Wriggle

coastalmanagement

Havelock Estuary

Fine Scale Monitoring Data 2017

Prepared for

Marlborough District Council

May 2017

Cover Photo: Havelock Estuary, installing sediment plates in very soft mud habitat at Site F

Havelock Estuary sediment plate Site F (NIWA historical coring site HV-2) in the western settling basin.

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by

Leigh Stevens

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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 for use in trend analysis, the two single years of data for the Havelock Estuary (2001 and 2014) are insufficient to reliably define temporal change from natural variation. Therefore it was recommended that this be rectified by annual repeat monitoring over 3-5 years to establish a reliable baseline.
2. It was also recognised that the two fine scale sites selected for monitoring in Havelock Estuary in 2001 were chosen as experimental test sites during development of the NEMP. The final NEMP criteria for site selection determined that sites should be located in the dominant mid-low water habitat. Very soft mud habitat dominates the bulk of the intertidal substrate in Havelock Estuary, but the 2001 sites were selected in firm muddy sand/soft mud habitat. Consequently, Robertson and Robertson (2014) recommended additional sites be established in the dominant very soft mud habitat, or the existing two sites (2001 Sites A and B) in Havelock be shifted to this habitat. In response to these issues MDC resolved to:
   - Establish two new sites (C and D) in the dominant very soft mud habitat in Havelock Estuary, including the establishment of buried sediment plates in order to measure ongoing sedimentation rates. This was undertaken in 2015.
   - Conduct fine scale monitoring at fine scale sites A, B, C, and D in 2015 (Stevens and Robertson 2015), with repeat sampling undertaken in 2017 (described in the current report), and again 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.

For the 2017 sampling, Wriggle Coastal Management were engaged by MDC to undertake the fieldwork and provide a data only report of results. A full report analysing all available data is scheduled for 2019 following completion of the baseline sampling.

Because sedimentation has also been recognised by MDC as a significant issue in the estuary, MDC engaged Wriggle to install two additional sedimentation rate monitoring sites in the western basin (the main intertidal deposition area in the estuary) in conjunction with other field sampling being undertaken in early 2017.

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 subsequent extensions (e.g. Robertson et al. 2016), 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 or RPmV).
- 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). Analyses are based on non-normalised whole sample fractions to allow direct comparison with ANZECC (2000) Guidelines.
- Macroinvertebrate abundance and diversity (sediment infauna and surface epifauna), and macroalgal cover (surface epiflora).
- Other potentially toxic contaminants: these are measured in certain estuaries where a risk has been identified.

For Havelock Estuary, four fine scale sampling sites have been established in the estuary (Figure 1). Sites A and B were established in 2001 in unvegetated, mid-low water firm muddy sand/soft mud habitat (Robertson et al. 2002) and, in 2015, Sites C and D were established in the dominant very soft mud habitat of the estuary. At both sites, a 60m x 30m area in the lower intertidal zone 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). The following sampling was undertaken:

Physical and chemical analyses.

- At each site, average apparent Redox Potential Discontinuity (aRPD) depth was recorded within three representative plots, and in 2015 and 2017, redox potential (RPmV) was directly measured in one plot with an oxidation-reduction potential (ORP) meter at 0, 1, 3, 6 and 10cm depths below the surface.
- 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 for chemical analysis. All samples were kept in a chilly bin in the field before dispatch to R.J. Hill Laboratories for chemical analysis (details of lab methods and detection limits in Appendix 1):
- Samples were tracked using standard Chain of Custody forms and results 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.

Infauna (animals within sediment) and epiflora/fauna (surface-dwelling plants and animals).

- From each of 10 plots, 1 randomly placed sediment core [130mm diameter (area = 0.0133m^2) tube] was taken.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled 0.5mm nylon mesh bag. Once all replicates had been collected at a site, the bags were transported to a nearby source of seawater and fine sediments were washed from the core. 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 sorted by experienced Wriggle staff before being sent to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants, Appendix 1).
- Where present, macroalgae and seagrass vegetation (including roots), was collected within each of three representative 0.0625m^2 quadrats, squeezed (to remove free water), and weighed in the field. In addition, the % cover of each plant type was measured.

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

2. Methods (Continued)

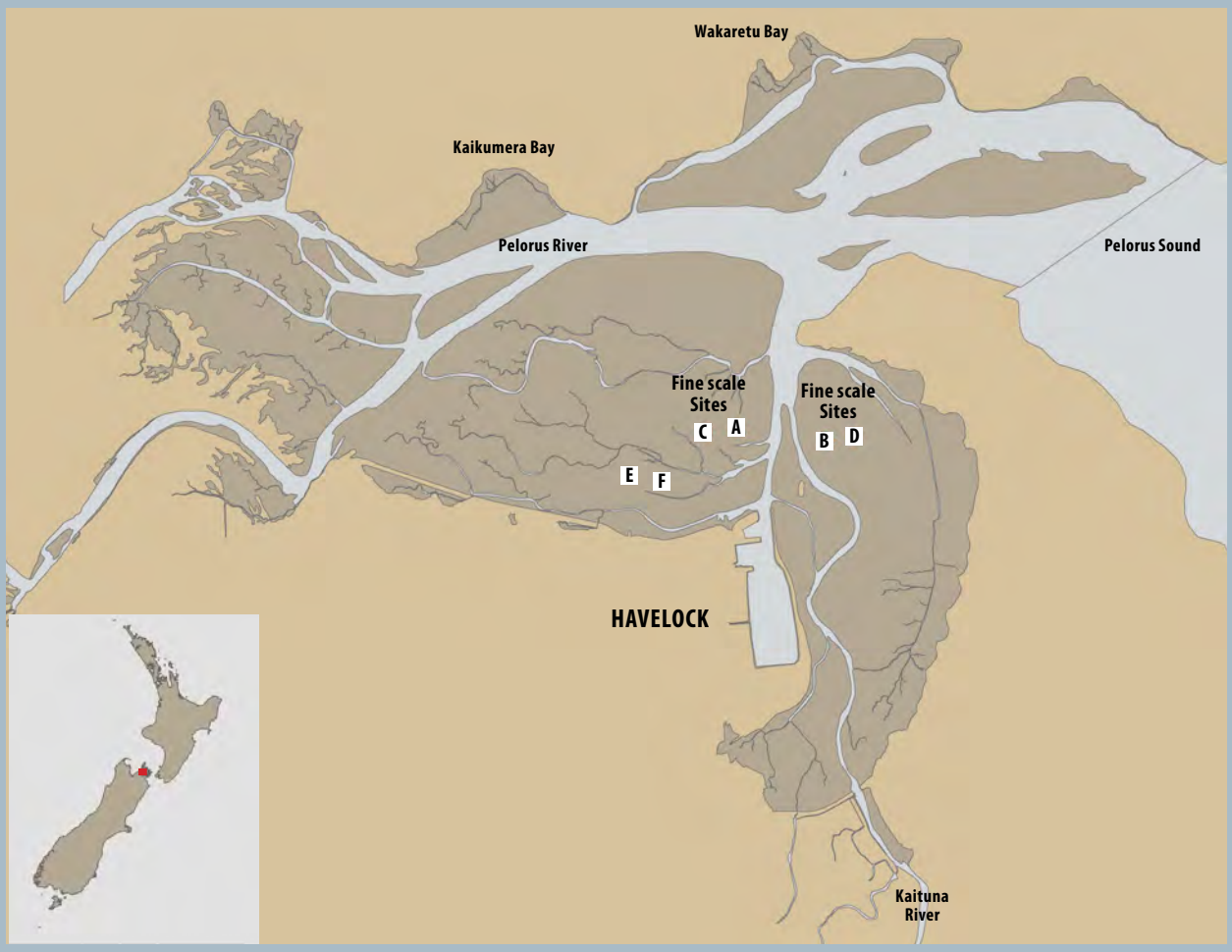

Figure 1. Havelock Estuary - location of fine scale (A-D) and sediment plate (A-F) monitoring sites.

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 previously been established in Havelock Estuary at fine scale Sites A and B (2014) and Sites C and D (2015). In 2017, two additional sites were established in the western basin of the estuary (Sites E and F). Site F corresponds to NIWA site HV-2, sampled in March 2017 to estimate the historical accrual of sediment in the estuary.

Plates were buried within the sediments where stable substrate was located and positioned 2m apart in a linear configuration along the baseline of each fine scale site or a transect line. Wooden pegs were used to mark the start, middle and end of each transect (0m, 5m and 10m respectively). 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 buried plates 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 using a 2m long strait edge, sediment probe, and ruler (results in Appendix 2). In the future, it is recommended that these depths be measured annually which, over the long term, will provide a measure of the rate of sedimentation in the estuary.

2. Methods (Continued)

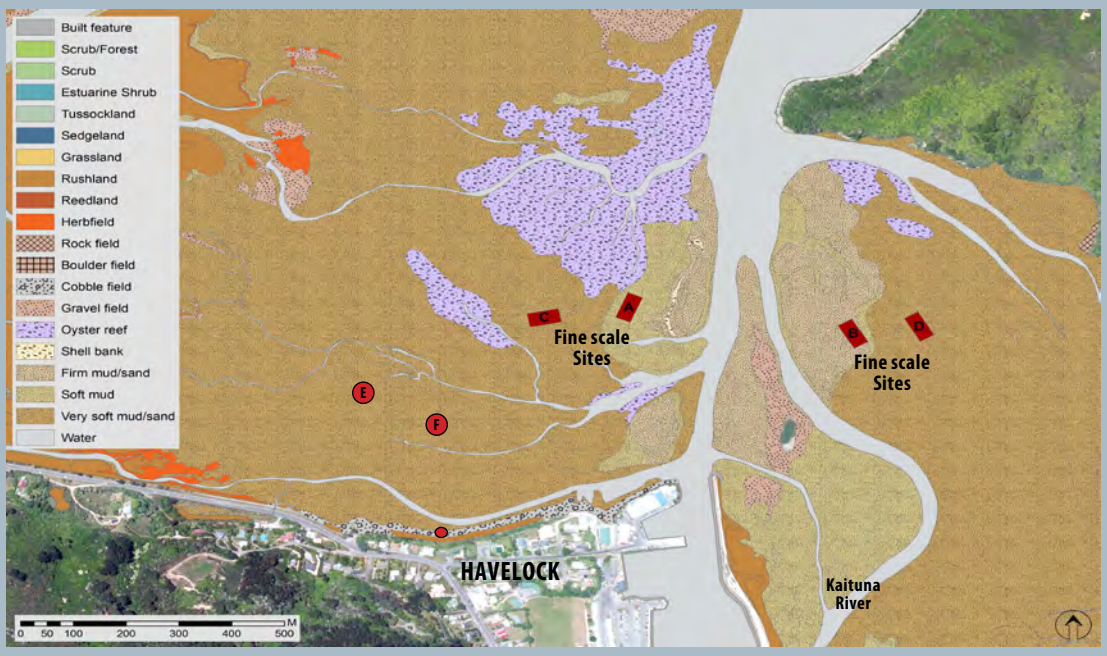

Figure 2. Havelock Estuary - location of fine scale monitoring sites A-D and sediment plate sites A-F in relation to dominant substrate types.

3. RESULTS

A summary of the results of the 19 March 2017 fine scale monitoring of Havelock Estuary are presented in Tables 1 and 2, with detailed results and 2001, 2014 and 2015 fine scale results presented in Appendices 2 and 3.

It was noted that recent flooding in the estuary appeared to have scoured fine sediment from fine scale sites B and D on the intertidal flats where the Kaituna River enters Havelock Estuary. No obvious change was observed at fine scale sites A and C in the western basin at the same time.

Detailed analysis of the results is scheduled to be undertaken following completion of the 5 year baseline monitoring block in 2019. This will include initial reporting of sediment plate results which be used to show trends in accrual or erosion over time once a sufficient baseline is established (sediment plate results are commonly reported as a multi-year average until sufficient data are collected to enable reporting of 5 yearly rolling means).

Table 1. Summary of fine scale physical and chemical results (means n=3), Havelock Estuary, 2017.

Year Site	aRPD	Salinity	TOC	Mud	Sand	Gravel	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	TN	TP
	cm	ppt	%				mg/kg									
2017 A	0.5	30-34	0.40	23.2	74.8	1.9	4.0	0.04	47.0	11.2	5.4	0.044	42.0	40.3	< 0.05	390
2017 B	0.5	30-34	0.35	19.8	78.8	1.4	3.1	0.03	36.0	9.3	4.5	0.035	32.2	33.3	< 0.05	217
2017 C	0.5	30-34	1.16	56.4	43.1	0.6	5.5	0.05	69.0	18.9	8.3	0.057	63.3	50.7	0.103	470
2017 D	0.5	30-34	0.75	39.4	59.4	1.3	2.9	0.03	22.3	10.6	5.2	0.029	21.0	29.7	0.063	320

Table 2. Summary of fine scale plant growth and macrofauna results (means), Havelock Estuary, 2017.

Year Site	Seagrass Biomass and Cover	Macroalgal Biomass and Cover	Macrofauna Abundance	Macrofauna Richness
	$g.m^{-2}$ wet weight (%)	$g.m^{-2}$ wet weight (%)	Individuals/m^2	Species/core
2017 A	-	110 (20%) *Gracilaria chilensis*	1605	8.8
2017 B	-	20 (<5%) *Gracilaria chilensis*	1085	6.9
2017 C	-	510 (<5%) *Gracilaria chilensis*	1093	7.2
2017 D	-	50 (<5%) *Gracilaria chilensis*	648	5.7

4. MONITORING RECOMMENDATIONS

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. Because of the magnitude of increased muddiness recorded between 2001 and 2014 (accompanied by changes in areas of dominant substrate, opportunistic macroalgae, and seagrass beds), and to establish whether the deteriorating results were truly representative of current conditions, Robertson and Robertson (2014) and Stevens and Robertson (2014) recommended that monitoring continue as follows:

Fine Scale Monitoring

In 2015, monitor existing Sites A and B, and establish and monitor two new sites (Sites C and D) in the dominant intertidal habitat type (very soft muds). Repeat fine scale monitoring at all 4 sites in February/ March 2017 and 2019 to establish a multi-year baseline and relationships between soft mud and very soft mud habitats so that the value of previous monitoring is not lost. To minimise costs to MDC, it was agreed that data only reports be prepared in 2015 and 2017, with a full report of all data undertaken following the completion of the scheduled fine scale baseline 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, and two new sites be established in the main settling basin in 2017.

5. ACKNOWLEDGEMENTS

This monitoring has been undertaken with the support and assistance of Steve Urlich (Coastal Scientist, MDC). Many thanks to Sally O'Neill, Ben Robertson and Reuben Lloyd (Wriggle) for field assistance.

6. REFERENCES

ANZECC. 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Davidson R. J., Duffy C.A.J., Gaze P., Baxter, A., DuFresne S., Courtney S., Hamill P. 2011. Ecologically significant marine sites in Marlborough, New Zealand. Co-ordinated by Davidson Environmental Limited for Marlborough District Council and Department of Conservation. 172p.

Hiscock, K. (ed.) 1996. Marine Nature Conservation Review: rationale and methods. Coasts and seas of the United Kingdom. MNCR Series. Joint Nature Conservation Committee, Peterborough.

Hiscock, K. 1998. In situ survey of subtidal (epibiota) biotopes using abundance scales and check lists at exact locations (ACE surveys). Version 1 of 23 March 1998. In: Biological monitoring of marine Special Areas of Conservation: a handbook of methods for detecting change. Part 2. Procedural guidelines (ed. K. Hiscock). Joint Nature Conservation Committee, Peterborough.

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J. and Tuckey, B.J. 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson, B.M. and Robertson, B. 2014. Havelock Estuary: Fine scale monitoring 2014. Report prepared by Wriggle Coastal Management for Marlborough District Council. 43p.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016. NZ Estuary Trophic Index. Screening Tool 2. Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.

Stevens, L.M. and Robertson, B.M. 2014. Havelock Estuary 2014. Broad Scale Habitat Mapping. Report prepared by Wriggle Coastal Management for Marlborough District Council. 43p.

Stevens, L.M. and Robertson, B.M. 2015. Havelock Estuary 2015. Fine Scale Monitoring Data. Report prepared by Wriggle Coastal Management for Marlborough District Council. 11p.

Tiernan, F. 2012. Coastal Monitoring Strategy, Marlborough. MDC Report No 12-101.

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	0.25m²	1.0m²	10m²	100m²	1,000m²
<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	3-24	10-99	100-999	1000-9999	>10,000
O	F	C	A	1-2	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 1. DETAILS ON ANALYTICAL METHODS (CONTINUED)

Macroinvertebrate sampling, sorting, identification and enumeration follows the general principles laid out in the protocol for processing, identification and quality assurance of New Zealand marine benthic invertebrate samples proposed by Hewitt et al. (2014). However, because the draft protocol does not address many important aspects for ensuring taxonomic consistency or required resolution, and provides limited explanation or support for many recommended procedures, Wriggle have instead adopted the following approach:

1. All sample processing follows the standard protocol guidance, and uses experienced sample sorters to cross check 10% of each others samples to ensure >95% of animals are being collected.
2. Species identification is conducted by a highly competent and experienced estuary taxonomist (Gary Stephenson, Coastal Marine Ecological Consultants - CMEC) who has a demonstrated ability to reliably and consistently identify all of the NZ species for which there are sensitivity data, and which are used in determining biological indices e.g. NZ AMBI.
3. Where any identifications are uncertain, they are evaluated against a comprehensive in-house reference collection of specimens from throughout NZ that have been compiled specifically by CMEC for this purpose.
4. Where this does not resolve uncertainty, specific taxonomic expertise is sought from either NIWA or Te Papa to further resolve uncertainty.
5. In addition, species lists published by other providers from comparable locations are also assessed to highlight any potential differences in identifications or naming, or where regionally specific animals may potentially be misclassified. Any discrepancies are noted in the reports provided.
6. Consistency in nomenclature is provided by reference to the most up to date online publications.
7. Taxa from NZ groups that are relatively poorly understood, or for which identification keys are limited (e.g. amphipods), are identified to the lowest readily identifiable groupings (i.e. Family or Genus) and consistently labelled and held in the in-house CMEC reference collection. Until species sensitivity information and taxonomic capacity are further developed for such groups, there is little defensible support for the further enumeration of such groups for the current SOE monitoring purposes.
8. The suggested requirement of Hewitt et al. (2014) that 10% of all samples be assessed for independent QAQC by another taxonomist is not supported in the absence of a list of taxa (relevant for SOE monitoring purposes) that taxonomic providers are expected to be able to readily identify to defined levels, combined with a minimum defined standard of competence for taxonomists to undertake QAQC assessments, and a defined process for resolving potential disagreements between taxonomic experts.

For the current work, no key specimens were collected that could not be reliably identified and, consequently, no additional taxonomic expertise was sought from either NIWA or Te Papa. The following table summarise the QAQC for Havelock Estuary samples (March 2017).

Evaluation Criterion	Staff	Assessor	Outcome
>95% picking efficiency (10% of samples randomly assessed)	Reuben Lloyd (Wriggle)	Leigh Stevens (Wriggle)	PASS
Enumeration of individuals (<10% difference in repeat counts)	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	PASS
Enumeration of common taxa (<10% difference in repeat counts)	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	PASS
Taxonomic identification possible with current expertise	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	PASS
Identification consistent with in-house reference collection	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	PASS
External validation to resolve any identification uncertainty	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	NOT REQUIRED
Comparison of site data with published data from other providers	Barry Robertson (Wriggle)	Barry Robertson (Wriggle))	PASS
Nomenclature checked against latest online publications	Gary Stephenson (CMEC)	Gary Stephenson (CMEC)	PASS

Hewitt, J.E., Hailes, S.F. and Greenfield, B.L. 2014. Protocol for processing, identification and quality assurance of New Zealand marine benthic invertebrate samples. Prepared for Northland Regional Council by NIWA. NIWA Client Report No: HAM2014-105.

APPENDIX 2. 2017 DETAILED RESULTS

Fine Scale Site Boundaries

Havelock Site A	1	2	3	4
NZTM EAST	1664422	1664446	1664418	1664395
NZTM NORTH	5430910	5430965	5430977	5430921

Havelock Site B	1	2	3	4
NZTM EAST	1664816	1664847	1664873	1664842
NZTM NORTH	5430902	5430850	5430865	5430917

Havelock Site C	1	2	3	4
NZTM EAST	1664292	1664287	1664226	1664231
NZTM NORTH	5430909	5430937	5430930	5430901

Havelock Site D	1	2	3	4
NZTM EAST	1664946	1664970	1664997	1664971
NZTM NORTH	5430919	5430865	5430831	5430937

Havelock Township Site	
NZTM EAST	1664063
NZTM NORTH	5430438

Fine Scale Station Locations

Havelock Site A	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664419	1664424	1664428	1664434	1664425	1664420	1664415	1664410	1664404	1664409
NZTM NORTH	5430917	5430928	5430944	5430956	5430969	5430950	5430937	5430919	5430928	5430945
Havelock Site B	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664821	1664831	1664840	1664846	1664854	1664848	1664840	1664835	1664843	1664849
NZTM NORTH	5430899	5430884	5430867	5430856	5430863	5430874	5430891	5430908	5430912	5430897
Havelock Site C	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664279	1664265	1664251	1664239	1664237	1664253	1664266	1664280	1664285	1664266
NZTM NORTH	5430933	5430931	5430929	5430928	5430917	5430919	5430922	5430925	5430914	5430922
Havelock Site D	1	2	3	4	5	6	7	8	9	10
NZTM EAST	1664950	1664959	1664963	1664971	1664963	1664967	1664975	1664979	1664970	1664979
NZTM NORTH	5430912	5430900	5430888	5430876	5430912	5430903	5430891	5430880	5430921	5430907

Redox Potential (mV) and aRPD depth (cm) for Havelock Estuary fine scale sites, 29 March 2017.

Year/Site	Redox Potential (mV)					aRPD depth
	0cm	1 cm	3cm	6cm	10cm	cm
2017 A	-25	-332	-344	-418	-432	0.5
2017 B	-28	-210	-327	-364	-375	0.5
2017 C	-25	-261	-292	-293	-320	0.5
2017 D	-70	-300	-333	-338	-355	0.5

Epifauna and macroalgal cover (0.25m² quadrats), Havelock Estuary Sites A, B, C, and D: 29 March 2017.

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		C		
	Batillariidae	*Zeacumantus lutulentus*	Spire shell	#	ii	C	C		
Red algae	Gracilariaceae	*Gracilaria chilensis*	Gracilaria weed	%	ii	C	0	0	0

APPENDIX 2. 2017 DETAILED RESULTS (CONTINUED)

Physical and chemical results for Havelock Estuary fine scale sites, 29 March 2017.

Year/Site/Rep [b]	RPD	Salinity	TOC	Mud	Sand	Gravel	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	TN	TP
	cm	ppt	%				mg/kg									
2017 A 1-4	0.5	30-34	2.2	24.1	73.5	2.20	4.2	0.046	51	12	5.8	0.041	45	43	0.05	400
2017 A-4-8	0.5	30-34	1.6	20.4	78.0	1.60	3.8	0.038	41	9.6	4.9	0.043	37	37	< 0.05	360
2017 A-9-10	0.5	30-34	2.0	25.2	72.8	2.00	3.9	0.044	49	12.1	5.5	0.048	44	41	< 0.05	410
2017 B-1-4	0.5	30-34	0.5	13.8	85.7	0.50	1.7	0.017	18.1	6.1	3.2	0.014	15.6	22	< 0.05	200
2017 B-4-8	0.5	30-34	0.5	15.1	84.4	0.50	2	0.023	23	7.1	3.7	0.011	20	26	< 0.05	220
2017 B-9-10	0.5	30-34	0.8	16.5	82.8	0.80	2.1	0.026	22	7.4	3.7	< 0.010	19.9	24	< 0.05	230
2017 C-1-4	0.5	30-34	0.2	59.7	40.0	0.20	5.7	0.061	70	20	8.8	0.064	64	52	0.12	500
2017 C-4-8	0.5	30-34	0.9	58.0	41.1	0.90	5.5	0.047	68	18.7	8.2	0.054	62	49	0.11	490
2017 C-9-10	0.5	30-34	< 0.1	51.6	48.2	< 0.1	5.2	0.054	69	18.1	8	0.053	64	51	0.08	420
2017 D-1-4	0.5	30-34	2.4	38.5	59.2	2.40	2.8	0.029	23	10.7	5.2	0.035	21	30	0.07	320
2017 D-4-8	0.5	30-34	1.0	38.8	60.3	1.00	2.9	0.031	22	10.1	5	0.029	21	29	0.07	320
2017 D-9-10	0.5	30-34	0.6	40.8	58.6	0.60	3	0.027	22	11	5.4	0.023	21	30	0.05	320
ISQG-Low [a]	-	-	-	-	-	-	20	1.5	80	65	50	0.15	21	200	-	-
ISQG-High [a]	-	-	-	-	-	-	70	10	370	270	220	1	52	410	-	-

[a] ANZECC 2000. [b] composite samples (2-4).

Expanded grain size results (5) for Havelock Estuary fine scale sites, 29 March 2017,

Year/Site/Rep	Gravel	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Mud (silt and clay)
	≥2mm	<2mm, ≥1mm	<1mm, ≥500µm	<500µm, ≥250µm	<250µm, ≥125µm	<125µm, ≥63µm	<63µm
2017 A 1-4 [b]	2.2	3.3	9.5	20.2	22.4	18.1	24.1
2017 A-4-8 [b]	1.6	3.2	9.4	20.8	24.9	19.7	20.4
2017 A-9-10 [b]	2.0	2.8	9.2	19.6	22.7	18.5	25.2
2017 B-1-4 [b]	0.5	0.4	0.7	1.2	25	58.4	13.8
2017 B-4-8 [b]	0.5	0.3	0.6	1.5	29.2	52.8	15.1
2017 B-9-10 [b]	0.8	0.4	0.7	1.6	23.9	56.2	16.5
2017 C-1-4 [b]	0.2	1.2	0.5	1.9	4.7	31.7	59.7
2017 C-4-8 [b]	0.9	1.3	0.7	2.4	6.2	30.5	58.0
2017 C-9-10 [b]	< 0.1	0.8	2.5	7.9	8.8	28.2	51.6
2017 D-1-4 [b]	2.4	0.4	0.5	1	1.9	55.4	38.5
2017 D-4-8 [b]	1.0	0.5	0.7	1.1	2.1	55.9	38.8
2017 D-9-10 [b]	0.6	0.3	0.5	0.9	1.8	55.1	40.8

Grain size results for sediment plate monitoring sites, Havelock Estuary, March/April 2017.

Sediment Plate	Mud	Sand	Gravel
	%		
Site A	23.2	74.8	1.9
Site B	19.8	78.8	1.4
Site C	56.4	43.1	0.6
Site D	39.4	59.4	1.3
Site E	74.9	24.4	0.7
Site F	65.5	30.6	3.9

APPENDIX 2. 2017 DETAILED RESULTS (CONTINUED)

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

Site A Sed Plates	NZTM EAST	NZTM NORTH	Peg Height/Plate Depth (mm)			
			28/3/2014	19/3/2015	29/3/17	
Peg 1			+150			FMS/SM - Firm Muddy Sand/ Soft Mud
Plate 1 @2m	1664438	5430967	-186	-185	-191	
Plate 2 @4m	1664436	5430967	-142	-143	-151	
Peg 2			+150			
Plate 3 @6m	1664434	5430968	-131	-130	-142	
Plate 4 @8m	1664431	5430969	-143	-144	-145	
Peg 3			+150			
Site B Sed Plates	NZTM EAST	NZTM NORTH	28/3/2014	19/3/2015	29/3/17	
Peg 1			+150			FMS - Firm Muddy Sand
Plate 1 @2m	1664844	5430850	-138	-147	-144	
Plate 2 @4m	1664845	5430852	-154	-165	-158	
Peg 2			+150			
Plate 3 @6m	1664846	5430853	-166	-176	-175	
Plate 4 @8m	1664849	5430855	-149	-159	-156	
Peg 3			+150			
Site C Sed Plates	NZTM EAST	NZTM NORTH		19/3/2015	29/3/17	
Peg 1	1664287	5430937		+150		VSM - Very Soft Mud
Plate 1 @2m	1664290	5430909		-93	-98	
Plate 2 @4m	1664288	5430908		-85	-91	
Peg 2	1664287	5430909		+150		
Plate 3 @6m	1664285	5430909		-98	-92	
Plate 4 @8m	1664283	5430909		-97	-91	
Peg 3	1664281	5430908		+150		
Site D Sed Plates	NZTM EAST	NZTM NORTH		19/3/2015	29/3/17	
Peg 1	1664970	5430865		+150		VSM - Very Soft Mud
Plate 1 @2m	1664972	5430865		-93	-103	
Plate 2 @4m	1664974	5430867		-85	-74	
Peg 2	1664975	5430868		+150		
Plate 3 @6m	1664975	5430868		-98	-68	
Plate 4 @8m	1664978	5430870		-97	-53	
Peg 3	1664978	5430870		+150		
Site E Sed Plates	NZTM EAST	NZTM NORTH			26/4/17	
Peg 1	1663894	5430726			+100	VSM - Very Soft Mud
Plate 1 @2m	1663892	5430725			-53	
Plate 2 @4m	1663890	5430725			-62	
Peg 2	1663889	5430724			+100	
Plate 3 @6m	1663888	5430724			-49	
Plate 4 @8m	1663886	5430724			-39	
Peg 3	1663883	5430724			+100	
Site F Sed Plates	NZTM EAST	NZTM NORTH			26/4/17	
Peg 1	1664016	5430692			+100	VSM - Very Soft Mud
Plate 1 @2m	1664014	5430692			-57	
Plate 2 @4m	1664013	5430693			-46	
Peg 2	1664011	5430692			+100	
Plate 3 @6m	1664009	5430693			-58	
Plate 4 @8m	1664008	5430693			-56	
Peg 3	1664006	5430694			+100	

Note sediment plate depth measurements for sites C and D in 2015 are indicative baseline depths only which were recorded during site establishment. They should not be used in estimates of sedimentation rate until supported by additional site measurements .

APPENDIX 2. 2017 DETAILED RESULTS (CONTINUED)

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

Havelock Estuary Sites A and B, 29 March 2017

Group	Species	AMBI	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	4	5	1			2	1			1						1	
NEMERTEA	Nemertea sp. 1	3									1	1	1	1								
	Nemertea sp. 3	3					1															
	Nemertea sp. 5	3															1					
POLYCHAETA	*Aonides* sp. 1	1	2	1									1									
	Boccardia (Paraboccardia) acus	2		1																		
	Boccardia (Paraboccardia) syrtis	2				1		1	1													
	Disconatis accolus	1	1							1												
	Goniadidae	2																				
	Heteromastus filiformis	3	3	1	3	10	2	4		4	4	1	1					1				1
	Macroclymenella stewartensis	2	1		1					1		1							1			
	Nereidae	3			1	1		1		1						1		1	1		1	1
	Nicon aestuariensis	3		1					2	1					1							
	Orbinia papillosa	1																				
	Paraonidae sp. 1	3		2	7	5	2	5	1	4	4	2	2	1	6		3	2	1		2	2
	Pectinaria australis	3			1	1		1	1		1			1	2		1				1	
	Perinereis vallata	2																		1		
	Prionospio aucklandica	2																				
	Scolecolepides benhami	4		2	2		1	2						1		1						
	Scoloplos cylindrifer	1				1					1	1										
OLIGOCHAETA	Oligochaeta	3				1																
GASTROPODA	*Amphibola crenata*	3																				
	Cominella glandiformis	3	8						1		1			1				1				
	Diloma subrostrata	2																				
	Haminoea zelandiae	1																				
	Notoacmaea helmsi	2					1								1	1					1	
	Zeacumantus lutulentus	1																				2
BIVALVIA	*Arthritica bifurca*	4								1								1			1	
	Austrovenus stutchburyi	2		7	11	6	7	12	7	8	2	7	7	6	2	4	12	7	3	7	13	7
	Cyclomactra ovata	2																				
	Macomona liliana	2	1	1	1	1					1					1	1				1	
	Paphies australis	2																				
	Theora lubrica	2																				
CRUSTACEA	*Amphipoda* sp. 2	NA	1							2			1									
	Amphipoda spp.	NA											2					1				
	Austrohelice crassa	5																				
	Austrominius modestus	2									1											
	Decapoda larvae unid.	NA																				
	Exosphaeroma planulum	NA																				1
	Halicarcinus whitei	3			1		1	1					1	2		1	1			2		
	Hemiplax hirtipes	3					1										1				1	
	Paracorophium sp.	NA																				
	Phoxocephalidae sp. 1	2		1										1	1							
	Pontophilus australis	NA								1							2	1				1
	Tenagomysis sp. 1	2				1								1								
Total individuals in sample			**17**	**17**	**29**	**32**	**21**	**28**	**13**	**24**	**18**	**14**	**16**	**15**	**14**	**9**	**22**	**15**	**6**	**10**	**22**	**15**
Total species in sample			**7**	**9**	**10**	**11**	**9**	**9**	**6**	**10**	**10**	**7**	**8**	**9**	**7**	**6**	**8**	**8**	**4**	**3**	**9**	**7**

APPENDIX 2. 2017 DETAILED RESULTS (CONTINUED)

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

Havelock Estuary Sites C and D, 29 March 2017

Group	Species	AMBI	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	1	1	1			1	1					1		
NEMERTEA	Nemertea sp. 1	3					1			1												
	Nemertea sp. 3	3							1	1	1		1	1		1			1		1	
	Nemertea sp. 5	3				1		1				1										
POLYCHAETA	*Aonides* sp. 1	1																				
	Boccardia (Paraboccardia) acus	2									1	1										
	Boccardia (Paraboccardia) syrtis	2																				
	Disconatis accolus	1							1									1				
	Goniadidae	2																				
	Heteromastus filiformis	3	2	4	5	5	3	4	3	7	4	6		1				2				1
	Macroclymenella stewartensis	2		1							2							1				1
	Nereidae	3	1	2					1	2		2				2		1	1			
	Nicon aestuariensis	3			1	1		1								1	1	1		1		
	Orbinia papillosa	1																				
	Paraonidae sp. 1	3	3	1	2	1	16	2		3		1		1								1
	Pectinaria australis	3			1					1		1			1							1
	Perinereis vallata	2																				
	Prionospio aucklandica	2																				
	Scolecolepides benhami	4																				
	Scoloplos cylindrifer	1																				
OLIGOCHAETA	Oligochaeta	3								1												
GASTROPODA	*Amphibola crenata*	3															1		1			
	Cominella glandiformis	3																1				
	Diloma subrostrata	2																				
	Haminoea zelandiae	1																				
	Notoacmaea helmsi	2																				
	Zeacumantus lutulentus	1																				
BIVALVIA	*Arthritica bifurca*	4								1							1	1	1			2
	Austrovenus stutchburyi	2	2							1	6	2	3	2	3		1	5	5	5	2	4
	Cyclomactra ovata	2																				
	Macomona liliana	2	2							1	1		1									
	Paphies australis	2																				
	Theora lubrica	2			2		4	2		1												
CRUSTACEA	*Amphipoda* sp. 2	NA				1		2				1						2	1			
	Amphipoda spp.	NA								1								1				
	Austrohelice crassa	5														1						
	Austrominius modestus	2																			3	
	Decapoda larvae unid.	NA																				
	Exosphaeroma planulum	NA																	1			1
	Halicarcinus whitei	3								1	1					1	1					1
	Hemiplax hirtipes	3				1	1													1		3
	Paracorophium sp.	NA																				
	Phoxocephalidae sp. 1	2		1						2	1				1		1					1
	Pontophilus australis	NA																				
	Tenagomysis sp. 1	2					1		1													
Total individuals in sample			**10**	**9**	**11**	**10**	**26**	**13**	**8**	**25**	**18**	**15**	**5**	**6**	**6**	**6**	**6**	**16**	**11**	**8**	**6**	**16**
Total species in sample			**5**	**5**	**5**	**6**	**6**	**7**	**6**	**15**	**9**	**8**	**3**	**5**	**4**	**5**	**6**	**10**	**7**	**4**	**3**	**10**

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APPENDIX 3. 2001, 2014 AND 2015 DETAILED RESULTS

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

Havelock Estuary Sites A and B, 2001

Group	Species	AMBI	A-01	A-02	A-03	A-04	A-05	A-06	A-07	A-08	A-09	A-10	A-11	A-12	B-01	B-02	B-03	B-04	B-05	B-06	B-07	B-08	B-09	B-10	B-11	B-12
NEMATODA	Nematoda	1			1	1															1		1			
NEMERTEA	Nemertea	3	1	1	1				2	1	1	1	1							1				2		
OLIGOCHAETA	Oligochaeta	3					2	3	7	8			5	3												
SIPUNCULA	Sipuncula	2			1				2		1															
POLYCHAETA	Ampharetidae	1																						1		
	Boccardia sp.	2									1															
	Capitella capitata	4			2	4	2	4					1													
	Glyceridae	3	1	1	2																					
	Heteromastus filiformis	3	3	3	3		7	3	2	2	4	4		2	1											
	Lumbrineris sp.	2	1																							
	Macroclymenella stewartensis	2	2		2	1	1			1	2	1	2	1			2	1	1	2	1			2	1	1
	Nereidae	3		1	1		1	1	1	2	1	1	1													
	Nicon aestuariensis	3								1						3	2	3		2	1		2	3	2	1
	Orbinia papillosa	1							1							1	1		1	1	2				1	1
	Paraonidae	3	4		3								1													
	Pectinaria australis	3		1											1											
	Phyllodocidae	2	1	1			1					1							1			1				
	Polydora sp. 1	3					1																			
	Prionospio sp.	2	2	4	2	3			2	2	2		3													
	Scolecolepides sp.	4								1													1	1		1
	Scoloplos cylindrifer	1		1					1					3				1								
	Spionidae sp. 1	3								1																
GASTROPODA	*Amphibola crenata*	3	2		1					2				1	2	1		1		1	2		2	2	2	
	Cominella glandiformis	3		1		1				1		1		1											1	
	Notoacmea helmsi	2		1	7	1			1	2			1	2	1								2			
	Zeacumantus lutulentus	2						1																		
BIVALVE	*Arthritica bifurca*	4	1		3		1		1	1	2			1	2	7	4	3	1	7	20	3	16	25	3	5
	Austrovenus stutchburyi	2	8	9	10	7	2	7	21	10	13	6	6	5	7	6	4	3	3	1	9		7	4	5	6
	Macomona liliana	2					1																			
	Mytilus galloprovincialis	NA									1															
CRUSTACEA	*Amphipoda* sp.	2			2		1	1	1							1						1			1	
	Copepoda	2		1									1													
	Halicarcinus cookii	3			1																					
	Halicarcinus whitei	3								1																
	Helice crassa	5								1																
	Macrophthalmus hirtipes	5	2		1		2			1	1		1	2						1						
	Natantia unid.	2							1				1													
	Ostracoda	1	1																							
Total individuals in sample			29	25	43	18	22	20	43	38	29	15	24	21	14	19	13	12	7	16	36	5	31	40	16	15
Total species in sample			13	12	17	7	12	7	13	17	11	7	12	10	6	6	5	6	5	8	7	3	7	8	8	6

APPENDIX 3. 2001, 2014 AND 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	AMBI	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		3			1		1			1		1		1	1	1				
NEMERTEA	Nemertea sp. 1	3			1	1							1			1						
	Nemertea sp. 3	3	1								1					1	1	1				1
POLYCHAETA	*Aonides* sp. 1	1							1													
	Boccardia syrtis	2			1						1											
	Disconatis accolus	1	1	1						1										1		1
	Goniadidae	2		1																		
	Heteromastus filiformis	3	3	3	7	1	6		1	1	4											
	Macroclymenella stewartensis	2	2	1	1		2		1	1	1	1	2	2	1	1	3		1	2	1	1
	Nereidae	3		2			2		1	1			1								1	2
	Nicon aestuariensis	3			1									1								
	Orbinia papillosa	1													2	2		2		1	1	1
	Paraonidae sp. 1	3	8	3	1	1	7	3	4	3	3	1				1	2					
	Pectinaria australis	3	1					1					4		1		2				1	
	Perinereis vallata	2										1										
	Prionospio aucklandica	2			1	1			1		1											
	Scolecolepides benhami	4													1	1						
	Scoloplos cylindrifer	1	4	3	2			2	2	3					1		2	1				
OLIGOCHAETA	Oligochaeta	3		2	13	2	1	12	8	1		1				1						
GASTROPODA	*Cominella glandiformis*	3		2																		
	Haminoea zelandiae	1			2																	
	Notoacmaea helmsi	2		2		5		1		1	1					1			1	2	9	
	Zeacumantus lutulentus	1												1								
BIVALVIA	*Arthritica bifurca*	4			2												1					
	Austrovenus stutchburyi	2	8	15	5	1	4	3	9	4	3	5	0	6	10	4	4	8	5	2	8	5
	Macomona liliana	2			1	2	2	1						1				2				
	Paphies australis	2		1														1				
CRUSTACEA	*Austrohelice crassa*	5																		1		
	Decapoda larvae unid.	NA																			1	
	Halicarcinus whitei	3			1	2		2			1			1	1		1	1			1	
	Phoxocephalidae sp. 1	2															1	1	1	1		1
	Tenagomysis sp. 1	2		1																		
Total individuals in sample			28	40	39	16	25	25	29	16	16	10	8	13	17	14	18	18	8	10	23	12
Total species in sample			8	14	14	9	8	8	10	9	9	6	5	7	7	10	10	9	4	7	8	7

APPENDIX 3. 2001, 2014 AND 2015 DETAILED RESULTS (CONTINUED)

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

Havelock Estuary Sites A and B, 19 March 2015

Group	Species	AMBI	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 3. 2001, 2014 AND 2015 DETAILED RESULTS (CONTINUED)

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

Havelock Estuary Sites C and D, 19 March 2015

Group	Species	AMBI	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

Epifauna and macroalgal cover (0.25m² quadrats, Havelock Estuary Sites A and B, 2001).

Group	Family	Species	Common name	Scale	Class	A	B
Topshells	Amphibolidae	*Amphibola crenata*	Mudflat snail	#	ii	A	A
	Buccinidae	*Cominella glandiformis*	Mudflat whelk	#	ii	F	F
	Batillariidae	*Zeacumantus lutulentus*	Spire shell	#	ii	C	-
Limpets	Lottiidae	*Notoacmaea helmsi*	Estuarine limpet	#	i	O	-
Bivalves	Veneridae	*Austrovenus stutchburyi*	Cockle	#	ii	A	O
	Ostreidae	*Crassostrea gigas*	Pacific oyster	#	ii	C	-
	Mytilidae	*Xenostrobus pulex*	Black mussel	#	ii	C	-
Crabs	Macrophthalmidae	*Macrophthalmus hirtipes*	Stalk eyed mud crab	#	ii	F	-
	Varunidae	*Hemigrapsus crenulatus*	Hairy-handed crab	#	ii	F	-

Source Robertson et al. (2002)

Epifauna and macroalgal cover (0.25m² quadrats, Havelock Estuary Sites A and B, 2014).

Group	Family	Species	Common name	Scale	Class	A	B
Topshells	Amphibolidae	*Amphibola crenata*	Mudflat snail	#	ii	A	A
	Buccinidae	*Cominella glandiformis*	Mudflat whelk	#	ii	O	-
	Haminoeidae	*Haminoea zelandiae*	White bubble shell	#	ii	O	-
	Batillariidae	*Zeacumantus lutulentus*	Spire shell	#	ii	O	-
Limpets	Lottiidae	*Notoacmaea helmsi*	Estuarine limpet	#	i	F	F
Red algae	Gracilariaceae	*Gracilaria sp. ?secundata*	Gracilaria weed	%	ii	R	R

Source Robertson and Robertson (2014)

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	O	O	O	O

Source Stevens and Robertson (2015)

APPENDIX 3. 2001, 2014 AND 2015 DETAILED RESULTS (CONTINUED)

Physical and Chemical Results for Havelock Estuary, 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 (2-4 plots). [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 3. 2001, 2014 AND 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 D (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