NIWA
Taihoro Nukurangi

Discharge consents for Omaha WWTP: benthic habitat considerations

Prepared for Aquatic Environmental Science Limited

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Executive summary

In December 2014 Aquatic Environmental Science Limited contracted NIWA to analyse and summarise existing data from the Waikokopu Arm of the Whangateau Harbour and to compare recent satellite imagery with a 2010 habitat map. This was to provide information on an area of the harbour that may potentially be impacted by the discharge of treated water.

Auckland Council monitors the intertidal areas of Whangateau at 7 sites; 4 of which are in the Waikokopu arm. This report summarises these four sites with respect to:

- Macrofaunal monitoring conducted approximately six monthly between from spring 2009 and autumn 2014.
- Sediment particle size and organic content collected approximately six monthly between spring 2009 and autumn 2014.
- Sediment chlorophyll *a* content collected approximately six monthly between spring 2012 and autumn 2014.
- And sediment concentrations of copper, lead, zinc, iron, arsenic, cadmium, chromium and nickel collected once only in November 2009.

Benthic macrofaunal community data at each site is discretely clustered with no trends over time. Different taxa are numerically dominant over time, with bivalves, polychaetes, amphipods and gastropods all appearing in the top 5 for abundance across the sites. The bivalves *Austrovenus stutchburyi* and *Macomona liliana* have been present at all sites since monitoring began, but have varied in abundances and size class structure. *Paphies australis* were not present at one site, and in low abundance at the remaining three.

Mud was not a large component of the sediment particle size across all four sites, but there were occasional spikes appearing over time at three of the four sites. Chlorophyll *a* content has been stable across all sites since October 2012.

The concentrations of metals were relatively low at all sites, with no exceedances of either the Auckland Council's Environmental Response Criteria 'Effects Range Low' (ERL) level or the Threshold Effect level (TEL).

Comparison of recent satellite images with the 2010 habitat map indicates that several changes have likely occurred. This is mostly the change in shape and expansion of both seagrass and mangrove habitat patches.

In terms of recommendations, there are three aspects relating to intertidal areas and the impacts of treated water for which further information would be useful. These are:

- The relative sensitivities of macrofaunal species to nutrient and organic enrichment.
- The condition of adult cockles and wedge shells.
- The status of the present mangroves with respect to nutrient limitation.

1 Introduction

In December 2014 Aquatic Environmental Science Limited contracted the National Institute of Water and Atmospheric Research to:

1. Analyse and summarise existing data from reports and unpublished data relevant to the area potentially impacted by the irrigation of treated water. The RFP specified the sites monitored by Auckland Council in the Waikokopu Arm and shellfish surveys, however, the shellfish surveys were later removed from the brief (Mark James pers. comm.).

2. Prepare Google Earth maps and undertake comparison with previous habitat maps; most recently from Townsend et al. (2010).

3. Provide recommendations and specialist advice on requirements for further information gathering.

Section 2 of this report outlines the processes for the acquisition, processing and analysis of relevant monitoring data; routinely undertaken as part of the Auckland Council Ecological monitoring. Section 3 reports on the findings of the monitoring data, while Section 4 focuses on the benthic habitats of the Whangateau Harbour and how they have changed over the last 5 year. Recommendations are provided in Section 5.

2 AC monitoring methods summary

Auckland Council monitors the intertidal areas of Whangateau Harbour at 7 sites, 4 of which are in the Waikokopu arm (Figure 1, Sites 1-4). This report summarises data from these four sites.

Data available from Auckland Council monitoring of Whangateau Harbour consisted of:

- Macrofaunal monitoring conducted approximately six monthly between spring 2009 and autumn 2014.
- Sediment particle size and organic content collected approximately six monthly between spring 2009 and autumn 2014.
- Sediment chlorophyll *a* content collected approximately six monthly between spring 2012 and autumn 2014.
- And sediment concentrations of copper, lead, zinc, iron, arsenic, cadmium, chromium and nickel collected once only in November 2009.

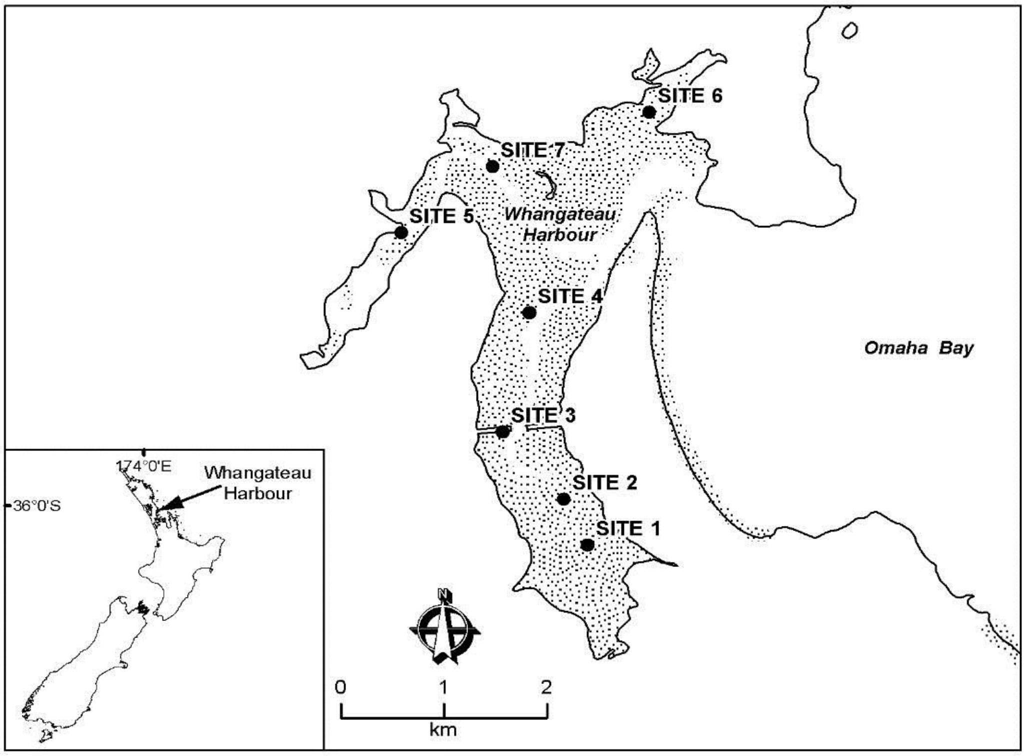

Figure 1: Map of the Whangateau Harbour and location of monitoring sites.

2.1 Macrofauna

Sampling occurs within a 6 week period centred on October and April, in time periods of low rainfall (see definition in Hewitt and Simpson 2012). At each site, six replicate macrofaunal cores (130 mm in diameter x 150 mm deep) are taken from random positions at each site, excluding the area within 5 m of a core location for the previous 6 months. Cores are sieved on a 0.5 mm mesh and the material retained preserved in 70% isopropyl alcohol with 0.01% rose bengal. Later the macrofauna are identified to the lowest practical taxonomic level (usually species) and counted. Individuals from three bivalve species (the cockle *Austrovenus stutchburyi*, the wedge shell *Macomona liliana* and the pipi *Paphies australis*) are placed into size classes (small < 5mm, medium 5-15 mm, and large > 15 mm).

2.2 Sediment characterisation

Sampling to characterise ambient sediment was coincident with macrofaunal sampling. Six sediment cores (2cm diam. collected to depth of 2 cm) were combined into a single sample which was frozen until further analysis could occur.

Particle size

An approximately 5 gm homogenous subsample was taken and organic matter was removed using 9% hydrogen peroxide until fizzing ceased. The sample is then wet-sieved on a stack of sieves (2000, 500, 250, 125 and 63 µm). Each fraction is dried to a constant weight at 60°C. Sediment percentage weight was then expressed for shell (>2000), coarse sand (500 - 1999), medium sand (250–499), fine sand (125–249), very fine sand (63–124) and mud (< 63 µm).

Sediment organic content.

An approximately 5 gm homogenous subsample was taken and dried to constant weight at 60°C, before being combusted for 5.5 h at 400°C and reweighed. Organic content was calculated as the percentage mass lost during combustion.

Sediment chlorophyll *a*

An approximately 5 gm homogenous subsample was taken and freeze dried. Chlorophyll *a* was extracted by boiling this freeze dried sediment in 90% ethanol, and the extract processed using a spectrophotometer. An acidification step is used to separate degradation products from chlorophyll *a*.

2.3 Sediment metal/metalloid concentrations

Three replicates cores of the top 2 cm of sediment were collected per site and analysed by R J Hill Laboratories Ltd (Hamilton) using standard ARC methods and protocols as outlined in Mills and Williamson (2008). Heavy metals (iron, manganese, chromium, nickel, cadmium, mercury, copper, lead and zinc) and arsenic concentrations were analysed from 3 replicates at each site. Chemical analysis was performed on total recoverable acid digested < 500 µm dry sieved fractions for all metals, and also, for copper, lead and zinc, on weak acid digestion of the < 63 µm wet sieved fraction. Measurements were also made of total organic content, PAHs (polycyclic aromatic hydrocarbons) and total PAH.

3 Description of Waikokopu Arm sediments and ecology

3.1 Methods used to summarise AC data

Macrofaunal taxa information was summarised using nonmetric multidimensional ordination (MDS) based on Bray-Curtis similarities of square root transformed data. Changes in the dominance structure of the macrofauna within and between years was summarised as changes in the five top ranked species over time. Differences between sites and over time in shellfish size structure were assessed visually.

Sediment particle size information was summarised using Principal component analysis (PCA) on unstandardized data. Differences over time within and between years were assessed using plots of mud content, organic content and chlorophyll *a* content over time at each site separately.

Sediment contaminant information was summarised using PCA on standardised data. PAH, Cadmium and Mercury were removed from the analysis as they were mainly below the detection limit. Heavy metal concentrations were then compared against present Auckland Council' Environmental Response Criteria Effects Range Low (ERL) and the 'Threshold Effect level (TEL) from MacDonald et al. (1996).

3.2 Macrofauna

A non-metric multidimensional scaling analysis was conducted on all taxa collected from the four sites from October 2009 to April 2014 (Figure 2). All sites were discretely clustered and there are no trends over time as the community composition from October 2009 and April 2014 are within the clusters. Neighbouring sites are generally more similar in terms of their community composition however, the community composition at site 1 is more similar to site 3 and 4 than site 2, and site 2 is the most dissimilar of the 4 sites (Figure 2).

Site 1 was numerically dominated by the small bivalve *Lasaea parengaensis* for the first few years (Table 1). Thereafter it was dominated by a mix of polychaetes (Lumbrineridae, Spionidae, Capitellidae and Nerieididae) and small bivalves (*Lasaea* and *Linucula*). Site 2 was more variable over time than site 1 in terms of which species dominated numerically. It was also generally dominated by a mix of taxonomic groups (amphipods, cumaceans, isopods and bivalves). Site 3 was dominated by a mix of bivalves, polychaetes and oligochaetes with only the occasional amphipod and cumacean (Table 1). The dominant bivalves were *Linucula* and *Austrovenus*, and *Prionospio aucklandica* was the most frequent dominant polychaete. Site 4 was the only site where a number of gastropod species were amongst the dominant taxa (Table 1). It was dominated mainly by bivalves (*Lasaea*, Linucula and *Austrovenus*), Oligochaetes and 3 species of gastropods (*Eationella abscenosam*, *Potamopyrgus estuarensis*, *Pisinna zosterophila*).

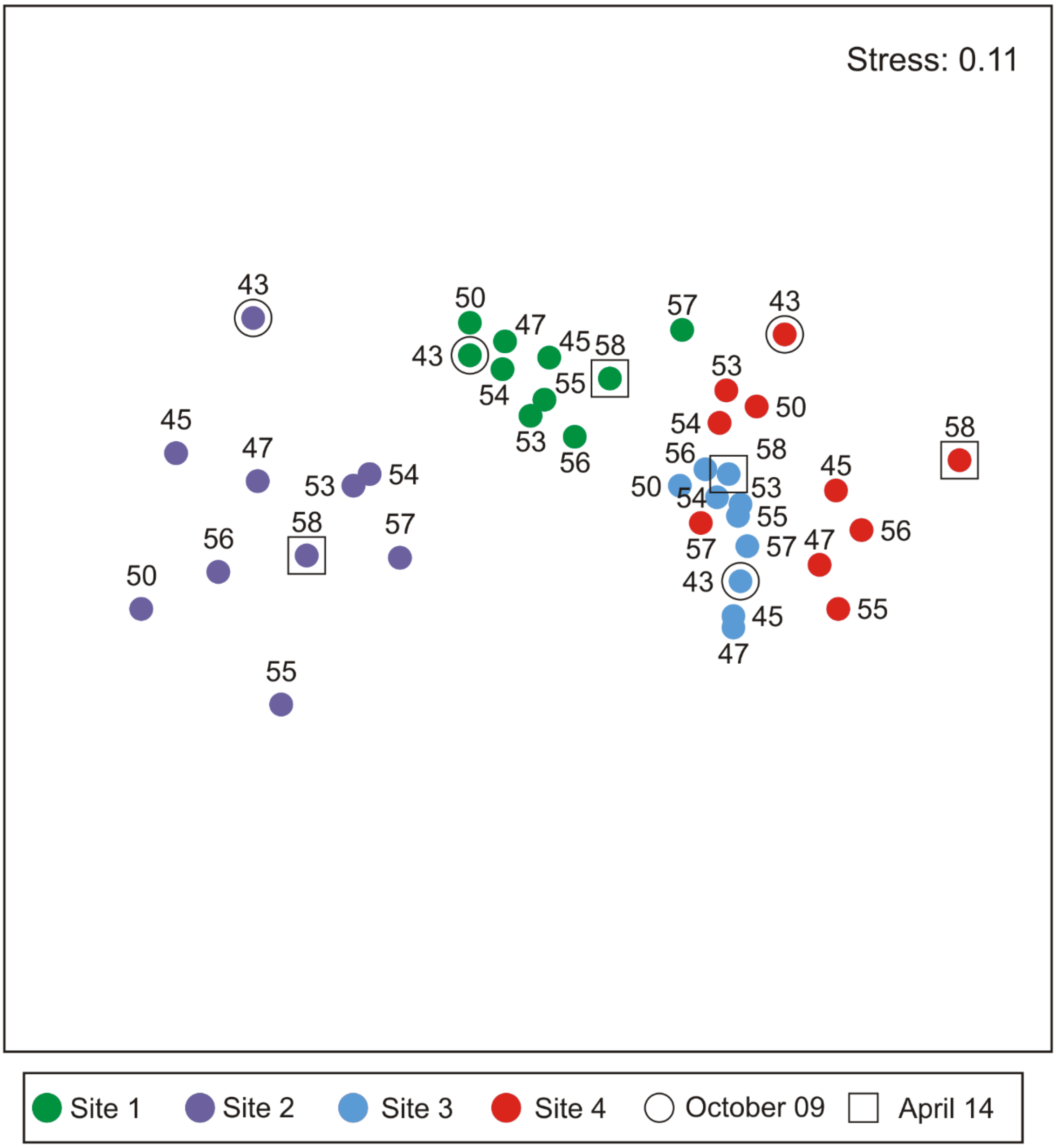

Figure 2: Non-metric multidimensional scaling plot (MDS) of Bray Curtis similarities of macrofaunal communities over time. (October 2009 (circle) – April 2014 (square). The closer the points are in ordination space, the more similar the community composition, data has been square-root transformed.

Table 1: The five most abundant taxa from each monitored site in October since 2009 until April 2014. Species or genera name in brackets indicates a previously accepted designation.

Site	Date	Most abundant				Less abundant
1	Oct-09	*Lasaea parengaensis*	*Macomona liliana*	*Parawaldeckia* sp	*Prionospio aucklandica*	*Phoxocephalidae other*
	Apr-10	*Lasaea parengaensis*	*Lumbrineridae*	*Ceratonereis*	*Oligochaete*	*Prionospio aucklandica*
	Oct-10	*Lasaea parengaensis*	*Colurostylis lemurum*	*Lumbrineridae*	*Scoloplos cylindrifer*	*Oligochaete*
	Apr-11	*Lasaea parengaensis*	*Lumbrineridae*	*Scoloplos cylindrifer*	*Ceratonereis*	*Macomona liliana*
	Oct-11	*Lasaea parengaensis*	*Perinereis vallata*	*Scoloplos cylindrifer*	*Oligochaete*	*Macomona liliana*
	Apr-12	*Lumbrineridae*	*Lasaea parengaensis*	*Nicon aestuariensis*	*Scoloplos cylindrifer*	*Parawaldeckia sp*
	Oct-12	*Lasaea parengaensis*	*Lumbrineridae*	*Lysianassidae*	*Oligochaete*	*Ceratonereis*
	Apr-13	*Prionospio aucklandica*	*Lumbrineridae*	*Lasaea parengaensis*	*Perinereis vallata*	*Colurostylis lemurum*
	Oct-13	*Linucula (Nucula) hartvigiana*	*Lumbrineridae*	*Heteromastus filiformis*	*Prionospio aucklandica*	*Ceratonereis*
	Apr-14	*Perinereis vallata*	*Lumbrineridae*	*Prionospio aucklandica*	*Lasaea parengaensis*	*Lysianassidae*
2	Oct-09	*Urothidae*	*Lasaea parengaensis*	*Colurostylis lemurum*	*Macomona liliana*	*Exosphaeroma waitemata*
	Apr-10	*Lasaea parengaensis*	*Waitangi brevirostris*	*Macomona liliana*	*Lumbrineridae*	*Paphies australis*
	Oct-10	*Waitangi brevirostris*	*Lasaea parengaensis*	*Exosphaeroma waitemata*	*Macomona liliana*	*Colurostylis lemurum*
	Apr-11	*Exosphaeroma waitemata*	*Waitangi brevirostris*	*Paphies australis*	*Macomona liliana*	*Colurostylis lemurum*
	Oct-11	*Microspio maori*	*Waitangi brevirostris*	*Lasaea parengaensis*	*Ceratonereis*	*Perinereis vallata*
	Apr-12	*Waitangi brevirostris*	*Lasaea parengaensis*	*Oligochaete*	*Microspio maori*	*Perinereis vallata*
	Oct-12	*Exosphaeroma waitemata*	*Waitangi brevirostris*	*Perinereis vallata*	*Colurostylis lemurum*	*Nicon aestuariensis*
	Apr-13	*Waitangi brevirostris*	*Lasaea parengaensis*	*Paphies australis*	*Exosphaeroma waitemata*	*Perinereis vallata*
	Oct-13	*Colurostylis lemurum*	*Waitangi brevirostris*	*Lasaea parengaensis*	*Exosphaeroma waitemata*	*Macomona liliana*
	Apr-14	*Lasaea parengaensis*	*Waitangi brevirostris*	*Perinereis vallata*	*Macomona liliana*	*Lumbrineridae*
3	Oct-09	*Linucula (Nucula) hartvigiana*	*Prionospio aucklandica*	*Torridoharpinia hurleyi*	*Oligochaete*	*Austrovenus stutchburyi*
	Apr-10	*Prionospio aucklandica*	*Linucula (Nucula) hartvigiana*	*Austrovenus stutchburyi*	*Paradoneis lyra*	*Cyclapsis thomsoni*
	Oct-10	*Torridoharpinia hurleyi*	*Prionospio aucklandica*	*Linucula (Nucula) hartvigiana*	*Colurostylis lemurum*	*Oligochaete*
	Apr-11	*Prionospio aucklandica*	*Linucula (Nucula) hartvigiana*	*Oligochaete*	*Austrovenus stutchburyi*	*Lasaea parengaensis*
	Oct-11	*Oligochaete*	*Linucula (Nucula) hartvigiana*	*Torridoharpinia hurleyi*	*Prionospio aucklandica*	*Austrovenus stutchburyi*
	Apr-12	*Prionospio aucklandica*	*Oligochaete*	*Linucula (Nucula) hartvigiana*	*Austrovenus stutchburyi*	*Ceratonereis*
	Oct-12	*Linucula (Nucula) hartvigiana*	*Oligochaete*	*Prionospio aucklandica*	*Austrovenus stutchburyi*	*Torridoharpinia hurleyi*
	Apr-13	*Linucula (Nucula) hartvigiana*	*Prionospio aucklandica*	*Lasaea parengaensis*	*Oligochaete*	*Ceratonereis*
	Oct-13	*Prionospio aucklandica*	*Linucula (Nucula) hartvigiana*	*Torridoharpinia hurleyi*	*Colurostylis lemurum*	*Oligochaete*
	Apr-14	*Prionospio aucklandica*	*Linucula (Nucula) hartvigiana*	*Oligochaete*	*Austrovenus stutchburyi*	*Lasaea parengaensis*
4	Oct-09	*Linucula (Nucula) hartvigiana*	*Eationella abscenosam*	*Phoxocephalidae other*	*Prionospio aucklandica*	*Austrovenus stutchburyi*
	Apr-10	*Oligochaete*	*Linucula (Nucula) hartvigiana*	*Prionospio aucklandica*	*Austrovenus stutchburyi*	*Zeacumantus lutulentus*
	Oct-10	*Oligochaete*	*Linucula (Nucula) hartvigiana*	*Prionospio aucklandica*	*Colurostylis lemurum*	*Austrovenus stutchburyi*
	Apr-11	*Eationella abscenosam*	*Linucula (Nucula) hartvigiana*	*Austrovenus stutchburyi*	*Ceratonereis*	*Prionospio aucklandica*
	Oct-11	*Linucula (Nucula) hartvigiana*	*Lasaea parengaensis*	*Prionospio aucklandica*	*Austrovenus stutchburyi*	*Ceratonereis*
	Apr-12	*Eationella abscenosam*	*Linucula (Nucula) hartvigiana*	*Lasaea parengaensis*	*Austrovenus stutchburyi*	*Prionospio aucklandica*
	Oct-12	*Potamopyrgus estuarensis*	*Linucula (Nucula) hartvigiana*	*Oligochaete*	*Colurostylis lemurum*	*Austrovenus stutchburyi*
	Apr-13	*Linucula (Nucula) hartvigiana*	*Potamopyrgus estuarensis*	*Oligochaete*	*Prionospio aucklandica*	*Austrovenus stutchburyi*
	Oct-13	*Linucula (Nucula) hartvigiana*	*Austrovenus stutchburyi*	*Prionospio aucklandica*	*Oligochaete*	*Eationella sp*
	Apr-14	*Pisinna zosterophila*	*Linucula (Nucula) hartvigiana*	*Austrovenus stutchburyi*	*Prionospio aucklandica*	*Zeacumantus subcarinatus*

The bivalves *Austrovenus* and *Macomona* have been present at all sites since monitoring began, but in varying abundances and size class structure (Figure 3). Site 1 has a high abundance of *Austrovenus* in the 5-15mm size class, whereas this size class is relatively low in abundance across all other sites for both species (Figure 3). Site 2 is largely dominated by adults (>15mm approx. 62%) for both *Austrovenus* and *Macomona* however, in October 2013 there was a large recruitment of juvenile Austrovenus at site 2.There is recruitment of *Macomona* in October annually and there were three large recruitment events at all four sites (October 2009, 2011 and 2013; Figure 3), with recruitment larger at sites 3 and 4.

Paphies were not present at site 1 and were rarely found at any of the other three sites. When they were found they were juveniles (<5mm) and were very low in abundance. Site 2 had the highest abundance of *Paphies* and since October 2009 there has been three recruitment events here (April 2010, 2011, 2013; Figure 4).

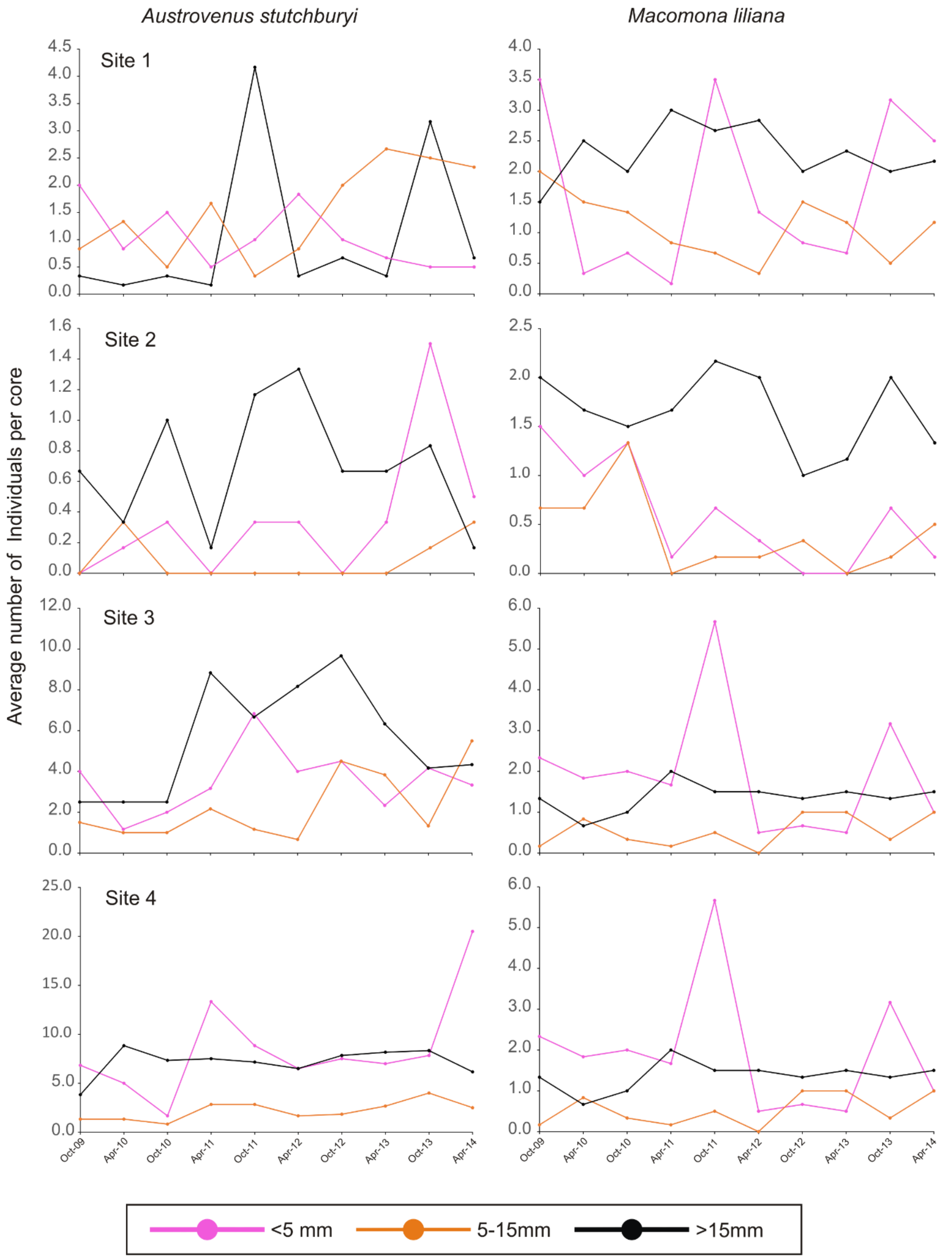

Figure 3: **Size class structure of bivalves *Austrovenus stutchburyi* and *Macomona Liliana*.** Collected from the four sites in the Waikokopu arm of the Whangateau estuary (average number per core, n = 6 cores) between October 2009 and April 2014.

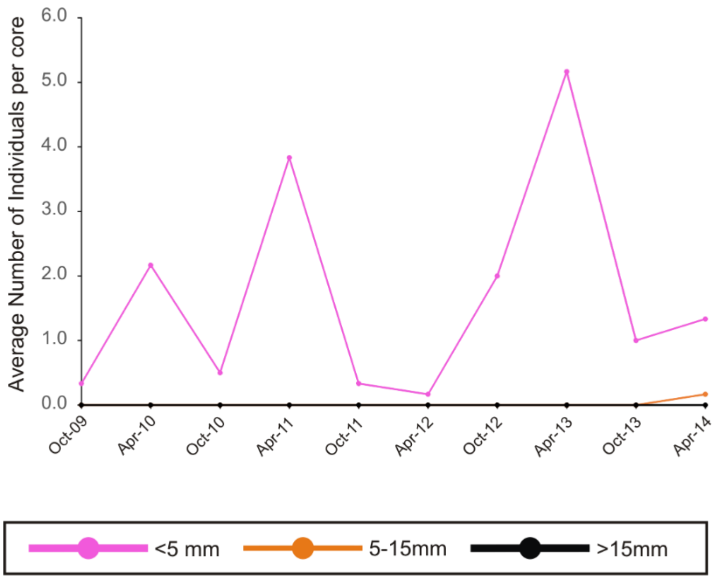

Figure 4: **Size class structure of *Paphies australis* at site 2.** (Average number per core, n= 6 cores) between October 2009 and April 2014.

3.3 Sediment character

A principal components analysis (PCA) was conducted on sediment particle sizes obtained from sediment samples collected from the four sites from October 2009 to April 2014 (Figure 5). The PCA shows that only one axis is required to explain 92.6% of the variability and 98.7% of the variability was explained by two axis. The particle size over time was most similar at site 1 followed by site 3, 2 and 4. The particle sizes in October 2009 and April 2014 were more similar at site 3 and 4 than at 1 and 2, however, overall all sites are closely clustered with low variability and there are no trends overtime. The sediment at all four sites was dominated by 'medium sand' sized particles over the period sampled, with the exception of the samples from sites 1, 3 and 4 taken in October 2011. These samples had a high component of mud.

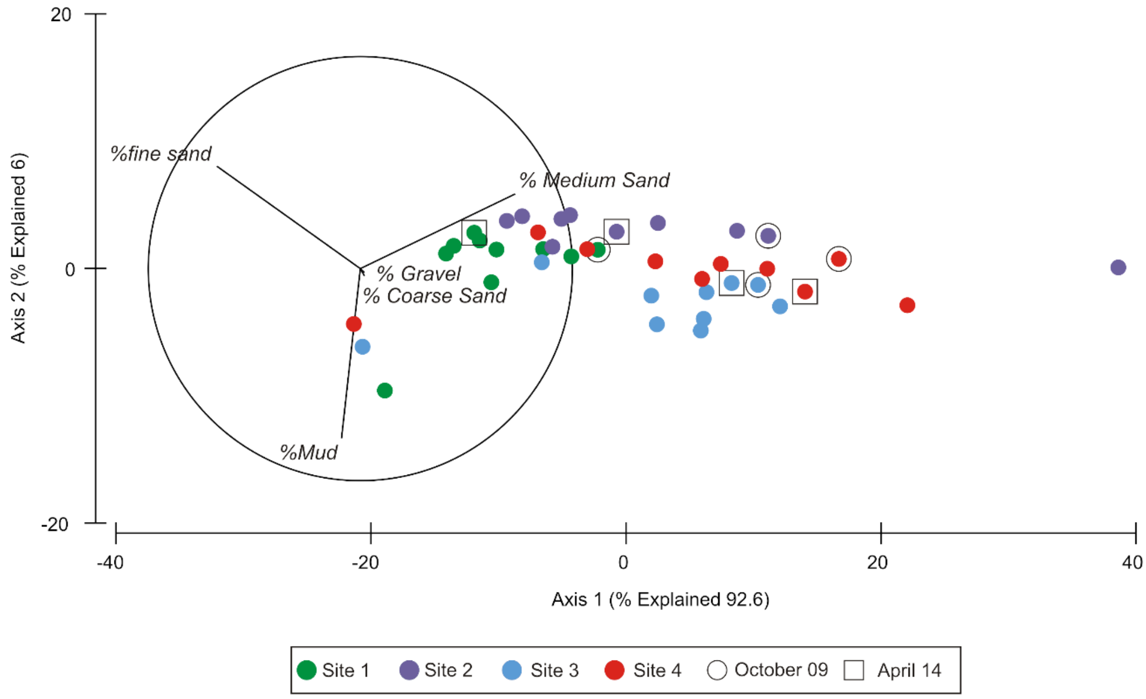

Figure 5: PCA of sediment particle size over time (October 2009 (circle) – April 2014 (square)).

Mud was not a dominant component of the sediment particle size across any of the four sites from October 2009 to April 2014 (0-12.6%). In October 2011 there was a spike in the mud content at three sites. This spike was more apparent at sites 1, 3 and 4 where mud content is generally higher and more variable, but was not observed at site 2 (Figure 6).

Sediment organic content was highest at site 3 (0.9-1.7%; Figure 7) and was more variable, along with site 4, than the other two sites. Organic content at site 2 has remained relatively stable since October 2009 (0.4-0.6%; Figure 7). The organic content at site 1 has also remained relatively stable with exception to a spike in October 2012, this increase in organic matter was also observed at site 3 and 4.

Sediment Chlorophyll *a* content was highest at site 3 and 4 (11.0-12.0µg/g sediment and 9.0-9.7 µg/g, respectively; Figure 8). Chlorophyll *a* content has been stable across all sites since October 2012.

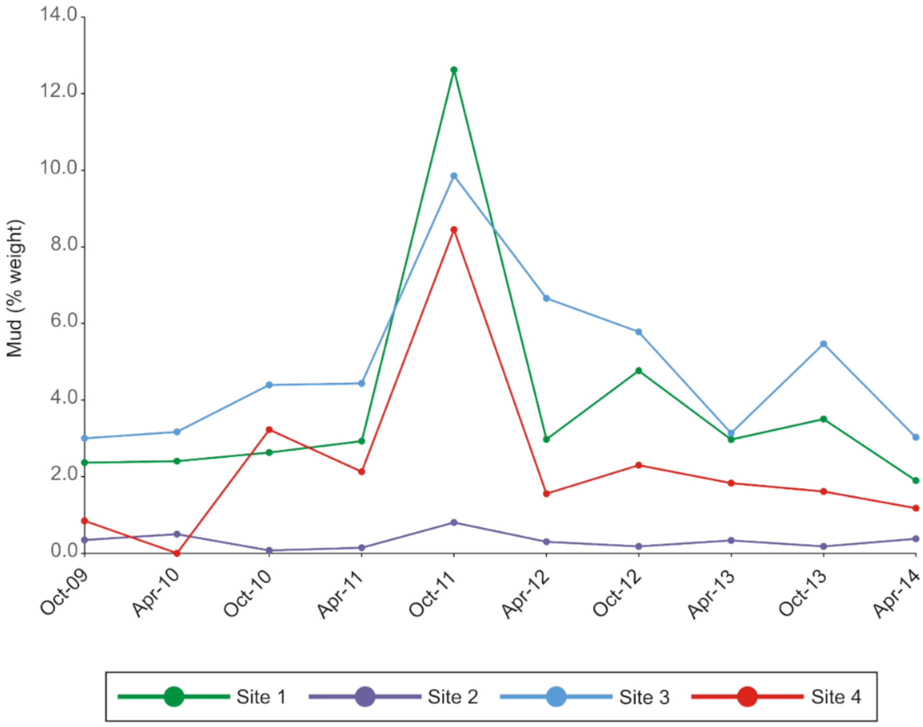

Figure 6: Sediment mud (<63 µm) content (% weight) of sediment. Collected from the four sites in the Waikokopu arm of the Whangateau estuary between October 2009 and April 2014.

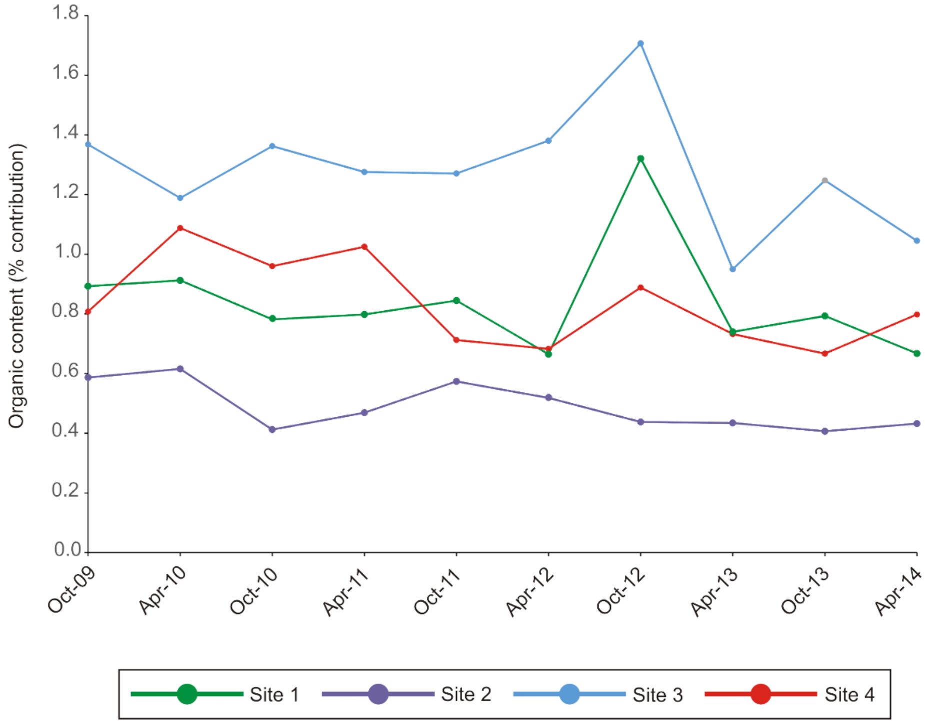

Figure 7: Percentage organic content of sediment. Collected from the four sites in the Waikokopu arm of the Whangateau estuary between October 2009 and April 2014.

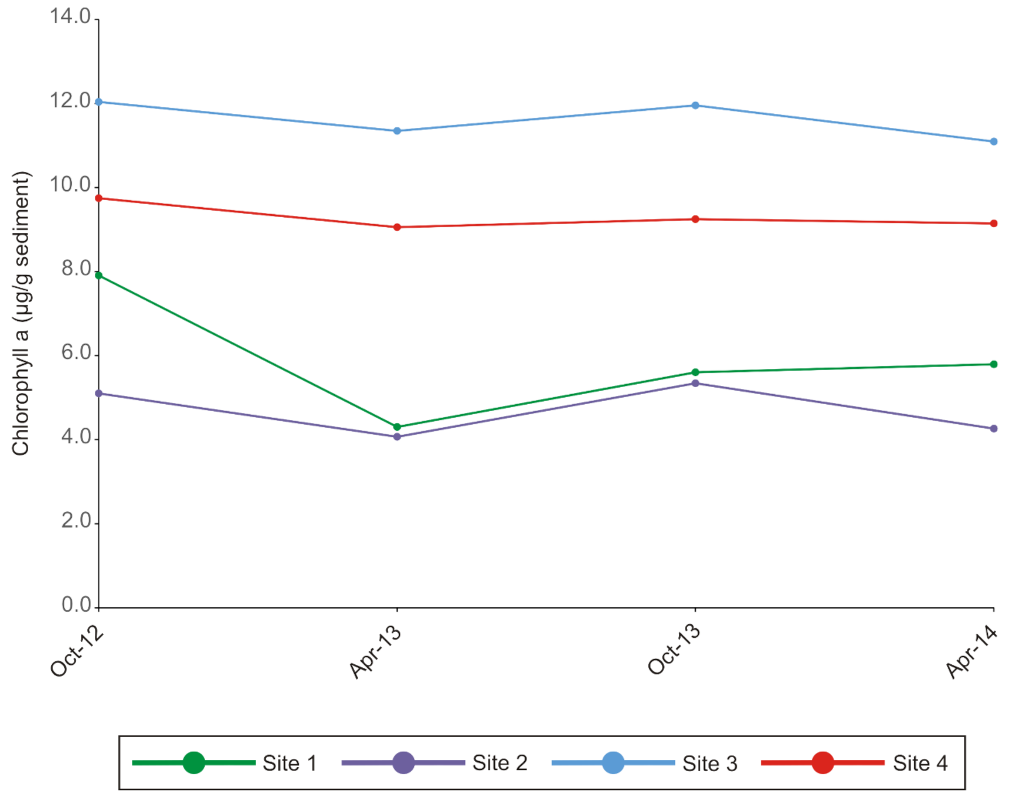

Figure 8: Chlorophyll *a* levels (µg/g sediment) of sediment. Collected from the four sites in the Waikokopu arm of the Whanagteau estuary between October 2012 and April 2014.

3.4 Sediment metal/metalloid concentrations

The PCA required only one axis to explain 100% of the variability. For all metals, measured concentrations were highest at site 3 and lowest at site 2 (Table 2). However, even concentrations at site 3 were relatively low with no exceedances of either the ERL or the lower TEL were observed. Total copper, lead and zinc concentrations were also below those of the sites used in developing the BHMmetals model developed by the Auckland Council for assessing estuarine health associated with heavy metals (Anderson et al. 2006).

Table 2: Mean concentrations (mg/kg dry wt) of metals/metalloids in the top sediment collected in November 2010. Exceedances of the Threshold Effect Concentration (TEL) (shaded) and Effect Range Low (ERL) (bold red) shown. Cu = copper, Pb = lead, Zn = zinc, As = arsenic, Cr = chromium, Fe = iron, Mn = manganese, Ni = nickel. Letter "s" next to a metal species indicates <63 µm grain size fraction of sediment using a weak acid extraction methodology. Taken from table 5.1 in Hewitt and Simpson 2012.

Estuary	Site	Cus	Pbs	Zns	Cu	Pb	Zn	As	Cr	Fe	Mn	Ni
Whangateau	1	9.4	5.7	35.0	0.9	0.8	8.3	1.6	5.6	3133	26.0	1.9
Whangateau	2	4.7	1.3	8.3	0.4	0.6	5.9	1.5	4.3	2143	21.7	1.4
Whangateau	3	10.4	7.5	42.0	1.6	1.2	10.9	2.5	7.5	4067	30.3	2.8
Whangateau	4	7.9	5.6	30.7	0.8	0.7	7.3	1.6	5.8	2900	26.3	2.1
	ERL	*34*	*46.7*	*150*	*34*	*46.7*	*150*	*8.2*	*81*			*20.9*
	TEL	*18.7*	*30.2*	*124*	*18.7*	*30.2*	*124*	*7.24*	*52.3*			15.9

4 Habitats Maps of the Whangateau Harbour

A comprehensive Habitat map of the Whangateau Harbour was first created in 2000, based primarily on aerial photography (Hartill et al. 2000). In October 2009, NIWA's Marine Ecology Group was contracted by the then Auckland Regional Council (ARC) to visit Whangateau Harbour with the purpose of updating the original habitat map and assessing the degree of change that had occurred over the ~10 year period (Figure 1). NIWA assessed the distribution and extent of different intertidal habitats using a series of transect surveys and satellite imagery with the result presented in Townsend et al. (2010). The habitat map was also updated to reflect the two hectares of mangroves which were illegally removed in May 2010 after the completion of the field survey. Conclusions from Townsend et al. (2010) were that there had not been substantive changes in habitat types since 2000, but that a number of the previously mapped habitats in Hartill et al. (2000) had shown change in distribution. This was principally in the southern section of the harbour (south of the Causeway, in the Waikokopu Arm) with expansion of mangrove habitat and changes in seagrass coverage.

4.1 Updating information

Five years since the 2009 update, satellite imagery can be used to assess changes in specific habitats[1] and help target further field-based surveying. Attention is focused on the area of the Harbour South of the Causeway which, i.) is most relevant to the discharge consent, ii.) showed the most changes between 2000 and 2009, and iii.) is where fine sediment accumulation has been noted (Kelly 2009).

[1] Aerial and satellite imagery are useful for insight as to how the habitat map may have changed for habitats that are conspicuous, if the image resolution is suitable and if the images are recent.

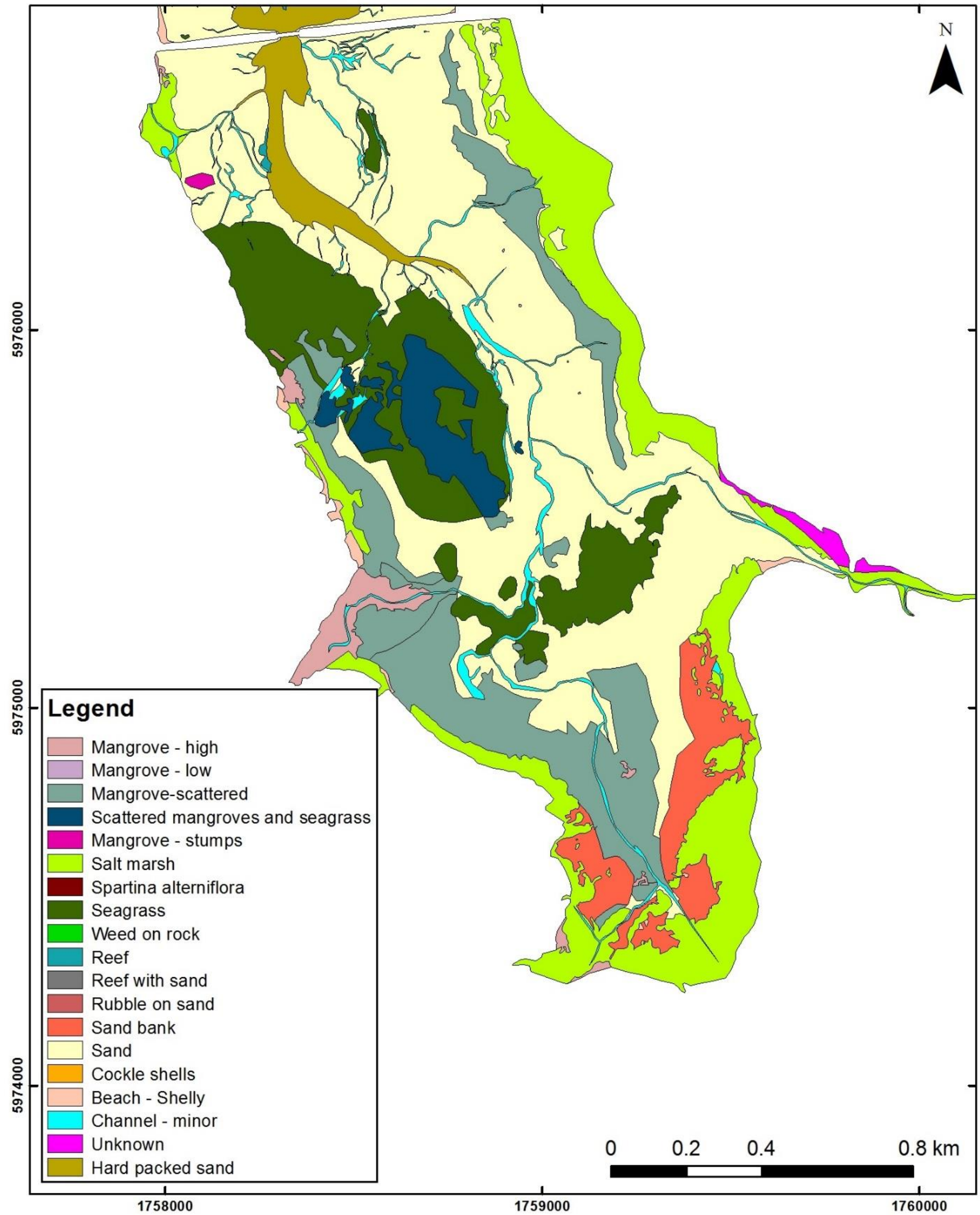

Figure 9: The habitat map of the Waikokopu arm of the Whangateau Harbour, south of the causeway. From Townsend et al. (2010) with permission from Auckland Council.

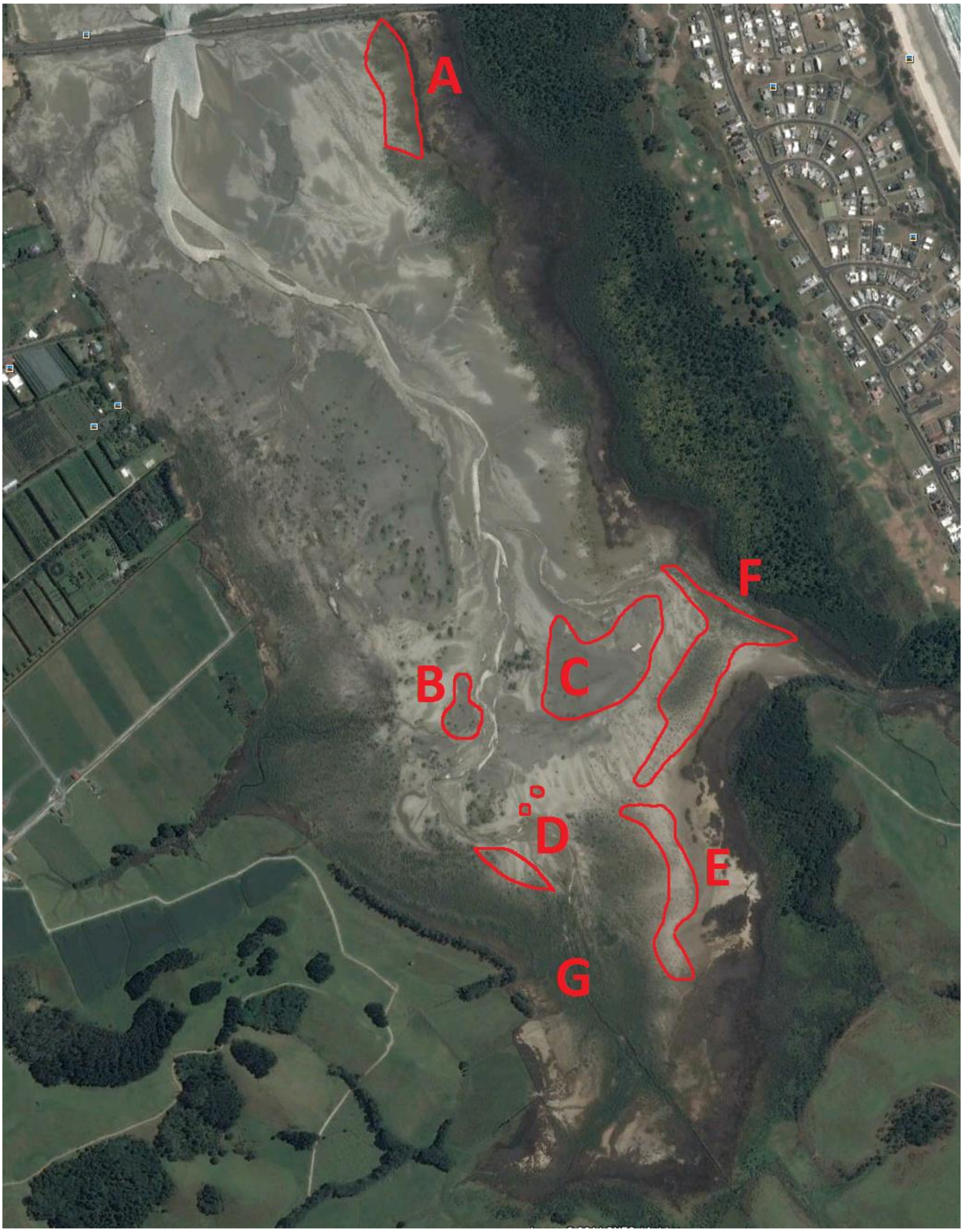

Figure 10: Whangateau Harbour aerial image captured on the 27/01/2014. A-F indicating possible areas where habitats have changed.

4.2 Recent Changes

Comparison of the 2009/10 habitat map (Figure 9) with recent aerial images of the Whangateau Harbour (Figure 10) indicates that several changes have likely occurred:

Figure 10 (A) – In 2009 there was patch of sand habitat between the scattered mangroves and the saltmarsh. Recent aerial images indicate that there has been backfilling by mangroves in this location, eroding the gap between these two vegetative habitats.

Figure 10 (B) – Recent aerial images indicate that this patch of seagrass has changed in shape; extending northwards and consolidating two smaller patches. See also Figure 11.

Figure 10 (C) – Similarly to (B) above, the patch of seagrass here has changed in shape and extent. This is mostly an expansion on the north-eastern edge of the large patch close to the creek and also an increase in size of some of the smaller satellite patches around the larger areas of seagrass (Figure 11).

Figure 10 (D) – Two patches of seagrass have increased in size and the scattered mangrove habitat is expanding seaward (Figure 11).

Figure 10 (E) – The previous area of sand habitat between the ‘scattered’ mangroves and sand bank is backfilling with ‘scattered’ mangrove habitat.

Figure 10 (F) – Mangrove habitat has expanded around Tokanui Point. In 2000 mangroves were largely absent around this area. In 2006, the some scattered mangroves are just visible in Figure 12A but not in Figure 12B and were below the level of detection used in the 2010 map. 2014 images show a patch of scattered mangroves ~100m across and ~200m in length connecting the mangrove habitat of the eastern and western shores (Figure 12C).

Figure 10 (G) – There is a large section of mangrove habitat that was listed as ‘scattered’ in 2010 (lower density of plants). Although there is a change in resolution, aerial images still indicate that density and size of plants has likely increased for mangrove habitat in this south eastern section of the harbour. It is likely that some ‘scattered’ habitat will change to ‘low’ and in a few places to ‘high’ mangrove habitat (Figure 11), but direct observations are needed to determine this.

Figure 11: Comparison between 2006* (top) and 2014 (bottom) for seagrass and mangrove habitats in the Whangateau Harbour. *year of historic image availability.

12A.)

12B.)

12C.)

Figure 12: Comparison between 2006* (A & B) and 2014 (C) for mangrove habitat around the Tokanui Point area in the Whangateau Harbour. *year of historic image availability.

5 Recommendations for further information gathering

There are three aspects related to intertidal areas for which further information would be useful for this project.

- Relative sensitivities of macrofaunal species to nutrient and organic enrichment. Species of macrofauna exhibit a variety of responses to nutrient and organic enrichment, varying from those that decrease in recruitment, growth rates and abundance at low levels, to those which prefer some level of enrichment, and finally those few which can withstand high levels of enrichment and deoxygenation of sediments and water. These responses have been known for many years internationally (e.g., Rosenberg 1977 and 1985) and lie behind such indices of health as AMBI (Borja et al. 2000) and BQI (Leonardsson et al. 2009). While information is not yet available for many New Zealand species a literature search of sensitivity of species presently observed in Whangateau should be undertaken.

- Condition of adult cockles and wedge shells. Under slight enhancement of nutrients and the resultant increase in microphytobenthos and phytoplankton and organic enrichment, physiological and physical condition would be anticipated to increase. There are sufficient densities of adult *Austrovenus* at sites 2, 3 and 4, and of adult *Macomona* at all sites for physical condition to be assessed. Measuring physiological condition of shellfish is more expensive and the results are generally more temporally variable due to strong seasonal reproductive cycles (Pridmore et al. 1990, Norkko and Thrush 2007).

- Nutrient status of the present mangroves. Mangroves have been demonstrated to be nutrient limited in some areas of New Zealand (Lovelock et al. 2007). This could be assessed for various habitat patches in the Waikokopu Arm.

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