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Ecological Monitoring of the Okura Estuary Report 4: Final report for the year 2002-2003.

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Ecological Monitoring of the Okura Estuary Report 4: Final report for the year 2002-2003.

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EXECUTIVE SUMMARY

The Brief

Two fundamental areas of concern will be addressed in the report (1) differential impacts within Okura estuary, as a consequence of certain areas having higher probability of sedimentation and certain areas having greater sensitivity to such inputs; and (2) impacts to and changes across the Okura estuary as a whole

To achieve these goals five estuaries were sampled (Puhoi, Waiwera, Orewa, Okura and Maunagamaungaroa) in two seasons (Winter Spring and Late Summer), with a rain and dry sampling in each season. Within each estuary 10 sites were sampled with 5 replicate macrofaunal cores at each site. Measurements of environmental characteristics (including a measure of sediment deposition) were also taken at each site to assess how much biological variation is coupled with environmental variation.

Primary Results

Firstly, relating to all estuaries:

- Okura estuary is intermediate to the extremes measured in the other four estuaries in terms of environmental characteristics (ambient sediment grain size, quantity of trapped sediment, the grain size of trapped sediment and bed height change) this makes this dataset extremely useful for gauging effects across the whole of Okura estuary.

- Three classes of sites could be defined that correlated to high, medium and low-energy environments. Three corresponding assemblage types could be defined from the assemblage data. Communities in high-energy environments were characterised by high counts of *Paphies* spp., and the crustaceans *Waitangi* sp. and *Colorustylis lemurum.* Communities in low-energy environments were characterised by high counts of polychaetes, particularly the *Nereid/Nicon complex*, and Capitellids and Oligocaheates. The intermediate communities in terms of environmental conditions showed high counts of the cockle *Austrovenus stuchburyi,* and the polychaetes *Notomastus* sp. and *Prionospio* sp and larger numbers of taxa then either biological community at the hydrodynamic extremes.

- Forty-six percent of the variation across all estuaries could be explained by variations in environmental factors. The variation that was estuarine specific across the whole study (3.5%) was small compared to the amount that could be explained by environmental factors (42.5%).

- The assemblage in low-energy environments showed the most significant temporal effects, showing both effects of Season and Precipitation, whereas high-energy assemblages showed no significant temporal effects. Temporal affects were mainly associated small differences between rare species (>1 on average per site) in different seasons or in rain versus dry samplings. This low temporal variation means a relatively stable baseline exists which we can then compare impacts against.

Then, relating to just Okura estuary:

- The longer time-series of data from the Okura estuary allowed us to examine the consistency of effects in Okura over time. The order of the strength of significant effects on the assemblage from strongest to weakest was: deposition, site, year, season and precipitation. Spatial effects (depositional class and site) were much stronger than temporal effects (year, season and precipitation). The strength of depositional and precipitation effects are similar in this report to those seen in previous years.

- The depositional classification of Cooper et. al. (1999) was still relevant in terms of classifying benthic communities in the Okura estuary. In this report High deposition sites showed the greatest densities of the polychaetes: Nereid/Nicon complex, *Cossura coasta* and *Capitella* sp. plus *Notomastus* sp. plus Oligochaetes. Medium deposition sites were characterised by high densities of cockles *Austrovenus stutchburyi* and the orbinid polychaete *Scoloplos cylindifer*. Low deposition sites showed the highest densities of the anemone *Anthopleura* sp.

- The depositional effects are relatively consistent in terms of which taxa characterise High Medium and Low Depositional sites within Okura estuary over time. In all three monitored years 2000-2001, 2001-2002 and 2002-2003 capitellid polychaetes have been more numerous in High deposition areas than Medium or Low depositional areas. The cockle *Austrovenus stutchburyi* has also consistently been more numerous in Low and Medium deposition sites in contrast to High deposition sites. By contrast the taxa correlated with the weaker precipitation effects were less common and differed between last years sampling (Anderson et al. 2002b) and the present report.

- Assessing trends over years in depositional communities was difficult given seasonal trends and only three years data. High and Low deposition communities did, however, appear to be changing in a similar direction in contrast to Medium deposition sites, which appeared more stable. Sharp changes in community structure were seen in all depositional environments, however these effects appear transitory, with communities usually returning to a more 'normal' composition at the following sampling. These sharp changes in community structure did not appear related to any of our monitored environmental parameters, including rainfall events.

Recommendations:

- A longer time series of data is needed to assess temporal change in the Okura estuary in the context of regional change. Data on existing sediment characteristics and ongoing sediment deposition are also needed from Okura and other estuaries in the future to explicitly link biological changes with potential sediment influxes. Therefore sampling should be continued using the same protocols.
- Future sampling for the Okura estuary should be combined with data from 2001-2003 to examine short-term and long-term patterns and directions of temporal change.
- Future sampling of the Puhoi, Waiwera, Orewa and Maungamaungaroa estuaries should be combined with data from 2002-2003 to examine short-term and long-term patterns and directions of temporal change in the estuaries in the region.

1. Introduction

1.1. Background

Increased rates of sedimentation in coastal ecosystems can cause important impacts on marine ecosystems (GESAMP 1990). Rain falls on catchments, flows through rivers and carries an estimated 400 million tonnes of sediment from the landmass of New Zealand to the ocean (Hicks and Griffiths 1992). Changes in land use can be a vital factor in determining the quantity of sediments eroded from the land, with land cleared for construction eroding at a rate approximately 2000 times that seen in forests (USEPA 1973). Increasing intensity of rainfall is predicted by climate change scenarios and is another factor likely to result in an increase in the amount of sediment transported by rivers through estuaries and to the ocean (Griffiths 1981, 1982, 1990, Hicks 1990). Sediment transported by rivers passes through estuaries on the way to the ocean, and estuaries are often characterized by high rates of sediment deposition (Dyer 1986). Changes in sediment inputs due to changes in land-use, climate or a combination of the two are therefore likely to show impacts in estuarine environments.

Sedimentation can affect macrofaunal community structure over a number of scales, from centimeters to hundreds of kilometers (Edgar and Barrett 2000; Benedetti-Cecchi *et al.* 2001). Previous reports by Auckland Uniservices for ARC on this topic have reviewed the literature in this area (Anderson *et al.* 2001b, Anderson *et al.* 2002, Honeywill *et al.* 2002). In the time since the last of these reviews, Hewitt *et al.* (2003) showed that local hydrodynamics can influence colonization of soft-sediment macrofauna, with more dynamic environments likely to be recolonised more quickly after impacts due to sedimentation. This study generalised impacts of sediment deposition across three sites separated by ~ 500 m within the Whangapoua estuary, Coromandel. In addition, Morrisey *et al.* (2003) have demonstrated how assemblages from two urban estuaries (Hellyers and Pakuranga) differed significantly from those found in two non-urban (rural) estuaries (Te Matuku on Waiheke Island and Paremoremo). They also found that these effects, detectable at the scale of whole estuaries, were correlated with differences in concentrations of contaminants, such as metals and hydrocarbons, in sediments.

Okura estuary is located near the Northern edge of the North Shore area of Auckland and is under increasing pressure from urbanisation This increasing pressure of development has raised concerns that potential associated increases in sedimentation will negatively impact the ecology of the estuary itself. Such concerns are particularly relevant given the status of the Okura estuary as a marine reserve.

Considerable research has been completed on various aspects of the estuary, including:

- the habitats in the estuary have been described (Honeywill *et al.* 2002);
- the sedimentation and hydrological patterns/characteristics of the estuary have been studied (Green and Oldman 1999; Stroud *et al.* 1999);
- the biology and ecology of the soft-sediment benthic fauna have been described (Hewitt *et al.* 1998; Norkko *et al.* 1999; Saunders and Creese 2000; Anderson *et al.* 2001a, b);
- the potential impacts of urbanisation resulting from increased sedimentation have been modelled (Cooper *et al.* 1999; Swales *et al.* 1999; Stroud and Cooper 2000); and
- fine sediment deposits to depths of greater than 2-3cm that resided for more than 7 days were found to be sufficient to kill almost all of the organisms in intertidal sediments in the Okura estuary (Norkko *et al.* 1999).

The pilot report of Anderson *et al.* (2001a) and subsequent annual report (Anderson *et al.* 2001b) showed that assemblages in Okura were found to vary significantly with depositional environment (High, Medium or Low, as modelled in Cooper *et al.* 1999) and with the rank distance of sites from the mouth of the estuary. More specifically, bivalves and gastropods were found to be more abundant in the Medium/Low depositional areas compared to the High depositional areas, whereas the abundances of certain worms and crabs were found to be greatest in the High depositional areas. It was clear from these studies that the depositional environments modelled by Cooper *et al.* (1999) were useful in predicting spatial patterns of changes in benthic assemblage structure.

In 2002, monitoring within Okura was expanded and intensified, focusing on the spatial scale of greatest variation: individual sites. A greater number of sites were sampled from within each depositional environment and, in addition, concomitant measurements were made of several environmental characteristics. This was an important change to the monitoring program, as it allowed explicit modelling of spatial variation in macrofaunal assemblages in response to environmental characteristics.. It was found that up to 70% of the spatial variation in biodiversity could be explained by the physical parameters measured (Anderson *et al.* 2002). In particular, the grain size characteristics of ambient and trapped sediments, the overall amount of sediment trapped, the distance from the mouth of the estuary and bed height movement were all useful in modelling assemblage dynamics.. Greater replication at the site level also allowed seasonal effects and effects of precipitation (temporal factors which were weaker in their impacts than spatial factors) to be detected. In addition, an examination of overall changes through time within Okura over longer time periods was initiated (Anderson *et al.* 2002).

1.2 Rationale for expansion of the design

The 2001-2002 sampling program (Anderson *et al.* 2002) was able to address potential differential impacts of sedimentation within Okura estuary, (i.e., to test for differences in communities between high and medium/low depositional areas in response to events of heavy rainfall). However, such a design cannot be used to identify potential impacts of sedimentation at the scale of the entire estuary. To do so, it is necessary to quantify natural spatial and temporal variation concomitantly at several reference estuaries within the Auckland region (Underwood 1991, 1992, 1994). This will allow any overall changes within Okura to be compared with natural spatial variation among estuaries in a regional context. Thus, the sampling program was enlarged in the 2002- 2003 year to incorporate four more estuaries: Puhoi, Waiwera, Orewa and Maungamaungaroa. Monitoring of environmental characteristics was also done for all estuaries, although these were reduced to include only those factors found to be especially relevant for modelling communities in Okura, namely bed height movement (erosion/accretion), sedimentation (as measured by sediment traps) and grain size characteristics of ambient and trapped sediments (Anderson *et al.* 2002). These changes allow the sampling program to retain the ability to detect differential impacts within Okura estuary, but also to detect potential changes to the estuary as a whole. They also allow sites across all of these estuaries within the region to be modelled in terms of specific environmental characteristics.

In order to test for the potential impacts of sedimentation due to heavy rainfall, sampling was again temporally structured to be "event-driven" and to encompass periods after heavy rain and after dry periods within each of two different seasons. The timing of the sampling by reference to rainfall events was chosen in order to examine impacts that are not expected to occur until at least 7 days after heavy rain, as indicated by previous studies (e.g. fatal smothering of bivalve species, Hewitt *et al.* 1998, Norkko *et al.* 1999).

1.3. Purpose of the present report

The purpose of the present report is to address the following questions:

(a) for all five estuaries included in the present study:

1. Do the physical characteristics of the sites within Okura fall within the range of physical characteristics measured for the other estuaries? That is, can the estuaries chosen be considered to be good reference estuaries for ongoing monitoring and detection of impacts at Okura?

2. Can the sites be characterized in terms of their measured environmental variables? More specifically, can we construct an overall gradient model of the sites (and/or a grouping of sites) according to their physical characteristics, regardless of which estuary they occur in?

3. Can the sites be characterized in terms of their biological communities? That is, can we construct an overall gradient model (and/or a grouping of sites) according to their biological communities, regardless of which estuary they occur in?

4. What is the relationship between the fauna and the environmental variables? Can the biological communities be successfully modelled by the environmental variables? If so, how variable is this through time and how specific is this to different estuaries? (i.e. will sites in different estuaries with similar physical characteristics have similar biological communities?)

5. Are there estuary-specific effects on communities (e.g. due to runoff of contaminants or other issues) that cannot be explained by the measured environmental variables?

6. What are the temporal patterns in assemblage structure observed for the 2002-2003 sampling year? Are there identifiable seasonal effects or effects due to precipitation? Are these effects, if present, consistent across sites characterised by different biota?

(b) for sites within Okura estuary alone:

7. What is the relative importance of effects of depositional environments, sites, years, seasons and precipitation on the faunal assemblages within Okura?

8. Are the measured effects for deposition or precipitation for the current year consistent with what has been observed in previous years at Okura? How can these effects be characterized in terms of changes in specific taxa?

9. What are the long-term patterns of variation for sites within Okura estuary? Are there any current signs of important sudden or gradual changes in the fauna since monitoring began in April 2000? If so, are such changes different for assemblages occurring in the different depositional environments?

2. METHODS

2.1. Location of Sites and Sampling Methods

2.1.a. Selection of Sites

Estuaries were chosen to compare to Okura on the basis of three criteria. First, estuaries needed to be to the North and South of Okura in order to avoid spatial confounding. Second, estuaries needed to have a similar geographical extent of area able to be sampled as Okura (~1-3 km in an upstream direction) so that similar numbers of sites, with similar spacing between them, could be sampled from each estuary. Third, estuaries needed to be aligned in an approximately East-West direction and opening out towards the East, so that events of heavy rainfall may be expected to impact them in similar ways. The estuaries chosen were Puhoi, Waiwera, Maungamaungaroa and Orewa (Fig. 1). The sites chosen for sampling within these estuaries were chosen on the basis of three criteria. First, sites needed to cover the gradient from the mouth to the upper reaches of the estuary. Second, sites needed to span the range of sediment grain sizes available within each estuary. Ideally, sites would also span the range of other environmental factors of interest (e.g., bed movement and sedimentation rates) found in Okura. However, at the time of site selection only ambient sediment grain-size composition could be gauged. Thirdly we attempted to avoid confounding of the gradient with the environmental variables (e.g., it was important that not all sites with fine sediments be located in the upper reaches of the estuary). Site locations are listed in Appendix A.

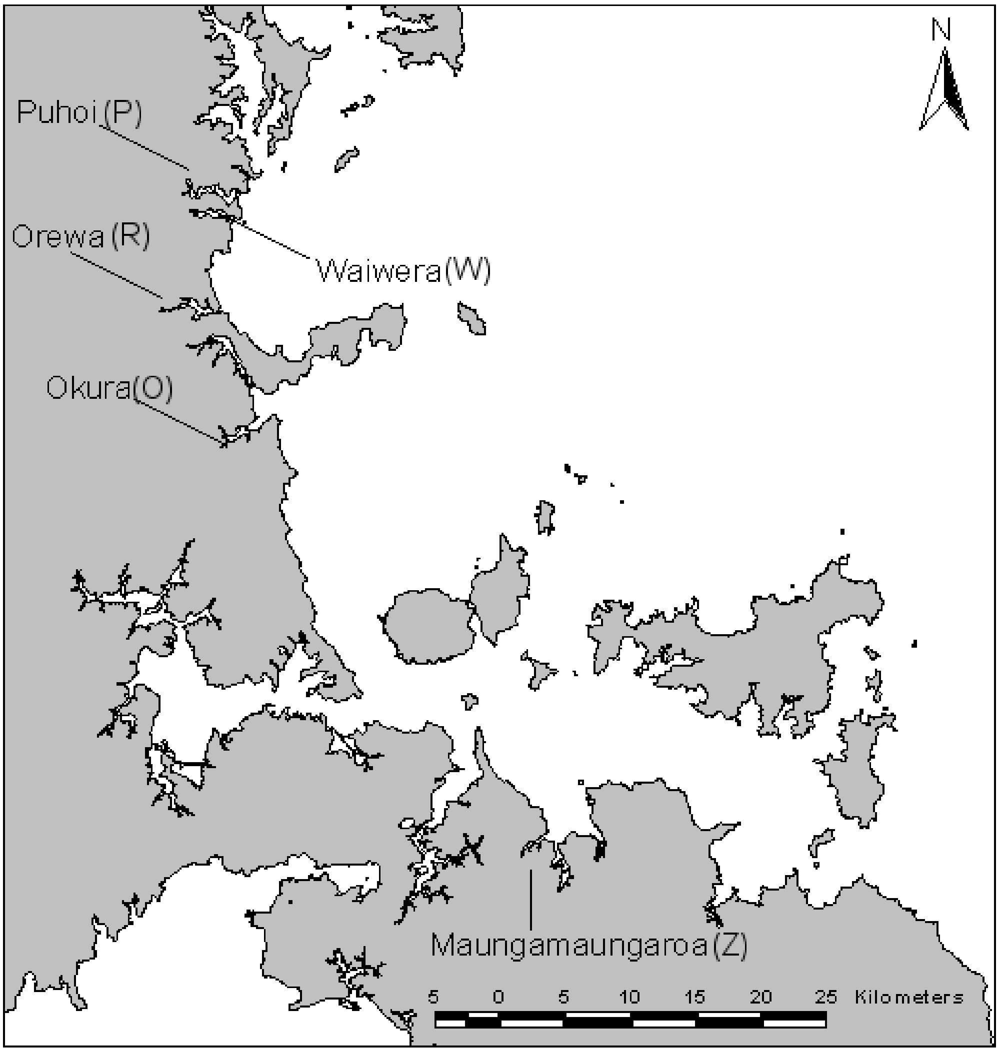

Fig. 1. Map of the East Coast of the Auckland Region showing all five estuaries sampled. Abbreviations used for estuaries in reporting results are shown in brackets after each name.

We sampled 10 sites in each estuary. Sites were labelled alphabetically and sequentially (A - J) from the mouth of the estuary (A) to its upper reaches (J). See Figs. 2-6 for positions of sites within each estuary. In Okura we chose three sites from each of the three previously modelled depositional classes (High, Medium and Low) plus an extra High depositional site. Sites A-J for Okura in the present report (Fig. 2) were labelled sites 2, 5, 6, 8, 9, 10, 11, 13, 14 and 15, respectively, in the previous report (Anderson *et al.* 2002)

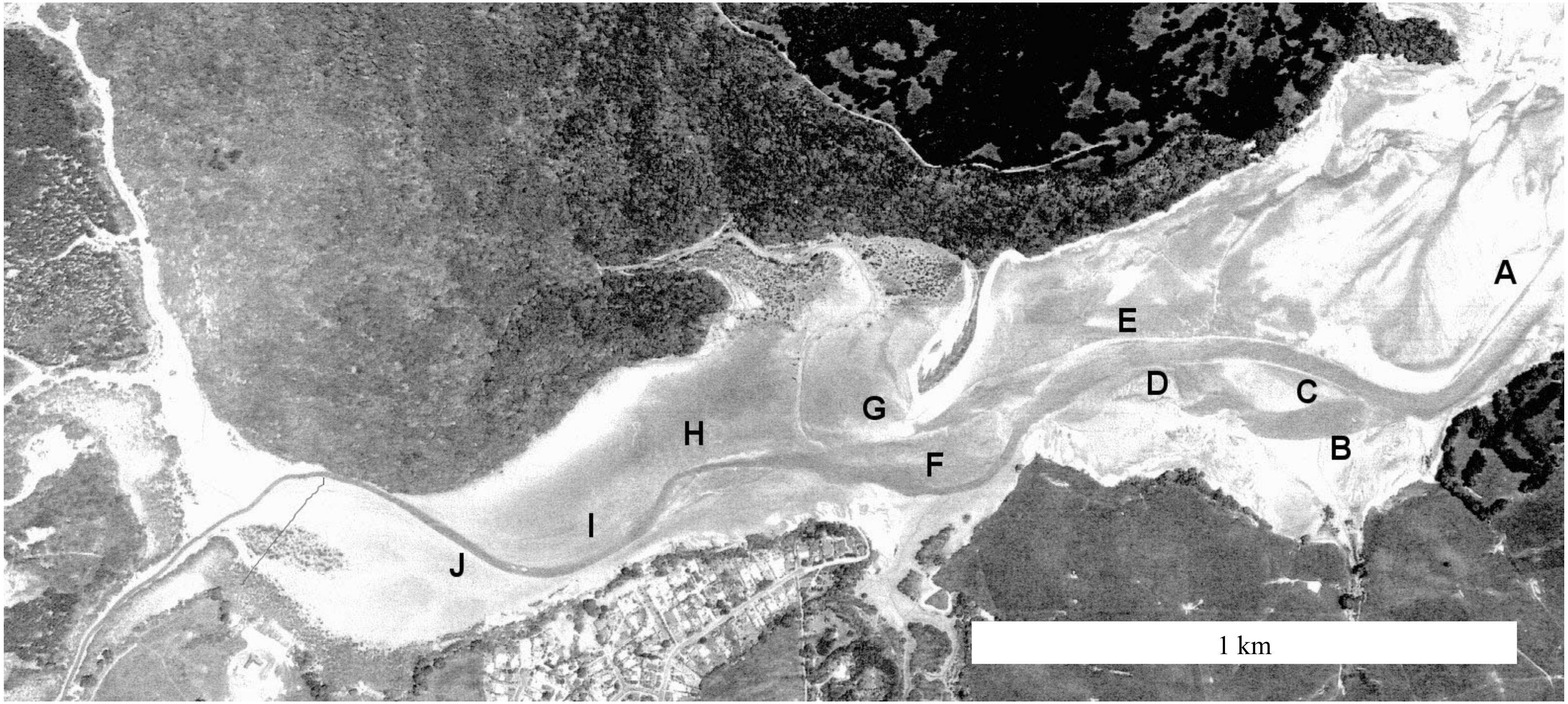

Fig. 2. Map of sampling sites within the Okura estuary. Sites are labeled alphabetically and sequentially from the estuary mouth (A) to the inner reaches of the estuary (J). The spatial extent of a site (50m x25m) is approximately as tall as each letter and twice as wide.

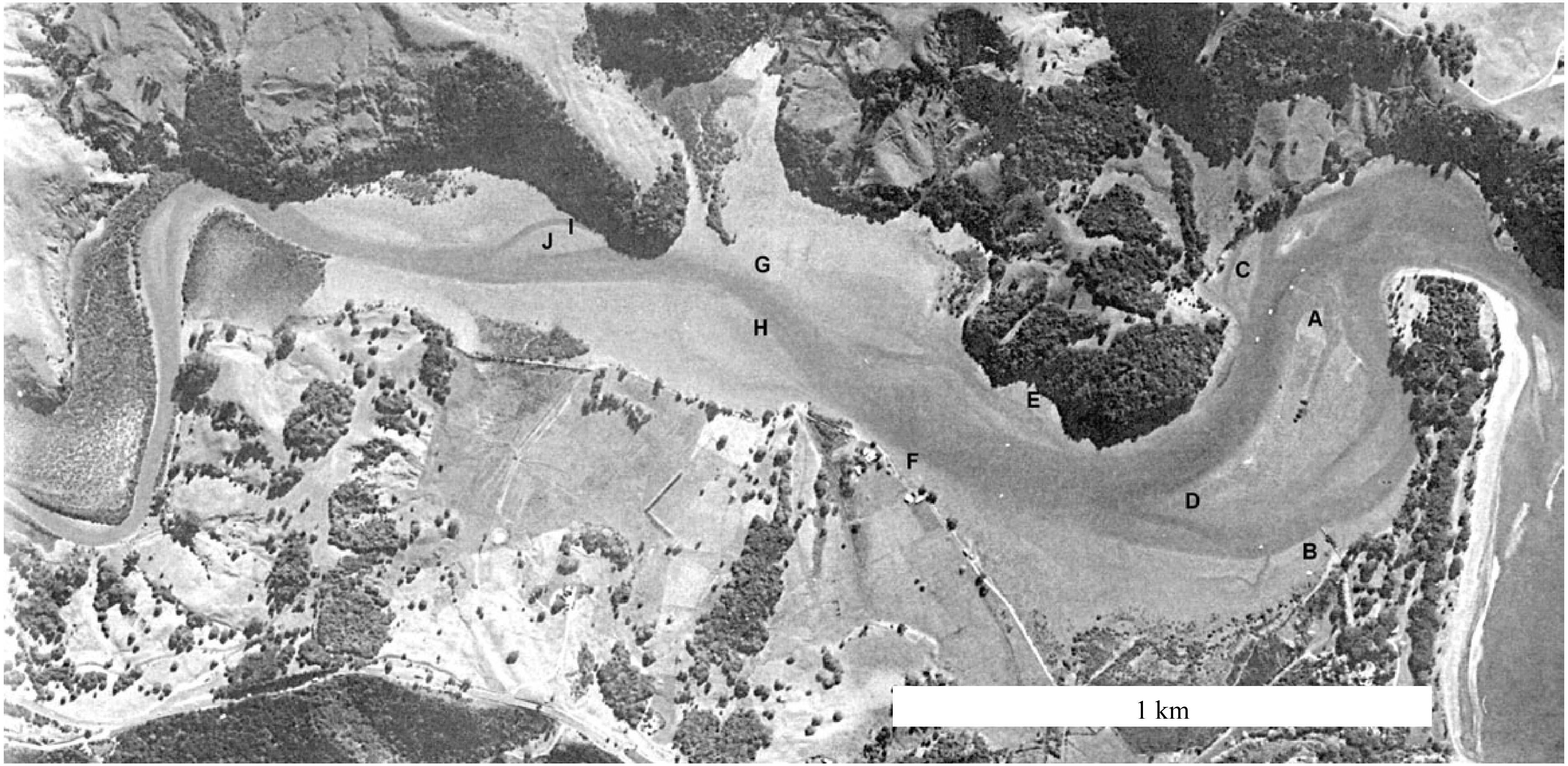

Fig. 3. Map of sampling sites within the Puhoi estuary. Sites are labeled alphabetically and sequentially from the estuary mouth (A) to the inner reaches of the estuary (J). The spatial extent of a site (50m x25m) is approximately as tall as each letter and twice as wide.

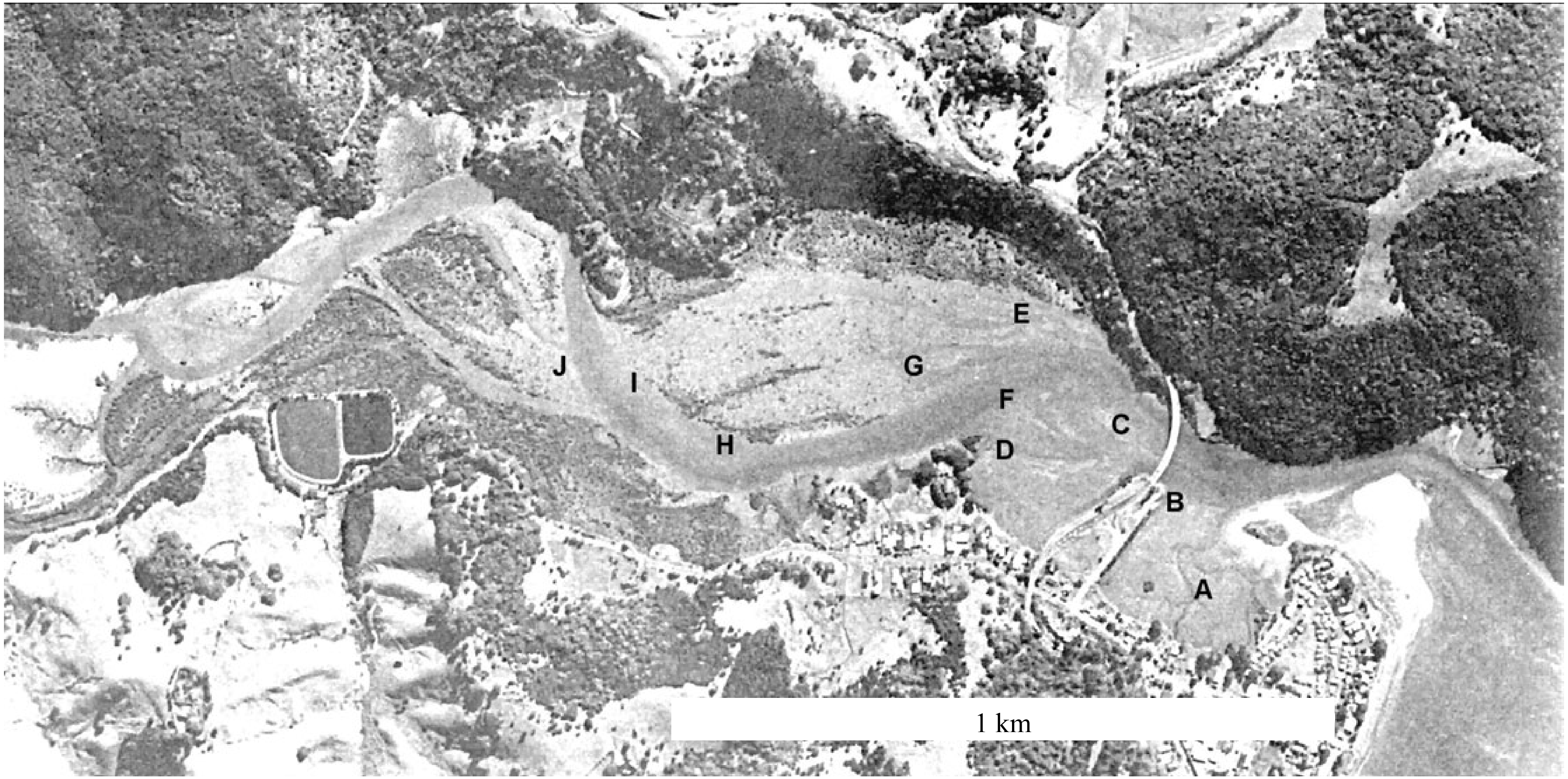

Fig. 4. Map of sampling sites within the Waiwera estuary. Sites are labeled alphabetically and sequentially from the estuary mouth (A) to the inner reaches of the estuary (J). The spatial extent of a site (50m x25m) is approximately as tall as each letter and twice as wide.