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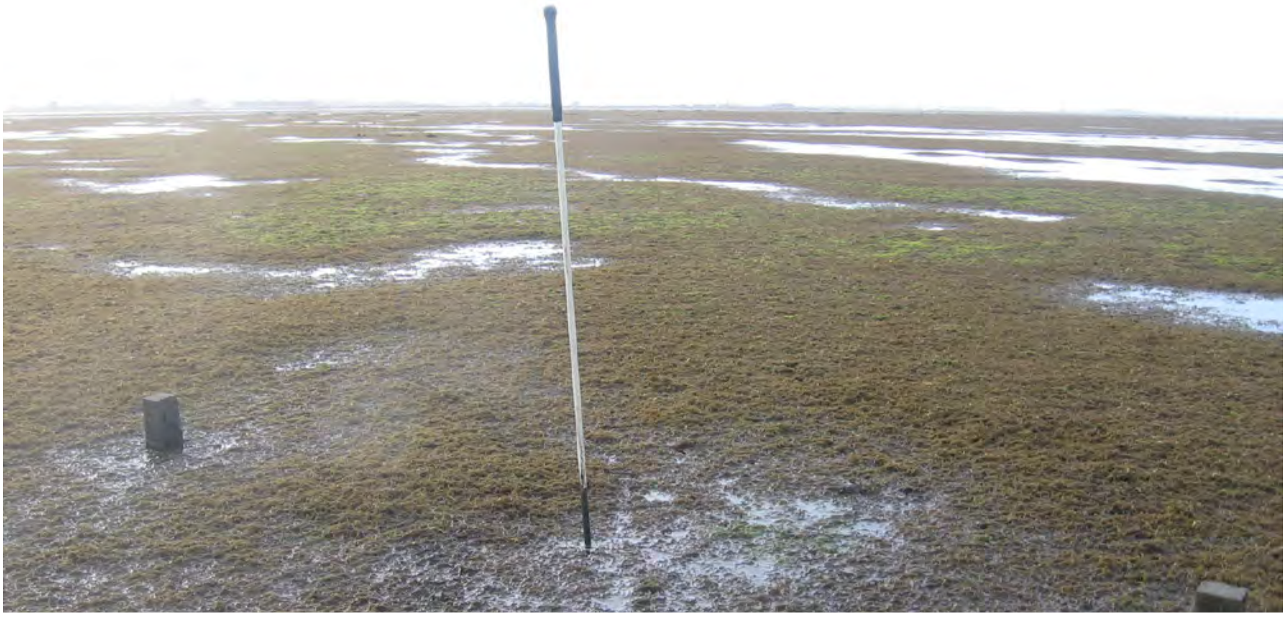
Waihopai Arm - New River Estuary

Preliminary Synoptic Assessment 2010-2011

Prepared for **Environment Southland**

August 2011

Cover Photo: Waihopai Arm, New River Estuary.



Site for synoptic monitoring in Waihopai Arm, New River Estuary.

Waihopai Arm - New River Estuary

Preliminary Synoptic Assessment 2010-2011

Prepared for
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By

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WAIHOPAI ARM PRELIMINARY SYNOPTIC ASSESSMENT 2011

New River Estuary is a large "tidal lagoon" type estuary (area 4,100ha), discharging to the east end of Oreti Beach. Situated at the confluence of the Oreti and Waihopai Rivers, it drains a primarily agricultural catchment but also receives stormwater and wastewater discharges from the city.

The results of annual broad scale macroalgal monitoring (2002-2011) has shown that the New River Estuary has extensive eutrophication and sedimentation problems (Stevens and Robertson 2011), particularly in natural settling areas (e.g. Waihopai Arm and Daffodil Bay). However, these problems have not been reflected in the fine scale monitoring results. The reason has been attributed to the inadequate representation of overall estuary condition by the existing three fine scale sites (Robertson and Stevens 2010). This situation only became apparent as catchment nutrient loads increased over the last 10 years and resulted in eutrophication of sensitive arms. In order to assess this sampling issue, a preliminary synoptic fine scale assessment was undertaken in the Waihopai Arm in February 2011 and is the subject of this report.

The assessment used a method of selecting a representative 10x10m square area of habitat in the Waihopai Arm (Site NR W Figure 1) and taking one composite sample for physical and chemical analyses and three core samples for macroinvertebrate analysis (details Appendices 1 and 2).

RESULTS

A summary of the 25 February 2011 synoptic monitoring results is presented alongside the long term fine scale monitoring results (2001-2005 baseline and 2010 results - Robertson and Stevens 2010) in Table 1. Detailed macroinvertebrate results are presented in Table 2. The results and discussion section is divided into three subsections based on the key estuary problems that the synoptic fine scale monitoring is addressing: eutrophication, sedimentation, and toxicity.

Table 1. Physical, chemical and macrofauna results for main basin New River Estuary (2001-2010 as means) and synoptic samples from Waihopai Arm New River Estuary (2011 - one chemical sample and 3 macroinvertebrate core samples).

Year	Site	RPD	TOC	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Abundance	No. of Species
		cm	%				mg/kg								No./m2	No./core
2001	NR B	3	0.30	1.2	98.8	0.1	0.100	8.4	3.6	0.7	4.3	15.4	<250	216	4131	7.7
	NR C	2	0.60	2.2	97.6	0.2	0.100	14.9	4.6	0.6	6.0	20.0	<250	365	3156	10.9
	NR D	3	0.28	1.2	98.2	0.6	0.100	12.3	3.6	0.5	5.2	17.4	<250	232	9594	8.8
2003	NR B	3	0.40	1.0	99.0	0.1	0.110	7.4	3.2	3.0	3.5	12.6	140	205	5085	10.3
	NR C	2	0.48	2.6	97.4	0.1	0.180	15.9	4.6	4.3	8.2	19.6	122	393	2888	12.0
	NR D	3	0.40	1.3	97.9	0.8	0.120	10.1	3.4	3.9	5.2	15.0	127	231	6338	8.9
2004	NR B	3	0.45	0.8	99.2	0.1	1.000	5.5	2.5	1.1	3.9	47.1	128	208	1343	6.6
	NR C	2	0.55	2.5	97.0	0.5	1.000	9.7	3.9	1.8	6.5	54.4	164	397	3548	10.7
	NR D	3	0.43	0.8	98.8	0.4	1.000	6.6	2.6	1.4	4.6	57.2	158	233	6143	10.6
2005	NR B	3	0.48	4.1	95.9	0.1	0.050	8.1	3.4	5.8	1.7	15.4	286	260	13598	9.5
	NR C	2	0.54	5.7	94.2	0.1	0.050	11.4	4.5	7.8	2.3	22.0	263	415	6750	12.2
	NR D	3	0.29	1.9	98.0	0.1	0.050	8.2	3.0	5.8	1.8	24.7	166	256	3293	6.4
2010	NR B	2	0.17	2.5	97.5	<0.1	0.018	7.6	3.6	5.5	1.5	16.7	<500	250	1800	8.3
	NR C	1	0.24	6.1	93.5	0.5	0.023	10.5	4.6	7.4	2.0	21.0	<500	380	2962	11.8
	NR D	2	0.22	4.6	94.9	0.5	0.028	10.3	4.3	7.1	2.1	21.0	<500	330	8175	9.9
2011	NR W	0	4	95	4.7	0.3	0.153	33	25	30	14.7	113	5900	1200	NA	NA

Figure 1. Location of Waihopai Arm site NR W, and other sites in New River Estuary (Photo LINZ).

Waihopai Arm - Photographs of three types of habitat sampled for macroinvertebrates.

Site NR W1 with fresh macroalgal layer

Site NR W2 with decaying macroalgal layer

Site NR W3 with no macroalgal layer

Table 2. Macrofauna results for Waihopai Arm, New River Estuary (2011) (3 core samples).

Group	Species	NR W 1 (fresh macroalgal layer)	NR W2 (decaying macroalgal layer)	NR W3 (no macroalgal layer)
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	1		
	Nicon aestuariensis	1		
	Scolecolepides benhami	11		
OLIGOCHAETA	Oligochaeta			11
GASTROPODA	*Amphibola crenata*	1		
	Potamopyrgus antipodarum	5		
	Potamopyrgus estuarinus	6		
BIVALVIA	*Arthritica sp.#1*	1		
CRUSTACEA	Amphipoda sp.#1	21		4
	Amphipoda sp.#7	25	12	5
	Exosphaeroma planulum	1		
	Macrophthalmus hirtipes	1		
	Paracorophium excavatum	61		10
	Total species in sample	12	1	4
	Total specimens in sample	135	12	30
Invertebrate Mud Tolerance Rating		5.6	7	6
Invertebrate Organic Enrichment Tolerance Rating		3	7	5

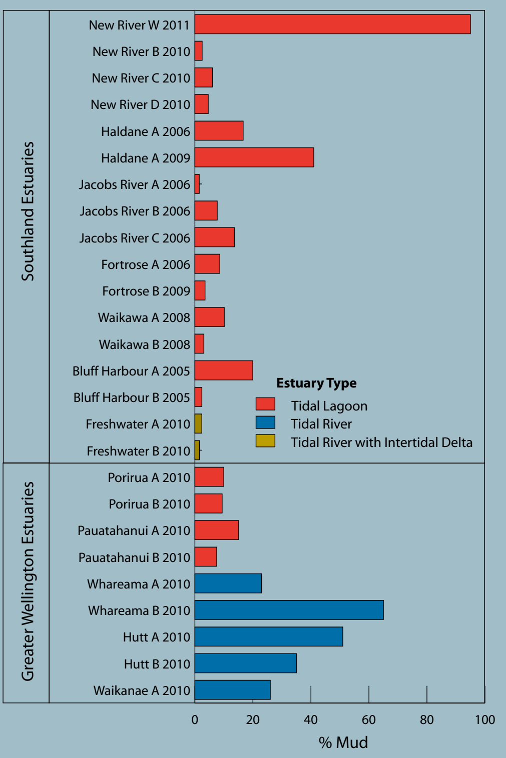


Figure 2. Percent mud content at fine scale monitoring sites, Southland and Greater Wellington estuaries.

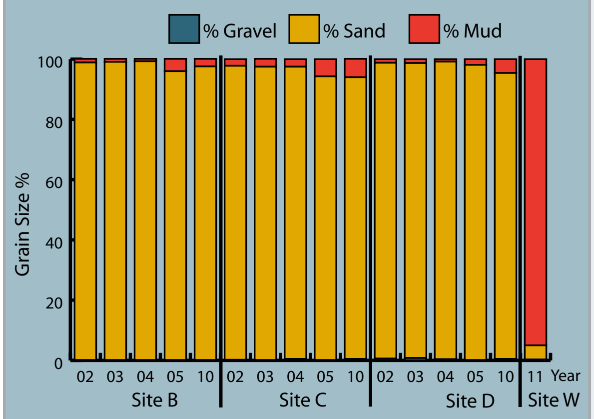


Figure 3. Grain size, New River Estuary.

SEDIMENTATION

Accelerated soil erosion from developed catchments is a major issue for tidal lagoon estuaries in New Zealand as they form a sink for fine suspended sediments. NZ estuaries are particularly sensitive to increased muddiness given the facts that they are generally sand dominated, have a diverse and healthy biology, and a short history of catchment development. Increased muddiness results in reduced sediment oxygenation, production of toxic sulphides, increased nuisance macroalgal growth and a shift towards a degraded invertebrate and plant community. Such a change reduces feeding grounds and habitat for bird and fish species. Unless the input of fine sediment is reduced to a level below the assimilative capacity of the estuary then they will rapidly infill, high value habitat will be lost and their value for fish, birdlife and humans greatly reduced.

Sediments containing high mud content (i.e. around 30% mud with a grain size < 63µm) are now typical in NZ estuaries that drain developed catchments. In such mud-impacted estuaries, the muds generally occur in the areas that experience low energy tidal currents and waves [i.e. the intertidal margins of the upper reaches of estuaries (e.g. Waihopai Arm, New River Estuary), and in the deeper subtidal areas at the mouth of estuaries (e.g. Hutt Estuary)] (Figure 2). In contrast, the main intertidal flats of developed estuaries (e.g. New River Estuary and Porirua Harbour) are usually characterised by sandy sediments reflecting their exposure to wind-wave disturbance and are hence low in mud content (2-10% mud). In order to assess sedimentation in the Waihopai Arm of New River Estuary, a number of indicators have been used: grain size, presence of mud tolerant invertebrates, and sedimentation rate. The results for sedimentation rate are reported separately (Stevens and Robertson 2011a).

Grain Size

Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The monitoring results for all New River Estuary sites (Figure 2) shows that the Waihopai Arm sediments were dominated by mud (95% mud), whereas the main basin sites were dominated by sands (>93% sand in all years). Compared with fine scale sites in other tidal lagoon type estuaries in the Greater Wellington and Southland regions, the Waihopai Arm mud content was very high (Figure 2). Such findings are not unexpected given the very high rates of infilling with muds in the Waihopai Arm (Stevens and Robertson 2011a). The source of these fine muds is almost certainly from the surrounding Oreti and Waihopai catchments rather than the sea (Blakely 1971, Thoms 1981, Denton 2008). To monitor the potential for ongoing sedimentation within the estuary and to measure its magnitude, sediment plates have been deployed in the Waihopai Arm of the estuary (Stevens and Robertson 2011a).

Macro-invertebrate Community. Three core samples were analysed for the presence of invertebrates in the Waihopai Arm. The samples were taken from the three different habitat types in the Arm; differing in the amount of cover of macroalgae over the underlying soft, organic and sulphide-rich muds. The first had no macroalgal cover (W3), the second (W2) had a moderate cover that was mostly decayed, and the third (W1) had a thick cover of fresh macroalgae (Figure 1).

The results (Table 2) showed that there were no invertebrates living within the soft anoxic muds, but the samples that had macroalgal cover on top had a relatively diverse community associated with the surface sediments and the fresh macroalgal layer. This latter community was dominated by;

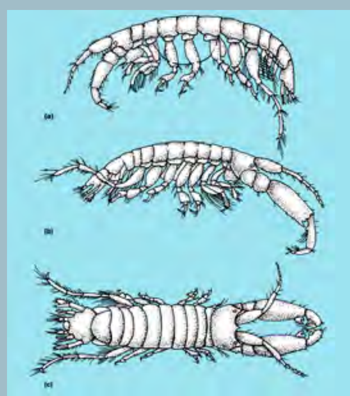
- The tube-dwelling amphipod *Paracorophium excavatum*, which is the dominant corophiod amphipod in the South Island. *Paracorophium* is well-known as a major primary coloniser (and hence indicator) of disturbed estuarine intertidal flats (Ford et al. 1999).
- Two unidentified amphipod species.
- The small native estuarine snails *Potamopyrgus estuarinus* and *P. antipodarum* that feed on decomposing animal and plant matter, bacteria and algae, and are intolerant of anoxic conditions but are tolerant of muds.
- The other abundant species was the surface deposit feeding spionid polychaete *Scolecolepides benhami*. This spionid is very tolerant of mud, fluctuating salinities, organic enrichment and toxicants (e.g. heavy metals). It is common in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark.

The benthic invertebrate mud tolerance rating for the Waihopai Arm of the New River Estuary (infauna) ranged from 5.7-7 (Table 2) and was therefore in the "poor" and "very poor " categories, indicating that the invertebrate community was dominated by mud tolerant organisms. Details on condition ratings are in Appendix 3.

Macoinvertebrate Organic Enrichment Rating	Very Good	Good	Fair	Poor	Very Poor
		↑ Main Basin Sites (2002-2010)		↑ Waihopai Arm Sites (2011)	↑

Scolecolepides benhami

Potamopyrgus aesturinus



Corophiod amphipod

The results of the multivariate analysis (NMDS Plot, Figure 4) further portray the difference in the benthic invertebrate communities between each of the sites sampled in the Waihopai Arm. In addition, the plot shows that the Waihopai Arm communities were very different from those sampled in the main basin in previous years. Such a difference is likely to be explained by the increasing mud content and organic matter at the Waihopai Arm sites compared with the much sandier main basin sites.

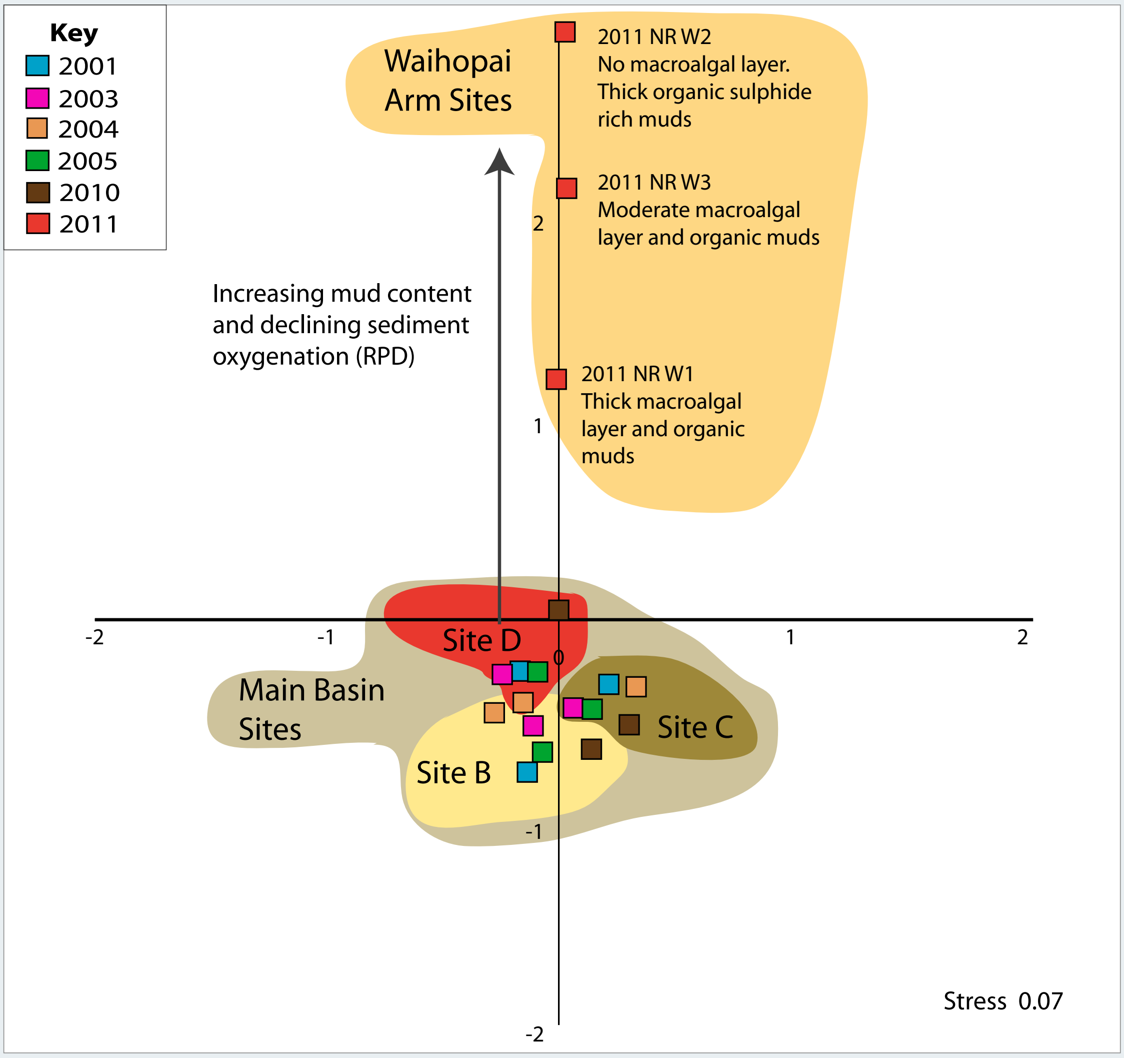


Figure 4. NMDS plot showing the relationship among mean samples in terms of similarity in macro-invertebrate community composition for New River Estuary Sites B, C and D, for 2001, 2003, 2004, 2005 and 2010. The plot shows the mean of each of the 10 (or 12 in 2001) replicate samples for each site and is based on Bray Curtis dissimilarity and fouth root transformed data.

The approach involves multivariate data analysis methods, in this case non-metric multidimensional scaling (NMDS) using PRIMER version 6.1.10. The analysis basically plots the site, year and abundance data for each species as points on a distance-based matrix (a scatterplot ordination diagram). Points clustered together are considered similar, with the distance between points and clusters reflecting the extent of the differences. The interpretation of the ordination diagram depends on how good a representation it is of actual dissimilarities i.e. how low the calculated stress value is. Stress values greater than 0.3 indicate that the configuration is no better than arbitrary, and we should not try and interpret configurations unless stress values are less than 0.2.

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EUTROPHICATION

The primary synoptic fine scale indicators of eutrophication are grain size, RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations and the community structure of certain sediment-dwelling animals. The broad scale indicators are the percentages of the estuary covered by macroalgae and soft muds (Stevens and Robertson 2011, 2011a).

Redox Potential Discontinuity (RPD). The results showed that the 2011 RPD depth in the Waihopai Arm fine scale sites was at the surface (0cm) and therefore the sediments were likely to be very poorly oxygenated. These RPD ratings were much shallower than those measured at the main basin fine scale sites during 2002-2010. Such shallow RPD values fit the "poor" condition rating (Appendix 3) and indicate that the benthic invertebrate community was likely to be dominated by a few pollution-tolerant species who live near the surface.

Organic Matter (Total Organic Carbon - TOC). Fluctuations in organic input are considered to be one of the principal causes of faunal change in estuarine and near-shore benthic environments. Increased organic enrichment results in changes in physical and biological parameters, which in turn have effects on the sedimentary and biological structure of an area. The number of suspension-feeders (e.g. bivalves and certain polychaetes) declines and deposit-feeders (e.g. opportunistic polychaetes) increase as organic input to the sediment increases (Pearson and Rosenberg 1978). The indicator of organic enrichment (TOC) at the Waihopai Arm site in 2011 was at high concentrations (4%) and met the "fair" condition rating. These concentrations were much more enriched than measured at the main basin sites during 2002-2010. Such conditions indicate a high extent of accumulation of organic matter in the sediments of the Waihopai Arm of the estuary. This is supported by measured high levels of macroalgal growth in this section of the estuary (Stevens and Robertson 2008 to 2011).

Total Phosphorus. Total phosphorus (a key nutrient in the eutrophication process) was present at 1200mg/kg in the Waihopai Arm in 2011 and met the "poor" condition rating. These 2011 results were much greater than those measured at the main basin sites during 2002-2010. Such conditions indicate a high extent of accumulation of phosphorus in the sediments of the Waihopai Arm.

Total Nitrogen. Total nitrogen (the other key nutrient in the eutrophication process) was present at 5900mg/kg in the Waihopai Arm in 2011 and met the "poor" condition rating. These 2011 results were much greater than those measured at the main basin sites during 2002-2010. Such conditions indicate a high extent of accumulation of nitrogen in the sediments of the Waihopai Arm.

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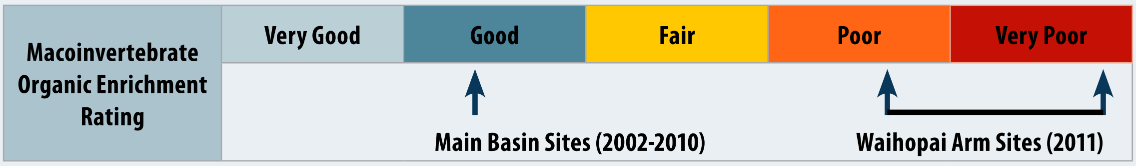
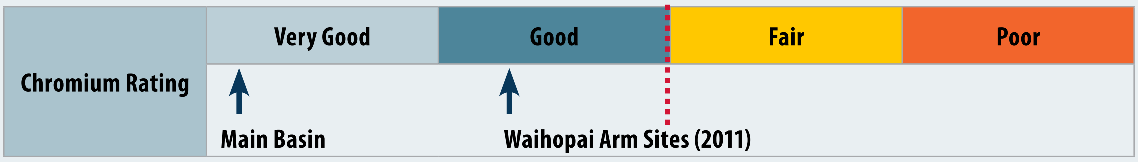
Macro-invertebrate Organic Enrichment Index. The benthic invertebrate organic enrichment rating for the Waihopai Arm of the New River Estuary (infauna) ranged from 3-7 (Table 2) and was therefore in the “poor” and “very poor ” categories, indicating high organic enrichment.

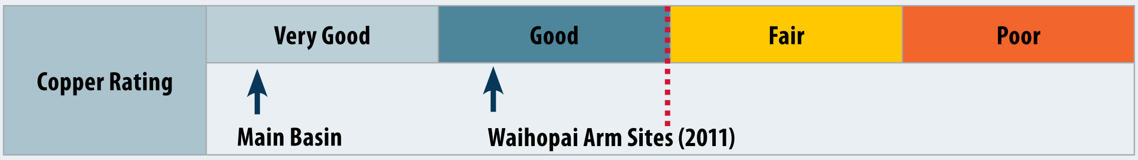


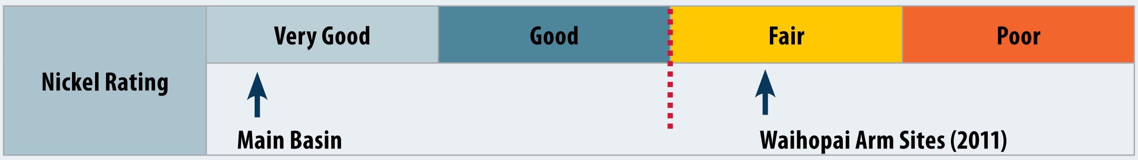
The results indicate that the invertebrate community below the sediment surface contained no living animals. A few hardy species were present on the sediment surface, particularly where the sediment surface was covered with fresh macroalgae.
Such a rating likely reflects the high sediment nutrient concentrations, the visible presence of sulphide bacteria in the cores, and the semi-sheltered nature of this upper part of the estuary. Compared with the ratings for the main body of the estuary, the Waihopai Arm ratings were very high (indicating very poor condition).

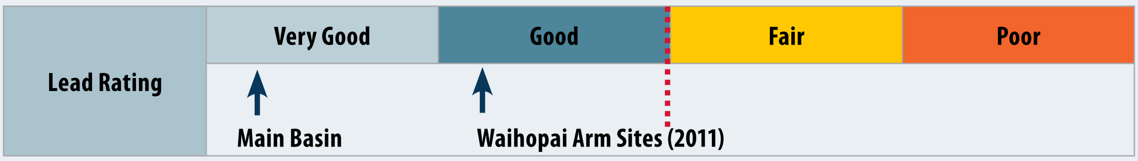
TOXICITY

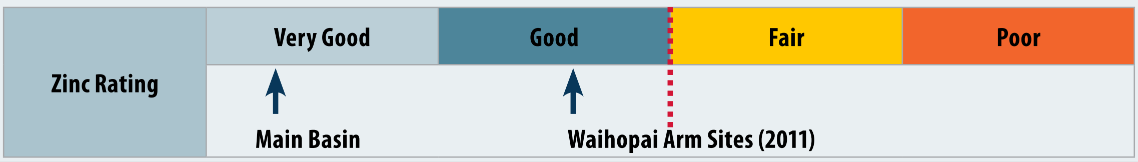
Heavy Metals. Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at moderate concentrations at the Waihopai Arm site with all values (except nickel) below the ANZECC (2000) ISQG-Low trigger values (not normalised). These concentrations were much higher than those measured at the main basin sites during 2002-2010. Such conditions indicate a moderate accumulation of heavy metals in the sediments of the Waihopai Arm of the estuary.











CONCLUSIONS

The 2011 synoptic monitoring results for the western side of the Waihopai Arm confirm the highly enriched, anoxic and muddy nature of the sediments in this extensive region of the New River Estuary.

- The sediments were so toxic (high sulphides) and low in oxygen, that animal life could not live within the sediments. Instead, the only signs of life were found in the macroalgal mats on the sediment surfaces.
- Concentrations of nitrogen, phosphorus and organic carbon in the sediments were extremely elevated ("poor" - condition rating).
- The mud content was very elevated (95% mud).
- Concentrations of heavy metals were elevated compared to sites in the main estuary basin, but still less than ANZECC (2000) ISQG-Low trigger values (except for nickel).

Compared with the results from the three fine scale monitoring sites located in the main estuary basin (rated "very good to fair"), the area of the Waihopai Arm that was sampled in 2011 must be rated as "very poor".

Such findings however, must be considered in relation to the estuary as a whole. The two key indicators that can be used to assess the extent of these gross nuisance conditions are the presence of high macroalgal cover and soft muddy sediments. If both are present, then a very poor rating is likely for invertebrate life within the sediments. Broad scale macroalgal and sediment type monitoring (Stevens and Robertson 2011, Robertson and Stevens 2007) indicated that:

- High macroalgal cover covered approximately 11% of the whole estuary in 2011 (compared with 7% in 2007 and 2% in 2001).
- Soft muddy sediments covered approximately 21% of the whole estuary in 2007, and 9% in 2002 (next sediment mapping planned for 2012).
- The area covered by both high macroalgal cover and soft muddy sediments in 2011 was estimated to be 8% of the whole estuary (with the majority in the western side of the Waihopai Arm and a smaller area in Daffodil Bay).

Given that gross nuisance conditions now occupy 8% of the estuary, compared with 1-2% in 2007 (Robertson and Stevens 2007) and <1% in 2001 (Robertson et al. 2002), there is clear evidence that the condition of the New River Estuary has deteriorated in the last 10 years. To date, this deterioration has been clearly presented in the results of the macroalgal mapping and broad scale habitat mapping since 2001 (see table below) but not in the fine scale results.

	2001	2007	2008-2011
Macroalgal Rating	Good	Fair	Poor
Soft Mud Rating	Fair	Poor	Not Monitored

The current report, however, provides additional fine scale type information to more fully describe the chemistry and invertebrate biology of areas with gross nuisance conditions.

These results clearly show that the current fine scale monitoring sites (NRE B, C and D) do not adequately reflect conditions in the more poorly flushed areas of the estuary (esp. Waihopai Arm), but that they are still representative of the majority of the estuary. This raises the question of including another fine scale in the Waihopai Arm so that areas more vulnerable to symptoms of eutrophication and sedimentation are more adequately represented by fine scale results. Given the rapid deterioration in the last 10 years, it would seem reasonable to include an additional representative site in the monitoring programme, but if cost is an issue then the broad scale results can be used to indicate likely fine scale conditions. In addition, because the western side of the Waihopai Arm has been the main area of seagrass habitat (Robertson et al. 2002, Robertson and Stevens 2007) in the estuary, it is recommended that annual seagrass monitoring be undertaken in tandem with the annual macroalgal monitoring.

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MONITORING

New River Estuary has been identified by Environment Southland as a high priority for monitoring, and is a key part of their coastal monitoring programme being undertaken in a staged manner throughout the Southland region. The future monitoring recommendations are outlined as follows:

Fine Scale Monitoring.

Expand the number of fine scale monitoring sites to include a site that is representative of more vulnerable poorly flushed areas in the estuary. Monitor the new site in February 2012 and again in February 2015 when the 5 yearly fine scale trend monitoring at three existing sites falls due.

Macroalgal and Seagrass Monitoring.

Continue with the programme of annual broad scale mapping of macroalgae. Next monitoring due in February 2012. In addition, in order to assess changes in seagrass cover (particularly in the Waihopai Arm), it is recommended that seagrass cover be also monitored annually in tandem with the macroalgal monitoring.

Broad Scale Habitat Mapping.

Continue with the programme of 5 yearly broad scale habitat mapping. Next monitoring due in February/March 2012.

Sedimentation Rate Monitoring.

Because sedimentation is a priority issue in the estuary it is recommended that all sediment plate depths be measured annually and that additional sediment plates be deployed at representative locations so that the sedimentation rate over much larger parts of the estuary can be determined (see Stevens and Robertson 2011a). These plates will also be used to gauge the success of actions taken to reduce sediment inputs.

MANAGEMENT

Eutrophication and sedimentation have been identified as a major issue in New River Estuary since at least 2007-8 (Robertson and Stevens 2007, Stevens and Robertson 2008), as has been the case for several other Southland estuaries (e.g. Jacobs River, Waimatuku and Waituna Lagoon). To address these issues, it is recommended that appropriate catchment nutrient and sediment guideline criteria be developed for each estuary type in Southland and that these guideline criteria are then used to assess the extent to which catchment loads meet these guidelines. Estuaries where guidelines are exceeded are prioritised for more extensive investigations, monitoring and management. The key steps in such an approach are as follows:

- Assign catchment nutrient and sediment load guideline criteria to each Southland estuary (using criteria appropriate to each type of estuary). Guideline criteria should be based on available catchment load/estuary response information from other relevant estuaries.
- Estimate catchment nutrient and suspended sediment loads to each estuary using available catchment models and stream monitoring data.
- Determine the extent to which each estuary meets guideline catchment load criteria.
- Rank estuaries according to exceedance of recommended guideline criteria.
- Assess the potential for requiring more detailed assessments of priority estuaries (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling).
- Develop plans for restoration of priority estuaries.

Overall, if the approach is followed, and the estuary and its surroundings are managed to ensure that the assimilative capacity is not breached, then the estuary will flourish and provide sustainable human use and ecological values in the long term.

ACKNOWLEDGEMENTS

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APPENDIX 1. METHODS

Physical and chemical analyses

- One fine scale sampling site (10x10m square) (Figure 1) was selected in mid-low water habitat of the dominant substrate type (avoiding channels).
- At the site, one random core was collected to a depth of at least 100mm and average redox potential discontinuity (RPD) depth (i.e. depth to light grey/black anoxic layer) recorded.
- At the site, one sample (a composite from 3 scoops from a 10m x 10m area) of the top 20mm of sediment (approx. 250gms) was collected. All samples were kept in a chilly-bin in the field.
- Chilled samples were sent to R.J. Hill Laboratories for analysis of the following (details see below):
    * Grain size/Particle size distribution (% mud, sand, gravel).
    * Nutrients- total nitrogen (TN), total phosphorus (TP), and total organic carbon (TOC).
    * Trace metal contaminants (total recoverable Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole sample fractions which are not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Samples were tracked using standard Chain of Custody forms and results are checked and transferred electronically to avoid transcription errors.

Macroinvertebrates (animals within and on sediments)

- Three sediment cores were taken from within the site using a 130mm diameter (area = 0.0133m^2) PVC tube. The samples were taken from three different habitats; differing in the amount of cover of macroalgae over the underlying soft, organic and sulphide-rich muds. The first had no macroalgal cover, the second had a moderate cover that was mostly decayed and the third had a thick cover of fresh macroalgae.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all cores had been collected at a site, the plastic bags were transported to a nearby source of seawater and the contents of the core were washed through a 0.5mm nylon mesh bag. The infauna remaining were carefully emptied into a plastic container, labelled and preserved (70% isopropyl alcohol - seawater solution).
- The samples were then transported to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

APPENDIX 2. ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Infauna Sorting and ID	CMES	Coastal Marine Ecology Consultants (Gary Stephenson) *	N/A
Grain Size	R.J Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total recoverable cadmium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal, Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

APPENDIX 3. CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for New River Estuary (based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-2mm/yr	Monitor at 5 year intervals after baseline established
Moderate	2-5mm/yr	Monitor at 5 year intervals after baseline established
High	5-10mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>10mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

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Benthic Community Index (Mud Tolerance)

Soft sediment macrofauna can also be used to represent benthic community health in relation to the extent of mud tolerant organisms compared with those that prefer sands. Using the response of typical NZ estuarine macro-invertebrates to increasing mud content (Gibbs and Hewitt 2004) a "mud tolerance" rating has been developed similar to the "organic enrichment" rating identified below.

The equation to calculate the Mud Tolerance Biotic Coefficient (MTBC) is a s follows;

$$MTBC = \{(0 \times \%SS) + (1.5 \times \%S) + (3 \times \%I) + (4.5 \times \%M) + (6 \times \%MM\}/100.$$

The characteristics of the above-mentioned mud tolerance groups (SS, S, I, M and MM) are summarised in Appendix 2.

BENTHIC COMMUNITY MUD TOLERANCE RATING

MUD TOLERANCE RATING	DEFINITION	MTBC	RECOMMENDED RESPONSE
Very Low	Strong sand preference dominant	0-1.2	Monitor at 5 year intervals after baseline established
Low	Sand preference dominant	1.2-3.3	Monitor 5 yearly after baseline established
Fair	Some mud preference	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
High	Mud preferred	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Very High	Strong muds preference	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Some mud preference	>1.2	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1 cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

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Total Phosphorus

In shallow estuaries like New River the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like New River, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Benthic Community Index (Organic Enrichment)

Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in N and S hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation. In particular, its robustness can be reduced: when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample, in low-salinity locations and naturally enriched sediments. The equation to calculate the AMBI Biotic Coefficient (BC) is as follows;

$BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100$.

The characteristics of the ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.

BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING

ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE
Very Low	Intolerant of enriched conditions	0-1.2	Monitor at 5 year intervals after baseline established
Low	Tolerant of slight enrichment	1.2-3.3	Monitor 5 yearly after baseline established
Moderate	Tolerant of moderate enrichment	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
High	Tolerant of high enrichment	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Very High	Azoic (devoid of invertebrate life)	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Trend to slight enrichment	>1.2	Initiate Evaluation and Response Plan

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

APPENDIX 4. MACROINVERTEBRATE DETAILS

Group and Species		Organic Enrichment Tolerance-AMBI Group *****	Mud Tolerance ****	Details
	Boccardia (Paraboccardia) syrtis and acus	I	S Optimum range 10-15% mud,* distribution range 0-50%*	Small surface suspension-feeding spionids (also capable of detrital feeding). Prefers sand with low-mod mud content but found in a wide range of sand/mud. **Prefers 10-15% mud but can live in 0-50% mud.** It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds.
	Nicon aestuariensis	III	M Optimum range 55-60%* or 35-55% mud**, distribution range 0-100%**.	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit feeding omnivore. **Prefers to live in moderate mud content sediments.**
	Scolecolepides benhami	III	MM Optimum range 25-30% mud,* distribution range 0-100%*	A Spionid, surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. **Strong Mud Preference but prefers moderate mud content (25-30% mud).** But also found in 0-100% mud environments. Rare in Freshwater Estuary (<1% mud) and Porirua Estuary (5-10% mud). Common in Whareama (35-65% mud), Fortrose Estuary (5% mud), Waikanae Estuary 15-40% mud. Moderate numbers in Jacobs River Estuary (5-10% muds) and New River Estuary (5% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. e.g. Waihopai Rrm, New River Estuary.
Oligichaeta	Oligochaete sp.	I ?	MM Optimum range 95-100% mud*, distribution range 0-100%**.	Segmented worms - deposit feeders. Classified as very pollution tolerant (e.g. Tubificid worms) although there are some less tolerant species.
	Amphibola crenata	NA	NA	A pulmonate gastropod endemic to NZ. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria.
	Potamopyrgus estuarinus	NA	M Tolerant of muds.	Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feed on decomposing animal and plant matter, bacteria, and algae. **Intolerant of anoxic surface muds. Tolerant of muds.**
	Arthritica bifurca	III	I Optimum range 55-60% mud*, or 20-40%***, distribution range 5-70%**.	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds. **Prefers 55-60% mud (range 5-70% mud).**
	Amphipoda sp.	NA	NA	An unidentified amphipod.
	Exosphaeroma sp.	NA	NA	Small seaweed dwelling isopod.

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Group and Species		Organic Enrichment Tolerance-AMBI Group *****	Mud Tolerance ****	Details
Crustacea	*Macrophthalmus hirtipes*	NA	I Optimum range 45-50% mud, distribution range 0-95%*.	The stalk-eyed mud crab is endemic to NZ and prefers waterlogged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunnelling mud crab, it feeds from the nutritious mud.
	Paracorophium sp.	III	MM Optimum Range 95-100% mud (found in 40-100% mud)*	A tube-dwelling corophioid amphipod. Two species in NZ, *Paracorophium excavatum* and *Paracorophium lucasi* and both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area of the South Island. *P. excavatum* has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum Range 95-100% mud (found in 40-100% mud) in upper Nth. Is. estuaries. In Sth. Is. and lower Nth. Is. common in Waikanae Estuary (15-40% mud), Haldane Estuary (25-35% mud) and in Fortrose Estuary (4% mud). Often present in estuaries with regular low salinity conditions. In muddy, high salinity sites like Whareama A and B (30-70% mud) we get very few.

NA=Not Allocated

* Preferred and distribution ranges based on findings from the Whitford Embayment in the Auckland Region (Norkko et al. 2001).
** Preferred and distribution ranges based on findings from 19 North Island estuaries (Gibbs and Hewitt 2004).
*** Preferred and distribution ranges based on findings from Thrush et al. (2003)

**** Tolerance to Mud Codes are as follows (from Gibbs and Hewitt, 2004, Norkko et al. 2001) :

1 = SS, strong sand preference.
2 = S, sand preference.
3 = I, prefers some mud but not high percentages.
4 = M, mud preference.
5 = MM, strong mud preference.

***** AMBI Sensitivity to Organic Enrichment Groupings (from Borja et al. 2000)

Group I. Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.
Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.
Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids.
Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.
Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.
The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with 5 levels, from 0 to 6.