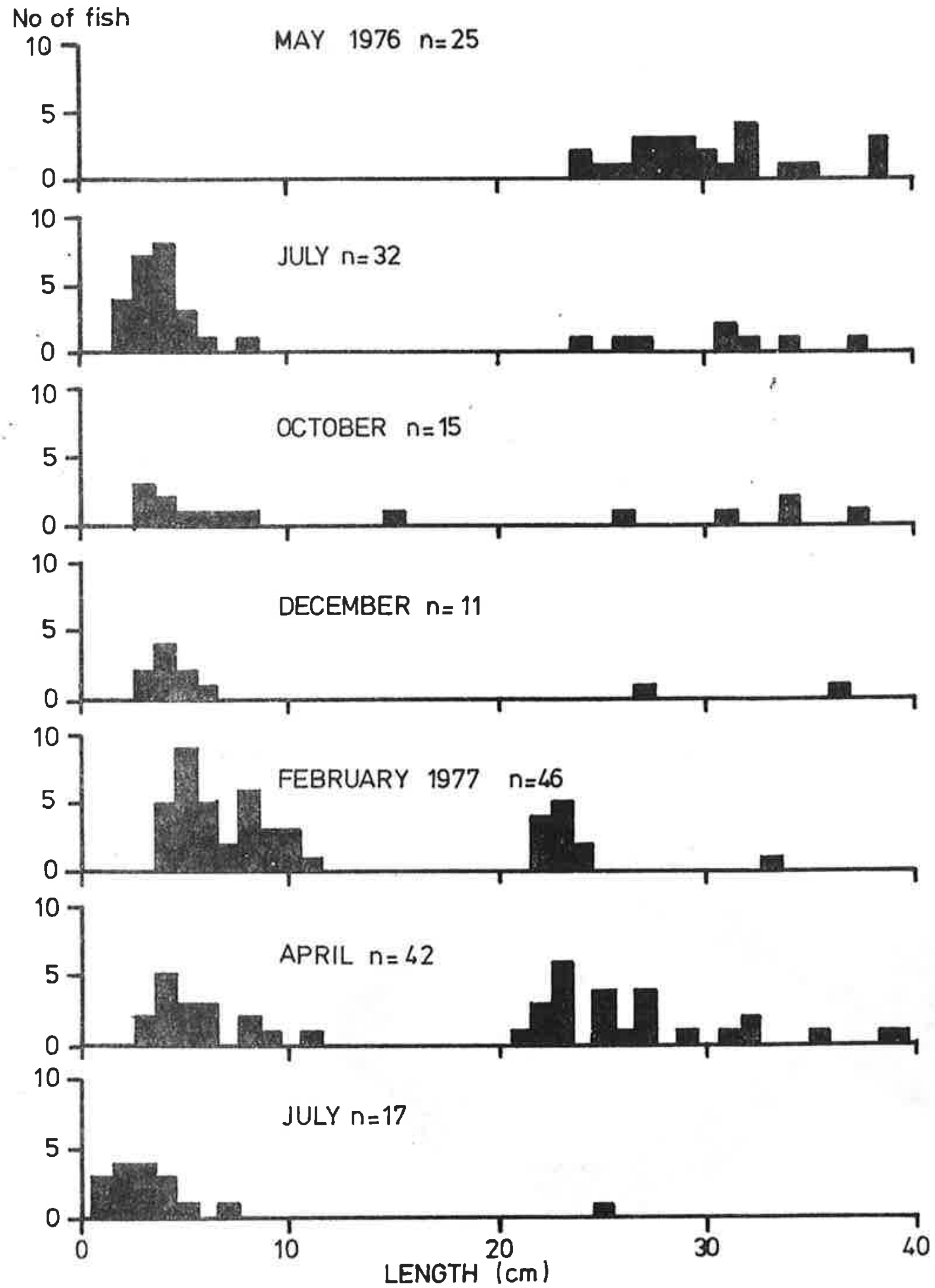


Fig.11 : Length frequency distribution of yellow-bellied flounder

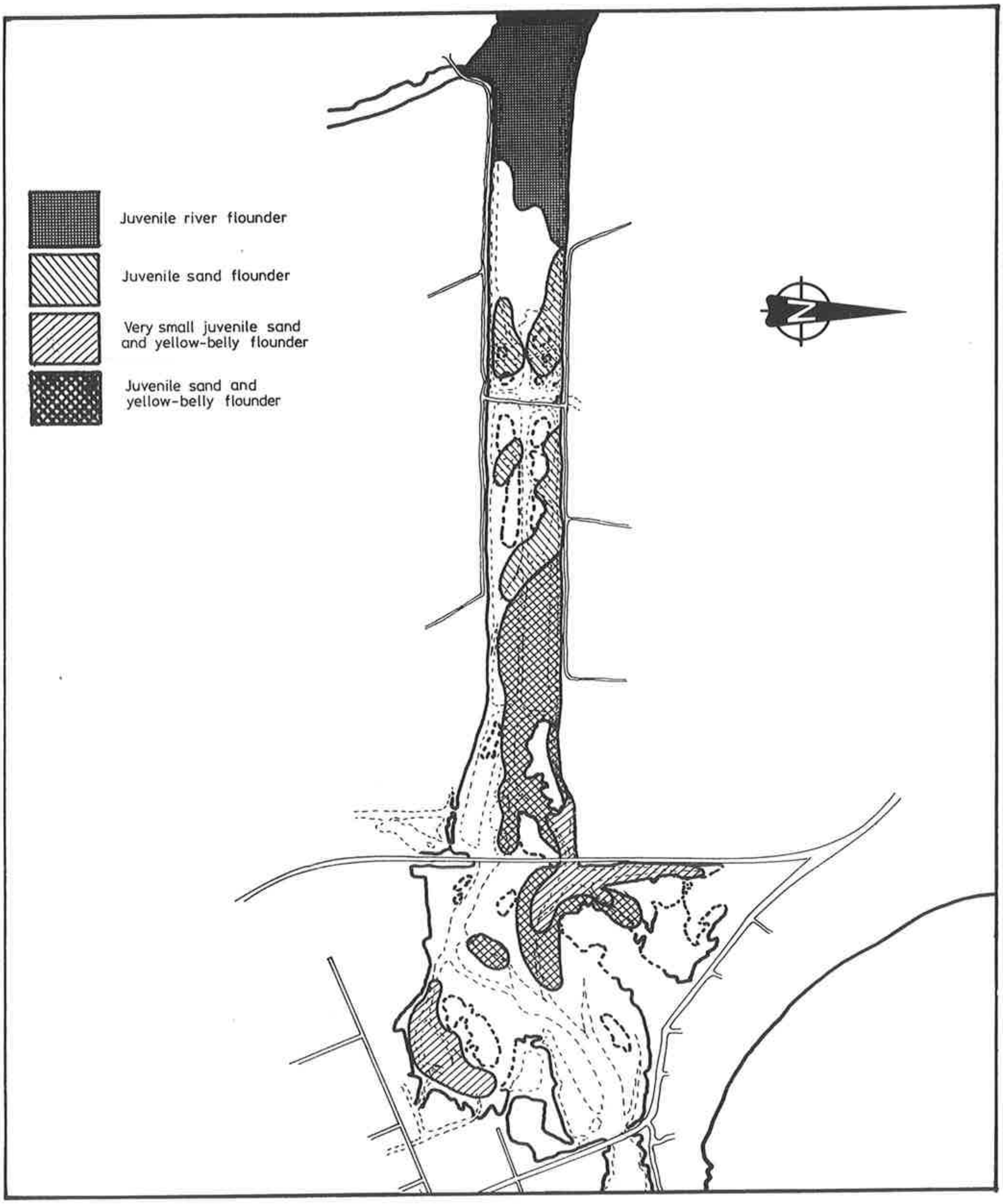


Fig.12 : Nursery areas for juvenile flatfish

There may be limited spawning in the estuary, but most spawning occurs offshore; the eggs and larvae are swept into the estuary from the sea. These small flounder first entered into the population sampled in July, and small fish continued to enter the estuary at least until December.

The estuary serves as a nursery for these young fish - favourable habitats for their early survival are the quiet waters of streams draining the tidal flats in the lower estuary (Fig. 12). In such streams the young fish avoid the extremes of salinity change and current velocity experienced in the main channels (Knox and Kilner, 1973). In these areas they appear to survive better than elsewhere in the estuary. The growth of young flounder in the stream draining the tidal flat area off the end of Humber Street can be seen by the shift of the peaks in the length frequency distributions (Fig. 13). The quieter waters of the middle and upper estuary to a lesser extent also act as a nursery for juveniles, many of them possibly moving into these areas from the lower estuary as they grow. The growth that occurs among the young flounder that survive allows them to reach the size where they can migrate to sea and continue the cycle again.

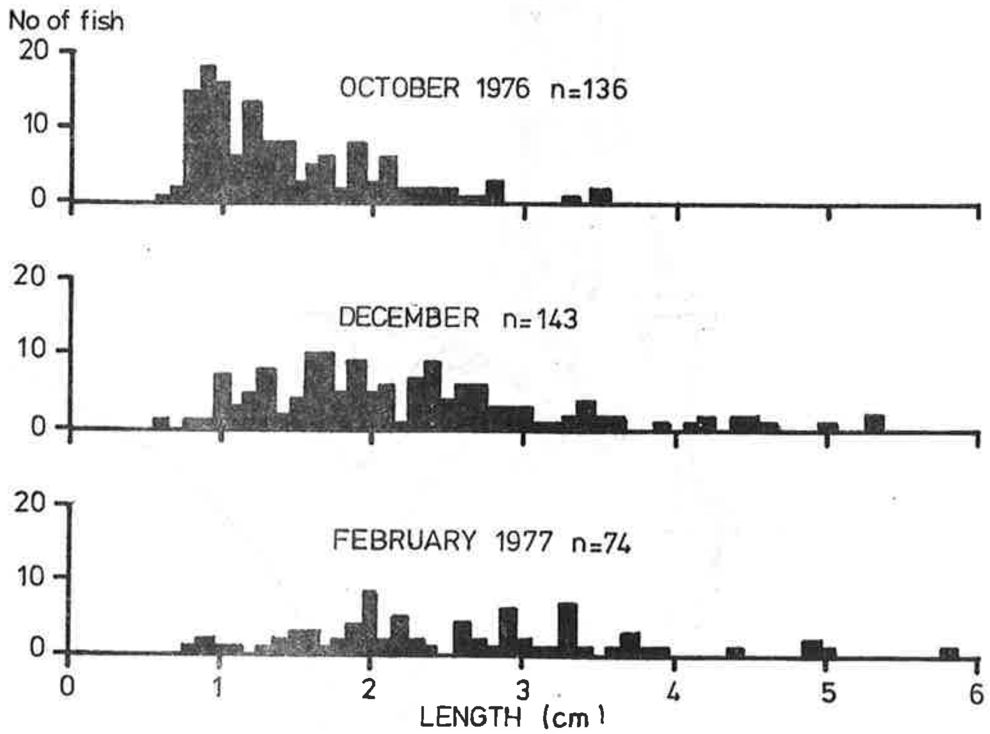


Fig. 13 : Length frequency distribution of very small juvenile flatfish captured in the tidal flat area west of Humber Street.

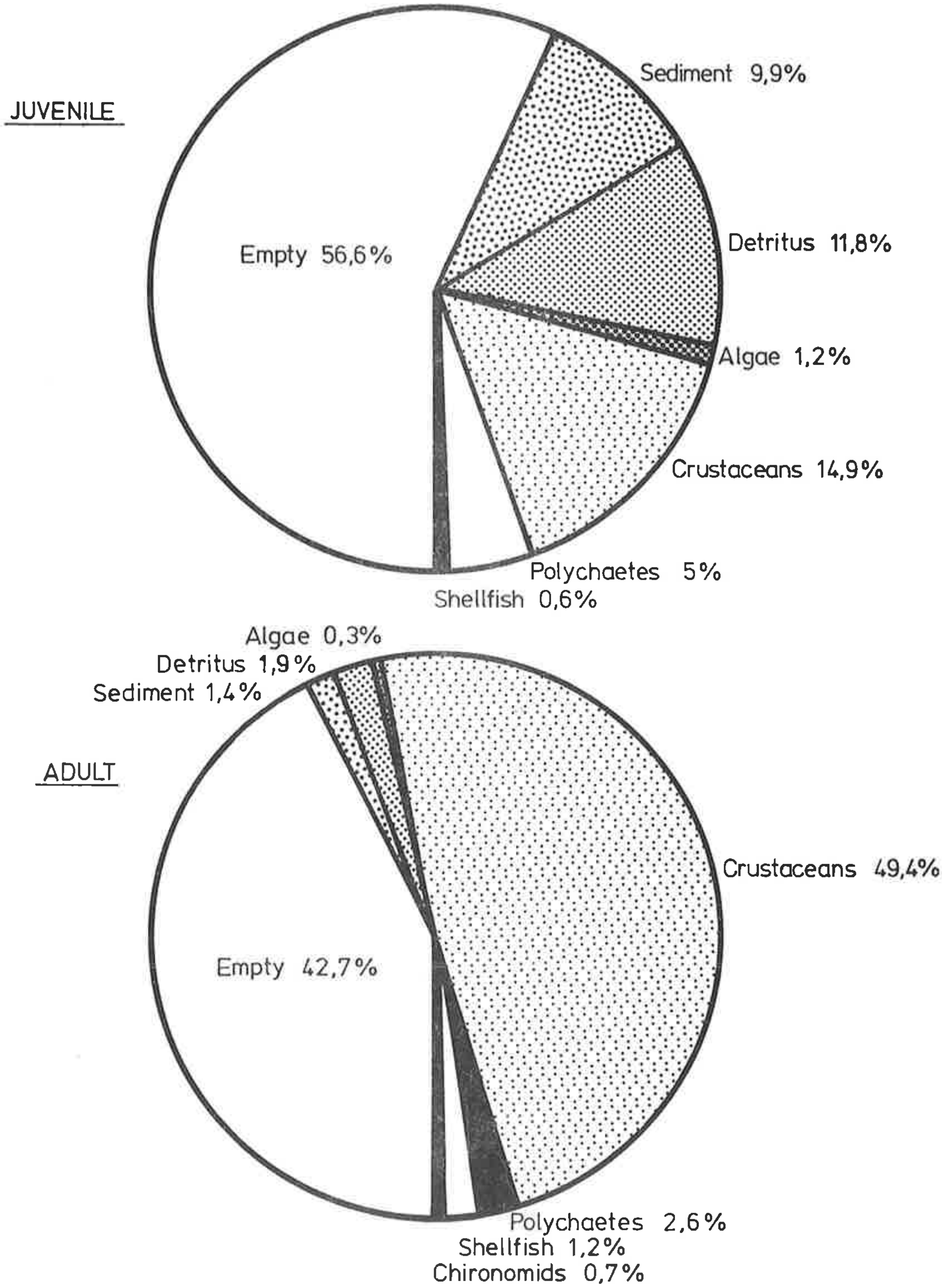
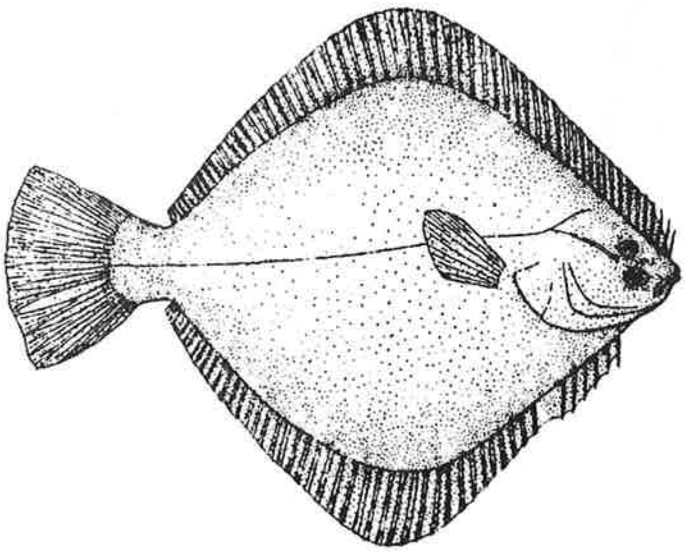


Fig.14 : Stomach contents of yellow-bellied flounder

Stomach contents for 134 yellow-bellied flounder were examined. A distinct difference in feeding habits between juvenile and larger fish was observed (Fig. 14). Juveniles (n = 69) ate small crustaceans 14.9% (mainly amphipods Paracorophium, isopods, shrimps), detritus 11.8%, sediment 9.9%, and polychaete worms 5%. Larger fish (n = 65) ate mainly crabs Helice 47.8% (only 0.4% in juveniles), while small crustaceans formed only 1.6%, detritus 1.9%, sediment 1.4% and polychaetes 2.6% (mainly Aonides trifidus) of their diet. It is apparent that the larger fish are able to deal with larger food items like crabs while juveniles chose smaller crustaceans, detritus, sediment and polychaetes. The sediment may be accidently ingested while foraging for the small crustaceans and polychaetes, but nearly all stomachs contained some sediment, and some to the exclusion of all other food. The sediment was sufficiently frequent in the stomach contents to suggest selective feed on this material.

Detritus is organic matter that cannot be attributed to any plant or animal group but which is classified as food.

Sand Flounder



Sand flounder, Rhombosolea plebeia, were almost solely caught as juveniles in the estuary. They occupied almost the same habitats as juvenile yellow-bellied flounder except they were more tolerant of low salinities, and thus they were also found further upstream in the quiet shallow waters of the upper estuary (Fig. 12).

The length frequency distribution indicates that the sand flounder captured were all small fish (Fig. 15), in their first year of life, as sand flounder grow to about 13 cm length at one year of age (Mundy, 1968).

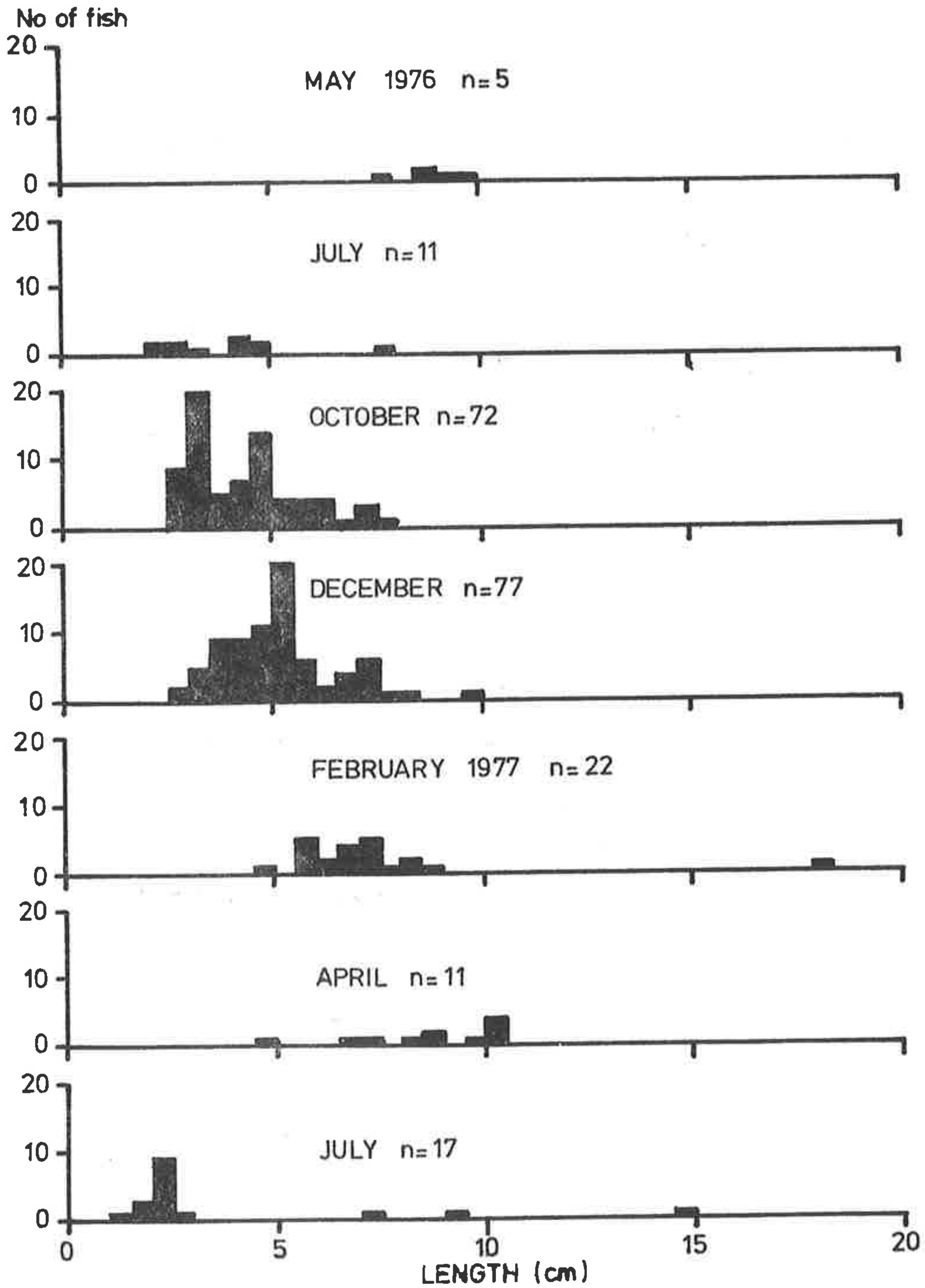


Fig.15 : Length frequency distribution of sand flounder

The life cycle of sand flounder is similar to that of the yellow-bellied flounder; eggs and larval fish are swept into the estuary from the sea, the estuary acting as a nursery for these young fish.

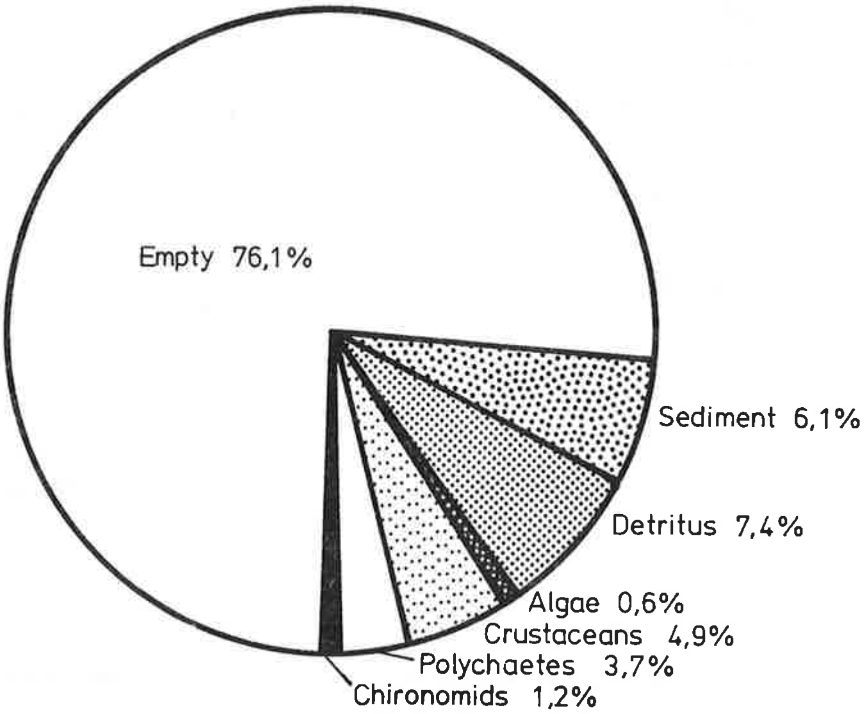
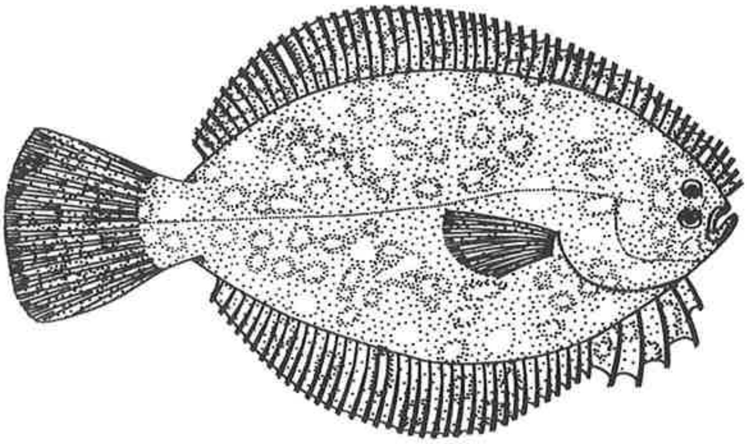


Fig. 16 : Stomach contents of sand flounder.

Sixty-two stomachs were examined (Fig. 16); 76.1% of the stomach volume was empty, sediment 6.1%, detritus 7.4%, algae 0.6%, amphipods (Paracorophium) 4.8%, isopods 0.1%, polychaetes 3.7%, and midge larvae (Chironomus) 1.2%. As in juvenile yellow-bellied flounder sediment and detritus figure highly in the diet of juvenile sand flounder. The presence of midge larvae in sand flounder diet reflects the fact that this fish is found further upstream, near to the influences of freshwater.

River Flounder

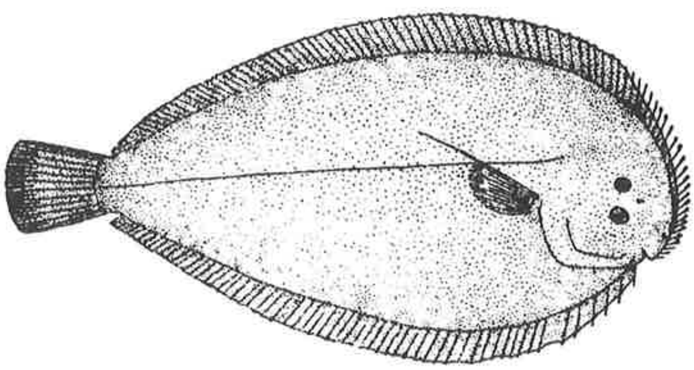


River flounder, Rhombosolea retiaria, prefer freshwater and estuarine habitats. They were mainly found in the upper estuary, and a few penetrated down into the middle estuary. With their tolerance of low salinity it was expected that they would be found in greater numbers much further upstream beyond the region sampled.

About equal numbers of adults and juveniles were found. They were caught in the estuary on some sampling trips only having presumably migrated downstream. Little is known about their life cycle, but it is assumed that they breed in estuarine areas.

Fourteen stomachs were examined; 62.5% of the stomach volumes were empty, detritus 13.2%, sediment 5.7%, crabs 7.5% (Helice , Halicarcinus), algae 0.7% and midge larvae 0.7% (Chironomus). River flounder forage over the mud for their food.

Common Sole



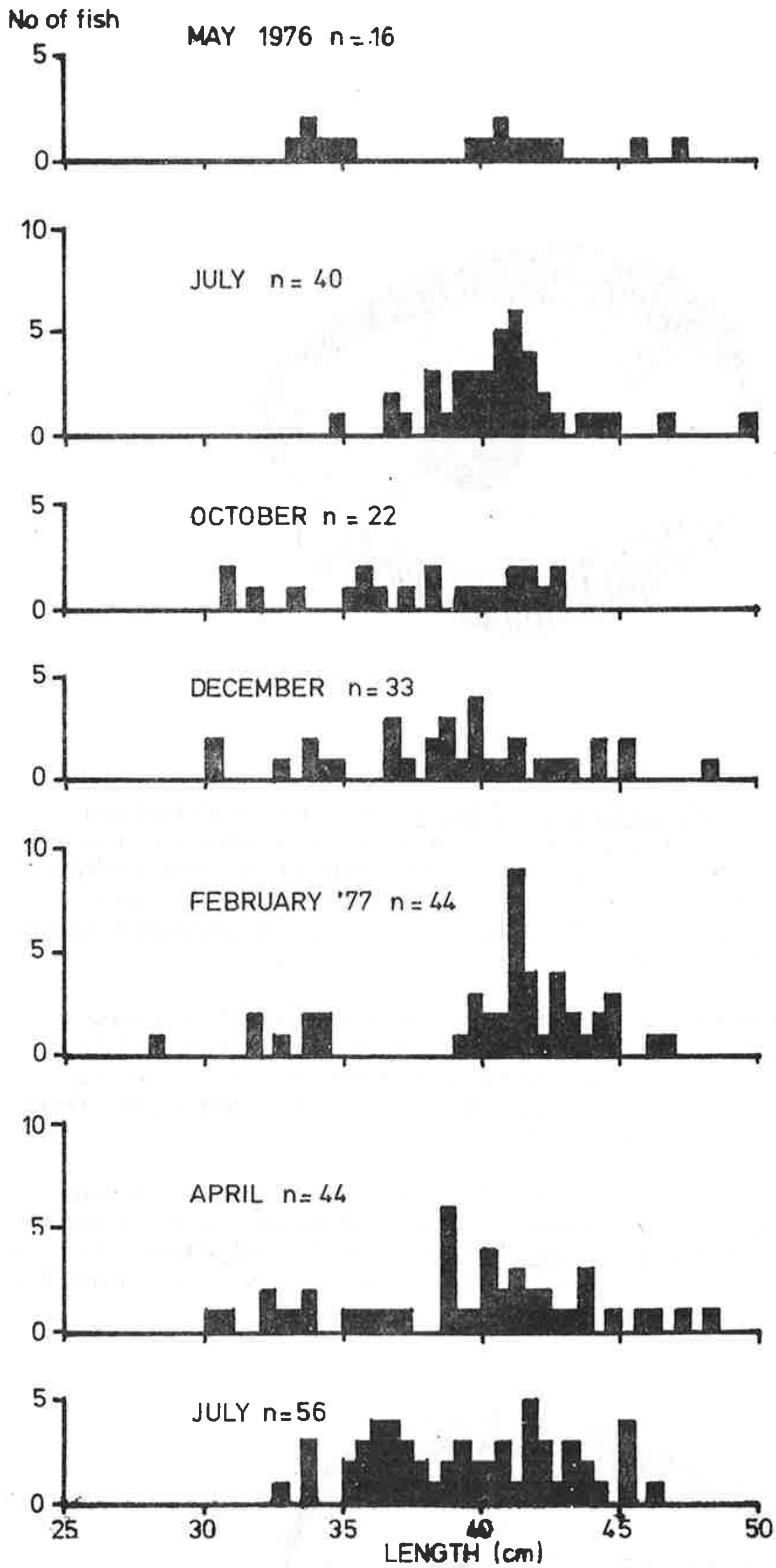
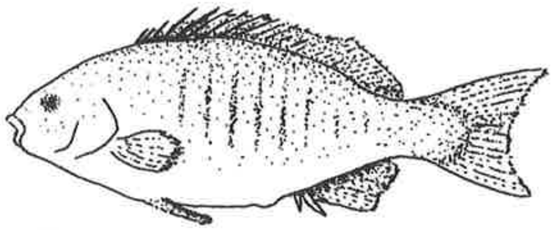


Fig.17 : Length frequency of distribution of parore

Common sole, Peltorhamphus novaezealandiae, were caught only infrequently. Their numbers appeared to be low, even as juveniles, in the area of estuary sampled. At first glance this might seem surprising as common sole are very common amongst the flatfish catches of the commercial fishermen in Hawke Bay. However, of the four flatfish species caught in the estuary, common sole was the least tolerant of low salinities and pollution and it can only be surmised that adult fish would be found downstream feeding in the boat harbour area. Common sole most likely would have been more abundant in the early days prior to the build-up of the industrial area and the facilities in the boat harbour.

Parore



Parore, Girella tricuspidata, was a common species that was found all through the year. Parore were found throughout the estuary, and at times they occurred up past Taipo Stream, but were more abundant between Embankment Bridge and Taipo Stream. Large shoals could be observed at times feeding around the outlets of the pumping stations. Parore are mainly a herbiverous (see below), presumably foraging anywhere in the estuary where there is sufficient plant growth. While they are principally a marine fish they apparently have high tolerance for low salinities, and can exploit the abundant beds of Ruppia in the upper estuary.

Length frequency distributions of parore catches did not show any definite patterns (Fig. 17). This species appeared to make frequent migrations between the sea and the estuary, presumably coming in to feed on the prolific plant growth in the estuary. Parore usually occurred in schools of 5-20 fish, occasionally larger schools were observed.

Stomach contents of 152 parore were examined. Some 39% of the total stomach volume was empty (Fig. 18), and most of the rest of the stomach volume was filled with plant material 53.5%. The plant Ruppia polycarpa formed 31.5%, Cystophora torulosa 10.9%, Enteromorpha intestinalis 5.9% and sea lettuce Ulva lactuca 5.2% of the diet.

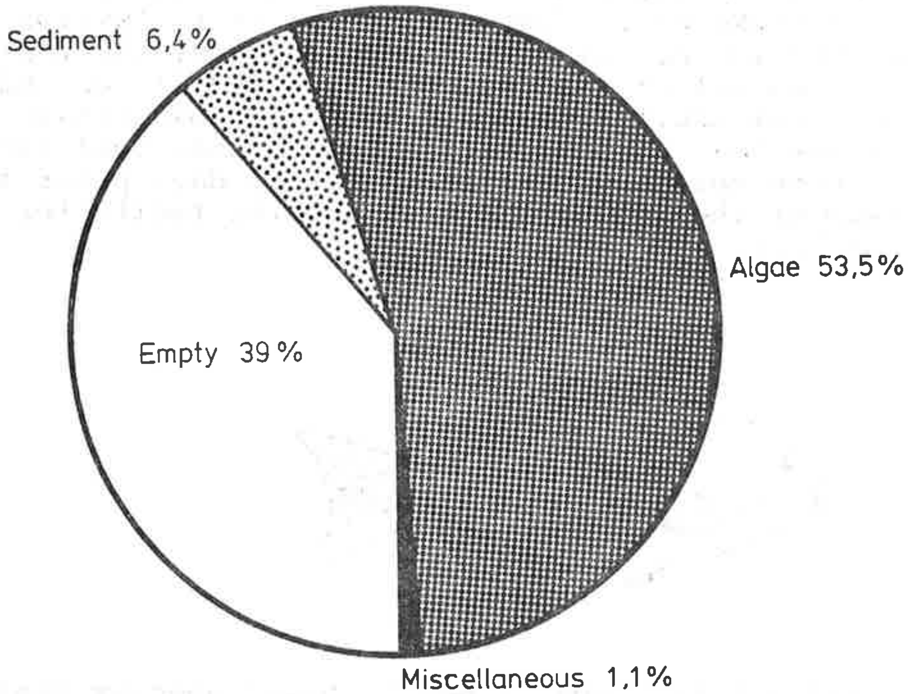


Fig. 18: Stomach contents of parore.

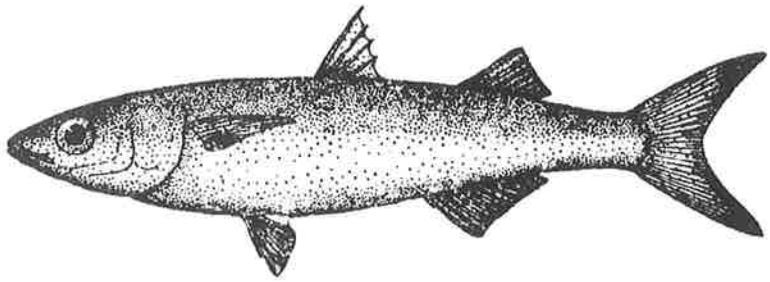
It is most probable that the sediment 6.4% and items in the miscellaneous group 1.1% consisting of crabs (Helice), polychaetes, gastropods (Zediloma subrostrata, Cominella glandiformis), isopods and amphipods (Paracorophium) were accidentally ingested along with the plant material. These latter items never occurred in large numbers in any one fish gut, but were only present as one or two items amongst the plant material.

Parore showed decreased feeding activity in the winter months, maximum fullness of stomachs with food occurred in February-April. The plants eaten also varied with the season - Cystophora and Enteromorpha were the main food in winter, while Ruppia predominated in summer when this plant flourishes in the estuary.

Males dominated in the catches of parore, 2.34 males to each female. Male and female gonads were immature through the winter, and started to mature in October. Most females were ripe and running in early December and were spent by February, while the males were near maturity or ripe and running from early December through to and including February. This greater spread of maturity and larger numbers of males could be an adaptation to increase the chance of fertilizing all ova produced by the females.

It is not known for certain whether parore breed in the estuary or not, but the ripe and running condition of the gonads for both sexes strongly suggested that they do breed there. Only one juvenile parore was captured (7.8 cm in length), but many shoals of small fish were observed from February to April. Fish were netted from some (probably 5%) of these shoals but always proved to be yellow-eyed mullet or common smelt. Limitations on time available for sampling the estuary prevented extensive searches for young parore, and they may have been present in the estuary in large numbers.

Yellow-eyed Mullet



Yellow-eyed mullet, Aldrichetta forsteri, were abundant in the estuary all year. They occurred throughout though fewer penetrated into the upper estuary especially any great distance above the pumping stations.

Yellow-eyed mullet are very mobile, therefore their distribution was complex showing tidal and seasonal differences. During the winter most adults retreated into the channels in the lower estuary, and then moved upstream with the flood tide to feed. During summer they penetrated further up the estuary to feed.

Young shoaling yellow-eyed mullet were first observed in February when there were many large shoals. These shoals occurred throughout the estuary penetrating at least as far as the pumping stations where large shoals were observed in the vicinity of the pump outlets. These small fish stayed in shallow quiet waters, retreating with the ebb tide and advancing on the flood, keeping close to the waters edge. When they had grown to 10-15 cm length they could be found in deeper waters.

Length frequency distributions of the catches yellow-eyed mullet showed young fish entering the population sampled in the estuary from February to July (Fig. 19). Growth of two size classes (age groups) was apparent in October and succeeding months, and by February three size classes were apparent with the entry of young fish into the population sampled.

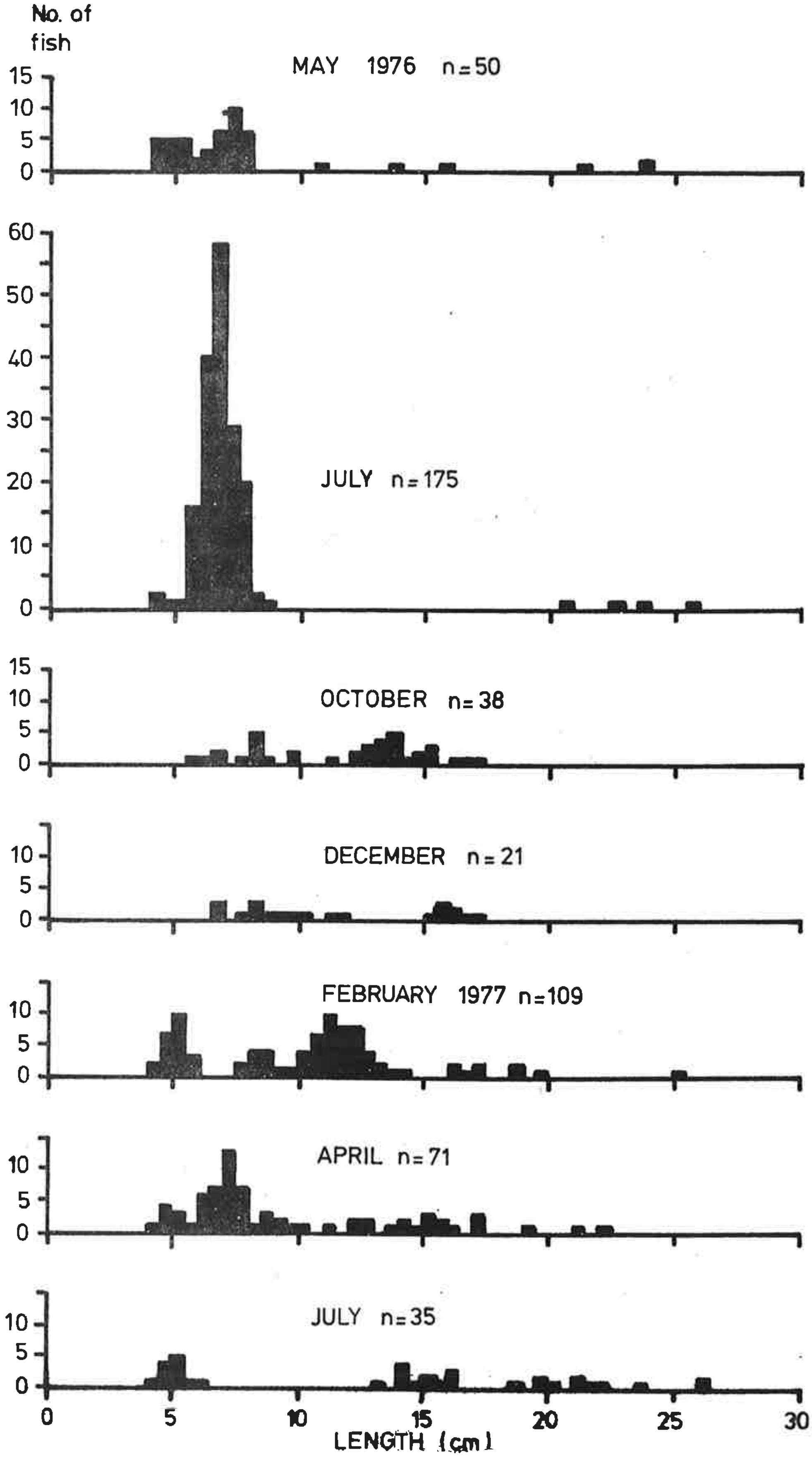


Fig.19 : Length frequency distribution of yellow-eyed mullet

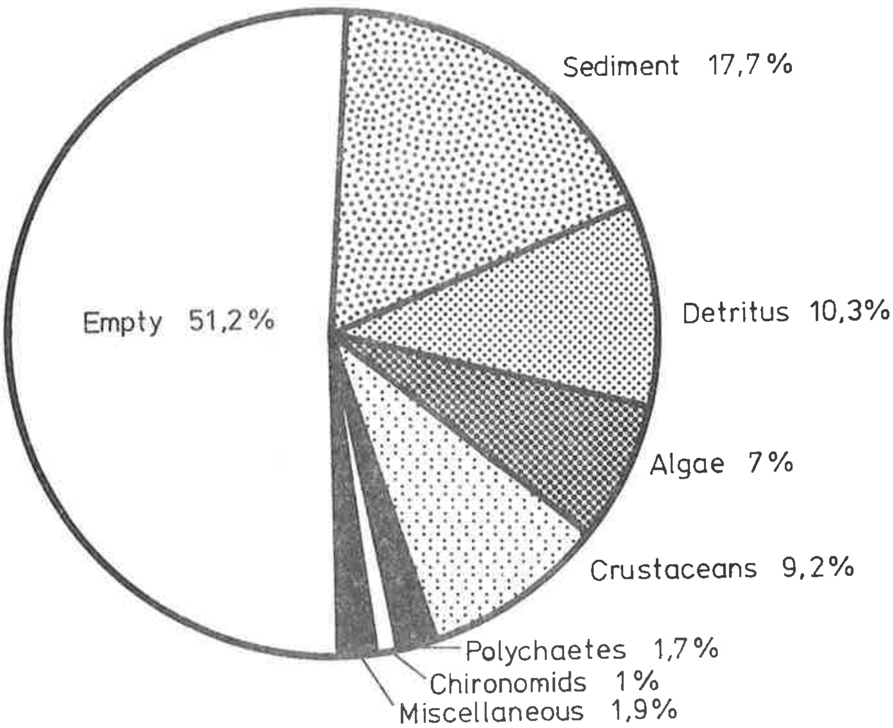
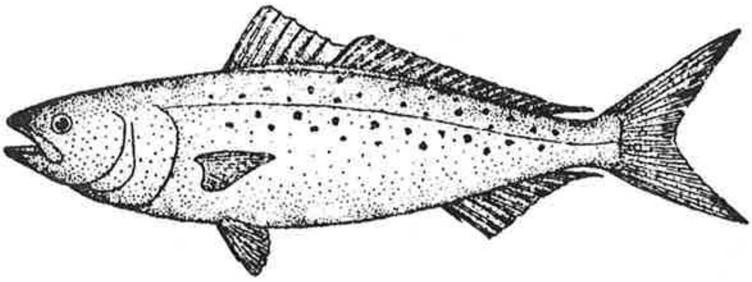


Fig. 20 : Stomach contents of yellow-eyed mullet.

Two hundred and forth-three stomachs were examined (Fig. 20); 51.2% of the volume was found to be empty, sediment 17.7%, detritus 10.3%, algae 7% (mainly Ulva, but also Enteromorpha, Ruppia, and an unidentified filamentous green alga), crabs 3.2% (mainly Helice), amphipods 1% (mainly Paracorophium), shrimps 5%, polychaetes 1.7% (unidentified remains), midge larvae 1% (Chironomus) and miscellaneous 1.9% (snail Potamopyrgus, water boatman Anisops assimilis, cockle Chione, isopods, and unidentified terrestrial insects). The presence of detritus and sediment sufficiently frequently in yellow-eyed mullet suggest selective feeding on this material. The sediments of the estuary are rich in nutrients which support a heavy population of micro-organisms. For instance, large quantities of the flagellate Euglena occur as a scum on the mud surface in the estuary and these were frequently observed amongst the sediment found in the yellow-eyed mullet stomachs.

Insufficient numbers of adult fish were captured to provide a comprehensive picture of the breeding cycle, but the few adults caught in July were ripe. It is assumed that they would have spawned in the estuary, hatching of these eggs and growth of the larval fish would provide the shoals of small fish first observed in February. It would appear that yellow-eyed mullet is a permanent resident of the estuary, reproducing and feeding, though with interchange of fish between the open sea and the estuary.

Kahawai



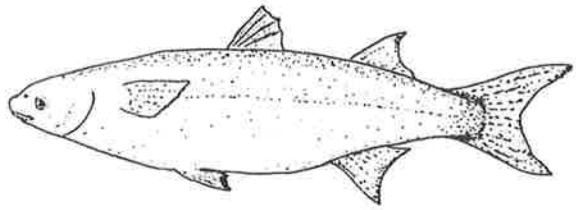
Kahawai, Arripis trutta, used the estuary as a feeding ground, individual fish making transitory migrations into the estuary from the sea. There were small numbers of kahawai caught in the estuary over most of the year. A seasonal migration into the estuary occurred from February until April, when larger numbers were caught.

Most kahawai were found in the channel system of the lower estuary, with a few penetrating into the middle estuary with the onset of the flood tide and retreating to the channels in the lower estuary at low tide.

Twenty-five stomachs were examined; 55.2% of the volume was found to be empty. Kahawai is principally a predator upon other fish, 32.2% of its diet was fish - most of this was yellow-eyed mullet, and some flatfish. Small amounts of various other items were eaten; polychaetes 4% (mainly Aonides, Haploscoloplos), crabs 3.2% (Helice, Halicarcinus), amphipods 1.4%, (Paracorophium), shrimps 2.4% and detritus 1.6%.

Most kahawai caught had gonads that were immature, but the April 1977 sample had gonads that were starting to mature. Kahawai breed in the sea.

Grey Mullet

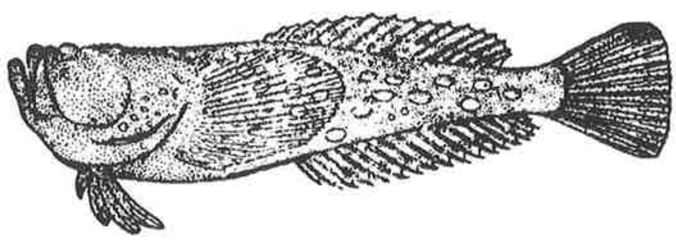


Grey mullet, Mugil cephalus, used the estuary for feeding and small numbers of fish made transitory migrations from the sea throughout the year. A seasonal run of fish occurred in February. Grey mullet were found in the deeper channels of the lower estuary at low tide, and moved into the shallower waters of the lower and middle estuary with the flood tide.

Stomach contents for 23 fish were anlysed; 65.7% of the volume did not contain food, sediment 27.6%, detritus 5.2%, algae 0.9% (Ulva and Cystophora) and miscellaneous 0.6% (unidentified polychaetes and gastropods Zeacumantus, Cominella). Grey mullet was principally a detrital feeder, digesting organic material out of the sediment and detritus.

The small numbers of grey mullet captured during the year all had immature gonads. However, the seasonal run of fish in February was predominantly of females, most of which had ripe and running gonads. Eggs spilled out of these fish as they were lifted from the water. This suggests a seasonal run of grey mullet into the estuary to spawn, though grey mullet are usually known to breed offshore overseas, the juvenile fish coming into estuaries to feed and grow (Iversen, 1976). Large shoals of small fish were observed in the estuary from February to July. Attempts were made to identify young grey mullet in these shoals but with no success, although some of the unsampled shoals may well have been young grey mullet. The estuary evidently has some importance in the breeding of this species.

Spotted Stargazer



Spotted stargazer, Geniagnus monopterygius, appeared to be restricted to areas of high salinity.

A few were disturbed out of the sediment in the main channels of the lower estuary or were caught by the small drag net and dip net in the channels for about 200 metres above Embankment Bridge.

Stargazers bury themselves in the mud or sand, and wait for their prey to swim past, hence they are probably territorial. Three fish were measured ranging from 6.8-10.9 cm, all juvenile fish. However, some of the fish observed in the lower estuary were much larger. They are probably permanent residents of the estuary, though little is known about their life cycle.

Cockabully

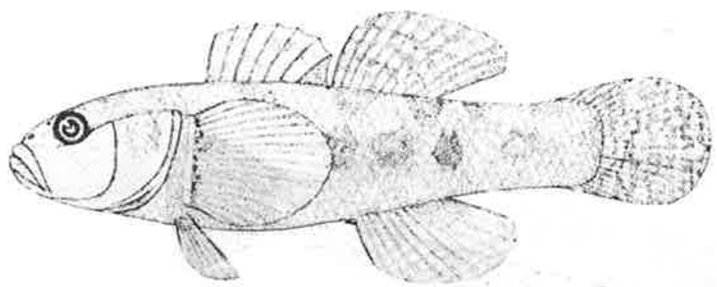
The cockabully, Tripterygion nigripenne, was a reasonably common small fish found in most parts of the estuary. This species had a habitat preference associated with rocks and algae along the shoreline. One group was found on the rocky shoreline by Pandora Bridge and a second group was associated with a similar shoreline around Embankment Bridge. A third group occurred along the outfall channel usually where rock material had been tipped on the edges of the stopbanks. This group was found at least as far as Taipo Stream.

Sixteen fish were measured ranging from 3.9-8.8 cm total length. Fyke nets, dip net and small drag net each captured a few bullies but none of these nets was considered efficient at sampling. This species was therefore considered to be considerably more common than indicated by the small numbers caught.

Partly mature fish were present in July and ripe and running adults occurred in October. This species breeds in the estuary, the life cycle is not well understood.

Fourteen stomachs were examined; empty 47.8%, crustaceans 30.7% (mainly shrimps, also isopods and crab Halicarcinus), sediment 7.1%, detritus 6.4%, midge larvae Chironomus 3.6%, algae 2.9% and polychaetes 1.5%.

Common Bully



The common bully, Gobiomorphus cotidianus, was found throughout the middle and upper estuary. It lives in tidal reaches when young and in streams and lakes when adult.

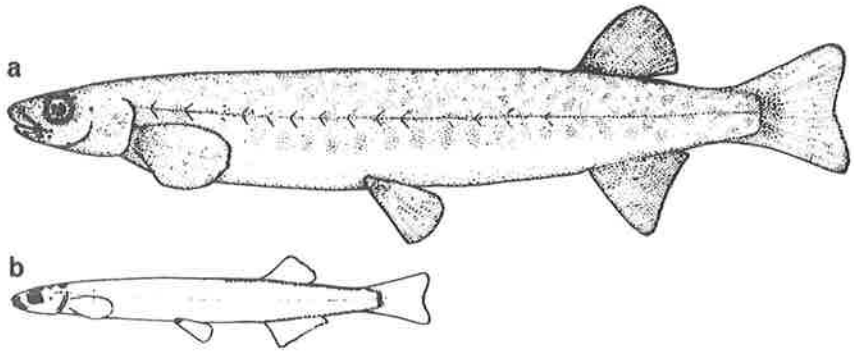
The adults spawn in these freshwater habitats, the larval fish coming downstream in late winter-spring (McDowall, pers. comm.). It is one of the commonest, most abundant and widespread of the eleotrids - freshwater bullies (McDowall, 1975).

As for the cockabully the nets used were not efficient at sampling the common bully. Eight fish were measured ranging from 4.4 - 7.6 cm. These fish were juveniles or subadults as common bullies reach a known length of 14.8 cm and large adults commonly exceed 11 cm (McDowall, 1975a). Although only eight fish were captured they were considered to be reasonably common in the quiet waters of the middle and upper estuary.

Five stomachs were examined; empty 61%, snail Potamopygus 17%, midge larvae Chironomus 12%, gastropod Zeacumantus 8% and filamentous green algae 2%.

Whitebait

Whitebait are juveniles of some of our freshwater fishes, all belonging to the genus Galaxias. The inanga, Galaxias maculatus, is the adult of a large proportion of the whitebait caught.

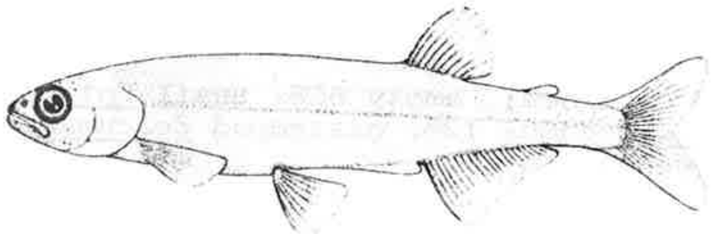


a: Adult. b: Whitebait.

The inanga spends the summer and autumn in streams and swamps and reaches maturity in autumn. Shoals of this fish then move down into the estuaries, and at high spring tide move out onto the grasses and vegetation marginal to the waters edge. They then spawn on this vegetation, the eggs dropping to the bases of the grasses where they are protected when the tide drops. When the next high spring tides occur, usually in a fortnight, the eggs are again covered with water and the larval fish hatch and are carried out of the estuary into the sea. These juvenile fish spend about six months at sea before returning in the spring and running up through the estuaries to the freshwater habitat. It is at this stage they are captured as whitebait (McDowall, 1975b).

Attempts were made in July and October 1976 to catch these whitebait but only six fish were taken. However, runs of whitebait are known in the estuary and they are probably more plentiful in the intervening months of August and September. One inanga of 8.6 cm total length was captured in April 1977 at the time when spawning occurs. There is suitable vegetation on the margins of the estuary for inanga to breed.

Common Smelt



A small number of common smelt, Retropinna retropinna, were caught from large shoals of this fish present in the estuary in summer (February). A few stragglers were present in April. This small slender fish is recognizable by its distinctive and strong cucumber-like smell.

The life cycle is not well understood, but during spring and summer shoals of adult smelt move in from the sea and spawn in the estuaries or upstream, probably a little beyond the influence of the tide, in quiet backwaters. The larval fish go out to sea after hatching (McDowall, 1975b).

Transitory Fish

A number of species were transitory, entering the estuary at irregular intervals to feed.

The following fish in this group were captured in the estuary: trevally Caranx lutescens (2 specimens), red cod Physiculus bachus (1), gurnard Chelidonichthys kumu (1), garfish Reporhamphus ihi (3), spotty Pseudolabrus celidotus (1).

Some other fish were observed or reported by other people to have been caught: snapper Chrysophrys auratus, moki Latridopsis ciliaris, spiny dogfish Squalus spp., school shark Galeorhinus australis, skate Raja spp., brown trout, Salmo trutta, barracouta Thyrisites atun, blue mackerel Scomber japonicus, kingfish Seriola grandis.

The above list is not exhaustive as there will be many other transitory species which use the estuary at irregular intervals. Some, mainly marine species, will only enter the lower regions of the estuary nearest the sea (i.e. the boat harbour), an area which was not sampled during this study. There will also be species which make migrations into the estuary for breeding or feeding which have not been detected during the course of this study either because these migrations occurred outside of sampling periods or because the fishing gear used was not suitable for catching them.

3.4 Discussion

Fish Species Caught in Ahuriri Estuary

In the following list the abundance of each species is recorded in one of three categories:

+ = rare; ++ = frequent; +++ = common

Short-finned eel	Anguilla australis schmidtii	+++
Long-finned eel	Anguilla dieffenbachi	+
Yellow-bellied flounder	Rhombosolea leporina	+++
Sand flounder	Rhombosolea plebeia	+++
River flounder	Rhombosolea retiaria	++
Common sole	Peltorhamphus novaezealandiae	+
Parore	Girella tricuspidata	+++
Yellow-eyed mullet	Aldrichetta forsteri	+++
Kahawai	Arripis trutta	++
Grey Mullet	Mugil cephalus	++
Stargazer	Genjagnus monopterygius	+
Cockabully	Tripterygion nigripenne	++
Common bully	Gobiomorphus cotidianus	++
Inanga (andjuveniles = Whitebait	Galaxius maculatus	+
Common Smelt	Retropinna retropinna	++
Trevally	Caranx lutescens	+
Red Cod	Physiculus bachus	+
Gurnard	Chelidonichthys kumu	+
Snapper	Chrysophrys auratus	+
Moki	Latridopsis ciliaris	+
Spotty	Pseudolabrus celidotus	+
Skate	Raja spp.	+
Spiny dogfish	Squalus spp.	+
School shark	Galeorhinus australis	+
Brown trout	Salmo trutta	+
Garfish	Reporhamphus ihi	+
Barracouta	Thyrsites atun	+
Blue Mackerel	Scomber japonicus	+
Kingfish	Seriola grandis	+

It is difficult to obtain reliable estimates of abundance of estuarine fish. Species composition, abundance, size and age vary from low salinity to high, from shore to deep water, from surface to bottom, from season to season and from year to year. Larger fishes are usually more successful in eluding fishing gear than smaller ones.

Different species are not caught in relative proportion to their abundance. Sizes, numbers and kinds of fish vary according to mesh size and type of fishing gear used.

The abundance category given to each species is the best that could be done in the circumstances and is an estimate based on past experience of fishing in estuaries.

Knox and Kilner (1973) for the Avon-Heathcote recognized five distinct groups of fish which use estuaries. These groups can also be recognized in the fish of Ahuriri Estuary.

(1) Seasonal species that move into the estuary predominantly to breed, e.g. common bully, whitebait.

(2) Permanent species whose entire life cycle occurs in the estuary, e.g. cockabully.

(3) Species which migrate freely between the estuary and the sea, but still spend their juvenile life in the estuary, e.g. sand flounder, yellow-bellied flounder, parore, grey mullet, common sole, stargazer, yellow-eyed mullet.

(4) Other species that are more transitory, enter the estuary at irregular intervals, e.g. kahawai, red cod, gurnard, moki, snapper, trevally,, garfish, and other seasonal species.

(5) Species that use the estuary principally as a migration route to other areas for the purpose of breeding, e.g. short and long-finned eels, smelt, brown trout.

In numbers those species in Group 3 are the predominant fish fauna of the estuary. As adults this group migrates freely between the sea and estuary, but their juvenile life is spent in the estuary. This emphasizes the importance of the estuary as a nursery, since numerically the greatest numbers of fish use it for this purpose but all these species feed in the estuary. All have reasonably wide salt tolerances.

Distribution

The distribution of the different fish species in the estuary is illustrated in Fig. 21. These distributions can be broken down into five main groups:

(1) Deep channels: This habitat has coarse substrates, swift currents and usually high salinities. Various fishes such as kahawai, trevally, snapper, yellow-bellied flounder, yellow-eyed mullet, used this region to enter from the sea and travel up the estuary. Others such as whitebait, smelt and brown trout used it to pass through from sea to freshwater.

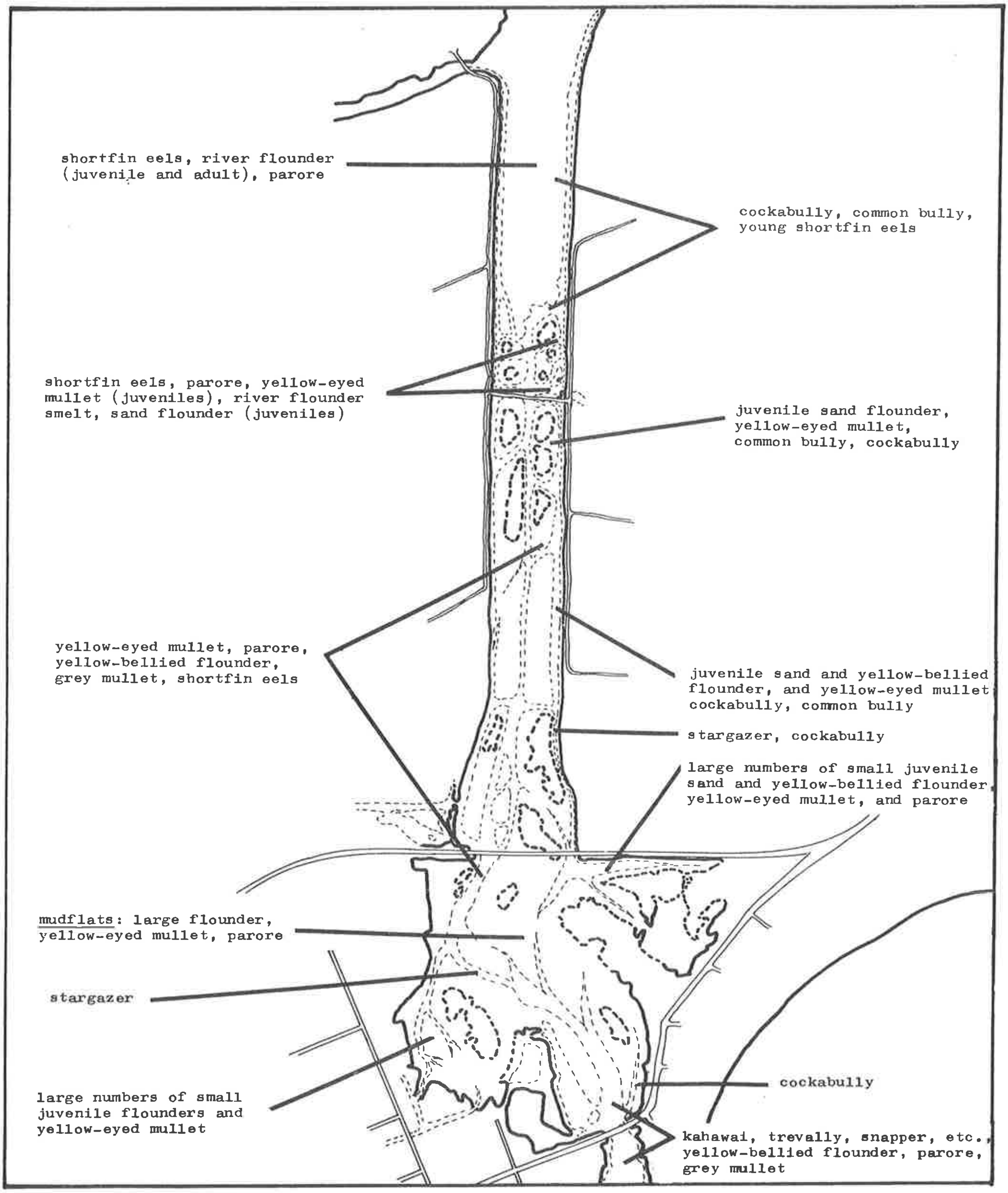


Fig.21 : Distribution of fish species in Ahuriri Estuary

(2) Shallow channels: This habitat varies from sand to mud substrate. Fish that reside here were yellow-eyed mullet, yellow-bellied flounder, sand flounder, parore, grey mullet (seasonally).

(3) Tidal-flat streams: Occur in lower areas of the tidal flats and are permanently filled with water, usually have soft mud substrates. Fish found here were juveniles of sand flounder, yellow-bellied flounder, yellow-eyed mullet and parore.

(4) Tidal flats: Extensive areas of stones, sand and mud in the lower and middle estuary. Various fishes such as short-finned eels, yellow-bellied flounder, parore, yellow-eyed mullet moved onto these tidal flats to feed with the rising tide.

(5) Rocky shoreline: Region composed of rocks and shingle interspersed with mud/sand and algal growth, exposed between tides. Young short-finned eels and cockabullies inhabited these areas.

The seasonal occurrence of the main species using the estuary was complex (Fig. 22). For some species the period of peak abundance had to estimated because of insufficient data, e.g. whitebait, smelt. The seasonal occurrence will change from year to year, especially for all seasonal migrants like kahawai, trevally and moki. The peak abundance shown for eels over the summer reflected the best catches made in this season and not their actual abundance. The seasonal abundance of larval fish was not investigated.

Feeding

Organic matter is transported by the rivers and washed in by heavy rain and enriches the estuary. This ensures the abundant development of plankton and other small organisms which provide a large proportion of the food of the majority of fishes in the estuary. Such enriched sheltered conditions are the principal reasons the estuary functions as a nursery.

It is not surprising that there are a variety of fish species such as grey mullet, yellow-eyed mullet, juvenile yellow-bellied flounder, sand flounder and river flounder, which selectively feed on this enriched sediment with its high population of micro-organisms.

The sheltered, nutrient rich conditions of the estuary also encourage the growth of algae such as *Ruppia*, *Ulva*, *Enteromorpha*, *Cystophora* and *Codium*. These are eaten by a number of fish, chiefly parore and yellow-eyed mullet.

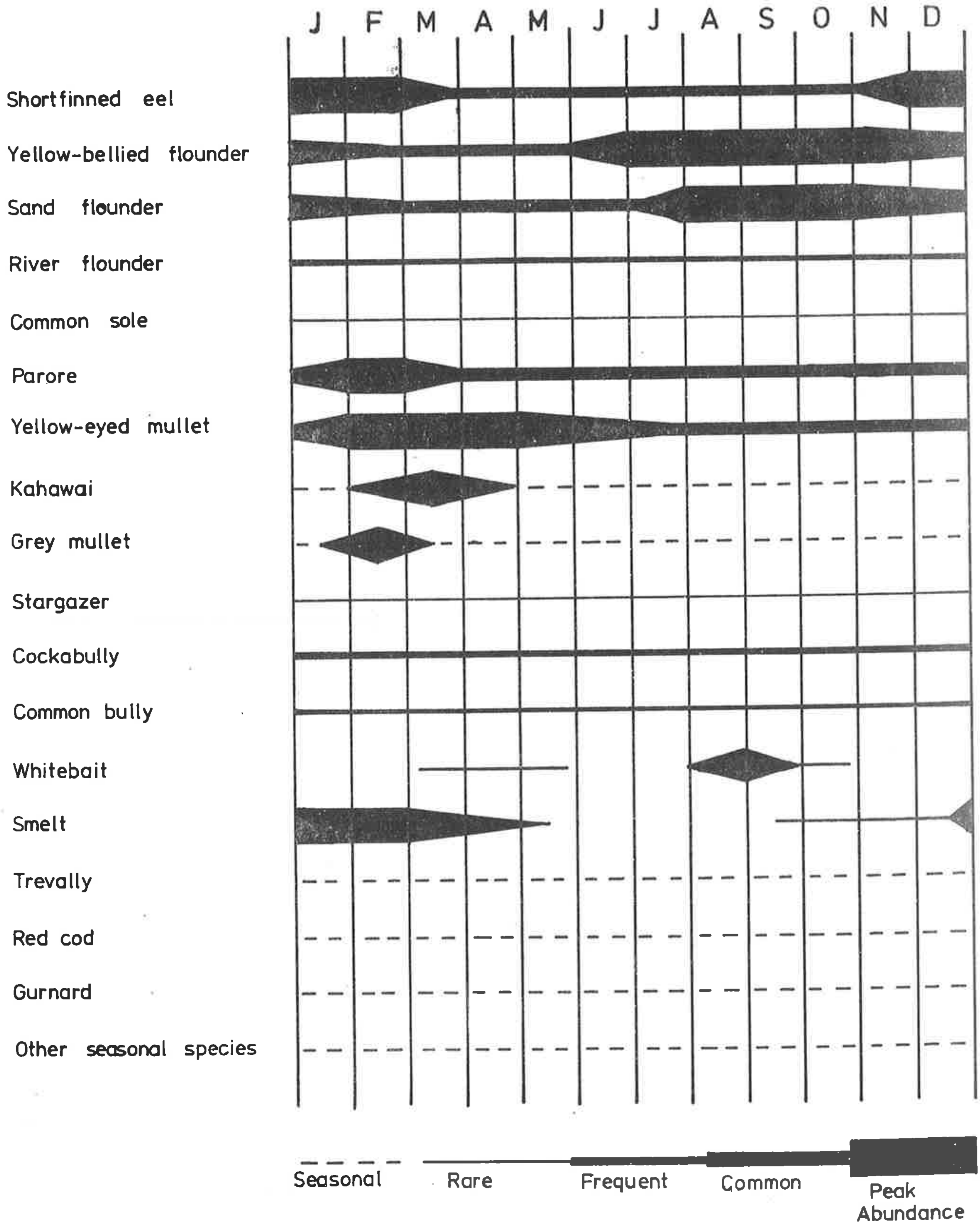


Fig.22 : Seasonal occurrence of fish species in Ahuriri Estuary

Ruppia and Ulva increase in abundance in summer and are used by those herbiverous fish which in winter feed on Cystophora, Enteromorphora and other species.

Crustaceans are the predominant animal food of the fish in the estuary; crabs, amphipods, shrimps and isopods feature highly in the diets of a number of fish, especially yellow-bellied flounder (adults eat crabs, juveniles smaller crustaceans), short-finned eels, river flounder, yellow-eyed mullet and kahawai.

Gastropods (especially Potamopyrgus estuarinus, Zeacumantus lutulentus) and polychaetes (especially Aonides trifidus, Perenireis nuntia, Scolecolepides benhami, Haploscoloplos cylindrifer) were eaten by a variety of fish. Zeacumantus is a very common gastropod in the estuary. It did not figure highly in the diet of any one species of fish, but did occur in the diet of nearly all species and on that basis ranks as an important food.

The relatively high proportion of fish stomachs without food is a reflection of the fact that mainly static fishing methods were used during this study. For set nets and fyke nets the time lapse between the fish being caught and being emptied from the net, allows digestion to continue. Also, much of the set netting was done during daylight and some species captured are mainly nocturnal feeders.

Importance of Estuaries

The high nutrient status, shallow water and sheltered conditions of estuaries make them a favourable environment for large numbers of marine organisms - thus estuaries are fertile and biologically productive. They provide nursery grounds for many species of fish, permanent residence for other species and feeding grounds for transient visitors from the open sea. All of these factors make an estuary an important component of the food web of the sea.

How valuable are estuaries to fisheries?

In North America investigations have shown that the commercial fishing on the continental shelf is largely for species which spend a part of their lives in estuaries. Nearly two-thirds (63%) of the commercial catch in landed value on the Atlantic coast and well over half of the entire U.S.A. commercial catch is made up of estuarine dependent species (McHugh, 1966, 1976; Clark, 1967). In the Gulf of Mexico the estuarine dependent species formed about 98% of the total commercial catch (Gunter, 1967).

In Australia in 1971-72 about 32% (37,818 tonnes) of the total marine fisheries production (117,543 tonnes) comprised species which spent all or some part of their life in estuaries (Newell and Barber, 1975). For New South Wales alone, over the ten year period 1962/3-1972/3 the estuarine dependent portion of the total fisheries catch was about 66% by weight and 70% by value. This was calculated to be worth $36 million contributed to the annual gross national product of N.S.W. by the estuaries dependent commercial fisheries (Pollard, 1976).

Biologists agree that if these estuarine areas were destroyed coastal fish would persist as species but their populations would be reduced to a small fraction of their present level.

Importance of Ahuriri Estuary

How important is the estuary to fisheries, and how does it compare with other estuaries?

The fish population study of Ahuriri Estuary has revealed a relatively high number of fish species there in comparison with other estuarine waters in New Zealand.

Avon-Heathcote Estuary (Christchurch) which is twice the size of Ahuriri has about 30 species, Pauatahanui Inlet (Porirua) which is about the same size as Ahuriri has about 28 species while Ahuriri has about 29 species (Knox and Kilner, 1973; Healey, pers. comm.).

Although for a good proportion of these fish the estuary serves as a feeding ground - with fish entering on the tide and returning to the sea on the outgoing tide after feeding on the crustacean, molluscan and fish fauna - the estuary also plays an important role in the life cycle of 11 species, which use the sheltered waters as a nursery or breeding ground. This can be compared with 13 species for Avon-Heathcote and 14 species for Pauatahanui (Webb, 1973a; Healey, pers. comm.).

Some of these species complete their life cycle within the estuary (e.g. cockabully), others are spawned there by adult fish coming in (i.e. parore, whitebait, common bully), while others enter as larvae or juveniles and grow to maturity before migrating to the open sea (e.g. yellow-bellied flounder, sand flounder). In Ahuriri about nine of the eleven species breeding in the estuary are commercial species: yellow-bellied flounder, sand flounder, grey mullet, stargazer, river flounder, whitebait, common sole, parore and yellow-eyed mullet.

Investigations have shown that six commercially valuable species are frequent or common in Ahuriri: short-finned eel, yellow-bellied flounder, sand flounder, river flounder, grey mullet, kahawai. Two other common fish have minor commercial importance: parore and yellow-eyed mullet. About another 12 commercial species also use the estuary at some time or other for breeding or feeding. It should be noted that one of the most common commercial fish in the estuary is the short-finned eel. Eels and snapper have been the most important commercial species of finfish in New Zealand in the last few years.

Not to be overlooked are the other mainly non-commercial species of fish which form part of the food webs of the estuary, and are important sources of food for some of the commercial fish. Yellow-eyed mullet, cockabully, and common bullies are common fish that fit into this category.

Ahuriri Estuary then, is an important estuary. It cannot compete in the amount of fisheries production with some of the larger estuaries in New Zealand (e.g. New River Estuary, Invercargill; Avon-Heathcote Estuary, Waimea Estuary, Ohiwa Harbour, Kaipara Harbour, etc.) because of its restricted size. However, in the context of the Hawke Bay region it is the most important estuary. We made a brief investigation of other estuaries in the region and found that most of the others had either brackish lagoonal or relatively unstable environments.

The brackish lagoons such as Whakaki Lagoon tend to have no regular sea entrance and therefore limited importance to marine fisheries. They will, however, have good eel fisheries and at times may have a flatfish population if the entrance has been open at the right time of the year for eggs and larvae to enter.

The unstable environments include most of the river mouths entering Hawke Bay (e.g. the Nuhaka, Wairoa, Ngaruroro and Tutaekuri River mouths), which are affected by river flooding which deposits sediment, tree stumps, etc., in some areas and removes material from other areas in the estuary. Thus preventing an established flora and fauna developing to any extent before the next flood occurs.

Ahuriri Estuary provides breeding and feeding opportunities for fish species that are not available in other estuaries in Hawke Bay. It is also an important source of organic production for the offshore continental shelf area of Hawke Bay. A large amount of nutrients, organic matter and living material are carried from the estuary to the offshore water and eventually contribute to the fisheries production offshore.

4. EFFECT OF PROPOSED MODIFICATIONS

4.1 Introduction

A number of modifications to the estuary have been proposed by various organisations and are outlined by Voice (1978). There will no doubt be other proposals of which the authors are unaware. Effects of some of these modifications on invertebrate macrofauna and fish populations are discussed but since details of many of the known proposals are necessarily vague the implications of the possible modifications and their effects cannot be fully assessed.

4.2 Dredging

Dredging where sediment is removed from the channels, tidal flats or marginal vegetation would alter many of the physical factors which determine the distribution and abundance of the invertebrate macrofauna. Hence the location and the extent of the dredging would have varying effects on the invertebrates and consequently on the feeding of fish. The location and extent of dredging would also have varying effects directly on the nursery grounds of fish.

Deep-water Port

There have been proposals for development of a deep-water port in the lower estuary, which would involve extensive dredging to depths of about 15 metres over a large area. Extensive dredging would destroy the intertidal areas and therefore, the intertidal invertebrate fauna would also be destroyed because of the changes in exposure, and also in salinity, substrate, etc.

A new flora and fauna community would develop but it would be subtidal - the type of community that forms depends on the physical and chemical conditions in the new dredged area. This subtidal population might provide suitable food for large fish, mainly the transitory species entering the area to feed. However, loss of the tidal flats by extensive dredging would destroy the shallow sheltered margins of tidal channel and tidal flat streams which are the nursery and feeding grounds of juvenile stages of fish (and feeding for wading birds).

Any extensive dredging in the lower estuary would affect physical and chemical factors for a considerable area adjacent to the dredged area, thereby having a wide ranging effect on much of the rest of the estuarine system. For instance, current velocities, sedimentation, exposure times, etc., would change. Large scale dredging means that the dredged areas would be able to contain more water than in their present natural state and a delay would occur before water filled it to the top and started to flow out over the tidal flats. Exposure times would be lengthened because of this delay. The invertebrate fauna of these adjacent affected areas would thus be changed. With increased exposure time of the adjacent tidal flats and the reduction in water level at low tide, the tidal flat streams would completely drain and these areas which are the main nursery areas of flatfish (and other species) would be lost.

It is difficult to assess the precise changes that would occur in sedimentation, current velocities, salinities, etc. The probable overall effect of the dredging would be to decrease the diversity and numbers of estuarine benthic animals with consequent effects on those species that depend on them for food. Extensive dredging whether to one metre or 15 metres in the lower or middle estuary in which large areas of permanent water were created would have similar effects.

Removal of Material for Spoil

Removal of material for spoil again involves dredging usually in a localised area. It would have varying effects depending on size and position of the area to be dredged, but again it would be extremely destructive of the intertidal habitat for plants and animals. Generally, the greater the area dredged the greater the effect - depending on the amount of material removed, the site it is taken from, etc. The operations would affect adjacent areas because of changes of current velocity, sedimentation, exposure, salinity, etc. as discussed above.

Depending on the site, some localised dredging could totally destroy fish nursery areas (and bird breeding areas) or modify them to the extent that they were not viable nurseries. For instance, destruction of the nurseries for very small flounder in the tidal flat areas west of Humber Street or around the northern side of Embankment Bridge (Fig. 12) would seriously reduce the ability of the estuary to act as a nursery for juvenile flounders. The larvae are carried in from the sea and it would appear initially survive better in these two areas than until such time as they grow sufficiently to move out into other areas of the estuary. In other words, these two are critical to the viability of the estuary as a flounder nursery.

Dredging operations would cause mortality of fish in the vicinity of the dredging by the release of trapped poisonous gases such as hydrogen sulphide from the bottom sediments.

Estuarine ecosystems are recognized world-wide as being in a critical state of balance with their physical, chemical and biological factors. Therefore, only minor changes in any one of these can cause widespread disruption to the whole system, i.e. tip the balance. The authors are of the opinion that further dredging of the estuarine wetlands and tidal flats, is likely to have an irreversible effect on the value of this estuary as a productive eco-system. The potential value of the estuary as a nursery area for fish would thus suffer markedly.

Ahuriri is the only estuary in Hawke Bay with well-established tidal flats, it must be contributing appreciably to the commercial fishing industry in the Bay. Hence damage to Ahuriri fish nurseries would eventually affect the Hawke Bay fishery.

Flood Control

Dredging and straightening of the channel in the estuary has been proposed to cope with floodwater drainage in times of heavy run-off. Dredging channels would have many of the effects described above. Deepened channels contain more water at low tide and this leads to

(1) increased exposure times due to the delay in water moving out over the tidal flats thus altering the animal life;

(2) tidal streams draining completely thus reducing the populations of animals using these areas (e.g. juvenile fish); and

(3) increased current velocities in the main channel, with more estuarine food organisms and juvenile fish being swept out of the estuary and lost. The overall result is a reduction in the numbers and diversity of intertidal macrofauna and fish.

While it is acknowledged that estuaries and rivers have a prime function in flood discharge, it must be recognised that straight deepened channels have serious consequences for the flora and fauna. The effects of channel dredging can be minimised by following the existing channels so that significant areas of tidal flats are not destroyed and by deepening the channels no more than is absolutely necessary to achieve flood control.

4.3 Reclamation

Reclamation of a marginal vegetation, intertidal or channel area would destroy that area as a habitat for plants and animals. It would also alter the surrounding area and have similar effects to those detailed above.

Motorway

(a) Bridge. The proposed route of the new notorway across the estuary is shown in Fig. 23. A causeway to carry the motorway across the estuary would have major effects on current velocities, flow rate and siltation build-up. Examples of some of the problems can be seen with the existing Farm Bridge. Such causeway bridging would completely alter the existing fauna and flora. Therefore, the motorway should be carried over on a bridge. Even then there would need to be careful designing of bridge piers to minimise effects on flow rates, siltation, etc. Acceleration of siltation within the estuary is a major hazard to the well-being of the estuarine ecosystem.

(b) Feeder Road. An extension of Humber Street is proposed as a feeder route between the motorway and the Port of Napier (Fig. 23). This feeder road would cut across the intertidal flats west of Humber Street which is one of the most important young flounder nursery areas (Fig. 12). This nursery area would be destroyed by construction of this road. In any event material for construction of the new road embankment should not be dredged from the estuary.

The feeder road should be realigned southwards so that it completely avoids the valuable intertidal flats. The feeder road should encroach as little as possible on the Southern Marsh. A marsh is not only a valuable habitat but also acts as a buffer zone between the land and an estuary.

(c) Old Embankment Bridge. Removal of this bridge is proposed after completion of the new motorway. The bridge and piers should be completely removed. All material being removed should not be dumped into any part of the estuary. Particular care needs to be taken to avoid disturbance to the adjacent backwater which is an important flatfish nursery area (Fig. 12).

(d) Railway. A new railway bridge is proposed. Similar problems in construction of the new bridge and removal of the old bridge exist as above hence similar precautions should be made.

4.4 Discharges

Various industrial discharges, run-offs, etc. already enter the estuary. These discharges should be severely curtailed and no new ones allowed to enter the estuary. Estuaries are vulnerable in that while they act as nutrient traps they also act as natural pollution traps for domestic, industrial and other wastes. Low or sub-lethal levels of pollution will affect the productivity of this estuary. Already the young flounder area west of Humber Street is being affected by the streams draining the industrial area to the south served by Thames Street. Further industrial discharges will destroy this flatfish nursery area.

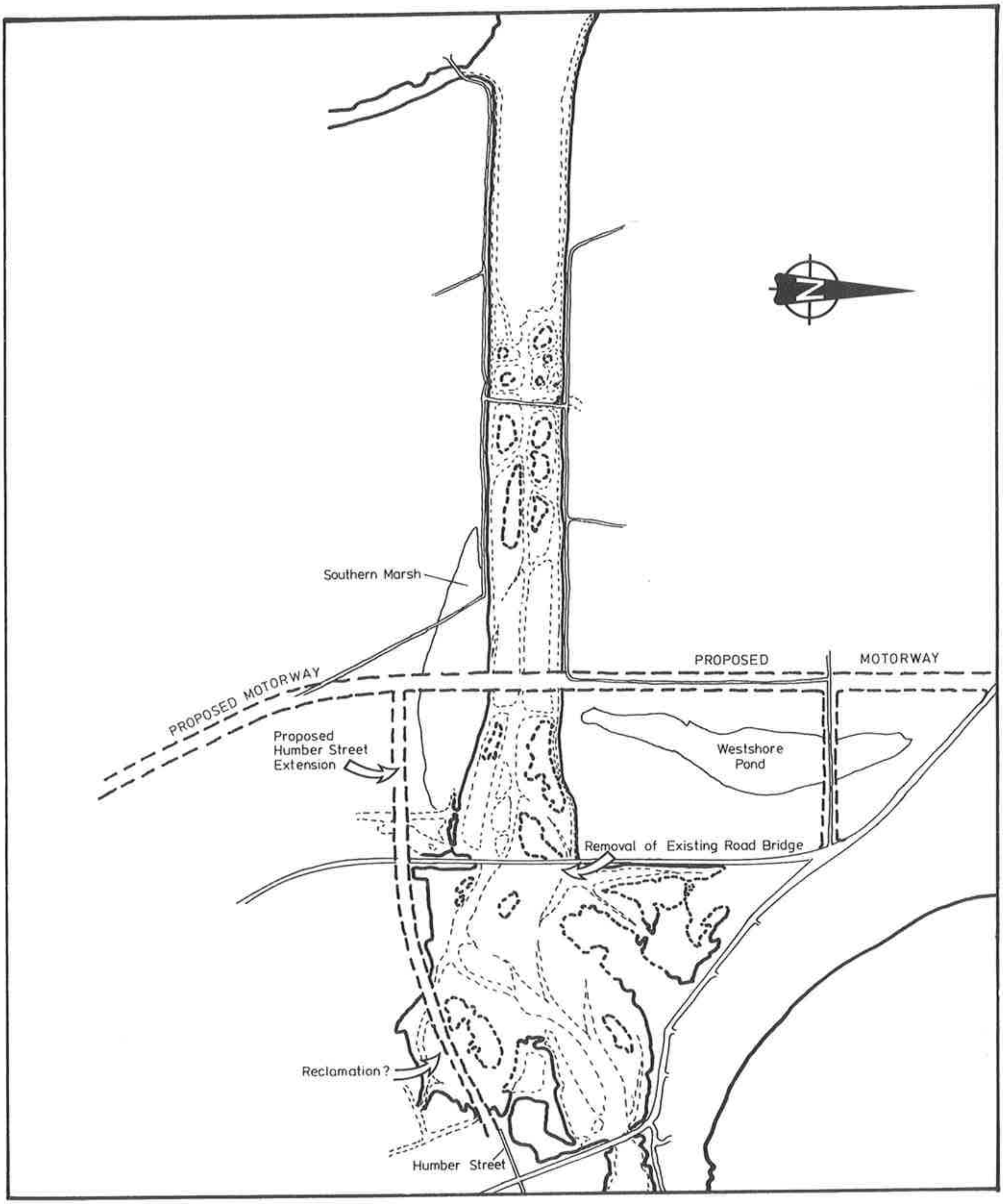


Fig.23 : Proposed motorway across Ahuriri Estuary. Redrawn from map prepared by Heretaunga Plains Transportation Study Committee, 1977

With industrial development and extension of the railway marshalling yards, effort must be made to prevent run-off and discharges from entering the estuary.

4.5 Disturbance

Power boating and water ski-ing should be excluded from the estuary. The noise disturbs not only the people enjoying it as a recreational resource but also the fish and birds. Power boating also disturbs the bottom sediments, plants and animals and their habitats. Also, if power boating were allowed, it would require extensive dredging, as the estuary is too shallow. The effects of this have been described above. Yachting, rowing, canoeing etc. would not cause such disturbance especially in the lower estuary providing no dredging was allowed. A proposal for a 2000 m rowing course would undoubtedly require extensive dredging to obtain sufficient length and width of rowable water. This proposal would seriously disrupt the ecology of the estuary as discussed above.

Picnic areas and walkways would be an acceptable use of areas near the margins of the estuary, providing sufficiently detailed planning was carried out to ensure that people were kept away from the breeding areas of birds and that walkways did not encroach on the tidal flats and marginal vegetation.

4.6 Alternative Areas for Breeding and Feeding

It has been suggested that loss of tidal flats by reclamation or dredging in the lower estuary could be compensated for by alternative areas upstream of Embankment Bridge. This is presumably by increasing the flow of salt water upstream and thus allowing estuarine communities present in the lower estuary to establish upstream.

It is considered that alternative breeding - nursery - feeding areas must have an expanse of intertidal area at least comparable in area to that which has been lost. This could only be satisfactorily provided by removal of the present stopbanks in the middle and upper estuary. Simply increasing the flow of salt water into the upper estuary is not sufficient as this area has almost a complete covering of water throughout the tidal cycle at present because of the formation of Farm Bridge causeway in the past.

Intertidal areas are required with tidal waters flowing out over them, and given the correct conditions of salinity, sediment, exposure time, etc., eventually an established tidal flat fauna and flora would form with marginal vegetation, etc.

A broad band on either side of the present outfall channel would then become intertidal. Thus the present stopbanks, farm roads and pumping stations would need to be removed and no doubt would have to be re-established at some distance further back from the present waterway. What area would be required cannot be estimated without computer modelling studies. The planning of these alternative areas would require extensive engineering, hydrological and biological investigations using computer modelling systems to ensure suitable habitats were formed.

Such alternative areas have been constructed in the United States of America but planning and preparation of alternative areas would be extremely expensive and therefore undoubtedly would seem an impractical proposition for Ahuriri Estuary.

4.7 Fish Farming

Suggestions for fish farming in the estuary have been made. This would be undesirable because the enclosure of an area for farming would impede water flow and lead to further siltation within the estuary, as well as interfering with other uses.

Prospects for fish farming would be more favourable in ponds constructed on farmland adjacent to the estuary. Much of this farmland has to be drained by pumps to keep the water table down to prevent salt water seepage. This seepage might be utilized for fish farming. Detailed investigations would be required on the merits and profitability of such a venture versus the existing farming of the land. Precautions would have to be taken that the ponds did not attract birds into the airport flight paths.

A number of fish species could be considered, including eels and grey mullet, which already use the estuary. Eels are a very valuable export fish for New Zealand. Grey mullet is well suited for farming, and are farmed widely overseas, notably in Israel.

5. SUMMARY

The invertebrate macrofauna and fish population of Ahuriri Estuary have been studied. The fauna is derived partly from freshwater and partly from the sea.

A detailed study has been made of the invertebrate macrofauna in relation to environmental factors, i.e. salinity, sediment, tidal height. The greatest faunal diversity is found in regions of high salinity and in sediments intermediate in grade between fine muds and coarse sands/shingle.

Thirty-three species of macro-invertebrates have been found in the estuary, the cockle *Chione stutchburyi* is the dominant species (in terms of numbers and biomass). Sub-dominant species are the bivalve *Macomona liliana*, gastropods *Potamopyrgus estuarinus*, *Zeacumantus lutulentus*, *Cominella glandiformis*, crab *Helice crassa*, and polychaete worms *Aonides trifidus*, *Scolecolepides benhami*, *Perinereis nuntia*.

The numbers of macro-invertebrates in Ahuriri Estuary are high, the bivalve shellfish are particularly abundant, but of a very small size compared with those of some other New Zealand estuaries.

Twenty-nine species of fish were found in Ahuriri Estuary. The dominant species are short-finned eels, yellow-bellied flounder, sand flounder, yellow-eyed mullet and parore.

The estuary has two prime functions for fish: as a nursery or breeding ground for many species, and as a feeding ground for many others. About eleven species breed in the estuary, nine of these are commercial species. Six commercially valuable species are frequent or common in abundance.

Ahuriri Estuary is a rich and productive estuary for fisheries. Estuaries are essential to fish production and therefore deserve more attention than they have received in the past. Sufficient information is not available at present to place actual catch or monetary values on its production, but in the context of Hawke Bay it is the most important estuary to fisheries production.

Some indications of the possible effects of certain modifications to the estuary have been outlined. Specific details of individual proposals are not available, hence the implications cannot be fully assessed.

Certain proposals for dredging (deep-water port, spoil, power boating, etc.) or reclamation (marina, causeways, etc.) of the estuary would be particularly destructive of the estuarine habitat. Such proposals should not be contemplated. Other modifications not identified as destructive should be required to have adequate environmental safeguards. Proposals such as yachting and rowing (assuming no dredging), walking, picnicking, can be

harmonious with the estuarine environment if precautions are taken.

Finally, we would like to emphasize a statement by McHugh (1976) which highlights the situation facing fishery scientists - "Few fishery situations can be interpreted with the elegant simplicity and finality of predicting the consequences of placing an impassable dam downstream of the spawning grounds of an anadromous species (-species which run in from the sea to spawn). The probability is fairly high that estuarine fisheries will continue to be managed poorly unless decision makers are willing to act prudently and forcefully without waiting for absolute proof of damage, and the people are willing to co-operate" (our emphasis).

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7. REFERENCES

BOLTON, L.A. & KNOX, G.A. 1977. The ecology of selected sites near Mapua, Waimea Inlet. Estuarine Research Unit, University of Canterbury.

BOWERS, A.B. 1954. Breeding and growth of whiting (*Gadus merlangus* L.) in the Isle of Man waters. *Journal of the Marine Biological Association of the U.K.* 33: 97-122.

CASSIE, R.M. & MICHAEL, A.D. 1968. Fauna and sediments of an intertidal mud flat: a multivariate analysis. *Journal of Experimental Marine Biology and Ecology* 2 : 1-23.

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

GRANGE, K.R. 1977. Littoral benthos-sediment relationships in Manakau Harbour New Zealand. *New Zealand Journal of Marine and Freshwater Research* 11 (1) : 111-123.

GUNTER, G. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico, *In*: Lauff, G.H. (ed.), *Estuaries*, pp. 621-638, American Association of Advances in Science, Publication No. 83.

HYNES, H.B.N. 1950. The food of freshwater stickleback (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods. *Journal of Animal Ecology* 19: 36-58.

HUNNABLE, E.J. & SPACKMAN, L.S. 1974. The ecology of the Ahuriri Estuary and Wildlife Refuge. Unpublished report to the Napier City Council by T.J. Sprott and Associates, Auckland, 67 pp.

JELLYMAN, D.J. 1977. Invasion of a New Zealand freshwater stream by glass eels of two *Anguilla spp.* *New Zealand Journal of Marine and Freshwater Research* 11(1): 193-209.

KNOX, G.A., BOLTON, L.A. & HACKWELL, K. 1977. Report on the ecology of the Parapara Inlet, Golden Bay, Estuarine Research Unit, University of Canterbury.

KNOX, G.A. & KILNER, A.R.1973. The ecology of the Avon-Heathcote Estuary. Unpublished report to the Christchurch Drainage Board by the Estuarine Research Unit, University of Canterbury, Christchurch, 358 pp.

McDOWALL, R.M. 1975a. A revision of the New Zealand species of *Gobiomorphus* (Pisces: Eleotridae). *National Museum of New Zealand Records* 1 (1) : 1-32.

McDOWALL, R.M. 1975b. Reclamation and swam drainage - their impact on fish and fisheries. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet* No. 6. 13 pp.

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

McHUGH, J.L. 1976. Estuarine fisheries: are they doomed? In : Wiley, M. (ed.), Estuarine Processes. I. Uses, Stresses, and Adaptation to the Estuary, pp 15-27. Academic Press, New York.

MORTON, J. & MILLER, M. 1968. The New Zealand Seashore. Collins, Auckland. 653 pp.

MUNDY, A.R. 1968. A study of the biology of the sand flounder Rhombosolea plebeia (Richardson) off the Canterbury Coast. Unpublished Ph.D. thesis in zoology, University of Canterbury.

NEWELL, B.S. & BARBER, W.E. 1975. Estuaries important to Australian fisheries. Australian Fisheries 34 : 17-22.

ODUM, E.P. 1971. Fundamentals of Ecology. W.B. Saunder Co., Philadelphia. 574 pp.

PARKER, R.H. 1975. The Study of Benthic Communities. A Model and Review. Elsevier Scientific Publishing Company, New York. 279 pp.

POLLARD, D.A. 1976. Estuaries must be protected. Australian Fisheries 36 : 6-10.

SPROTT, T.J. & ASSOCIATES 1976. Environmental Impact Assessment regarding dredging in Ahuriri Estuary. Unpublished report prepared on behalf of the Hawke's Bay Harbour Board. 90 pp.

STEPHENSON, W. 1973. The use of computers in classifying marine bottom communities. In : Fraser R. (ed.), Oceanography of the South Pacific 1972, pp 463-473. New Zealand National Commission for UNESCO, Wellington.

THOMPSON, R.B. 1951. Food of squawfish Ptychocheilus oregonesis (Richardson) of the lower Columbia River. United States Fish and Wildlife Service, Fishery Bulletin 60 (158) : 43-58.

VOICE, A.J. 1978. Resource evaluation and management alternatives : Ahuriri Estuary, Napier. Unpublished M.Sc. thesis, Joint Centre for Environmental Sciences, University of Canterbury and Lincoln College. 168 pp.

WEBB, B.F. 1972. Fish populations of the Avon-Heathcote Estuary. 1. General ecology, distribution and length frequency. New Zealand Journal of Marine and Freshwater Research 6 (4) : 570-601.

WEBB, B.F. 1973a. Fish populations of the Avon-Heathcote Estuary. 2. Breeding and gonad maturity. New Zealand Journal of Marine and Freshwater Research. 7 (1 & 2) : 45-66.

WEBB, B.F. 1973b. Fish populations of the Avon-Heathcote Estuary. 3. Gut contents. New Zealand Journal of Marine and Freshwater Research. 7 (3) : 223-234.

WEBB, B.F. 1973c. Fish populations of the Avon-Heathcote Estuary. 4. Parasites. New Zealand Journal of Marine and Freshwater Research 7 (4) : 307-321.

WEBB, B.F. 1973d. Fish populations of the Avon-Heathcote Estuary. 5. Records of less common species. New Zealand Journal of Marine and Freshwater Research 7 (4) : 307-321.