ISSN 0110-5205

NZOI Oceanographic Field Field Report 25

Some Observations on Suspended Particulate Matter in Rangaunu Harbour

by R.A. Pickrill and J.S. Mitchell

DSIR Division of Marine and Freshwater Science

1986

SOME OBSERVATIONS ON SUSPENDED PARTICULATE MATTER IN RANGAUNU HARBOUR

R.A. Pickrill and J.S. Mitchell

ABSTRACT

Rangaunu Harbour receives suspended particulate matter (SPM) from the open ocean and from freshwater runoff. Each source has a distinctive composition and concentration that make it readily identifiable. During normal river flows, SPM-rich fresh water is ponded in the upper harbour and deposited as mud. The lower harbour is flushed by oceanic water where surface sediments are sand.

Keywords: estuary, Rangaunu, suspended particulate matter, diatoms, scanning electron microscope

INTRODUCTION

Following the clearing of kauri (*Agathis australis*) forests and the departure of gum diggers from the swamps of Northland more than 50 years ago, man's impact on Rangaunu Harbour has been small. In the last five years, however, several proposals have been made for major developments in and around the harbour, including tourism on the Karikari Peninsula, the siting of a barging port at the harbour entrance, and the mining of kauri gum in the Kaimaumau swamp on the western shore. Any of these developments could have a major impact on the harbour. With development proposals in mind, the N.Z. Oceanographic Institute started multidisciplinary studies of the sedimentology, physical oceanography, and benthic ecology of Rangaunu Harbour in 1979. These studies were extended in 1981 when joint research with the Northland Harbour Board focused on problems of port location and operation within the harbour entrance. Most of the findings from these studies have been published (Heath *et al.* 1984; Pickrill 1985, in press a, b). This paper presents data on suspended particulate matter (SPM) within the harbour waters.

BACKGROUND

Rangaunu Harbour is an oval-shaped estuary enclosed by sandy barrier beaches connecting Karikari Peninsula to the mainland (Fig. 1). The harbour encompasses 97 km^2, two-thirds intertidal, of which half is open sand flats and half muddy sand colonised by the mangrove *Avicennia marina* var. *resinifera*. A dendritic channel system drains northwards from the principal river, the Awanui, into Rangaunu Bay.

The harbour drains a small catchment, little more than twice the surface area of the harbour itself (200 km^2). As Heath *et al.* (1983) point out, much of the catchment is low-lying and sandy and, under low rainfall, does not produce significant inflow into the harbour. The Awanui River is gauged at Kaitaia where the catchment area is 23.5 km^2. The mean flow is 5.95 m^{3}s^{-1} (MWD, Auckland, pers. comm.), with the maximum mean monthly flow in winter (10–11 m^{3}s^{-1} and minimum flows in summer (2–4 m^{3}s^{-1}; Heath *et al.* 1983, fig. 2). Unfortunately, no sediment ratings have been carried out in this catchment. During our sampling period in January 1979, flows were generally lower than normal (Fig. 2), except for a period on 20 January when 23 mm of rain at Kaitaia produced a small peak on the hydrograph.

SAMPLING PROGRAMME AND LABORATORY TECHNIQUES

Eight temperature, salinity, and SPM stations were occupied in a longitudinal profile down the Awanui Channel from the harbour entrance to the Awanui River (Fig. 1). At each station, 1.25-litre NIO water bottles with reversing thermometers were used to sample the water column, at the surface, at 1 m above the bottom, and at mid-water depths. The survey was carried out at high-water spring tides on 15 January 1979 and repeated on 20 January during low-water springs. At shallower stations, particularly during the low-water survey, the mid-water depth was not sampled. Standard techniques to determine temperature and salinity have previously been described by Heath *et al.* (1983).

Concentrations of SPM were determined by filtering 1-litre water samples under vacuum through preweighed 0.8-µm "Sartorius" membrane filters, using a method described by Strickland and Parsons (1968). Subsamples approximately 1 cm^2 in area were cut from the filters and mounted on scanning electron micro-

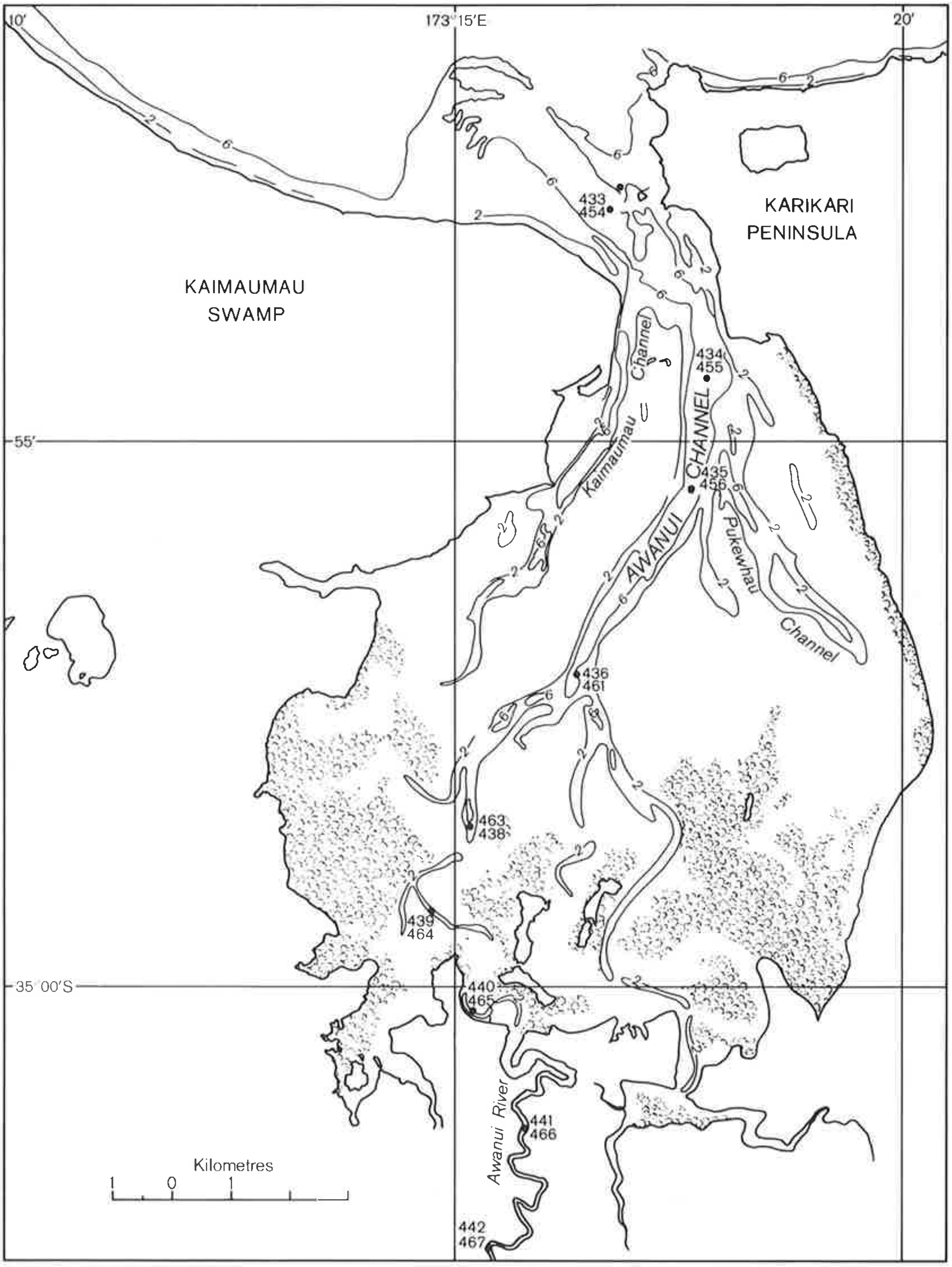


Fig. 1. Rangaunu Harbour, showing temperature/ salinity/ SPM station positions. Stations 433–443 were at high tide, stations 454–467 at low tide.

scope (SEM) stubs. SPM composition was estimated by inspection and counting of 100 grains on an ISI TV mini-SEM. Grain counts of 100 were made from each stub to determine the SPM composition.

At each station, a Hydro Products Model 912S transmissometer was lowered through the water column to give percentage light transmittance (T) from which beam attenuation coefficients (C) can be determined from the relationship,

$$T = 100\ e^{-Cd},$$

where d is the path length in metres. Attenuation of light in water is a product of both absorption of light by dissolved materials and scattering due to suspended solids. Under laboratory conditions, good correlations have been produced between beam attenuation and monomineral concentrations of SPM (e.g., McCarthy *et al.* 1974). Correlations between

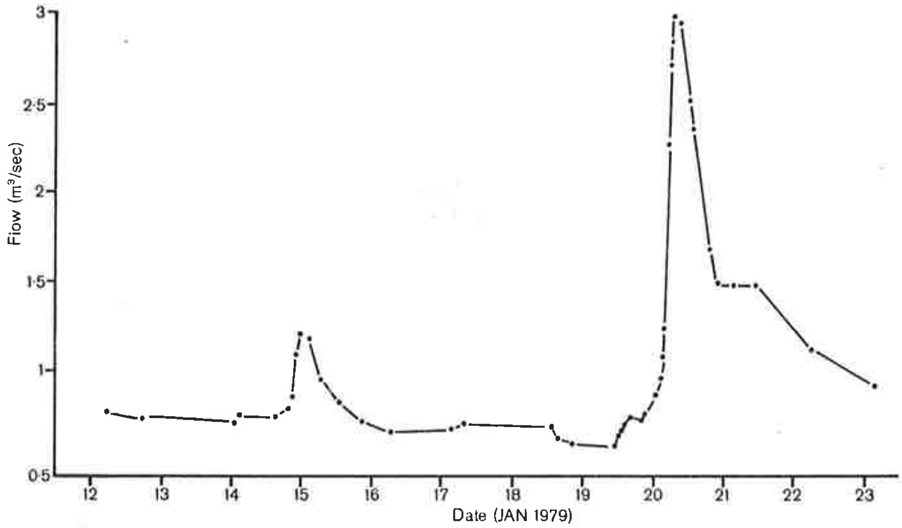


Fig. 2. Flow in the Awanui River (at School Cut, 35°07′S, 173°16′E) during the period of survey.

beam attenuation and SPM in Rangaunu Harbour have been reported by Pickrill *et al.* (1986).

SPM CONCENTRATIONS AND TRANSMISSIVITY

At high tide, a strong gradient is developed near the mouth of the Awanui River between the cooler saline water and the warmer brackish river water (Fig. 3A). Within the harbour, salinities decrease seawards from a maximum of 35.7‰ at the head of the harbour to 35.3‰ near the entrance. Heath *et al.* (1983) suggested that this salinity maximum results from harbour evaporation.

At high tide, concentrations of SPM within the harbour are low, typically less than 2 $mg.\ell^{-1}$. There is little variation through the water column, although concentrations were sometimes higher in surface waters where floating mangrove litter may occur in the sample. The temperature/salinity gradient at the mouth of the Awanui River also marks a strong gradient in SPM concentration, with a jump from 2 to 9 $mg.\ell^{-1}$ across the saline/brackish-water boundary (Fig. 3A). The transmissometer shows a similar pattern, with relatively turbid river water, a sharp gradient across the saline/brackish-water boundary, and clearer waters in the harbour (Fig. 3A). Variations in transmissivity through the water column are small. The main difference between the transmissivity and SPM pattern is the gradual increase in light transmissivity towards the open ocean, which is not paralleled by a similar decrease in SPM concentrations. Differences between the two patterns can be produced by two factors. At low SPM concentrations, small differences between stations are almost as large as experimental errors in the filtering techniques, and variations between the two profiles may be experimentally derived. Percentage light transmittance is a product of scattering due to suspended solids and absorption by dissolved material. Variability in the composition and size of SPM, and amount of dissolved material can therefore produce different transmittance values for common SPM weights.

At low tide, the temperature/salinity/SPM gradient weakens and moves further seawards to approximately midway between the Awanui River mouth and harbour entrance (Fig. 3B). Seaward of this gradient, SPM concentrations are similar to those found in the inflowing water at high tide (> 2 $mg.\ell^{-1}$). On the landward side, concentrations are higher, reaching a maximum of 37 $mg.\ell^{-1}$ in the Awanui River. Preceding the high-tidal survey on 15 January, the weather was dry and the Awanui River flowed at less than summer base flows (Fig. 2). Measured SPM concentrations of 10 $mg.\ell^{-1}$ are typical of base flows in Northland streams (e.g., Schouten 1976). The day before the low-tidal survey, 23 mm of rain were recorded at nearby Kaitaia, increasing stream discharge (Fig. 2) and presumably increasing SPM loadings in the Awanui River. The transmissivity profile shows an increase in percentage light transmittance from the Awanui River through to the harbour entrance. At all stations except the entrance, transmittance is lower than at high water.

SPM COMPOSITION

Six different types of suspended particulate matter were identified — mineral grains, diatoms, zooplankton, coccoliths, dinoflagellates, and mangrove litter. Material difficult to identify was grouped into an indeterminate class and included fine colloidal material and waste products introduced to the Awanui River, probably from the outfall of the Northland Co-operative Dairy Company.

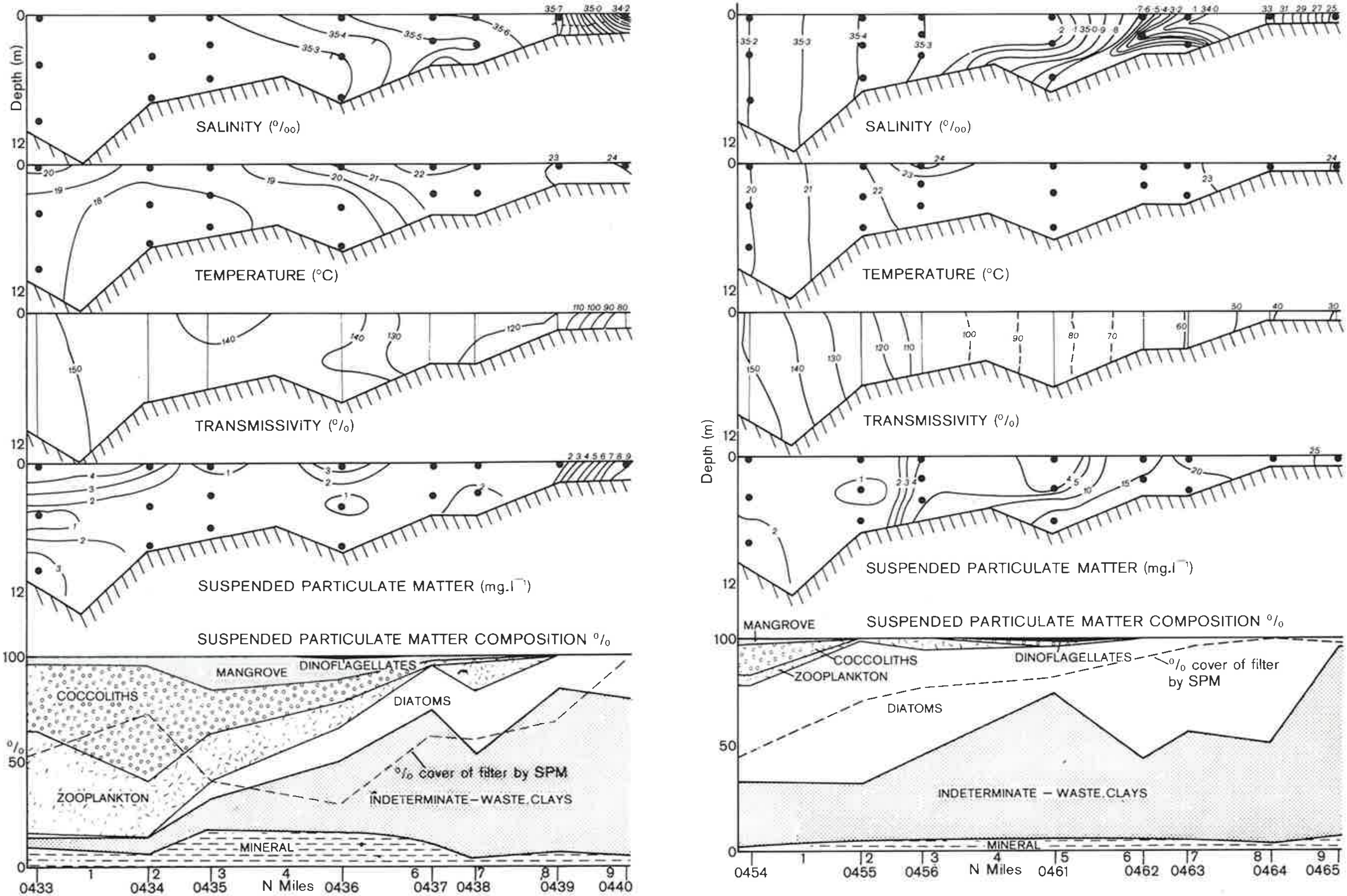


Fig. 3. Sectional plot of salinity (‰), temperature (°C), transmissivity (%), and SPM concentration (mg.ℓ⁻¹) at mid-depth. The range of transmissivity values is from 0–200%; 0–100% with a 10-cm path length and 100–200% with a 100-cm path length. **A**, high tide; **B**, low tide.

At high tide, all SPM components were found in the saline water, with coccoliths and zooplankton making up more than 80% of the SPM at the harbour entrance (Fig. 3A). There is a landward decrease in the coccolith and zooplankton components and an increase in the proportion of diatoms and indeterminate matter. Filters from this saline water (Fig. 4A, B) typically show low concentrations of SPM and minimal indeterminate matter or mineral grains. Diatoms were mainly fragmented *Chaetoceros* species or *Guinardia flaccida.*

In the brackish river water only indeterminate matter, diatoms, and mineral grains were found. The filters were clogged with indeterminate material (Fig. 4C) and matted diatoms, principally *Chaetoceros*, *Amphiprora*, and *Thalassiosira* sp.

At low water, compositional differences between the saline and brackish-water SPM are maintained, except that the three major components of the brackish water are found well seaward of the temperature/salinity/SPM gradient (Fig. 3B). Coccoliths and zooplankton make up a small but significant proportion (20%) of the SPM at the harbour entrance; photomicrographs (Fig. 5A) show the filters to be relatively clean with no clogging. By contrast, filters from the middle and upper harbour had a background cover of indeterminate matter and diatoms (Fig. 5B, C).

DISCUSSION AND CONCLUSIONS

Temperature, salinity, and SPM characteristics identified two water masses within the harbour — saline oceanic water and brackish river water. Saline oceanic water entering the harbour each flood tide contains very low concentrations of SPM. Composition of the SPM is typical of oceanic water, with predominantly marine organisms. Freshwater input from the Awanui River is warm and brackish with high SPM concentrations and components typical of a terrigenous source, with clays, waste products, mineral grains, and diatoms dominant.

The ability of harbour waters to retain terrestrially derived SPM or pollutants is largely a function of the time that a parcel of water remains in the inlet. This residence time is difficult to measure directly, and is different for different parcels of water. Heath *et al.* (1983) used three different techniques to derive residence times for Rangaunu Harbour; the tidal-prism technique provided an estimate of approximately 1 day; current observations from the harbour entrance suggested about 2.6 days; the volume of fresh water within the harbour suggested 4.5 days. Low concentrations of SPM and contrasting SPM composition between high- and low-tidal surveys indicate that the exchange of water within the harbour is rapid. The change in SPM composition in the outer half of the harbour between high and low tides indicates that the water of the outer harbour is exchanged each tidal cycle. Frequently, a parcel of water leaving a harbour at ebb tide re-enters the harbour at the next flood tide and there is little renewal by oceanic water. Efficient renewal of harbour water at Rangaunu is brought about by the development of separate ebb- and flood-tidal channels seaward of the harbour entrance. Water leaves the harbour in an ebb jet directed to the north-west across the ebb-tidal delta. Before the ebb flow finishes, however, flood waters bring new oceanic water into the harbour via a marginal flood-tidal channel, aligned north-south against the Karikari Peninsula (Pickrill 1985). In this way, very little of the water leaving the harbour at ebb tide re-enters at the following flood and the harbour is refilled with new oceanic water.

Freshwater inflow is low; at high tide, oceanic water penetrates the whole harbour and fresh water backs up in the Awanui River. At ebb tide this fresh water is released and can be traced as brackish water seawards to mid-harbour but it does not flow out through the entrance. Even at low tide, therefore, SPM-rich fresh water is trapped in the harbour. With a spring-tidal compartment of $1.3 \times 10^8 m^3$ (Heath *et al.* 1983) mean annual freshwater inflow produces only 0.02% of this volume each tidal cycle. At such low percentages, fresh water probably mixes with the saline water in the middle and upper harbour and is eventually flushed seawards in a very dilute form rather than as a discrete water mass. Fresh water may possibly flow directly out to sea during periods of high river discharge. Ponding of fresh water in the upper harbour allows SPM to settle, depositing muddy sediments in the lower river channel and under the mangroves (Pickrill, in press a). In the lower harbour, sediments are sand and shell gravel, originating from the open coast rather than from fluvial sources.

ACKNOWLEDGMENTS

We thank B.S. Shakespeare for assistance in collecting the field data. The Ministry of Works and Development, Auckland, made the river-flow data available. D.A. Burns kindly identified the diatoms, and L. Carter reviewed the manuscript.

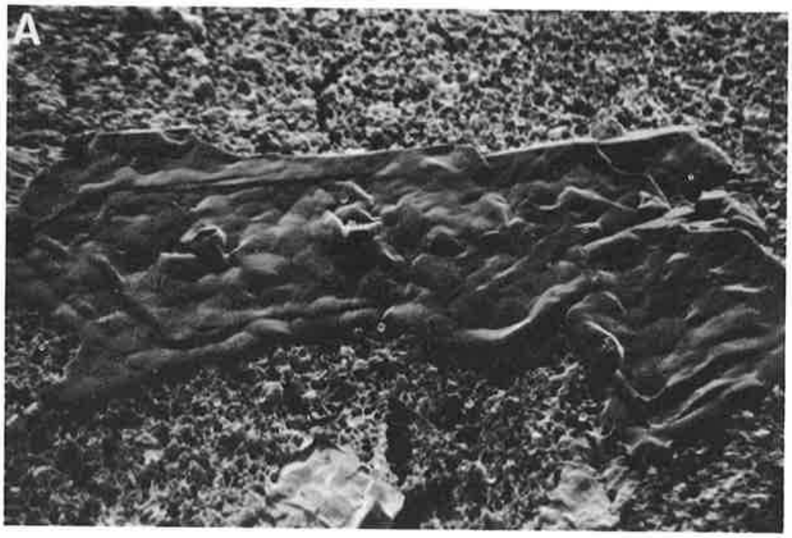
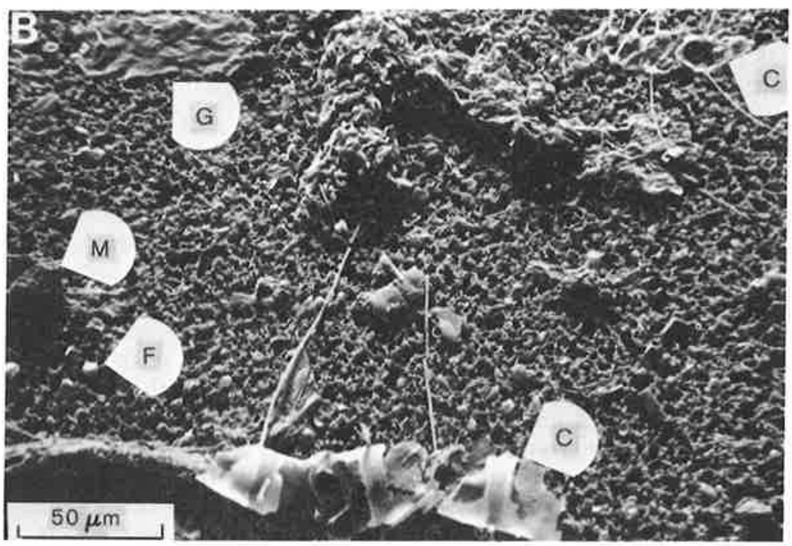
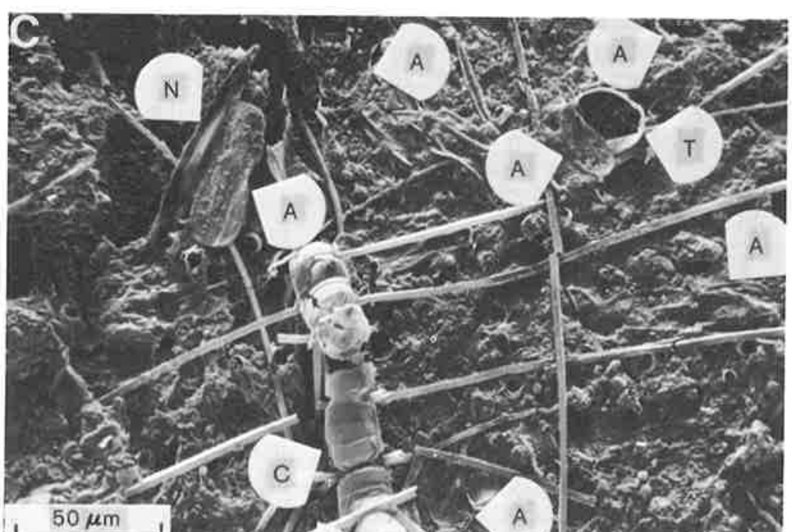


Fig. 4. Scanning electron micrographs of SPM from Rangaunu Harbour at high tide; all stations at mid-depth.
A, NZOI Stn O 433 from the harbour mouth. The percentage cover of SPM is low, the large fragments are organic debris.



B, Stn O 436 from mid-harbour saline water. The percentage cover of SPM is low and the pisolitic filter surface is clearly visible. Indeterminate matter, occasional mineral grains, and diatoms predominate (G = *Guinardia flaccida*, F = *Fragilariopsis pseudonana*, C = *Chaetoceros* sp., M = mineral grains).



C, Stn O 440 from brackish water at the mouth of the Awanui River. The filter has almost 100% cover of largely indeterminate matter, overlain with diatoms (A = *Amphiprora* sp., N = *Nitzschia* sp., C = *Chaetoceros concavicornis*, T = *Thalassiosira delicatula*).

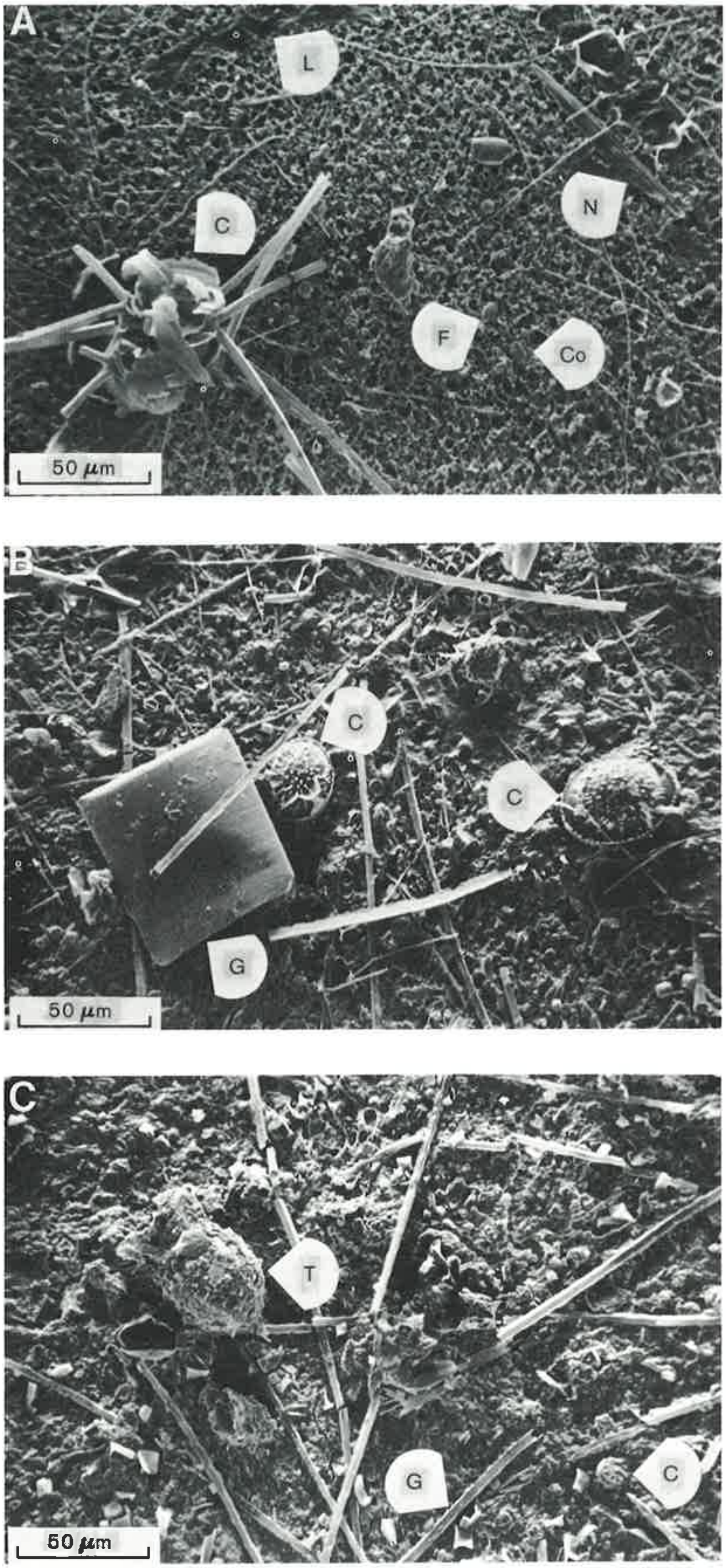


Fig. 5. Scanning electron micrographs of SPM from Rangaunu Harbour at low tide (NZOI Stn O 454), mid-depth (Stn O 461), and bottom (Stn O 475).

A, Stn O 454 from the mouth of the harbour. The percentage cover of SPM is low and largely made up of indeterminate matter and diatoms (C = *Chaetoceros concavicornis*, L = *Leptocylindricus* sp., F = *Fragilariopsis pseudonana*, Co = *Cocconeis* sp., N = *Nitzschia* sp.).

B, Stn O 461 from mid-harbour, close to the SPM gradient. Percentage cover of the filter is high, with a background cover of indeterminate matter, overlain with occasional mineral grains and diatoms (C = *Chaetoceros* sp. resting spore, G = *Grammatophora* sp.).

C, Station O 465 from brackish water at the mouth of the Awanui River. As at station O 461, the filter has a background cover of indeterminate matter overlain with occasional diatoms (T = tintinnid, A = arms of *Chaetoceros concavicornis*, C = *Cyclotetta* sp.).

REFERENCES

HEATH, R.A.; SHAKESPEARE, B.S.; GREIG, M.J.N. 1983: Physical oceanography of Rangaunu Harbour, Northland, New Zealand. *N.Z. Jl mar. Freshwat. Res. 17(4)*: 481–93.

McCARTHY, J.C.; PYLE, T.E.; GRIFFIN, G.M. 1974: Light transmissivity, suspended sediments and the legal definition of turbidity. *Mar. Sci. 2(3)*: 291–99.

PICKRILL, R.A. 1985: Sedimentation in an ebb-tidal delta, Rangaunu Harbour, Northland, New Zealand. *N.Z. Jl Geol. Geophys. 28(3)*: 531–42.

PICKRILL, R.A. (in press, a): Rangaunu Harbour and Bay sediments, 1:40,000. *N.Z. oceanogr. Inst. Chart, Misc. Ser.*

PICKRILL, R.A. (in press, b): Quantification of sediment transport through estuarine entrance channels, Rangaunu Harbour, New Zealand. *Sedimentology.*

PICKRILL, R.A.; MITCHELL, J.S.; HILL, P.J. 1986: Calibration and use of an optical transmissometer to determine concentrations of suspended particulate matter. *NZOI oceanogr. Fld Rep. 23*: 8 p.

SCHOUTEN, C.J.J.H. 1976: Origin and output of suspended and dissolved material from a catchment in Northland (New Zealand), with particular reference to man-induced changes. *Publtiës fys.-geogr. Bodemkundig Lab. Univ. Amst. 23*: 178 p.

STRICKLAND, J.D.H.; PARSONS, T.R. 1968: A practical handbook of seawater analysis. *Bull. Fish. Res. Bd Can. 167*: 311 p.

(Received for publication — 23 August 1985)