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Moutere Inlet Fine-Scale Benthic Baseline 2006

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Paul Gillespie
Kim Clark

Prepared for

Tasman District Council

Cawthron Institute
98 Halifax Street East, Private Bag 2,
Nelson, New Zealand.
Ph. +64 3 548 2319,
Fax. + 64 3 546 9464
www.cawthron.org.nz

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EXECUTIVE SUMMARY

A baseline survey using a suite of fine-scale benthic indicators of ecological condition at two representative locations in the Moutere Inlet is reported here. A companion report describing a broad scale habitat characterisation of Moutere Inlet is provided in Clark et al. (2006). The primary objective of the fine scale survey was to provide a point-in-time (March 2006) description of habitat condition that can be used as a baseline for monitoring change over time.

The two study locations were comparable to other moderately productive sand-dominated estuarine sites in New Zealand. Nutrient and organic contents of the sediments were not unusually elevated although TP concentrations were near the high end of the range. Low TN:TP atomic ratios suggest that nitrogen was the more limiting plant nutrient and phosphorous alone would not result in symptoms of over enrichment. Core profiles showed no signs of oxygen depletion (*e.g.* black anoxic zones or sulphide odours) but they were typical of other estuarine sites that have been affected by low to moderate sources of enrichment. No nuisance-level microalgal mat development or excessive macroalgal coverage was observed at the time of the survey.

Sediment cadmium, chromium, copper, lead and zinc concentrations were well below various guideline levels that are often used to indicate potential biological effects. Nickel concentrations, however, exceeded ANZECC (2000) guideline levels indicating “probable” biological effects. Elevated nickel concentrations are not unusual for estuaries and near shore coastal sediments in the Nelson region, and can be linked to erosional input from natural catchment sources.

Animal communities were typical of those observed at sandy sites at a variety of other New Zealand estuaries that are affected (but not necessarily adversely) by low to moderate sources of enrichment. Infauna communities were relatively diverse and dominated by polychaetes and bivalves with gastropods, nemertea, cumaceans and anthozoa also common. Although some species of opportunistic polychaetes were present that can indicate enriched conditions (*e.g. Heteromastus filiformis*), the densities of these species were not unusually high. Epifauna communities were dominated by snails and cockles with low numbers of limpets, anemones and crabs.

These results suggest overall that, with regard to the reference sites selected, the Moutere Inlet ecosystem is in a relatively healthy and functional condition. However, indications of low to moderate enrichment suggest that further investigation (*e.g.* at peripheral muddy sites) and/or ongoing monitoring of nutrient inputs might be warranted. Some uncertainties also remain with regard to the potential for nuisance macroalgal blooms to develop in the Inlet as high densities are known to occur periodically.

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1. INTRODUCTION

1.1. Background

Through a Ministry for the Environment Sustainable Management Fund (SMF) grant, with support from 11 councils throughout New Zealand, Cawthron developed a standardised protocol for the assessment and monitoring of New Zealand estuaries (Robertson et al. 2002). The initial protocol development included baseline surveys of fine-scale benthic characteristics of representative sites in nine estuaries ranging from Northland to Southland. This provided a comparative database that councils use to facilitate interpretation of State of Environment (SOE) and consent-related estuarine monitoring data. During the past five years a number of additional estuaries have been surveyed using the protocol and some have been (or are scheduled to be) resurveyed in order to monitor change in condition.

Cawthron Institute was commissioned by the Tasman District Council to similarly establish a baseline of benthic characteristics for Moutere Inlet as part of their coastal SOE monitoring strategy. To this end, a suite of indicators of estuary condition/health were assessed according to the estuary monitoring protocol (EMP) and the results are provided here with brief interpretation as a basis for on-going monitoring. A broad scale GIS-based map of the dominant structural and vegetative habitat types is described in a companion report (Clark et al. 2006).

1.2. Study area

The Moutere Inlet is located approximately 24 km northwest of Nelson near the town of Motueka (Figure 1). It is a bar-built, tidal estuary open to the sea at two locations (Port Motueka and the north western end of Kina Peninsula). Having near-complete drainage at low tide, it encompasses a total intertidal area of 713 ha (Spencer & Westcott 1980). The intertidal habitats are characterised by open mud flats fringed with salt marsh in peripheral regions and productive sand flats in central regions that are colonized by microalgae and, in some areas, macroalgae or eelgrass.

The Inlet receives a relatively small freshwater input from the Moutere River (~1280 litres/s) and a number of smaller inflow streams with a total mean flow of ~450 litres/s (Gillespie et al. 1995). Sources of freshwater nutrients and the enrichment status of benthic habitats in the estuary are described by Gillespie et al. (1995) in a detailed assessment of Moutere Inlet ecosystem characteristics. That study determined that, as of 1991, a majority of 22 sites surveyed remained in a relatively natural and unenriched state while three sites near the northern (Port Motueka) tidal outlet exhibited symptoms consistent with nutrient enrichment.

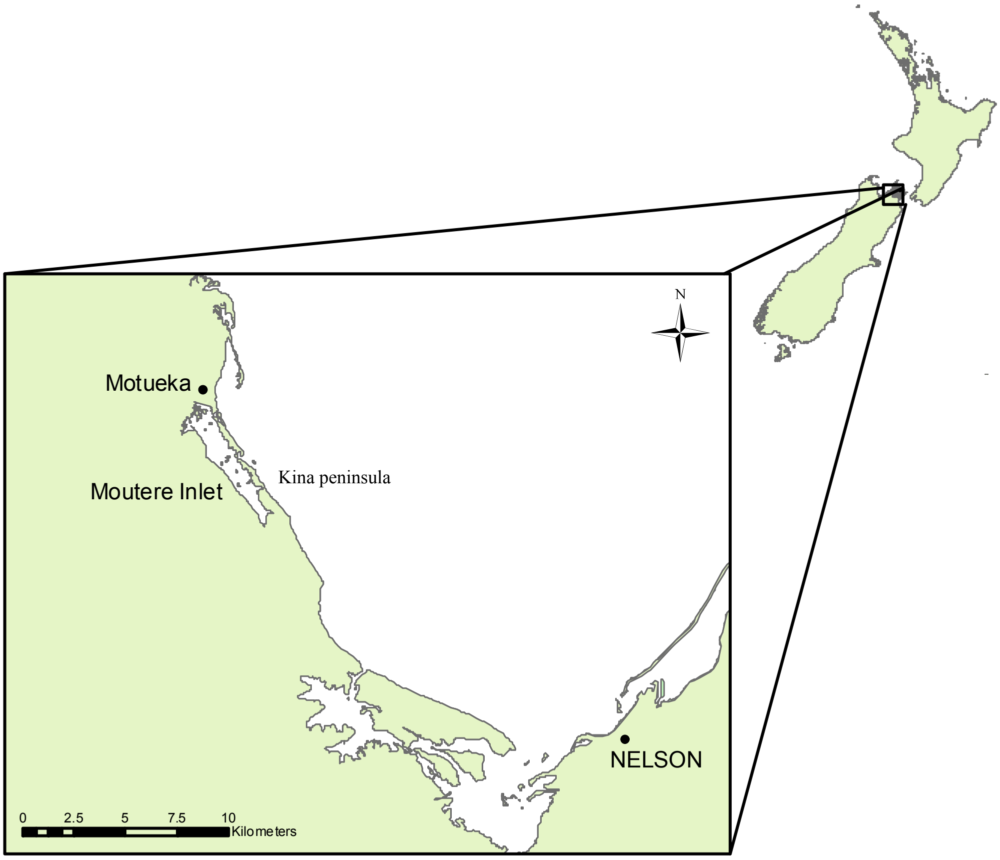

Figure 1. Moutere Inlet location diagram.

2. METHODS

2.1. Sampling procedures

Fine-scale sampling followed the EMP procedures described by Robertson et al. (2002). These are summarised in Figure 2. Two Moutere Inlet study locations were chosen; location A within the south eastern arm and location B within the north western arm (Figure 2). Sand-dominated, unvegetated regions were selected from lower intertidal reaches to be representative of the most common substrate type in the estuary. No attempt was made to select regions of the Inlet that had previously been reported to be in an enriched state (Gillespie et al. 1995) as the objective here was to establish a baseline for sites that are more representative of the estuary as a whole.

Sampling was carried out on the 30th and 31st March 2006. At each location, a 30 x 40 m area containing twelve 10 m^2 grids was marked out. Sediment samples for physical and chemical analyses were scraped from the top 25 mm within each of 10 randomly selected grid squares (*i.e.* 10 replicates per site), returned to the laboratory and stored at -20ºC until analysed. A 0.25 m^2 quadrat was placed randomly within each grid square and photographed. Any visible epibiota (animals or macroalgae) on the sediment surface within the quadrat were identified and counted. Samples for chlorophyll *a* (chl *a*) analyses were collected in order to determine the potential for development of nuisance microalgal blooms. The top 5 mm of sediment was sliced from four 15 mm diameter syringe barrel cores (one from each corner of the quadrat). These were mixed to provide a single composite for each grid square. Animals buried within the sediment matrix (infauna) were collected by inserting a 131 mm diameter core to a depth of at least 150 mm into the sediment. The core contents were gently washed through a 0.5 mm mesh sieve attached to one end of the core and the residual was preserved with 50% ethanol (in seawater and 1% glyoxal) for later sorting, identification and counting. Additional sediment cores were collected with 62 mm diameter Perspex tubes. These were extruded onto a white viewing tray and photographed. Sediment colour profiles were described and the depth of any visible redox discontinuity layer was recorded. Any obvious signs of pollution (*e.g.* sulphide odours, fats, oils, unnatural debris *etc.*) were noted.

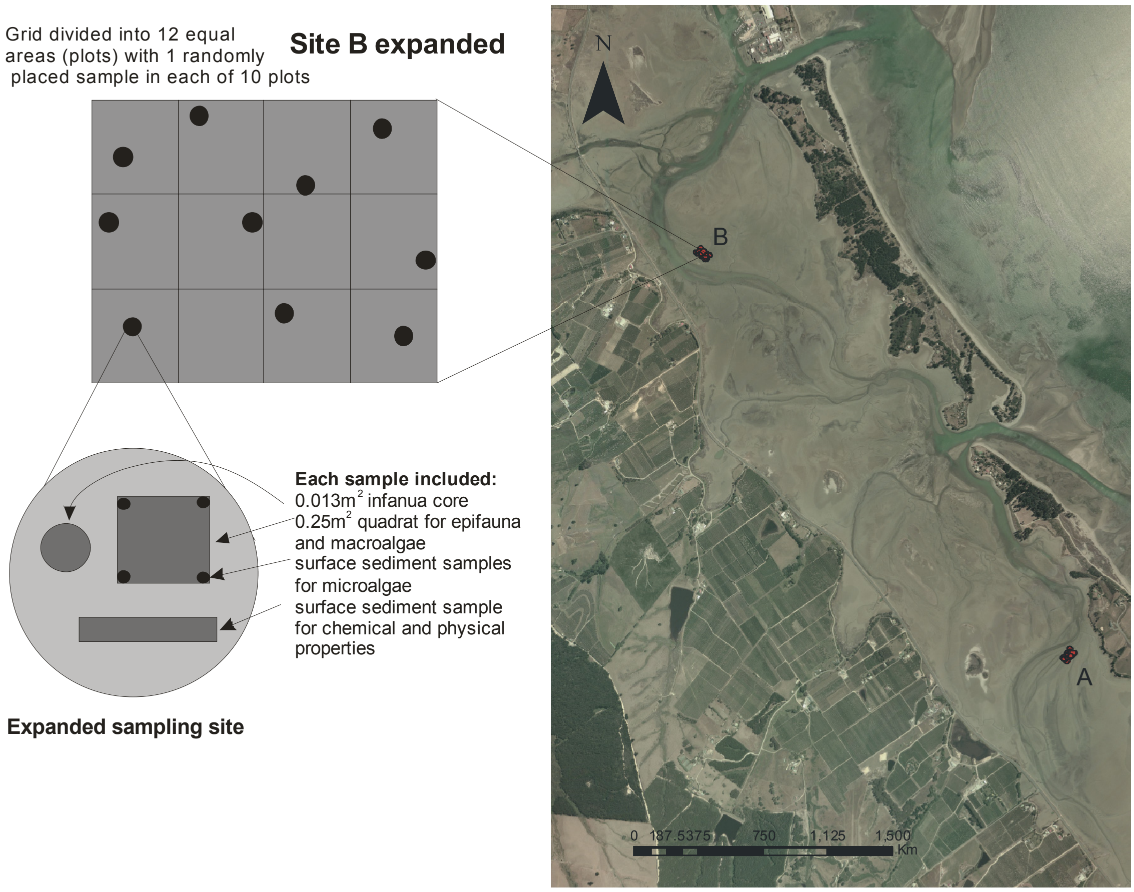

Figure 2. Aerial photograph of Moutere Inlet showing locations of the study sites and the sampling strategy (modified from Robertson et al. 2002).

2.2. Analytical method

Sediments were analysed for a range of indicators to assess the environmental condition of the estuary. Table 1 summarises the analytical methods used and their corresponding detection limits.

Table 1. Analytical methods and detection limits for sediment indicators.

Parameter	Method	Detection Limit
Metals	Perchloric/nitric acid digestion and flame atomic absorption spectrometry	
Cadmium	ASTM 3974 Dig A	0.1 mg kg $^{-1}$
Chromium	ASTM 3974 Dig A	1.0 mg kg $^{-1}$
Copper	ASTM 3974 Dig A	0.5 mg kg $^{-1}$
Nickel	ASTM 3974 Dig A	2.0 mg kg $^{-1}$
Lead	ASTM 3974 Dig A	0.5 mg kg $^{-1}$
Zinc	ASTM 3974 Dig A	0.2 mg kg $^{-1}$
Ash Free Dry Weight	Dry sediment weight loss after combustion at 550 °C (APHA 1999, 20th Edn, modified 2540D + E).	-
Chlorophyll a	Limnology & Oceanography 1967 No 12	-
Grain Size	Wet sieving and calculation of dry weight percentage fractions	-
Total Nitrogen	APHA 20th Edn 4500N C	100 mg m $^{-3}$
Total Phosphorus	ICP-MS Aqua Regia Digest	20 mg kg $^{-1}$
Macroinvertebrates	Microscope enumeration of species retained on a 0.5mm sieve	n/a

When results were below or equal to the analytical detection limit, site and estuary averages were calculated using the detection limit, providing a conservative measure of potential sediment contamination. In this case a "<" symbol was placed in front of the average to indicate that the actual value will be less than the average value calculated. Standard deviations were only calculated where all data were above the analytical detection limit.

2.3. Sediment Quality Guideline application

The ANZECC (2000) Sediment Quality Guidelines have been used, where applicable, to assess and interpret the analytical results. These guidelines present Interim Sediment Quality Guideline-Low (ISQG-Low) and –High (ISQG-High) as two threshold levels under which biological effects are predicted (ANZECC 2000). The lower threshold indicates a possible biological effect while the upper threshold (ISQG-High) indicates a probable biological effect. These trigger values are essentially conservative criteria (*e.g.* for water or sediment quality) that, if complied with, will ensure that specified environmental values are protected. Note, however, that the converse is not necessarily true (*i.e.* exceeding of trigger values does not necessarily suggest environmental damage) hence the intent of these values is to act as a trigger for more intensive assessment if they are not met.

3. RESULTS AND DISCUSSION

3.1. Sediment physical and chemical characteristics

The physical and chemical properties of the two Moutere Inlet sites are described in Appendix 3 and summarised in Table 2.

Table 2. Average sediment physico-chemical and microalgal properties of Moutere Estuary sites.

		Site A	Site B	Overall Estuary Results				ANZECC 2000	
Parameter	Units	Average	Average	Average	SD	Min	Max	ISQC-Low	ISQC-High
Mud	(<63µm)	12.9	10.3	11.6	2.4	8.1	15.3	-	-
Sand	(<2mm & >63µm)	86.6	88.8	87.7	2.4	83	91.2	-	-
Gravel	(>2mm)	0.5	1.0	0.8	0.7	0.1	2.7	-	-
AFDW	% w/w	1.7	1.4	1.6	0.4	0.63	2	-	-
TN	mg/kg	368.0	309.0	338.5	41.1	280	450	-	-
TP	mg/kg	513.4	545.5	529.5	36.7	474	590	-	-
Chl a	mg/g	1.8	1.4	1.6	0.6	0.3	2.4	-	-
Cd	mg/kg	<0.01	<0.01	<0.01	-	<0.01	<0.01	1.5	10
Cr	mg/kg	29.6	33.8	31.7	3.3	26	38	80	370
Cu	mg/kg	6.1	6.0	6.1	0.4	5.3	7	65	270
Ni	mg/kg	58.4	76.1	67.3	9.6	55	81	21	52
Pb	mg/kg	4.6	3.7	4.2	0.6	3.2	5.5	50	220
Zn	mg/kg	25.0	26.8	25.9	2.0	23	33	200	410

Particle grain size

Particle grain size analyses show that both sites were dominated by sand (A = 87 % and B = 89 %). This was expected as the two sites were chosen to be representative of the dominant substrate type (sand) in the estuary.

Nutrient and organic composition

Sediment total nitrogen (TN), total phosphorus (TP) and organic content (AFDW) are indicators of organic nutrient enrichment that are closely linked with sediment grain size characteristics. In general terms, higher nutrient and organic contents are associated with muddier substrata. Indicator concentrations observed during the present survey were generally similar to those of sand-dominated habitats surveyed previously (March 1991) in Moutere Inlet (Table 3). A comparison of these indicators amongst similar sand-dominant sites in other New Zealand estuaries is also provided in Table 3. The comparative locations extend from the relatively natural Delaware Estuary (largely native and exotic forestry catchment), through moderately enriched sites affected by a variety of nutrient sources. The comparisons show that concentrations at the two Moutere study sites were within a range typical for relatively undisturbed to slightly enriched sandy sites in other New Zealand estuaries, although TP concentrations were near the high end of the range. Low TN:TP ratios at Moutere sites A and B (*i.e.* 1.6 and 1.3, respectively) compared to the optimum of 16:1 for microalgal growth suggest that nitrogen is the more limiting of the two and that phosphorous alone will not stimulate plant production. Thus, in terms of sediment nutrient and organic matter composition, centrally located sites in Moutere Inlet do not appear to be under serious threat with regard to over enrichment. We note, however, that other indicators such as incidence of macroalgal blooms also need to be considered in order to effectively assess the enrichment status of the Inlet.

Table 3. Comparison of average physico-chemical characteristics of sediments from the Moutere Inlet monitored in 2006 and 1991, sandy sites from the estuaries examined in the EMP study (2002) and some other New Zealand estuarine sites (pre 2001).

Location	Sand %	Mud %	TN $mg\ kg^{-1}$	TP $mg\ kg^{-1}$	AFDW %
Moutere Inlet					
Present Study	88	12	339	530	1.6
1991 study (sites 1, 2, 4, 9, 13)[a]		<20	387	356	1.5
Other NZ Estuaries					
2001 Comparisons					
Ohiwa (sites B, D)[b]	87	11	524	248	1.7
Ruataniwha (sites A,B,C)[b]	86	9	263	458	1.2
Waimea (sites B,C)[b]	87	13	304	377	1.0
Havelock (sites A,B)[b]	77	19	422	330	1.6
Avon-Heathcote (sites A, B, C)[b]		5	301	327	1.0
Waimea Inlet (Bell Isl site 4)[c]		1.8	668		1.4
Pre 2001 Comparisons					
Delaware Inlet (sites 1, 2, 3, 5)[d]		7	303	540	2.3
Nelson Haven (sites 1-6)[e]		23	347	403	1.8

a Slightly modified estuary near Motueka, affected by food processing industry wastes and urban runoff (Gillespie et al. 1995).
b Subsets of sandy sites from an inter-estuary comparison (Robertson et al. 2002).
c Site slightly affected by a sewerage wastewater outfall.
d Largely undisturbed, moderately productive estuary near Nelson (Gillespie & MacKenzie 1990).
e Slightly modified estuary at Nelson affected by urban, port and marina development (Gillespie & MacKenzie 1990).

Microalgal biomass

Microalgae, which colonise the entire benthic surface area of a tidal inlet, are the major primary producers over large areas of sand and mud flats (Gillespie 1983). They consist primarily of diatoms but in some instances may include euglenoids and/or cyanobacteria. Microalgal production rates per m^2 are generally low although they provide a significant beneficial contribution to the coastal food web considering the large area that they occupy. Under conditions of excessive enrichment, however, noticeable green to olive coloured mats may develop to a level that can result in a degradation of estuarine health/condition.

No potentially problematic microalgal growths were observed during the baseline field assessment (see photographic records in Appendix 1). This was consistent with the relatively low sediment chl *a* concentrations that were used as a proxy for microalgal biomass (see Table 2). Average chl *a* concentrations at sites A and B were 1.8 and 1.4 $mg\ g^{-1}$, respectively.

Significant mat development would not be indicative at concentrations less than about 5 mg g^{-1}.

Core profiles

No black anoxic zones or hydrogen sulphide (H_2S) odours were noted at the sites, however a gradation of colouration from light grey-brown at the surface to darker grey was observed (see photographic records in Appendix 2). Based on the observed gradient, the average redox discontinuity depth (RDD) ± sd at site A was 2.6 ±0.5 cm and at site B it was 1.9 ±0.6cm. These observations indicate slight to moderate enrichment that would be typical for relatively productive estuaries in the Nelson region. Under highly enriched conditions the RDD would be expected to occur at or very near the surface of the sediment and the objectionable "rotten egg" odour of hydrogen sulphide would be evident.

Metals

In terms of potentially toxic contaminants, both sites showed very low levels of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn), with all values well below ANZECC (2000) ISQG-Low trigger values. The nickel (Ni) levels were above ANZECC (2000) ISQG-High trigger values. This was probably due to erosional input of sediments containing naturally high Ni concentrations. Elevated sediment Ni concentrations have been observed in other coastal and estuarine locations in the Nelson/Marlborough region and linked to natural catchment geological characteristics (Robertson et al. 2002, Gillespie & Asher 2004). For example, a naturally occurring mineral belt in the upper Motueka River catchment results in the periodic discharge of Ni-contaminated sediments into Tasman Bay just to the north of Moutere Inlet (Gillespie unpub.). The concentrations of other metals found were within the range reported for a variety of other New Zealand estuaries, and much lower than values reported for some overseas estuaries (Table 4).

Table 4. Average concentrations of heavy metals in sediments from the Moutere Inlet monitored in 2006 and 1991, the eight estuaries examined in the EMP study (Robertson et al. 2002) and a selection of New Zealand and overseas estuaries that have been contaminated to varying degrees. Some values drawn from other studies are approximate as they were estimated from figures.

		Cd mg kg-1	Cr mg kg-1	Cu mg kg-1	Pb mg kg-1	Ni mg kg-1	Zn mg kg-1
	ANZECC (2000) ISQG-Low	*1.5*	*80*	*65*	*50*	*21*	*200*
	ANZECC (2000) ISQG-High	*10*	*370*	*270*	*220*	*52*	*410*
Present study 2006	**Moutere Inlet 2006**	**<0.01**	**31.7**	**6.1**	**4.2**	**67.3**	**25.9**
Previous monitoring	Moutere Inlet 1991						
EMP study	Otamatea Arm	0.4	20.5	13.8	11.4	9.4	54.5
	Ohiwa	0.1	7.4	4	3.4	3.9	27.7
	Ruataniwha	0.1	24	7.1	4.7	13.7	37.5
	Waimea	0.3	67.6	9.6	7.4	72.5	41.8
	Havelock	0.3	48.8	10.7	5.6	26.5	43
	Avon-Heathcote	0.1	15.6	3.2	6.3	6.6	38.3
	Kaikorai	0.1	48.4	16.8	45.3	15.6	184.2
	New River	0.1	11.1	3.8	0.7	5	17.1
Other NZ sites	Tamaki A (E1) [a]		14.5	27.8	132.1	56.9	136.1
	Tamaki B (E2) [a]		20.6	26.1	72.9	6.6	167
	Tamaki C (E3) [a]		17.3	29.4	69.7	9.3	173
	Tamaki D (E4)[a]		35.9	38.5	145.2	12.8	233
	Manukau (rural catch)[b]	0.03		20	9	15	114
	Manukau (industrial catch) [b]	0.25		90	58	14	285
	Waitemata Harbour [h]	<0.5	52	60	65	28	161
	Lampton Harbour, Wellington [c]		91	68	183	21	249
	Porirua Harbour, Wellington [d]		20	48	93	20	259
	Aparima Estuary[e]	0.067	15	12	11	10	49
	Mataura Estuary[e]	0.024	7.1	6.6	6.2	6	27
Overseas sites	Delaware Bay, USA [f]	0.24	27.8	8.3	15		49.7
	Lower Chesapeake Bay, USA[f]	0.38	58.5	11.3	15.7		66.2
	San Diego Harbour, USA [f]	0.99	178	218.7	51		327.7
	Salem Harbour, USA [f]	5.87	2296.7	95.1	186.3		238
	Rio Tinto Estuary, Spain[e]	4.1		1400	1600		3100
	Restronguet Estuary, UK[e]	12	1060	4500	1620		3000
	Nervión Estuary, Spain[g]	0.2-15	50-300	50-350	50-400	20-100	200-2000
	Sorfjord, Norway[f]	850		12000	30500		118000

Sources: a Thompson (1987), b Roper et al. (1988), c Stoffers et al. (1986), d Glasby et al. (1990), e Robertson (1995), f Kennish (1997), g Jezus Belzunce et al. (2001).

3.2. Benthic animal communities

Infauna (animals living within the sediment)

The composition of infauna in the Moutere Inlet (Table 5) is fairly typical of most New Zealand estuaries as it is characterised by polychaetes and bivalves (Robertson et al. 2002). Gastropods (snails), nemertea (ribbonworms), cumaceans (small crustaceans), and anthozoa (anemones) were also common.

Table 5. Summary of the top 15 infaunal species, in order of abundance, from the two sampling sites in Moutere Inlet. Estuary and site data are presented as average species abundance per core (0.0133 m^2).

Group	Taxa	Common Name	Feeding Type	Estuary	SiteA	SiteB
Polychaeta	*Prionospio sp.*		Surface deposit feeder	26.9	20.5	33.3
Polychaeta	*Heteromastus filiformis*		Infaunal deposit feeder	12.6	17.7	7.5
Polychaeta	Paraonidae		Infaunal deposit feeder	9.3	0.8	17.8
Bivalvia	*Macomona liliana*	Wedge shell, Hanikura	Infaunal suspension feeder	7.4	6.7	8.1
Bivalvia	*Austrovenus stutchburyi (0- 5mm)*	Cockle (0- 5mm)	Infaunal deposit feeder	6.1	9.7	2.5
Gastropoda	*Zeacumantus subcarinatus*	Small Mud Snail	Microalgal & detrital grazer	2.6	2.2	2.9
Bivalvia	*Nucula hartvigiana*	Nut Shell	Infaunal deposit feeder	2.6	1.6	3.5
Anthozoa	*Edwardsia sp.*	Burrowing anemone	Filter and deposit feeder	1.6	1.6	1.6
Polychaeta	*Nicon aestuariensis*	Rag worm	Omnivorous	1.5	0.0	3.0
Polychaeta	*Aglaophamus macroura*		Infaunal carnivore	1.4	2.7	0.0
Gastropoda	*Cominella glandiformis*	Mud Flat Whelk	Carnivore & scavenger	1.1	1.1	1.0
Nemertea	Nemertea	Ribbon worms	Carnivorous	1.0	0.8	1.1
Cumacea	Cumacea	Cumaceans	Infaunal filter or deposit feeder	1.0	1.3	0.6
Bivalvia	*Soletellina sp.*		Infaunal suspension feeder	0.8	0.6	0.9
Polychaeta	Maldanidae	Bamboo Worms	Infaunal deposit feeder	0.8	1.1	0.4

Infaunal species richness was high with 49 taxa present in total. This is relatively diverse compared to those estuaries studied by Robertson et al. (2002) which ranged from 13 to 53 taxa per core (average 37). Although some species of opportunistic polychaetes were present that can indicate enriched conditions (*e.g. Heteromastus filiformis*), their abundance was not unusually high. *Capitella capitata,* which is an indicator of highly enriched conditions when found in high numbers, was present but very rare (*i.e.* only one individual was observed). A full list of the taxa observed in the Moutere samples is provided in Appendix 4.

Epibiota (plants and animals visible at the sediment surface)

In general, epifauna were dominated by snails and cockles, with limpets, anemones and crabs only present in low numbers (Table 6). A total of seven epifaunal taxa were present. This reflects the pattern commonly found in other New Zealand estuaries (Robertson et al. 2002).

Table 6. Summary of epifaunal species, in order of abundance, sampled in Moutere Inlet. Estuary and individual site data are presented as average species abundance per quadrat ($0.25m^2$).

Group	Taxa	Common Name	Feeding Type	Estuary	Site A	Site B
Gastropoda	*Zeacumantus lutulentus*	Spire shell	Microalgal & detrital grazer	6.2	2.3	10
Gastropoda	*Diloma surostrata*	Mudflat topshell	Microalgal & detrital grazer	5.8	2.4	9.2
Bivalvia	*Austrovenus stutchburyi*	Cockle	Infaunal deposit feeder	3.4	6	0.7
Gastropoda	*Notoacmea helmsi*	Estuarine limpet	Microalgal & detrital grazer	1.5	0.8	2.1
Anthozoa	*Anthopleura aureoradiata*	Mudflat anemone	Filter feeder	0.9	1.5	0.2
Gastropoda	*Cellana radians*	Limpet	Microalgal & detrital grazer	0.1	0	0.2
Crustacea	*Pagurus* sp	Hermit crab	Carnivore and scavenger	0.1	0.1	0
			Total	17.75	13.1	22.4

Macroalgae were rare at the sites surveyed. Two species, *Gracilaria* sp. and *Ulva* sp. were observed in very small amounts. However, macroalgal production and coverage can vary considerably both spatially and temporally. The species observed and some others occurring within the Inlet (notably *Enteromorpha* spp.) may have the potential to reach nuisance proportions. This nuisance potential could not adequately be assessed through the one point-in-time survey reported here. See Clark et al. (2006) for the broadscale distributions of macroalgal beds within the inlet.

Further analysis of the infauna and epifaunal community patterns (*e.g.* univariate and multivariate assessments of community characteristics) are beyond the scope of the current report, but will be addressed in conjunction with subsequent monitoring surveys.

4 SUMMARY

The two Moutere Inlet study locations were comparable to a number of other moderately productive sand-dominated estuarine sites in New Zealand. Nutrient and organic contents of the sediments were not unusually elevated although TP concentrations were near the high end of the range. Low TN:TP atomic ratios suggest that nitrogen was the more limiting plant nutrient and phosphorous alone would not result in symptoms of over enrichment. Core profiles showed no signs of oxygen depletion (*e.g.* black anoxic zones or sulphide odours) but they were typical of other estuarine sites that have been affected by low to moderate sources of enrichment. No nuisance-level microalgal mat development or excessive macroalgal coverage was observed at the time of the survey.

Sediment cadmium, chromium, copper, lead and zinc concentrations were all well below various guideline levels that are often used to indicate potential biological effects. Nickel concentrations, however, exceeded ANZECC (2000) sediment quality guideline levels indicating “probable” biological effects. Elevated nickel concentrations are not unusual for estuaries and near shore coastal sediments in the Nelson region, and can be linked to erosional input from natural catchment sources.

Animal communities were typical of those observed at sandy sites at a variety of other New Zealand estuaries that are affected (but not necessarily adversely) by low to moderate sources of enrichment. Infauna communities were relatively diverse and dominated by polychaetes and bivalves with gastropods, nemertea, cumaceans and anthozoa also common. Although some species of opportunistic polychaetes were present that can indicate enriched conditions (*e.g. Heteromastus filiformis*), their abundance was not unusually high. *Capitella capitata,* which can indicate highly enriched conditions when found in high densities, was not present in significant numbers at either site (*i.e.* only one individual was observed). Epifauna communities were dominated by snails and cockles with low numbers of limpets, anemones and crabs.

These results indicate overall that, with regard to the reference sites selected, the Moutere Inlet ecosystem remains in a relatively healthy and functional condition. However, indications of low to moderate enrichment suggest that further investigation (*e.g.* at peripheral muddy sites) and/or monitoring of nutrient inputs would be warranted. Some uncertainties also remain with regard to the potential for nuisance macroalgal blooms to develop in the Inlet as high densities are known to occur periodically.

4. ACKNOWLEDGEMENTS

Physical and chemical analyses were carried out by Cawthron’s Laboratory Services Section. Rod Asher carried out infauna analyses and Barry Robertson and Leigh Stevens assisted with the field assessment.

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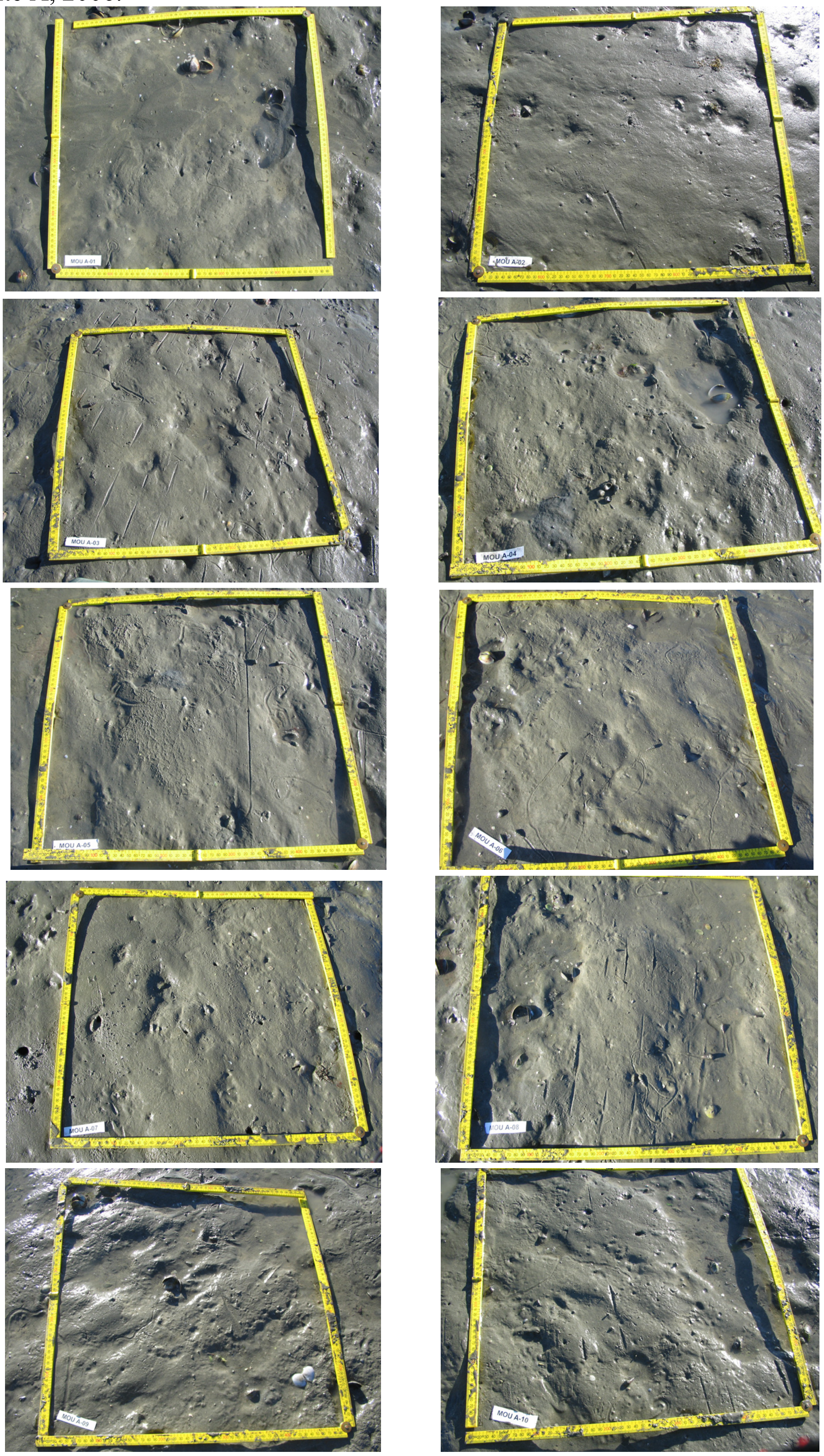
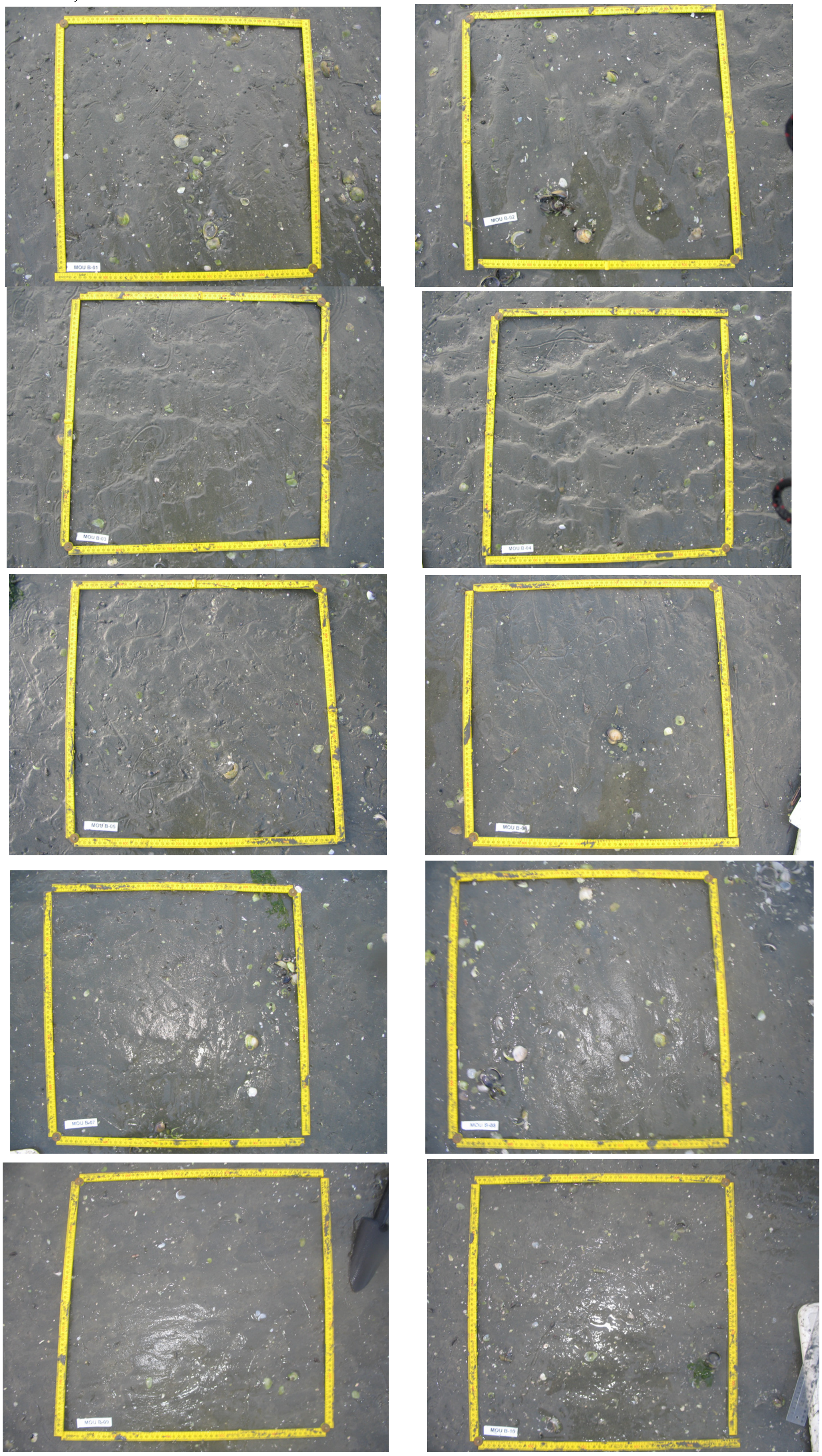
6. APPENDICES

Appendix 1. Quadrat photographs

Moutere Inlet, site A, 2006.

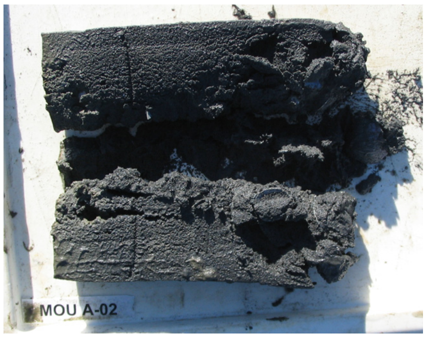


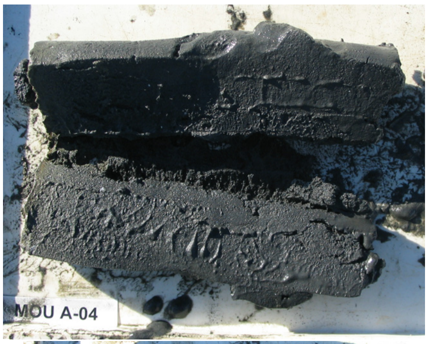
Moutere Inlet site B, 2006.



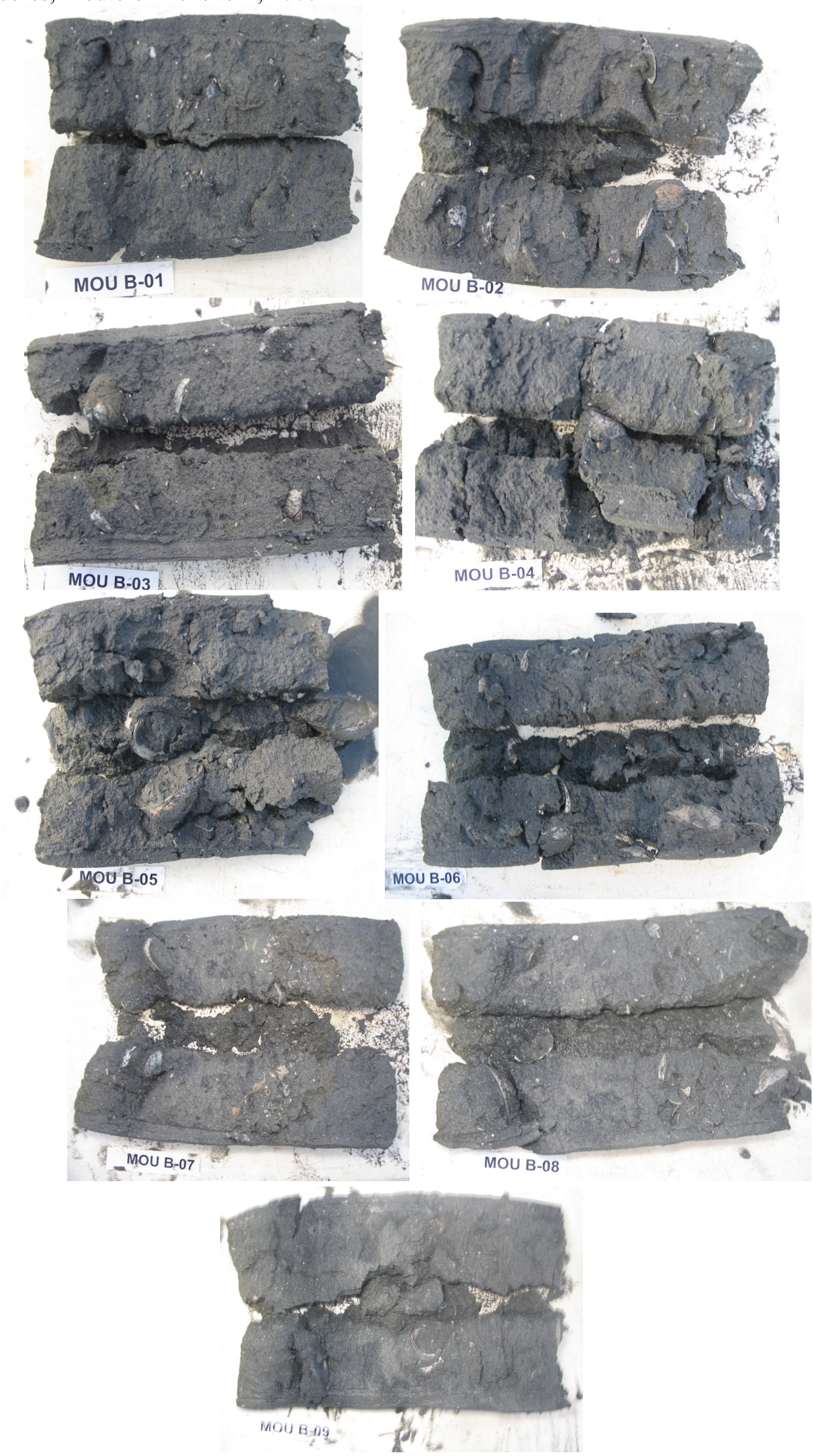
Appendix 2. Sediment cores

Moutere Inlet site A, 2006





Sediment cores, Moutere Inlet site B, 2006



Appendix 3. Physico-chemical and microalgal properties of sediments from Moutere Inlet

Moutere Inlet	AFDW % w/w	Chl a ug/g	Mud (<63µm)	Sands (<2mm & >63µm)	Gravel (>2mm)	Cd mg/kg	Cr mg/kg	Cu mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	TN mg/kg	TP mg/kg
A-01	0.98	2	15.1	84.8	0.1	<0.1	30	6.1	61	4.8	25	390	549
A-02	1.6	2.4	12.3	87.1	0.6	<0.1	33	5.8	60	4.1	25	360	587
A-03	1.9	2.2	14.7	84.9	0.4	<0.1	26	5.8	56	4.3	28	450	479
A-04	1.6	1.7	13.5	86.0	0.6	<0.1	29	6.0	58	4.7	25	360	481
A-05	1.9	1.8	14.4	84.3	1.3	<0.1	28	6.4	59	5.5	25	350	496
A-06	1.8	2.2	11.4	88.5	0.1	<0.1	27	6.0	57	4.8	25	330	502
A-07	1.9	2	12.2	87.8	<0.1	<0.1	30	7.0	58	4.6	25	350	561
A-08	1.9	1.9	13.2	86.7	0.1	<0.1	33	6.8	60	4.8	25	350	474
A-09	1.9	0.32	9.2	89.7	1.1	<0.1	31	6.0	60	4.5	24	360	519
A-10	2.0	1.9	13.3	86.3	0.4	<0.1	29	5.5	55	4.3	23	380	486
Average	1.7	1.8	12.9	86.6	0.5	<0.01	29.6	6.1	58.4	4.6	25.0	368.0	513.4
SD	0.3	0.6	1.8	1.7	0.4	0.0	2.3	0.5	2.0	0.4	1.2	33.3	39.4
Min	0.98	0.32	9.2	84.3	0.1	-	26	5.5	55	4.1	23	330	474
Max	2	2.4	15.1	89.7	1.3	<0.01	33	7	61	5.5	28	450	587
B-01	1.8	0.49	10.8	87.9	1.3	<0.1	28	5.3	75	3.2	24	310	548
B-02	0.92	1.9	10.5	89.1	0.4	<0.1	33	6.0	80	3.5	27	310	590
B-03	0.71	1.6	8.7	90.9	0.3	<0.1	36	6.1	80	3.7	27	340	545
B-04	0.63	2.1	8.1	91.2	0.7	<0.1	33	5.7	80	3.6	26	280	544
B-05	1.3	2.3	10.1	87.2	2.7	<0.1	37	5.8	73	3.4	26	320	539
B-06	1.6	1.2	8.6	90.0	1.3	<0.1	32	5.7	74	3.5	26	280	516
B-07	1.7	1.3	8.6	90.7	0.7	<0.1	35	6.3	78	4.1	26	340	500
B-08	1.7	1.7	8.8	91.0	0.2	<0.1	38	6.3	81	4.0	27	280	544
B-09	1.8	0.56	13.0	86.5	0.6	<0.1	33	6.6	70	3.7	26	310	544
B-10	1.6	1.1	15.3	83.0	1.7	<0.1	33	6.4	70	4.0	33	320	585
Average	1.4	1.4	10.3	88.8	1.0	<0.01	33.8	6.0	76.1	3.7	26.8	309.0	545.5
SD	0.5	0.6	2.3	2.6	0.8	0.0	2.9	0.4	4.3	0.3	2.3	22.8	26.9
Min	0.63	0.49	8.1	83	0.2	-	28	5.3	70	3.2	24	280	500
Max	1.8	2.3	15.3	91.2	2.7	<0.01	38	6.6	81	4.1	33	340	590

Appendix 4. Infauna and epibiota found in Moutere Inlet in 2006.

General group	Taxa	Common Name	Feeding Type
Anthozoa	*Anthopleura aureoradiata*	Mud flat anemone	Filter feeder
Anthozoa	*Edwardsia* sp.	Burrowing anemone	Filter and deposit feeder
Nemertea	Nemertea	Ribbon worms	Carnivorous
Nematoda	Nematoda	Roundworm	
Gastropoda	*Amphibola crenata*	Mud Snail	Microalgal grazer
Gastropoda	*Cellana radians*	Limpet	Microalgal & detrital grazer
Gastropoda	*Cominella glandiformis*	Mud Flat Whelk	Carnivore & scavenger
Gastropoda	*Diloma surostrata*	Mudflat topshell	Microalgal & detrital grazer
Gastropoda	*Diloma zelandica*	Mudflat topshell	Microalgal & detrital grazer
Gastropoda	*Micrelenchus tenebrosus*	Grazing snail	Microalgal grazer
Gastropoda	*Notoacmea helmsi*	Estuarine limpet	Microalgal & detrital grazer
Gastropoda	*Zeacumantus lutulentus*	Spireshell	Microalgal & detrital grazer
Gastropoda	*Zeacumantus subcarinatus*	Small Mud Snail	Microalgal & detrital grazer
Opisthobranchia	*Haminoea zelandiae*	Bubble shell	Microalgal & detrital grazer
Bivalvia	*Arthritica bifurca*	Small bivalve	Infaunal deposit feeder
Bivalvia	*Austrovenus stutchburyi (0-5mm)*	Cockle (0-5mm)	Infaunal deposit feeder
Bivalvia	*Austrovenus stutchburyi (06-10mm)*	Cockle (6-10mm)	Infaunal deposit feeder
Bivalvia	*Austrovenus stutchburyi (11-20mm)*	Cockle (11-20mm)	Infaunal deposit feeder
Bivalvia	*Austrovenus stutchburyi (21-30mm)*	Cockle (21-30mm)	Infaunal deposit feeder
Bivalvia	*Austrovenus stutchburyi (31+mm)*	Cockle (>31mm)	Infaunal deposit feeder
Bivalvia	*Macomona liliana*	Wedge shell, Hanikura	Infaunal suspension feeder
Bivalvia	*Nucula hartvigiana*	Nut Shell	Infaunal deposit feeder
Bivalvia	*Soletellina* sp.		Infaunal suspension feeder
Polychaeta: Capitellidae	*Capitella capitata*		Infaunal deposit feeder
Polychaeta: Capitellidae	*Heteromastus filiformis*		Infaunal deposit feeder
Polychaeta: Maldanidae	Maldanidae	Bamboo Worms	Infaunal deposit feeder
Polychaeta: Orbiniidae	*Orbinia papillosa*		Infaunal deposit feeder
Polychaeta: Paraonidae	Paraonidae		Infaunal deposit feeder
Polychaeta: Glyceridae	Glyceridae	Blood worm	Infaunal carnivore & deposit feeder
Polychaeta: Nephtyidae	*Aglaophamus macroura*		Infaunal carnivore
Polychaeta: Nereididae	*Nicon aestuariensis*	Rag worm	Omnivorous
Polychaeta: Magelonidae	*Magelona dakini*		Surface deposit feeder
Polychaeta: Spionidae	*Aonides* sp.		Surface deposit feeder
Polychaeta: Spionidae	*Boccardia* sp.		Surface deposit feeder
Polychaeta: Spionidae	*Polydora* sp.		Surface deposit & filter feeder
Polychaeta: Spionidae	*Prionospio* sp.		Surface deposit feeder
Polychaeta: Spionidae	*Scolecolepides benhami*		Surface deposit feeder
Polychaeta:	*Scolelepis* sp.		Surface deposit & filter

Spionidae feeder

Appendix 4 cont.

General group	Taxa	Common Name	Feeding Type
Polychaeta: Cirratulidae	Cirratulidae		Deposit feeder
Polychaeta: Pectinariidae	*Pectinaria australis*	Sand mason worm	Infaunal deposit feeder
Mysidacea	Mysidacea	Mysid shrimp	Filter and deposit feeder
Cumacea	Cumacea	Cumaceans	Infaunal filter or deposit feeder
Amphipoda	Amphipoda a	Amphipods	Epifaunal scavenger
Amphipoda	Amphipoda b	Amphipods	Epifaunal scavenger
Amphipoda	Amphipoda c	Amphipods	Epifaunal scavenger
Decapoda	*Callianassa filholi*	Ghost Shrimp	
Decapoda	*Halicarcinus whitei*	Pill-box Crab	Eats small organisms & some weed
Decapoda	*Helice crassa*	Tunnelling, Mud Crab	Deposit feeder & scavenger
Decapoda	*Macrophthalmus hirtipes*	Stalk-eyed Mud Crab	Deposit feeder & scavenger
Decapoda		Hermit Crab	Carnivore and scavenger
Insecta	Dolichopodidae larvae	Small fly larvae	Algal grazer
Holothuroidea	*Trochodota dendyi*	Sea cucumber	Epifaunal deposit feeder
Chlorophyta	*Ulva* sp.	Green seaweed	Photosynthetic
Rhodophyta	*Gracilaria* sp.	Agar seaweed	Photosynthetic