Wriggle
coastalmanagement

Havelock Estuary

Fine Scale Monitoring Data 2015

Prepared for

Marlborough District Council

June 2015

Cover Photo: Havelock Estuary Site B


Havelock Estuary looking across the large western settling basin.

Havelock Estuary

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Prepared for
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by

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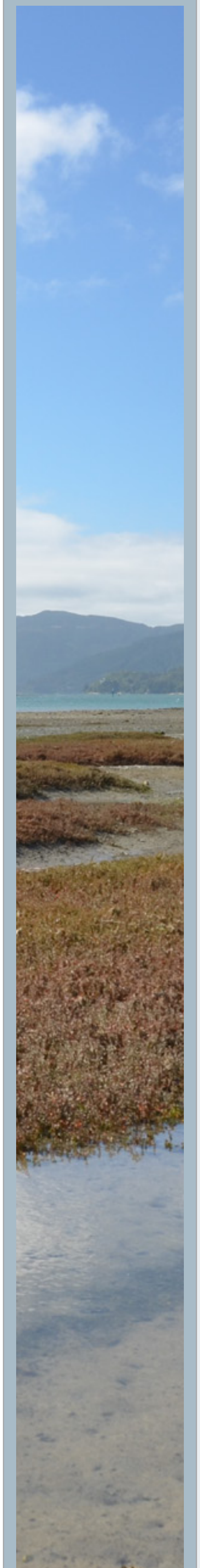
1. INTRODUCTION

OVERVIEW



Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. These objectives, along with understanding changes in condition/trends, are key objectives of Marlborough District Council's State of the Environment Estuary monitoring programme. Recently, Marlborough District Council (MDC) prepared a coastal monitoring strategy which established priorities for a long-term coastal and estuarine monitoring programme (Tiernan 2012). The assessment identified Havelock Estuary as a priority for monitoring.

The estuary monitoring process consists of three components developed from the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) as follows:

1. **Ecological Vulnerability Assessment** (EVA) of estuaries in the region to major issues and appropriate monitoring design. To date, neither estuary specific nor region-wide EVAs have been undertaken for the Marlborough region and therefore the vulnerability of Havelock to issues has not yet been fully assessed. However, in 2009 a preliminary vulnerability assessment was undertaken of the Havelock Estuary for NZ Landcare Trust (Robertson and Stevens 2009), and a recent report has documented selected ecologically significant marine sites in Marlborough (Davidson et al. 2011).
2. **Broad Scale Habitat Mapping** (NEMP approach). This component documents the key habitats within the estuary, and changes to these habitats over time. Broad scale mapping of Havelock Estuary was undertaken in 2001 (Robertson et al. 2002) and was repeated in 2014 (Stevens and Robertson 2014).
3. **Fine Scale Monitoring** (NEMP approach). Monitoring of physical, chemical and biological indicators. This component, which provides detailed information on the condition of Havelock Estuary, was undertaken once, in 2001 (Robertson et al. 2002), and repeated in 2014 (Robertson and Robertson 2014).

The 2014 fine scale monitoring report (Robertson and Robertson 2014) raised two fundamental monitoring design issues that required resolution:

1. Because the NEMP requires 3-4 consecutive years of data for establishing a defensible baseline, the two single years of data that exist for the Havelock Estuary (2001 and 2014) are insufficient for use in trend analysis (i.e. trends in change between 2001 and 2014 data). Therefore it was recommended that this be rectified by repeat monitoring over the next 3-5 years.
2. Another very relevant aspect of the Havelock monitoring was the extent to which the two existing fine scale sites represented the bulk of the intertidal habitat in Havelock Estuary. The choice for the site locations was initially made back in 2001, when they were chosen as experimental test sites for the development of the NEMP. However, based on the final NEMP criteria for site selection (i.e. sites should be located in the dominant mid-low water habitat, which in the case of Havelock would be very soft mud rather than the firm mud sand/soft mud habitat that they are currently located in) additional sites need to be established in the dominant very soft mud habitat in Havelock Estuary, or the existing two sites in Havelock be shifted to this habitat.

In response to these issues MDC resolved to:

- Establish two new sites in the dominant very soft mud habitat in Havelock Estuary in 2015, including the establishment of buried sediment plates in order to measure ongoing sedimentation rates.
- Undertake fine scale monitoring at the existing and new sites in 2015, with repeat sampling scheduled for 2017, and 2019 to establish both a multi-year baseline and relationships between soft mud and very soft mud habitats so that the value of previous monitoring is not lost.

Wriggle Coastal Management were engaged by MDC to undertake this work in March 2015. To minimise costs, it was agreed that data only reports would be prepared for the 2015 and 2017 monitoring, with a full report of all data undertaken at the next scheduled 5 yearly monitoring interval in 2019.

The current report provides a brief overview of the new site locations and presents the 2015 data.

2. METHODS

FINE SCALE MONITORING

Fine scale monitoring is based on the methods described in the National Estuary Monitoring Protocol (NEMP; Robertson et al. 2002) and provides detailed information on indicators of chemical and biological condition of the dominant habitat type in the estuary. This is most commonly unvegetated intertidal mudflats at low-mid water (avoiding areas of significant vegetation and channels). Using the outputs of the broad scale habitat mapping, representative sampling sites (usually two per estuary, but varies with estuary size) are selected and samples collected and analysed for the following variables.

- Salinity, Oxygenation (apparent Redox Potential Discontinuity - aRPD), Grain size (% mud, sand, gravel).
- Organic Matter and Nutrients: Total organic carbon (TOC), Total nitrogen (TN), Total phosphorus (TP).
- Heavy metals and metalloids: Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), and Zinc (Zn) plus mercury (Hg) and arsenic (As) for Havelock.
- Macroinvertebrate abundance and diversity (infauna and epifauna).
- Other potentially toxic contaminants: these are measured in certain estuaries where a risk has been identified.

For Havelock Estuary, two fine scale sampling sites (Sites A and B, Figure 1) were previously selected in unvegetated, mid-low water tidal flats (Robertson et al. 2002). At both sites, a 60m x 30m area in the lower intertidal was marked out and divided into 12 equal sized plots. Within each area, ten plots were selected, a random position defined within each (precise locations are in Appendix 1). In 2015, two additional sites were established in the dominant very soft mud habitat of the estuary (Sites C and D, Figures 1 & 2). The following sampling was undertaken:

Physical and chemical analyses.

- Within each plot, one random core was collected to a depth of at least 100mm and photographed alongside a ruler and a corresponding label. Colour and texture were described and average apparent Redox Potential Discontinuity depth recorded.
- At each site, three samples (two a composite from four plots and one a composite from two plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to each core. All samples were kept in a chilly bin in the field. For semi-volatile organic contaminants (SVOCs), a composite sample was collected from each of the 4 sites (by subsampling each of the 10 replicates).
- Chilled samples were sent to R.J. Hill Laboratories for analysis of the following (details of lab methods and detection limits in Appendix 1):
    - Grain size/Particle size distribution (% mud, sand, gravel).
    - Nutrients - total nitrogen (TN), total phosphorus (TP), and total organic carbon (TOC).
    - Trace metals (Cd, Cr, Cu, Ni, Pb, Zn, Hg), arsenic, and semi-volatile organic compounds (SVOCs). 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 were checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.
- Salinity of the overlying water was measured at low tide.

Epifauna (surface-dwelling animals).

Visually conspicuous epifauna within the 60m x 30m sampling area were semi-quantitatively assessed based on the UK MarClim approach (MNCR 1990, Hiscock 1996, 1998). Epifauna species were identified and allocated a SACFOR abundance category based on percentage cover (Appendix 1, Table A), or by counting individual organisms >5mm in size within quadrats placed in representative areas (Appendix 1, Table B). Species size determined both the quadrat size and SACFOR density rating applied, while photographs were taken and archived. This method is ideally suited to characterise often patchy intertidal epifauna, and macroalgal/microalgal cover.

Infauna (animals within sediments).

- One randomly placed sediment core (130mm diameter (area = $0.0133m^2$) PVC tube) was taken from each of ten plots.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates 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 with a waterproof label and preserved in 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 1).

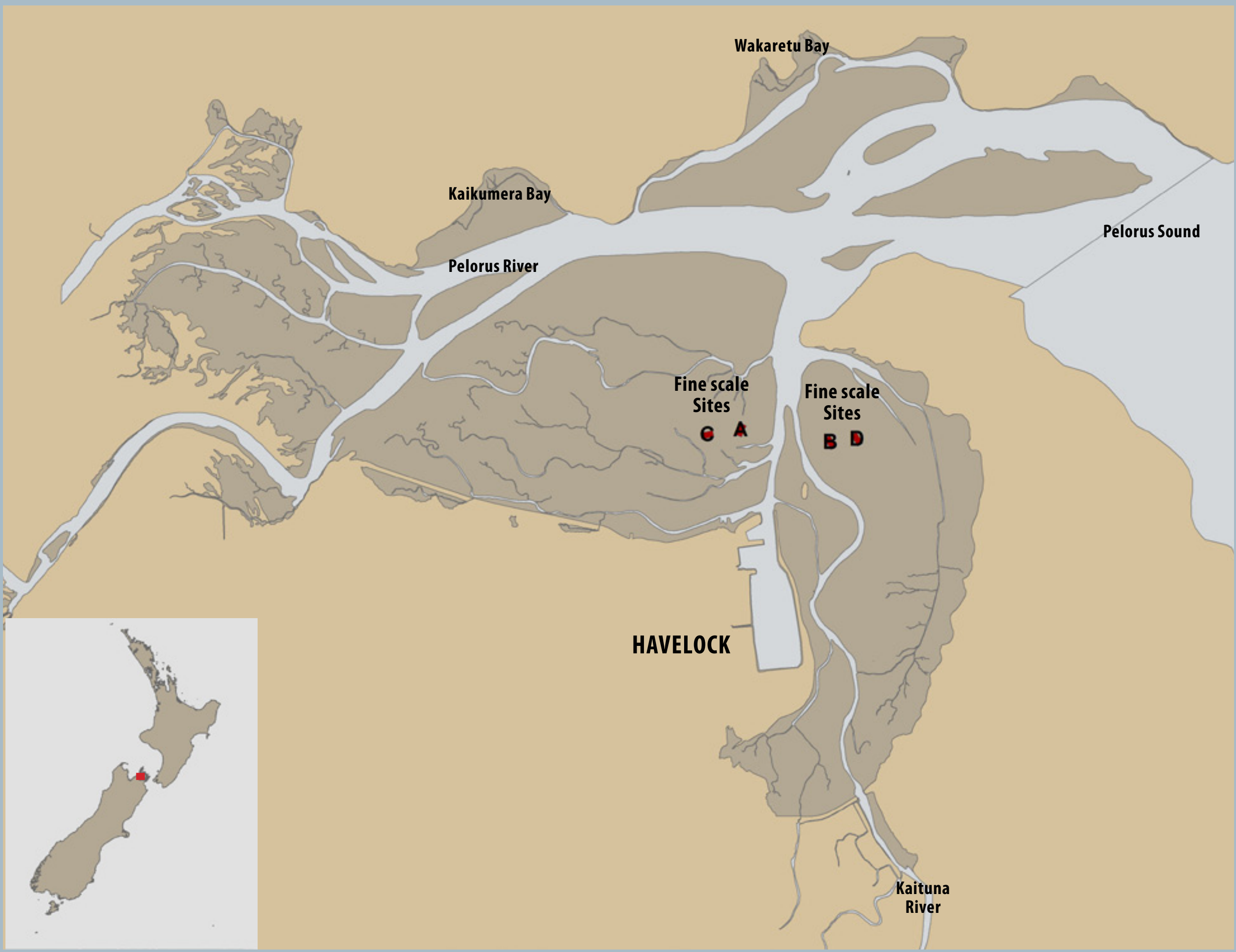
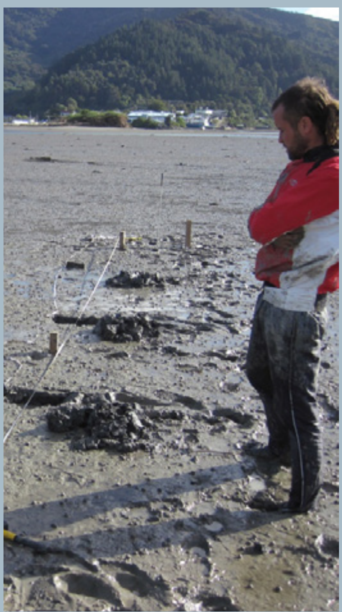


Figure 1. Havelock Estuary - location of fine scale monitoring sites.



Installing sediment plates at Site D in 2015.

Sedimentation Plate Deployment

Determining the future sedimentation rate involves a simple method of measuring how much sediment builds up over a buried plate over time. Once a plate has been buried and levelled, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance.

Four sites, each with four plates (20cm square concrete paving stones) have now been established in Havelock Estuary at fine scale Sites A, B, C and D. Plates were buried deeply in the sediments where stable substrate was located and positioned 2m apart in a liner configuration along the baseline of each fine scale site. To ensure plate stability, steel waratahs (0.8 or 1.6m long) were driven into the sediments until firm substrate was encountered beneath the plates, and the plates placed on these. Steel reinforcing rod was also placed horizontally next to each buried plate to enable relocation with a metal detector.

The GPS positions of each plate were logged, and the depth from the undisturbed mud surface to the top of the sediment plate recorded (Appendix 1). In the future, these depths will be measured annually and, over the long term, will provide a measure of the rate of sedimentation in the estuary.

2. Methods (Continued)

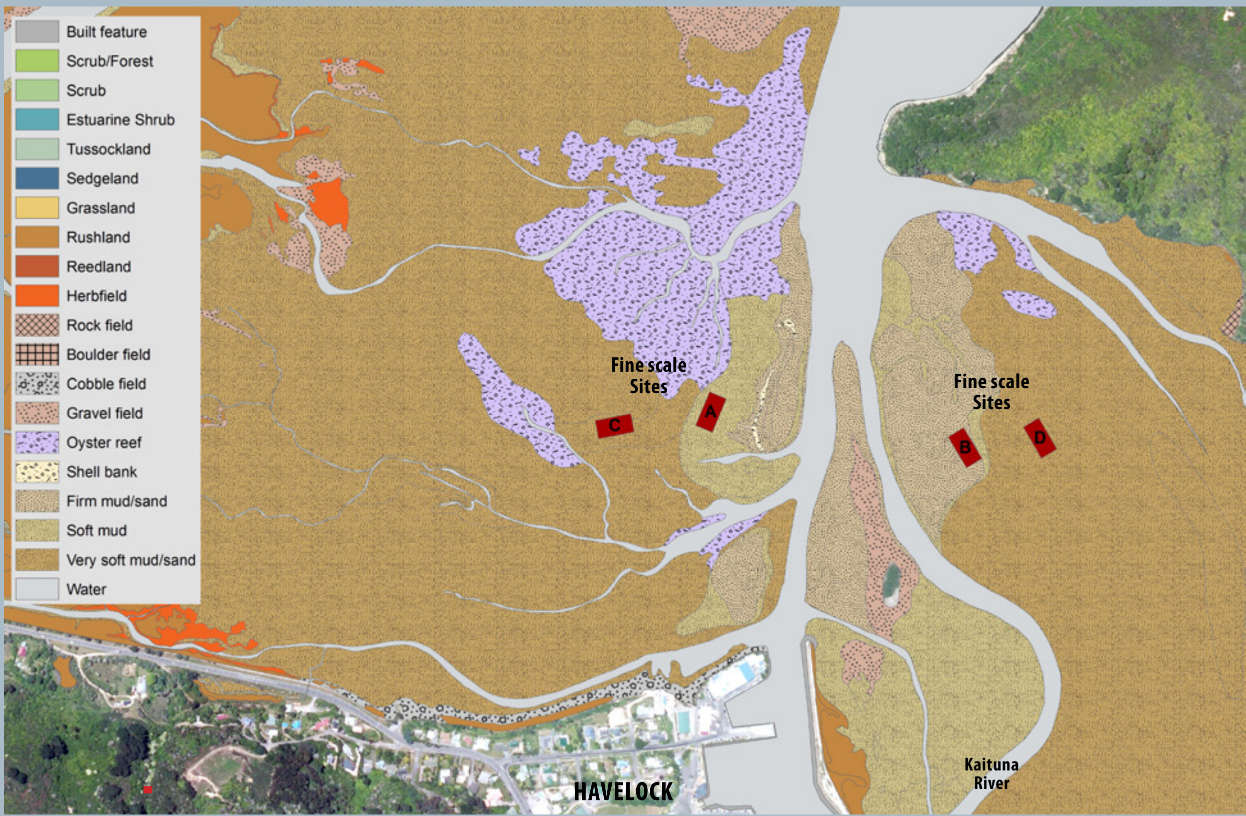


Figure 2. Havelock Estuary - location of fine scale monitoring sites in relation to dominant substrate types.

3. RESULTS

A summary of the results of the 19 March 2015 fine scale monitoring of Havelock Estuary, together with the 2001 and 2014 fine scale results, is presented in Table 1, with detailed results in Appendix 2.

Analysis and discussion of the results is scheduled to be undertaken following completion of the 5 year monitoring block in 2019.

Table 1. Summary of fine scale physical, chemical[a] and macrofauna results (means), Havelock Estuary 2001, 2014 and 2015).

Site	aRPD	Salinity	TOC AFDW [b]	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP	Species Abundance	Species Richness
	cm	ppt	%				mg/kg								No./core	No./core
2001 A	1	30	0.67	20.4	73.6	6.0	0.40	70.1	11.2	38.1	5.6	51.1	608	394	27.3	11.5
2001 B	1	30	0.51	17.8	80.6	1.6	0.41	27.4	10.1	14.8	5.7	34.8	700	266	18.7	6.3
2014 A	1	30	0.65	27.2	70.9	1.9	0.04	50.7	11.6	39.3	5.8	41.7	650	380	24.1	9.2
2014 B	1	30	0.49	16.9	82.0	1.2	0.02	24.0	7.9	18.8	4.0	26.3	<500	223	13.9	7.1
2015 A	1	30	0.78	36.9	61.1	2.0	0.04	54.3	14.3	45.7	7.4	46.7	900	490	21.2	8.2
2015 B	1	30	0.48	18.3	81.3	0.4	0.03	23.3	8.3	20.2	4.6	28.0	600	260	17.6	7.7
2015 C	1	30	1.18	59.9	38.5	1.6	0.04	66.3	18.4	58.0	9.1	50.0	1133	457	18.2	6.6
2015 D	1	30	0.95	54.2	44.7	1.1	0.04	29.0	13.1	25.7	7.1	37.3	933	383	10.5	5.8

[a] Data for arsenic, mercury and semi-volatile organic compounds are presented in Appendix 2.
[b] 2001 TOC values estimated from AFDW as follows: 1g AFDW as equivalent to 0.2 g TOC (± 100%) based on a preliminary analysis of NZ estuary data.

4. SUMMARY

Havelock Estuary has been identified by MDC as a priority for monitoring, and is a key part of MDC's coastal monitoring programme being undertaken in a staged manner throughout the Marlborough region. Based on the 2014 monitoring results and risk indicator ratings, it was recommended that monitoring continue as follows:

Fine Scale Monitoring

Given the magnitude of the muddiness changes between 2001 and 2014, and to establish whether the deteriorating results observed in 2014 are truly representative of current conditions, monitoring is recommended as follows: Sites A and B continue to be monitored, but two new sites also be established in the dominant intertidal habitat type (very soft muds) with all 4 sites be monitored in February 2015, 2017 and 2019 to establish both a multi-year baseline and relationships between soft mud and very soft mud habitats so that the value of previous monitoring is not lost. This change is supported by the 2014 broad scale mapping results of dominant substrate types, opportunistic macroalgae, and seagrass beds in the estuary (Stevens and Robertson 2014). It is agreed that data only reports be prepared in 2015 and 2017, with a full report of all data undertaken at the next scheduled 5 yearly monitoring interval in 2019.

Broad Scale Habitat Mapping, Including Macroalgae

Continue with the programme of 5 yearly broad scale habitat mapping. Next monitoring due in February/March 2019. Undertake a rapid visual assessment of macroalgal growth annually, and initiate broad scale macroalgal mapping if growth appears significant, or if conditions appear to be worsening over the 5 years before broad scale mapping is repeated.

Sedimentation Rate Monitoring

Because sedimentation is a priority issue in the estuary it is recommended that sediment plate depths be measured annually.

5. ACKNOWLEDGEMENTS

This monitoring has been undertaken with the support and assistance of Steve Urlich (Coastal Scientist, MDC).

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APPENDIX 1. DETAILS ON 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	Wet sieving, gravimetric (calculation by difference).	0.1 g/100g dry wgt
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 mercury	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	<0.27 mg/kg dry wgt
Total recoverable arsenic	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	<10 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
Organochlorine Pesticides	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Organonitro/phosphorus Pesticides	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Dry Matter (Env)	R.J. Hill	Dried at 103°C (removes 3-5% more water than air dry)	

* 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.

Epifauna (surface-dwelling animals).

SACFOR Percentage Cover and Density Scales (after Marine Nature Conservation Review - MNCR).

A. PERCENTAGE COVER	Growth Form	
	i. Crust/Meadow	ii. Massive/Turf
>80	S	-
40-79	A	S
20-39	C	A
10-19	F	C
5-9	O	F
1-4	R	O
<1	-	R

SACFOR Category

- S = Super Abundant
- A = Abundant
- C = Common
- F = Frequent
- O = Occasional
- R = Rare

- Whenever percentage cover can be estimated for an attached species, it should be used in preference to the density scale.
- The massive/turf percentage cover scale should be used for all species except those classified under crust/meadow.
- Where two or more layers exist, for instance foliose algae overgrowing crustose algae, total percentage cover can be over 100%.

B. DENSITY SCALES

SACFOR size class				Density				
i	ii	iii	iv	$0.25m^2$	$1.0m^2$	$10m^2$	$100m^2$	$1{,}000m^2$
<1cm	1-3cm	3-15cm	>15cm	(50x50cm)	(100x100cm)	(3.16x3.16m)	(10x10m)	(31.6x31.6m)
S	-	-	-	>2500	>10,000			
A	S	-	-	250-2500	1000-9999	>10,000		
C	A	S	-	25-249	100-999	1000-9999	>10,000	
F	C	A	S	1-9	10-99	100-999	1000-9999	>10,000
O	F	C	A		1-9	10-99	100-999	1000-9999
R	O	F	C			1-9	10-99	100-999
-	R	O	F				1-9	10-99
-	-	R	O					1-9
-	-	-	R					<1

APPENDIX 2. 2015 DETAILED RESULTS

Fine Scale Station Locations

Havelock Site A	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664419.22	1664424.10	1664427.73	1664434.08	1664424.67	1664420.36	1664414.91	1664410.15	1664403.91	1664409.24
NZTM NORTH	5430917.19	5430927.73	5430943.84	5430956.31	5430968.56	5430949.85	5430937.14	5430919.34	5430928.19	5430944.63
Havelock Site B	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664820.51	1664830.79	1664840.50	1664845.76	1664854.06	1664848.10	1664839.56	1664835.47	1664842.84	1664849.15
NZTM NORTH	5430899.04	5430884.43	5430867.24	5430856.13	5430863.27	5430873.91	5430891.44	5430908.16	5430912.37	5430897.05
Havelock Site C	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664419.22	1664424.10	1664427.73	1664434.08	1664424.67	1664420.36	1664414.91	1664410.15	1664403.91	1664409.24
NZTM NORTH	5430917.19	5430927.73	5430943.84	5430956.31	5430968.56	5430949.85	5430937.14	5430919.34	5430928.19	5430944.63
Havelock Site D	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664820.51	1664830.79	1664840.50	1664845.76	1664854.06	1664848.10	1664839.56	1664835.47	1664842.84	1664849.15
NZTM NORTH	5430899.04	5430884.43	5430867.24	5430856.13	5430863.27	5430873.91	5430891.44	5430908.16	5430912.37	5430897.05
Havelock Township	1									
NZTM EAST	1664063.31									
NZTM NORTH	5430437.56									

Sediment plate locations and depth of plate (mm) below surface.

Havelock Site A	NZTM EAST	NZTM NORTH	2014	2015
Plate 1	1664438	5430967	186	185
Plate 2	1664436	5430967	142	143
Plate 3	1664434	5430968	131	130
Plate 4	1664431	5430969	143	144
Havelock Site B	NZTM EAST	NZTM NORTH	2014	2015
Plate 1	1664844	5430850	138	147
Plate 2	1664845	5430852	154	165
Plate 3	1664846	5430853	166	176
Plate 4	1664849	5430855	149	159
Havelock Site C	NZTM EAST	NZTM NORTH	2014	2015
Plate 1	1664290	5430909		93
Plate 2	1664288	5430908		85
Plate 3	1664285	5430909		98
Plate 4	1664283	5430909		97
Havelock Site D	NZTM EAST	NZTM NORTH	2014	2015
Plate 1	1664972	5430865		93
Plate 2	1664974	5430867		85
Plate 3	1664975	5430868		98
Plate 4	1664978	5430870		97

Note sediment plate depth measurements for sites C and D are indicative baseline depths only which were recorded during site establishment. They should not be used in estimates of sedimentation rate.

Epifauna and macroalgal cover (0.25m² quadrats, Havelock Estuary Sites A, B, C, and D: March 2015).

Group	Family	Species	Common name	Scale	Class	A	B	C	D
Topshells	Amphibolidae	*Amphibola crenata*	Mudflat snail	#	ii	A	A	A	A
	Buccinidae	*Cominella glandiformis*	Mudflat whelk	#	ii		F		
	Batillariidae	*Zeacumantus lutulentus*	Spire shell	#	ii	F	F		
Limpets	Lottiidae	*Notoacmaea helmsi*	Estuarine limpet	#	i	F	F		
Red algae	Gracilariaceae	*Gracilaria chilensis*	Gracilaria weed	%	ii	0	0	0	0

APPENDIX 2. 2015 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.01327m² core) **(Note NA = Not Assigned)**

Havelock Estuary Sites A and B, 28 March 2014

Group	Species	WEBI	A-01	A-02	A-03	A-04	A-05	A-06	A-07	A-08	A-09	A-10	B-01	B-02	B-03	B-04	B-05	B-06	B-07	B-08	B-09	B-10
ANTHOZOA	*Edwardsia* sp. 1	2	1	5	3	5		2	5	2	3	3		2	1	1	1	4	2	2	1	
NEMERTEA	Nemertea sp. 1	3						1							2							1
	Nemertea sp. 3	3												2			1	1		1		1
	Nemertea sp. 3	3																				
POLYCHAETA	*Aonides* sp. 1	1			1																	
	Boccardia (Paraboccardia) acus	2																				
	Boccardia (Paraboccardia) syrtis	2																				
	Disconatis accolus	1			1									1								
	Goniadidae	2						1														
	Heteromastus filiformis	3		5	4	4	4	2	6	1	8											
	Macroclymenella stewartensis	2		1	2									4	2	4		5	1	2	2	3
	Nereidae	3	3	4				1	1	1	1					1						
	Nicon aestuariensis	3														2						
	Orbinia papillosa	1														1	2	2		2	2	1
	Paraonidae sp. 1	3	1	2	4				2		5			1		2	1	1	1		3	1
	Pectinaria australis	3							1					1	1			1				
	Perinereis vallata	2																				
	Prionospio aucklandica	2																				
	Scolecolepides benhami	4			1													1				
	Scoloplos cylindrifer	1		3	3	1		2			1	1			1		1	2				
OLIGOCHAETA	Oligochaeta	3																				
GASTROPODA	*Amphibola crenata*	3						1	1			1	1	2				2				
	Cominella glandiformis	3	1	6	1	3													1	1		
	Diloma subrostrata	2							1				1									
	Haminoea zelandiae	1																				
	Notoacmaea helmsi	2	1			1		2	1		1	2		1		2						
	Zeacumantus lutulentus	1			2		1															
BIVALVIA	*Arthritica bifurca*	4														2						
	Austrovenus stutchburyi	2	6	6	12	4	7	8	3	1	2	9	15	8	5	4	6	4	8	7	7	6
	Cyclomactra ovata	2				1																
	Macomona liliana	2			2					1					1	1	1			1		
	Paphies australis	2																				
	Theora lubrica	2	1		1		3					1										
CRUSTACEA	*Amphipoda* sp. 2	NA		1																		
	Amphipoda spp.	NA										1	1									
	Austrohelice crassa	5																				
	Decapoda larvae unid.	NA																				
	Halicarcinus whitei	3		1							3	1		1		1						
	Hemiplax hirtipes	3																				
	Paracorophium sp.	NA																	1			
	Phoxocephalidae sp. 1	2									1	2				1		3		1	2	
	Tenagomysis sp. 1	2																				
Total individuals in sample			**14**	**34**	**37**	**19**	**15**	**20**	**21**	**6**	**25**	**21**	**18**	**23**	**13**	**22**	**13**	**26**	**14**	**17**	**17**	**13**
Total species in sample			**7**	**10**	**13**	**7**	**4**	**9**	**9**	**5**	**9**	**9**	**4**	**10**	**7**	**12**	**7**	**11**	**6**	**8**	**6**	**6**

APPENDIX 2. 2015 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.01327m² core) **(Note NA = Not Assigned)**

Havelock Estuary Sites A and B, 28 March 2014

Group	Species	WEBI	C-01	C-02	C-03	C-04	C-05	C-06	C-07	C-08	C-09	C-10	D-01	D-02	D-03	D-04	D-05	D-06	D-07	D-08	D-09	D-10
ANTHOZOA	*Edwardsia* sp. 1	2	1	2						1	1	1	1	1				2	2	2		
NEMERTEA	Nemertea sp. 1	3												1								
	Nemertea sp. 3	3					1										2					1
	Nemertea sp. 3	3								1												
POLYCHAETA	*Aonides* sp. 1	1																				
	Boccardia (Paraboccardia) acus	2	1								2											
	Boccardia (Paraboccardia) syrtis	2																				
	Disconatis accolus	1						1														
	Goniadidae	2																				
	Heteromastus filiformis	3	1	7	9	4	9	5	9	20	5	10	1									1
	Macroclymenella stewartensis	2	1		2	1	1		1		1		1	1		1	1	1		1		
	Nereidae	3	1	2						1		1	2			2	1	1	1			1
	Nicon aestuariensis	3						1				1		1		1		3	1	1	2	1
	Orbinia papillosa	1																				
	Paraonidae sp. 1	3		2	1	6	2		1	3	3	4										
	Pectinaria australis	3	1		2	1					3									1		2
	Perinereis vallata	2																				
	Prionospio aucklandica	2								1												
	Scolecolepides benhami	4																				
	Scoloplos cylindrifer	1			1						1			1								
OLIGOCHAETA	Oligochaeta	3																				
GASTROPODA	*Amphibola crenata*	3									1										1	
	Cominella glandiformis	3			1						1											3
	Diloma subrostrata	2																				
	Haminoea zelandiae	1																				
	Notoacmaea helmsi	2											1								1	
	Zeacumantus lutulentus	1																				
BIVALVIA	*Arthritica bifurca*	4											1		2	5		1	1		5	
	Austrovenus stutchburyi	2	6			1				3	5		4	5	3	3	6	3	5	2	4	1
	Cyclomactra ovata	2														1			1			
	Macomona liliana	2																				
	Paphies australis	2																				
	Theora lubrica	2	1	2	3	3		2	2	1	5	2										
CRUSTACEA	*Amphipoda* sp. 2	NA																				
	Amphipoda spp.	NA																				
	Austrohelice crassa	5																				
	Decapoda larvae unid.	NA																				
	Halicarcinus whitei	3						1		3	2		1									
	Hemiplax hirtipes	3												1	1						1	
	Paracorophium sp.	NA																				
	Phoxocephalidae sp. 1	2																				
	Tenagomysis sp. 1	2																				
Total individuals in sample			13	15	19	16	13	10	13	34	30	19	12	11	6	13	10	11	11	7	14	10
Total species in sample			8	5	7	6	4	5	4	9	12	6	8	7	3	6	4	6	6	5	6	7

APPENDIX 2. 2015 DETAILED RESULTS (CONTINUED)

Physical and Chemical Results for Havelock Estuary (Sites A and B), 2001, 2014, 2015.

Year/Site/Rep [c]	RPD	Salinity	TOC [d] AFDW	Mud	Sand	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	As	Hg	TN	TP
	cm	ppt	%				mg/kg									
2001 A-01	1	-	1.2	19.5	76	4.5	<0.2	74	11	41	5.6	51	-	-	500	385
2001 A-02	1	-	1.9	15.6	75.9	8.5	<0.2	70	11	39	6.2	52	-	-	500	413
2001 A-03	1	-	2	17.6	73.1	9.3	<0.2	67	11	41	5.4	52	-	-	600	433
2001 A-04	1	-	1.2	17.9	76.7	5.4	<0.2	68	10	39	5	50	-	-	500	376
2001 A-05	1	-	2.2	16.7	76.2	7.1	<0.2	71	11	40	5.6	51	-	-	900	365
2001 A-06	1	-	2	18.7	73.8	7.5	<0.2	63	11	41	5.7	52	-	-	600	411
2001 A-07	1	-	2.1	20.9	73.6	5.5	<0.2	57	11	36	5	51	-	-	600	385
2001 A-08	1	-	2.1	20.8	74.7	4.5	<0.2	73	11	36	5.5	52	-	-	500	388
2001 A-09	1	-	1.7	25.4	70.9	3.7	<0.2	82	12	36	4.8	52	-	-	700	380
2001 A-10	1	-	2.3	21.5	74.5	4.1	0.4	72	11	36	4.2	51	-	-	600	389
2001 A-11	1	-	1	26.1	68.3	5.6	0.4	73	12	35	5.3	53	-	-	700	387
2001 A-12	1	-	1.3	24.5	69.6	5.8	0.4	71	12	37	8.5	46	-	-	600	410
2001 B-01	1	-	1.3	25.8	72.8	1.5	0.3	29	11	16	3.5	39	-	-	700	284
2001 B-02	1	-	1.1	18.4	80.4	1.2	0.3	28	11	17	3.1	39	-	-	<500	284
2001 B-03	1	-	1.8	17.2	81.1	1.7	0.3	23	10	15	3.4	36	-	-	<500	274
2001 B-04	1	-	1	19.9	79.5	0.5	0.3	25	10	14	6.8	31	-	-	<500	255
2001 B-05	1	-	1.2	13.5	85	1.5	0.4	25	9.1	14	5.9	31	-	-	<500	257
2001 B-06	1	-	0.7	16.4	82.4	1.2	0.4	26	9.2	13	5.7	33	-	-	<500	241
2001 B-07	1	-	1.8	17.3	81.4	1.3	0.4	27	10	16	6.5	35	-	-	<500	273
2001 B-08	1	-	1.7	20.7	76.9	2.4	0.5	32	11	17	6.7	36	-	-	<500	295
2001 B-09	1	-	0.8	20.2	76.3	3.5	0.5	37	12	17	7.6	40	-	-	<500	284
2001 B-10	1	-	1.4	13.4	84.8	1.8	0.5	25	9.2	13	6.3	32	-	-	<500	248
2001 B-11	1	-	2.3	16.4	82.6	1	0.5	27	10	13	6.5	33	-	-	<500	248
2001 B-12	1	-	1	14.4	83.6	2	0.5	25	9.2	13	6	33	-	-	<500	243
2014 A 1-4 [b]	1	30	0.64	27.4	71	1.6	0.043	49	11.4	39	5.9	42	4.7	0.047	<500	410
2014 A-4-8 [b]	1	30	0.68	28.9	69.5	1.6	0.044	55	12.1	41	6	43	4.5	0.039	700	370
2014 A-9-10 [b]	1	30	0.62	25.2	72.3	2.5	0.041	48	11.3	38	5.6	40	4.1	0.038	600	360
2014 B-1-4 [b]	1	30	0.46	17	82	1	0.026	26	8.2	20	4.1	27	2.1	0.012	<500	230
2014 B-4-8 [b]	1	30	0.59	18.7	80	1.4	0.028	25	8.1	20	4.1	27	2.1	0.015	<500	230
2014 B-9-10 [b]	1	30	0.42	15.1	83.9	1.1	0.02	21	7.4	16.5	3.8	25	2	0.012	<500	210
2014 Marina [b]	1	30	NA	64.6	33.1	2.4	0.075	62	66	47	15.5	88	6.1	0.23	NA	NA
2015 A 1-4 [b]	1	30	0.7	33.4	63.9	2.7	0.045	54	14.2	45	7.3	47	5.5	0.049	800	500
2015 A-4-8 [b]	1	30	0.77	39.1	59.8	1.2	0.038	55	14.3	46	7.5	46	5.6	0.049	900	470
2015 A-9-10 [b]	1	30	0.87	38.2	59.6	2.2	0.046	54	14.4	46	7.4	47	5.5	0.044	1000	500
2015 B-1-4 [b]	1	30	0.35	20.1	79.8	0.2	0.029	20	7.6	17.7	4.3	26	2.3	0.019	<500	250
2015 B-4-8 [b]	1	30	0.53	16.5	82.8	0.6	0.025	24	8.4	19.9	4.7	28	2.5	0.017	800	250
2015 B-9-10 [b]	1	30	0.56	18.3	81.2	0.5	0.03	26	8.8	23	4.8	30	2.8	0.022	500	280
2015 C 1-4 [b]	1	30	1.19	56.3	42.5	1.2	0.038	65	17.7	57	8.7	49	5	0.082	1100	470
2015 C-4-8 [b]	1	30	1.1	59.7	36.8	3.4	0.041	68	18.5	59	9.1	50	4.9	0.075	1100	430
2015 C-9-10 [b]	1	30	1.26	63.6	36.1	0.3	0.048	66	19.1	58	9.6	51	5.5	0.064	1200	470
2015 D-1-4 [b]	1	30	0.78	49.5	50	0.6	0.03	26	11.9	23	6.5	34	3.6	0.022	800	340
2015 D-4-8 [b]	1	30	1.02	54.4	44.9	0.6	0.035	29	13.2	25	7.2	38	3.8	0.029	900	390
2015 D-9-10 [b]	1	30	1.05	58.7	39.3	2	0.04	32	14.3	29	7.6	40	4.3	0.036	1100	420
ISQG-Low [a]	-	-	-	-	-	-	1.5	80	65	21	50	200	20	0.15	-	-
ISQG-High [a]	-	-	-	-	-	-	10	370	270	52	220	410	70	1	-	-

[a] ANZECC 2000. [b] composite samples. [c] 2001 results from Robertson et al. 2002.
[d] 2001-2011 TOC values estimated from AFDW as follows: 1g AFDW as equivalent to 0.2 g TOC (± 100%) based on a preliminary analysis of NZ estuary data.

APPENDIX 2. 2015 DETAILED RESULTS (CONTINUED)

Non-normalised semi volatile organic compounds (SVOCs), Havelock Estuary, 28 March 2014 and 19 March 2015. Note: results are for a single composite sample for each site, with no analysed compound present at detectable levels (all reported as mg/kg d.w.).

GROUP	Organic Chemical	Havelock Township (2014)	Havelock A (2014)	Havelock B (2014)	Havelock C (2015)	Havelock C (2015)
Polycyclic Aromatic Hydrocarbons Screening in Soil	*Acenaphthene*	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Acenaphthylene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Anthracene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Benzo[a]anthracene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Benzo[a]pyrene (BAP)	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Benzo[b]fluoranthene + Benzo[j]fluoranthene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Benzo[g,h,i]perylene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Benzo[k]fluoranthene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Chrysene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Dibenzo[a,h]anthracene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Fluoranthene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Fluorene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Indeno(1,2,3-c,d)pyrene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Naphthalene	< 0.3	< 0.15	< 0.16	< 0.5	< 0.4
	Phenanthrene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
	Pyrene	< 0.05	< 0.03	< 0.04	< 0.09	< 0.07
Polychlorinated Biphenyls Screening in Soil	*PCB-18*	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-31	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-44	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-49	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-52	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-60	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-77	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-81	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-86	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-101	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-105	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-110	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-114	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-118	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-121	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-123	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-126	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-128	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-138	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-141	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-149	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-151	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-153	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-156	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-157	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-159	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-167	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-169	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-170	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-180	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-189	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-194	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-206	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
	PCB-209	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Tributyl Tin Trace in Soil samples by GCMS	*Dibutyltin (as Sn)*	0.011	< 0.005	< 0.005	< 0.005	< 0.005
	Monobutyltin (as Sn)	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
	Tributyltin (as Sn)	0.028	< 0.004	< 0.004	< 0.004	< 0.004
	Triphenyltin (as Sn)	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003