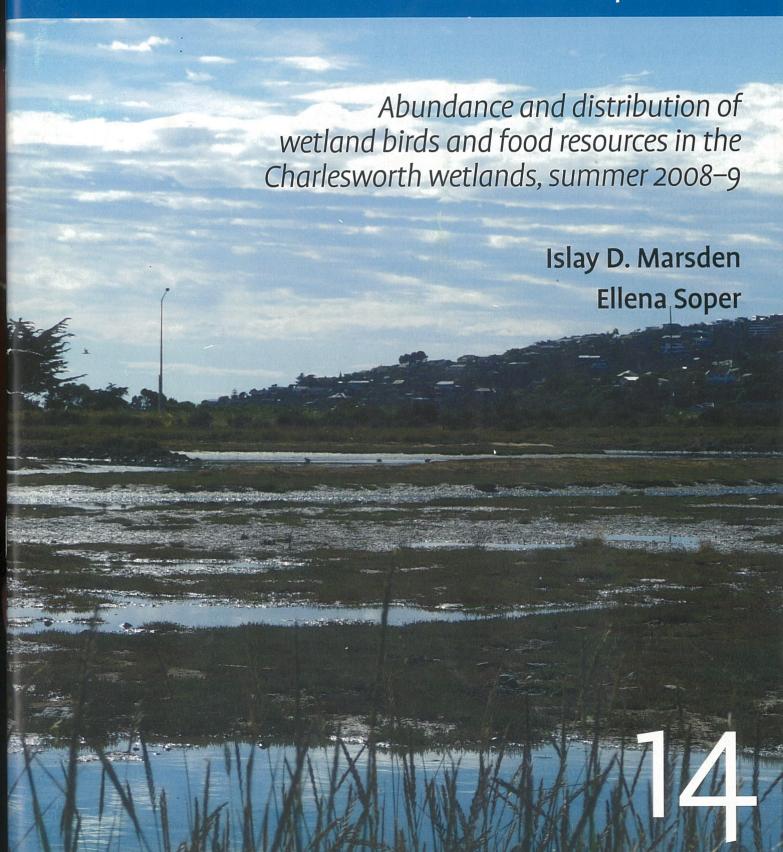
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Estuarine Research Report 40



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Abundance and distribution of wetland birds and food resources in the Charlesworth wetlands, summer 2008–9

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Abstract

The Charlesworth wetlands were created in two parts, in 1991 and 2001 to provide roosting, nesting and feeding habitats for shore and wading birds of the Avon-Heathcote Estuary/Ihutia. Between 8 December 2008 and 26th of January 2009, the numbers and distribution patterns of the wetland birds were recorded in different marsh locations, the drain, the old marsh and new marsh areas. Observations were made on bird behaviour at high and low tide periods. The food resources available to the birds was investigated by sampling benthic invertebrates in the sediment at low tide and at high tide, organisms were collected from the water of the pools, drain and culvert. Trace metals and nutrient levels were analysed from sediment samples.

The wetland was widely used by shore, wading and passerine bird species and provided an important roosting place for shore and wading birds at high tide. Twenty four wading, shore and passerine bird species were observed, including pied stilts, bar-tailed godwits and white –faced herons. Bird abundances and diversity were higher in the new marsh compared with the old marsh. The wading and shore bird species displayed a range of behaviours whilst utilising the Charlesworth wetlands.

The benthic sediments present in the wetlands comprised mainly fine sediments which were often anoxic just a few mm below the surface. Percent volatile solids was highest in the drain and old marsh areas (>6%) and lowest in the culvert area (<3.5%). Nitrogen and phosphorus levels followed this pattern. Trace metal concentrations were overall low but elevated for all metals in the high tide level of the new marsh.

Aquatic food resources during high tide comprised of terrestrial insect larvae, polychaete worms and small marine invertebrates including crustaceans and other worms. Marine invertebrates were present within the benthos of the restored wetlands provide additional food resources for wading and shore birds when the estuary is inundated by water at high tide. *Helice crassa* was the most conspicuous invertebrate species being present in both the old and new areas, especially the culverts. The mudsnail *Amphibola crenata* was most abundant in the drain and decreased in abundance in the older marsh area. Polychaetes were absent from the old Charlesworth wetland and areas furthest away from the culverts in the new wetland.

Results indicate that Charlesworth wetlands, having been established for 17 and 7 years, provide important roosting and nesting habitat for wading and shore bird species. In addition the more established wetland areas and culverts provide additional food resources for birds at high tide. Following earthquake activity in 2010 and 2011 there was considerable disruption to the marsh areas, flattening of the channel edges and input of sediment. While it is hoped that these areas will recover over time, there is a need for more rigorous research to be conducted within the Charlesworth wetland and other restored salt marsh wetlands in the Avon-Heathcote Estuary/Ihutai to determine whether these restorations projects are successful.

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Introduction

The Avon-Heathcote Estuary/Ihutai and surrounding wetlands

The Avon-Heathcote Estuary/Ihutai covers an area of approximately 880ha and was formed around 450 years ago. The estuary is situated 12 kilometres from Christchurch city and provides important habitat for wading and shore bird species, and is an internationally important site for migratory wading birds (Crossland, 2010). In addition the estuary provides habitat for a wide range of fish and invertebrate species. Salt marsh wetlands are highly productive ecosystems and are found on all major continents except Antarctica, they occur along low energy coastlines and are usually protected by estuaries, islands, deltas or bunds (Greenburg et al., 2006). They are important habitats for wading birds including many migratory species, and act as nurseries for fish plus provide habitat for macro invertebrates. They are also important areas for specialised salt tolerant plant communities and act as a buffer between the land and sea.

Salt marsh wetlands provide a range of ecosystem services such as acting as a carbon sinks, filtering runoff and flood retention. In addition they have historically provided food and fibre resources for humans (Owen, 1992). The Avon Heathcote Estuary/Ihutai was an important mahinga kai site prior to European settlement and used to be an important site for local iwi and others for collecting shellfish (Owen, 1992). Unfortunately like many urban estuaries the Avon-Heathcote has ongoing pollution issues from contaminants such as heavy metals and sewage. Yet it is still an important site for native and migratory wading birds to feed and breed and has recently been proposed as a Ramsar site.

Salt marsh vegetation occurs on the edge of the estuary and in the mouths of the Avon and Heathcote Rivers which drain into the estuary. These fragile ecosystems have suffered through fragmentation, weed invasion and habitat loss because of urbanisation. The reduction in the saltmarsh edge poses a threat for many wading and shore bird species which traditionally would use these areas for roosting sites at high tide, nesting during the breeding season and additional food resources when the estuary in inundated with water at high tide.

To mitigate the loss of these vital edge habitats the Christchurch City Council (CCC) over the past 20 years has put resources into restoring and creating new saltmarsh habitats for wading and shore bird use, especially for high tide roost sites. One of these restored sites is Charlesworth wetland which will be the focus of this research.

History of Charlesworth wetlands

Charlesworth wetlands were first proposed as part of the Green Edge concept presented by Christchurch City Council as part of a 15 year Wastewater disposal plan. The Green Edge plan was to restore or enhance coastal areas along the western edge of the Avon-Heathcote Estuary/Ihutai and these areas would assist with the reduction of pathogens and sediment load whilst providing habitat for wading and shore birds at high tide and during the breeding season. The areas included Bexley wetland, Sandy Point, Linwood Paddocks and Charlesworth wetlands (Wastewater Management Consultation Report 2000, Christchurch City Council).

Charlesworth wetlands lie adjacent to Humphreys Drive and Linwood Avenue, and cover an area of approximately 20 ha. The wetlands are man made and were created in two parts. This involved the conversion of a group of paddocks by excavating various islands and channels. The older area was created in 1991 adjacent to a remnant stand of *Plagianthus divaricartus* in the eastern corner of the wetlands and is known as the sandpiper pools. This was followed by a large extension forming islands and channels in 2001 known as new Charlesworth. Both sites can be currently seen from Humphreys Drive or via the walking track which runs along the SE edge of the wetlands and can be accessed from Charlesworth Street off Ferry Road. (Proposed Charlesworth Tidal Wetlands and the Associated Sale of Residential Land, Christchurch City Council).

The old Charlesworth wetland was created in 1991 using an existing culvert which runs under Humphreys Drive from the Avon-Heathcote Estuary/Ihutai. Once the pools and islands were formed, the culvert allowed seawater to flow into the wetlands at high tide. The introduction of saline water saw the establishment of saltmarsh vegetation such as glasswort (*Sarcocornia quinqueflora*) and saltmarsh ribbonwood (*Plagianthus divaricatus*) as well as the use of the pools and islands by wading birds for roosting, nesting and feeding (Proposed Charlesworth Tidal Wetlands and the Associated Sale of Residential Land, Christchurch City Council).

Numerous islands and channels were created for shore and wading bird use at both high and low tide for roosting, nesting and feeding. The wetlands were constructed so that only the top half of a tide typical of the area would have an effect. This allowed the wetlands to be drained for a time period suitable for a habitat designed specifically for wader birds (Proposed Charlesworth Tidal Wetlands and the Associated Sale of Residential Land, Christchurch City Council).



Photo. Birds roosting on Charlesworth islands at high tide and areas of the new marsh showing marsh plants planted by CCC staff and local volunteers.

Restoration of Charlesworth wetlands

The Charlesworth tidal wetlands were created primarily as roosting and nesting habitat for estuarine bird species (personal correspondence Andrew Crossland) and were constructed using the 'ecosystem restoration approach' (Mitsch et al., 1998). This method involved the deliberate introduction of a few select species into the ecosystem being restored, with success being measured by whether these species survived or not (Mitsch et al., 1998). At Charlesworth wetland, a number of saltmarsh plants were introduced including, *Juncus maritimus* (common sea rush), *Leptocarpus similis* (jointed rush), *Plagianthus divaricatus* saltmarsh ribbonwood) and *Phormium tenax* (New Zealand flax) (Thomsen, 1999). Of these four species, the only one not to survive was *L. similis* (Thomsen, 1999).

In addition to the wetland providing habitat for roosting and nesting it also has the potential to provide food resources by supporting a benthic macro-invertebrate community. This involves a concept different to that of the 'ecological restoration approach' known as 'self-design' (Mitsch et al., 1998). The 'self-design' concept is where an ecosystem can develop in complexity and structure through the introduction of various species' or propagules (these introductions can be natural or deliberate), through selection processes the species that endure is most suited to local conditions (Mitsch et al., 1998). In the Charlesworth wetlands this process is apparent, with a number of saltmarsh plants having self colonized in addition to those deliberately introduced. These include glasswort (*Sarcocornia quinqueflora*), sea spurrey (*Spergularia media*) and selliera (*Selliera radicans*) (Thomsen, 1999). Therefore, it is conceivable that organisms could self introduce in the same way into the Charlesworth wetlands. A benthic macro-invertebrate community could therefore develop through the introduction of propagules and/or larvae using the culverts that feed the wetlands with water at high tide.

While there has been extensive research done on restoring plant communities in wetlands, very little has been done on restoring invertebrate communities (Brown et al., 1997). Examples of other wetland restoration projects that have seen the successful establishment of a macro-invertebrate community may then help to validate the theory of self design. A study on the importance of self design in wetlands found that over a three year period as many as 30 species of macro-invertebrates were introduced into two created wetlands (one planted and

the other not) (Mitsch et al., 1998). These introductions were accredited to the fact that the wetlands were open systems, with invertebrates and or their larval forms being transported in on the water current, flowing into and out of the wetland (Mitsch et al. 1998). Consequently, Charlesworth wetlands could have macro-invertebrates entering through its own tidal system. As a result, one of the aims of this study is to establish the extent (if any) of the macro-invertebrate community in the wetland benthos.

As previously noted the Charlesworth wetlands are made up of an older marsh and a more recently created marsh. Previous research on the benthic macro-invertebrates has been carried out primarily in the older area and while there has been some research in the new area, a significant amount of time has lapsed since this research was conducted. This project will investigate bird abundances and the availability of food resources for wading and shore birds as a whole, as well as the difference in food resource availability between the old (est. 1991) and the new area (est. 2001).

Previous Research on the Charlesworth Wetlands

Love (1997) carried out research in the older part of Charlesworth wetland for part of his Master of Science thesis. He measured the availability of food resources and habitat for wading birds in various saltmarsh wetlands (both remnant and restored) within the Avon-Heathcote Estuary. His research focused chiefly on four common wader species: South Island pied oystercatcher, eastern bar-tailed godwit, white-faced heron and Australasian pied stilt. At the time of his study, all of these species except the eastern bar-tailed godwit were observed in the Charlesworth wetlands, (Love, 1997). Preliminary observations of Charlesworth wetlands in November 2008 showed that eastern bar-tailed godwit now frequent this area, highlighting the need for further research to be carried out. It is important to note that Love's research did not focus on the Charlesworth wetlands exclusively.He undertook a comparison of the wetlands with mudflat areas within the central estuary.

Webster (1997) investigated the macro-fauna and marsh plant associations in the Avon-Heathcote Estuary for her Masters of Science thesis. She sampled the Avon-Heathcote Estuary as a whole, with Charlesworth one of the selected site within the estuary. So yet again, it is important to note that the Charlesworth wetlands were not the sole focus of this research. This highlights a real need for research specifically aimed at Charlesworth to be

undertaken, integrating research on bird life, benthic macroinvertebrates and physio-chemical elements.

Other areas of interest

Because the Charlesworth wetlands have been established on a paddock area which had been recently disturbed was uncertain if marine organisms would readily recolonise the mudflat areas. Also, the shallowness of the pools together with potentially high contaminants could affect the establishment of marine organisms. The sediment was inspected to determine if they were anoxic and samples analysed for trace metals. The organisms in the sediment were sampled to determine their diversity and abundance as a food source for birds.

At high tide, the incoming water brings in water from the main estuary and also disturbs the sediments within the marsh providing food for wading birds. Because invertebrate diversity and density in marine environments change throughout the tidal cycle and it is possible that organisms that are not present at low tide may be present at high tide, providing an additional food source for the wading and shore birds that feed within the wetlands at high tide.



Figure 1. New and old Charlesworth wetland areas

Research objectives

This research assessed the diversity and density of wading and shore bird species using Charlesworth wetlands for roosting, nesting and feeding. Of particular importance were the wader species, since their prey is primarily macro-invertebrates and it has been proposed that macro-invertebrate density/biomass and diversity can determine wader density in coastal wetlands and estuaries (Spruzen et al., 2007). This research will provide data on the diversity of bird species present in the wetlands, their general distributions and will lay the foundations for further studies. This data will act as a foundation that can be built upon at a later date, providing baseline ecological information for the Charlesworth wetland complex. Given disturbances that occurred in the wetland and mudflats of the estuary as a result of the 2010 and 2011 earthquakes, it was important to document the status of the marshes in 2009 so that we can follow the ongoing development of marsh systems in the Canterbury Region.

Methods

Bird species, distribution and abundance

Distributions of the bird species observed at Charlesworth wetlands were plotted onto maps. This was done by hand whilst in the field, with the distributions subsequently being transferred onto an aerial photograph of the wetlands. These distribution maps were plotted for the exact height of high tide and low tide, between low and high tide and between high and low tide. Distributions for each of these tidal heights were repeated over the December/January period in order to allow any large scale patterns to be observed. To accompany the distribution maps, notes were taken for each individual tidal observation, these included notes on behaviour, environmental conditions and any unusual occurrences. If a bird was seen flying over the wetlands but did not land it was also recorded (but it was noted that the bird did not to land in the wetland).

Quantitative sampling was also carried out for four focal bird species; South Island pied oystercatcher (*Haematopus ostralegus finschi*), eastern bar-tailed godwit (*Limosa lapponica baueri*), pied stilt (*Himantopus himantopus leucocephalus*) and white-faced heron (*Ardea novaehollandiae*). These species were chosen because they are waders that generally feed on macro-invertebrates in the sediment.

Bird counts were carried out weekly (December '08 – February '09), one count at high tide and one count at low tide. Because of the small size of the study area it was possible to do counts of the birds present rather than just counting a small proportion of the birds present to make inferences about total numbers of individuals. The new and old area counts were carried out separately so that differences between the two could be ascertained. It was not possible to see the entirety of both wetlands from one point; therefore the new areas of wetland were divided into three sections to carry out the count. Three observation points were marked with painted tomato stakes (Fig. 1). Bird species within these areas were counted separately and the counts for the three sections were combined to get the total bird numbers for the new area. In the old marsh all the birds were counted from a single observation point (Fig. 2).



Figure 2. Observation points for carrying out bird counts in the new and old Charlesworth wetland

Within these four sections three replicate counts for each of the wader species were carried out, with the average then being taken for each species. For the new area of wetland the averages obtained for each of the three sections were added together to obtain the overall average for each of the focal species, pied stilts, eastern bar-tailed godwits and South Island pied oystercatchers. Special attention was given to the white-faced heron, which were seen on a daily basis at Charlesworth wetlands. The total number of white-faced heron (as with the other three focal species) and the number of birds actively foraging during the observation

period were recorded. White faced heron were classed as foraging if they exhibited behaviours such as; walking with its head thrust forward, actively searching for prey. Heron were recorded as inactive if they did not exhibit this behaviour for over a minute (the bird is stationary and presumably resting) during the observation period.

Benthic Macro invertebrates

Sampling Design

Sediment samples were taken near pools in both the old and new areas of the wetlands where wading birds had been observed feeding. Sampling was carried out at low tide when the wetlands had drained and the pools became more obvious.

Macroinvertebrate samples were stratified within three key areas of the Charlesworth wetlands, the drain, which receives estuary water and supplies the old area with saltwater, the older more established area of wetland, and the more recently created area of wetland. Four sites were sampled along the drain, two sites (pools) were sampled in the older area of wetland and eight sites (pools) sampled in the new area of wetland. The sampling was arranged so that the sites in each of the three areas coordinate with each other in a grid like pattern (Fig. 3).

For the drain, each sample site had a high zone and a low zone. The high zone was sediment along the drain that was covered by water only at high tide. The low zone was sediment from the middle of the drain that was perpetually covered by water (or in dry periods is the sediment that is exposed for the least amount of time).

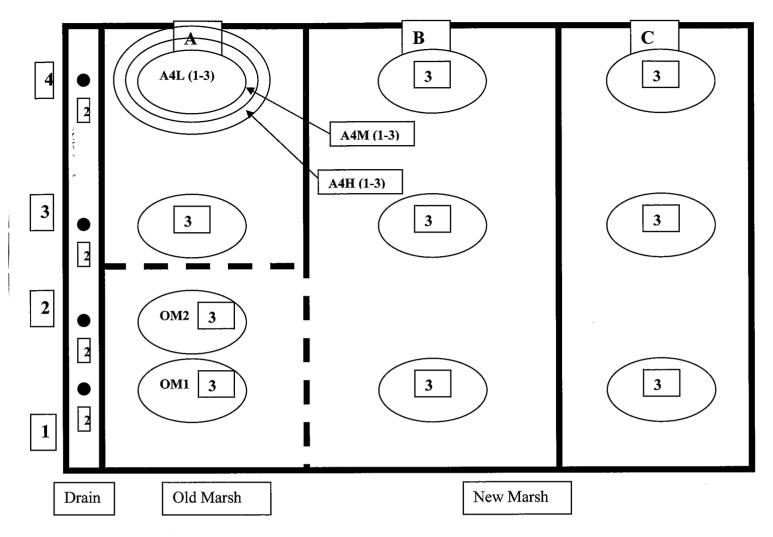


Figure 3. Design for benthic sampling at low tide and high tide pool sampling. The numbers represents zones at each sample site. The drain samples had two zones, while the new and old wetlands had three zones. Two culverts drain the marshes, culvert 1 from area B and culvert 2 from area C.

For the old and new areas, the sample sites were located at pools within the wetlands, two pools were sampled within the old area of wetland and eight pools were sampled within the new area of wetland. The reason that there were more sites (pools) sampled within the new area was due to the difference in size between the two areas of wetland (the old area is significantly smaller).

For each sample site within these two areas there was a high zone, a mid zone and a low zone. The high zone was sediment only covered at high tide, the mid zone was sediment covered halfway through a tidal cycle and the low zone was in the very centre of the pools (sediment that is continuously covered by water or exposed for the shortest period of time). A diagrammatic representation of the layout of the sample sites shows how each of the samples

were coded (Figure 3). An aerial photograph shows the exact location of sites that were sampled in the wetlands in accordance with the diagram (Fig. 4).



Figure 4. Benthic sample sites as depicted in the diagram in Fig. 3

Three replicate samples were taken within each zone of the pool for macro-invertebrates. These samples were taken using a corer with a diameter of (10.2 cm) and a 5cm depth; the samples were then put through a 0.425 mm sieve while still in the field.

Helice crassa and Amphibola crenata were collected and individuals measured while in the field. Individuals of Helice crassa (mud crab) were measured across their carapace using vernier callipers, with the width recorded in mm. Amphibola crenata (mudflat snail) found on the surface and within the sample were measured from their spire to the base of their shell and the length recorded in mm.

Invertebrates including polychaete worms in the sample were collected and taken back to the University of Canterbury's School of Biological Sciences. Any additional macro-invertebrates found within the samples collected were taken back to the lab for identification. Macroinvertebrates taken back to the university were placed in a solution of 10% formalin in seawater for preservation purposes, allowing identification at a later date. Polychaete worms in the formalin samples were counted using a dissection microscope in a fume hood. The use

of a microscope allowed me to determine whether a polychaete was whole or had been chopped in half. Whole polychaetes and anterior ends were only included in the count this prevented overestimation of polychaete numbers within the samples. Other properties of the sediment (e.g. whether it was anoxic), % cover of algae over the sample surface and number of crab holes were also recorded.

Sediment analysis

In addition to the three core samples taken for the assessment of the macro-invertebrate community, two other smaller core samples were taken from each zone at each sample site as seen in Fig. 3. The corer used was 5 cm in diameter, with the sample pushed down to 5 cm in depth. One of each of these core samples was sent to Hill's Laboratory, Hamilton for chemical analyses. The elements measured were total recoverable phosphorus, nitrogen and trace elements, arsenic, cadmium, chromium, copper, lead, nickel and zinc. The remaining core was retained to assess pore water content and organic content (total volatile solids). This resulted in independent samples from each habitat, 8 from the drain, 6 from the old marsh, 6 from the culvert areas, and 9 each from the mid and upper new marsh areas.

Pore water content for each of the samples was evaluated by placing 2 or more grams of sediment in a small ceramic container, with the initial weight being recorded. The samples in their ceramic containers were placed in a drying oven for two days and were reweighed upon drying. The change in weight was recorded and this was used to work out the percentage of pore water for each sample.

Organic content within the samples was assessed by taking the samples in their ceramic containers (once they had been dried) and placing them in an ashing oven at 500°C for 5 hours. The samples were then reweighed and the loss in mass was used to work out the percentage of organic content (volatile solids) within each sample.

Plankton and water sampling

Sampling of the water column at the sites (Fig. 3) was carried out at high tide. Using a sweep net with plankton net fixed in its interior, three samples were taken of the pool water over each sampling area. There were 4 locations within the drain and two pools in the old marsh. In the new marsh there were 3 pools in the upper marsh furthest away from the estuary, two pools in the mid marsh and two culvert. Each sample consisted of three sweeps of the pool with the net. The net was then washed into a container containing water from the site. The contents were then poured through a 300 µm sieve, with the contents in the sieve being

washed back into a small portion of retained water put into a contained and taken back to the laboratory for sorting. The water samples were taken back to the university and mixed with 10% formalin in seawater. The amount of formalin mixed with each sample was equal to the water, meaning that the formalin will be diluted down to 5% formalin in seawater. The samples were retained for analysis under a microscope in order to detect any plankton present and determine their diversity and abundance.

Results

Bird observations

Pied stilt (Himantopus himantopus leucocephalis):

Pied stilts were one of the four wading bird species of particular interest to this study and were seen consistently in the wetlands over the entire tidal cycle and fed throughout this time. They fed on both the mudflats and in the water but they were limited to where they could feed because of the water height. Therefore, at high tide their feeding was generally restricted to the pool margins, and they only ventured across pools when the tide was waxing or waning and water depth was shallow. When feeding in water, the stilts did not penetrate the substrate with their beaks; instead they made a scooping action with their beaks across the water's surface. Previous observations of the wetlands led me to believe that the birds were consuming small invertebrates found on the surface of the water. This supposition was confirmed when speaking with the CCC wetland ranger, Andrew Crossland, he stated that these macroinvertebrates form a significant part of the base of the wetland food web and are self-introduced. However, pied stilts do not feed exclusively on these invertebrates in the water column. At low tide they moved onto the mudflat and fed on the macroinvertebrates on the surface, they also probed the substrate for polychaete worms, they was observed throughout the wetlands feeding in both of these manners.

Pied stilts tended to rest at high tide and would form flocks on the islands, generally keeping separate from other species. There were a few islands that they favoured for roosting as shown on the distribution maps. Sometimes stilts would form large mixed groups with oystercatchers and godwits, however within these mixed roosts there were smaller sub groups of single species. They would also commonly produce alarm calls upon sighting the observer

and while they would continue feeding, they would usually continue calling for the majority of the observation.

South Island pied oystercatcher (Haematopus ostralegus finschi):

South Island pied oystercatchers did not really become a major part of the wading community until early December when their numbers began increasing (from the occasional sighting). They generally did not use the wetlands for feeding and were present in their highest numbers at high tide. At high tide they used the wetlands for roosting since the soft edges of the estuary no longer existed, meaning that at high tide there is no dry land to roost on bordering the estuary. This species favoured two islands for roosting; one was the star shaped island in the north-west corner of the wetland, the other being a long island more or less in the centre of the wetland with a small peninsula coming off its eastern side. They roosted in large groups with Eastern bar-tailed godwits (though generally in sub groups). Also, an important note to make was that scattered within the group of South Island oystercatchers there were variable oystercatchers present (as single individuals). These variable oystercatchers were not included in the counts of South Island oystercatchers and the variable oystercatchers were not plotted on the distribution maps.

While pied stilts did not generally feed on the wetlands, a few individual birds were seen feeding in two places, either the most northern culvert (coded C1 in the sediment samples or in the old area of wetland in a pool between the two land masses (an area that was unfortunately not included in the sediment sampling). At the northern culvert, the oystercatchers were thought to be feeding on a newly established cockle bed. No cockles were found in the sediment samples but there were large numbers of loose cockle shells present on the surface sediment.

Eastern bar-tailed godwit (Limosa lapponica baueri):

This species increased in numbers in the wetland following the start of December when this research commenced. Godwits have exceptionally long bills and feed by probing deeply into soft sediment in search of polychaetes. This means they are restricted in their feeding activities by sediment type, being able to feed only in very fine, soft sediment. As with South Island pied oystercatchers, godwits did not generally use the wetlands for feeding (although they were observed feeding more than oystercatchers within the wetland). The areas that godwits were observed feeding was the eastern part of the wetlands (the culvert side where water runs in from the estuary). This fits in with the macroinvertebrate data which generally

only found polychaetes in the samples on this side of the wetlands (nearest to where water enters the wetlands from the estuary). More commonly godwits used the wetlands for roosting at high tides in much the same way as the South Island oystercatchers.

During the observation period an exceptionally strong spring tide occurred that submerged all of the islands in the wetlands, so that they could not be used for roosting. As the water rose there was a progressive departure of godwits and oystercatcher from the wetlands, but where they went remains a mystery since the primary roosting areas of Southshore Spit were also underwater at that time.

White-faced Heron (Ardea novaehollandiae):

White-faced heron were one of the four focal wader species given special consideration in this study. They generally fed at low tide on mud crabs found on the mud surface (the crabs would move out of their holes to feed/bask). They fed primarily using visual cues when hunting and did not probe the substrate like the other three waders (eastern bar-tailed godwit, South Island oystercatcher and pied stilt). They moved along the mud flat at a slow pace, before becoming rigid and remaining completely still upon sighting potential prey. The position in which they paused was very characteristic, with its neck extended out from its body, with the head poised with the bill pointing downwards ready to strike. The strike occurred if the prey did not detect the heron's presence and then it captured its prey using a swift jabbing action. There was a small period of handling time as the heron moves the crab down its bill and this increased with prey size.

White-faced herons were found throughout the wetlands as single birds but there were a few areas where they particularly like to congregate in groups (both to feed and roost). These areas were the old area of wetland and the area of new wetland directly behind it. There was also a 'bay' along the western boundary of the wetlands that commonly had a group of herons resting.

Royal spoonbill (Platalea regia):

One sighting of a pair of royal spoonbill flying over the wetlands was made in late November. The pair circled for approximately ten minutes and on occasion looked as though they were preparing to land, but did not. The pair eventually flew away in the direction of the Linwood Paddocks. This is interesting because obviously some factor was preventing the Spoonbills from landing in Charlesworth wetlands and if this factor could be identified possibly a change could be made to attract this wading bird species into the wetlands.

Pukeko (Porphyrio porphyrio):

A pair of pukeko was consistently seen on the southern end of the wetlands near the junction between the old and the new area. The pair was aggressive and produced a lot of noise if the observer got to close to the scrub bordering the wetland. While no chicks were seen for quite some time, it was apparent that this was a nesting pair due to the unusual hostility being shown and that they were always located in a very specific area.

In early January the pair was spotted moving through the old area of wetland with a large chick, confirming the previous hunch that they were nesting in the nearby scrub. This then made the pukeko along with the black-backed gull, the only two known bird species to have successfully nested in the wetlands over the 2008/2009 period. Other pukeko were observed at various times in both the new and old area of wetland as individuals, though it was unclear if they were one of the breeding pair out foraging or a different adult.

Grey Teal (Anas gracilis):

Grey teal were the predominant water fowl in the wetlands during the time of this study. They were also the species with the most consistent numbers throughout an entire tidal cycle. They fed at both high and low tide, using two distinct methods. At low tide grey teals walked onto the mud and fed directly off the substrate. At high tide they swam in the pools and sieved the water through their beaks. However, grey teal seemed to feed in greater numbers at low tide, with many resting during high tide.

Grey teal were distributed throughout the entire wetlands but were found more commonly in the new area. This pattern may be because the older Charlesworth area is substantially smaller than the new area and can be attributed to probabilities related to land area. There were a few periods when they were very sparse or completely absent from the wetlands for no apparent reason, sometimes for days at a time. Two possible theories were that this was due to the presence of a food source somewhere else or a large disturbance at the wetlands. The identity of the food source remains unclear it may have been a disturbance, for example when Christchurch City Council would send restoration workers to maintain the outer perimeter of the wetlands. Sometimes this maintenance work would involve loud machinery and I observed on at least one occasion this noise spooking flocks of birds on the wetlands into flight. Teals would also on occasion spook into flight if the observer got too near them or seemingly for no apparent reason. Speaking to Andrew Crossland about this, he

suggested that it could be due to a bird of prey sighting, which was seen on at least one occasion.

Paradise shelduck (Tadorna variegata):

The Paradise shelduck was the other major species of water fowl present in the wetlands. They moved around with their mates (in pairs) and fed on the mud in much the same way that Grey teal did but did not venture out onto the water at high tide to feed. A possible reason could be that they were too large to swim in the water that was on average quite shallow. Nearing the end of the observation period, the Paradise Shelduck began to frequently congregate in the area of new wetland immediately behind the old area for both feeding and roosting.

Mallard Duck (Anas platyrhynchos):

A large flock of mallards lived on the side of Linwood Avenue. However, they rarely ventured into the wetlands this is probably due to the fact that on a regular basis, people would stop and feed them large quantities of bread. They therefore did not rely on natural sources for food and as a result did not need to venture away from the foot bridge. They were not entirely wild, their behaviour having been affected by human influence. However, mallards were not entirely absent from the wetlands, on occasion they were recorded in the old area of the wetland. This is interesting to note because this is the area furthest away from the footbridge. Therefore it may be that these birds originate from a population different to that near the footbridge.

Chestnut Teal (Anas castanea):

While we did not personally observe this bird, a group of photographers from the UK happened to be on the wetlands just prior to one of our visits. On arrival the Grey teal were exhibiting unexplained flightiness as they sometimes did. After talking to the photographers they claimed to have seen what they thought was lone a chestnut teal amongst the grey. They did not however, get a photograph of the bird and they lost sight of it when the grey teals took off in a flock, so could not point it out to me. Whether this particular species was really present on the wetlands remains purely speculative.

Canada goose (Branta canadensis):

A single aerial sighting was made of these geese as they flew from the direction of the Linwood Paddocks in the direction of the Avon-Heathcote Estuary. A small group broke off from the main flock and flew over the Charlesworth Wetlands, circling for a short period of time. They then flew in direction of the main flock, all the while producing honking sounds.

Black-backed Gull (Larus dominicanus):

While black-backed gull were not the most numerous gull species in the wetlands, they had a unique importance in that a single pair bred successfully on one of the islands. This made the black-backed gull one of only two species observed to have bred successfully on the islands within the Charlesworth wetlands during my study.

Throughout the field work, the chick was observed growing into a juvenile bird that would frequently roam from the nest site as it got bigger. Early on while the chick was still very small, an observation of one of the parent birds feeding the chick was made. The item being fed to the young black-backed gull was another chick of a similar size. The species of the unfortunate chick was not readily apparent but it is thought to have been a Pukeko chick or another black-backed gull chick due to its size. Whether or not this was an observed case of cannibalism is unsure but it could be an important factor that prevented other species' such as the Pied stilt from re-nesting (Black-backed gull are known to readily predate on their young).

Speaking to Andrew Crossland provided some insight into this. The Charlesworth wetlands used to be used as a nesting ground by a small colony of black-billed gulls. A few years ago the landfill at Bromley was closed and this landfill had a population of black-backed gull associated with it (they used it as a food resource). Upon the landfills closure, the black-backed gull population became transient and moved about searching for food. The black-billed gull nests in the Charlesworth then became a target and the colony was decimated. The next year the black-billed gulls did not return to nest.

Other black-backed gulls were observed at various times in both the old and the new area, quite often in pairs. Quite often fights between pairs would break out and would result in the departure of one pair. This was observed between the nesting pair and stranger pairs, as well as between pairs of strangers. It may be that in years to come the wetlands may have more than one pair breeding (depending on how large a black-backed gull territory is).

Black-billed Gull (Larus bulleri):

Black-billed gull were a common occurrence, using the wetlands as a feeding site. As previously mentioned, the Charlesworth wetlands used to have a nesting colony of black-billed gulls present during their breeding season but following the closing of the Bromley landfill, the chicks of this colony were targeted by black-backed gulls and the colony no longer exists. Black-billed gulls were found in both the new and old area, scattered as individuals, in twos or sometimes as small groups. However, there was no evidence of nesting behaviour.

Black-billed gulls fed on polychaetes in the mud, using visual cues to pick the worms off the surface. If the mud was disturbed by the observer walking, it was not uncommon for gulls to follow behind, picking out polychaetes from the deep footprints that exposed them.

Red-billed Gull (Larus novaehollandiae):

Red-billed gulls were also commonly seen in the wetlands, as individuals or in small groups (e.g. \approx 3). They too were feeding on the polychaetes worms present in the mud. The Red-billed gulls could be a lot more aggressive than Black-billed gulls, with the observer being frequently dive-bombed by groups of flying gulls making loud vocalisations at the same time. This was especially common when sediment sampling was being carried out on the exposed mud and the reason for the aggression is unclear.

Caspian Tern (Sterna caspia):

These large birds began arriving on the wetlands around mid January with only one previous aerial sighting having been made. They tended to roost amongst the South Island Pied Oystercatcher and Eastern Bar-tailed Godwit, favouring the star shaped island in the north western corner of the wetlands and the long island in the centre of the wetlands with a small peninsula on its eastern side. While there was generally more than one tern present in the wetland, they tended to roost by themselves, rather than with a partner or in a group, possibly because their breeding season was over and they no longer needed to maintain close social contact with their mates?

Pied Shag (Phalacrocorax varius):

Pied shags were observed twice within the wetlands and on one of these occasions the shag was swimming in the part of the new area directly behind the old area. It was at high tide and

raised the obvious question of how drastically did benthic community structure change with the tidal cycle and whether fish might enter the wetland through the culverts.

There was a pied shag that lived with the mallard population near the footbridge, was seen on a daily basis. This shag (like the mallards) was very tame, with its behaviour being significantly different to that of the shags seen in the wetlands. The shag by the footbridge would allow very close human contact, while the shag seen swimming in the wetlands spooked and flew away while the observer was still approximately 20m.

Spur-winged Plover (Vanellus miles):

This species was regularly observed in the wetland and usually kept to the islands, where they tended to roost. They were generally in pairs and it could be assumed that they were looking for somewhere to nest. No observations of actual nests were made during the observation period, however, an eggshell was found early on in the observation period that was thought to be a plover egg. This could suggest that the spur-winged plovers had already nested prior to mid November and may have already raised their chicks upon commencement of observations.

Whether nesting was successful is unclear, it most probably was not. According to Andrew Crossland, 2008 was a particularly bad year for rats, resulting in the unsuccessful nesting of all of the pied stilt pairs. It then stands to reason that plovers may have been met with similar difficulties.

Rock Pigeon (Columba livia):

Rock pigeons were occasionally observed in the wetland. While it is not readily apparent whether they were from a wild population or if they were racing pigeons, it is likely that they were racing pigeons using the wetlands to rest in. This is because they were only present in small numbers and they did not seem to be feeding at all. It also seems unlikely that a wild population would exist in an area so removed from large groups of people (and therefore food), since many 'wild' populations are reliant on people to a large degree e.g. in city centres etc.

Australasian Harrier (Circus approximans):

All harrier hawk observations were aerial sightings, with no instances of them landing or making a kill in the wetlands. Sometimes, these sightings would be accompanied by a mass disturbance of much of the wetland bird population, with flocks of many species taking off

and circling over the wetland before resettling, often only to repeat the pattern. Harriers would often circle over the wetlands for an extended period, which is interesting given the problem with the rat population explosion that has occurred this year. It is possible that the presence of the observer deterred the hawk from landing or caused the rats to remain hidden from sight, so that there was no readily visible prey.

Starling (Sturnus vulgaris):

While the starling is a scrub bird rather than a wetland bird they were sighted on the wetlands throughout the observation period. This is most likely due to the fact that there was a large amount of planting around the perimeter of the wetlands and the proximity of the wetlands to suburban areas with private gardens.

As stated earlier, starlings were observed on a number of the islands within the wetlands. The vast majority of Starling sightings were on islands towards the west side of the wetlands, this pattern was seen in both the old and new areas and the assumption was that this was because the west side was more vegetated and was probably where the starling were accessing the wetlands (this is also true of the old area which has a raised, vegetated ridge that connects it to the western planting at the back of the new area). Starlings were thought to be feeding on the grasses growing on the islands (or possibly insects) and therefore were not a species that was relying on benthic macro-invertebrates as a food source.

Welcome Swallow (Hirundo tahitica):

While not a wetland bird, Welcome swallow were observed around the perimeter of the wetlands in the grass and scrub, feeding on insects. A nearby footbridge may have been being used as a nesting site, as it was not uncommon to have swallows fly out from under the bridge when crossing it to gain access to the wetlands.

Yellowhammer (Emberiza citrinella):

Sightings of yellowhammers in the vegetation surrounding the wetlands were made periodically throughout the observation period, though this species never ventured onto the wetlands.

Skylark (Alauda arvensis):

These birds were commonly seen in the grasses surrounding the wetland and were usually not observable until disturbed, when they would fly out from right under your feet. They may have been the unidentified brown passerines mentioned in the notes for 15th December at low tide. However, am not sure if these birds ever exhibit flocking behaviour, in all other instances that I observed them they were as single animals.

Bird distributions at Charlesworth wetland from December 2008- January 2009

Colour Code for bird species (common names)
Black – Pied Stilt
Blue – Grey Teal
Yellow Yellow – White-faced Heron
Purple – Eastern Bar-tailed Godwit
Green – Spur-winged Plover
Red – Paradise Shelduck
Light Blue – Black-backed Gull
Lilac - Pukeko
Grey – South Island Pied Oystercatcher
Orange – Black-billed Gull
Dark Green – Mallard Duck
Sea Green – Pied Shag
Maroon – Starling
Pink – Red-billed Gull
White – Caspian Tern
Plum – Rock Pigeon

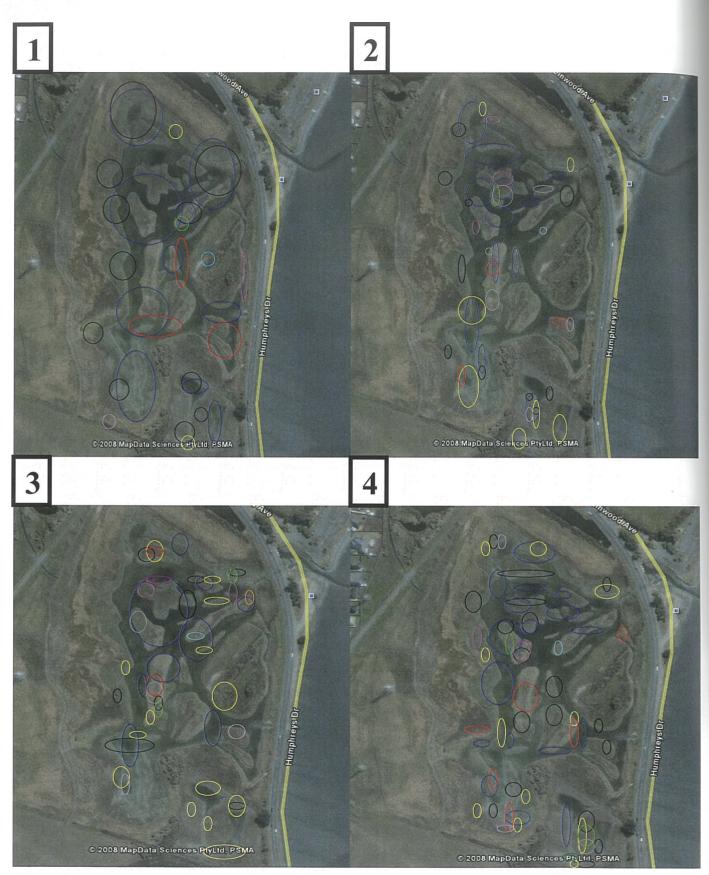


Figure 5. Bird distribution maps 1-4





Figure 5: Bird distribution maps 5-6

Colour Code for bird species (common names) Black - Pied Stilt Blue - Grey Teal YellowYellow - White-faced Heron Purple - Eastern Bar-tailed Godwit Green - Spur-winged Plover Réd – Paradise Shelduck Light Blue - Black-backed Gull Lilac – Pukeko Grey - South Island Pied Oystercatcher Orange - Black-billed Gull Dark Green - Mallard Duck Sea Green - Pied Shag Maroon - Starling Pink - Red-billed Gull White - Caspian Tern Plum - Rock Pigeon



Figure 5.Bird distribution maps 8–9 (Data missing for map 7)

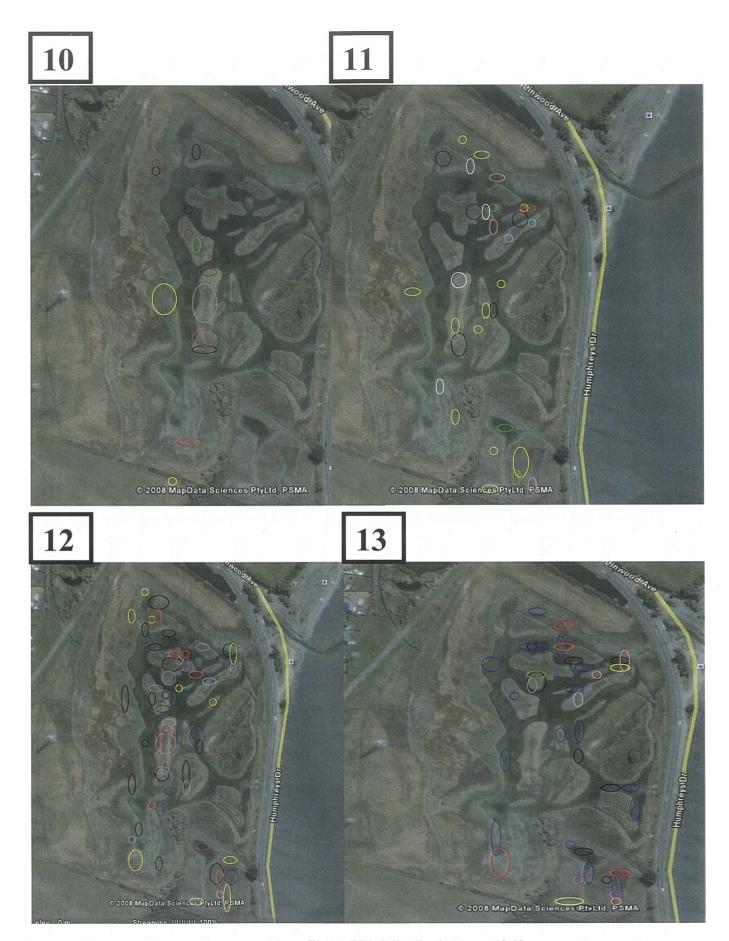


Figure 5.Bird distribution maps 10-13



15 16



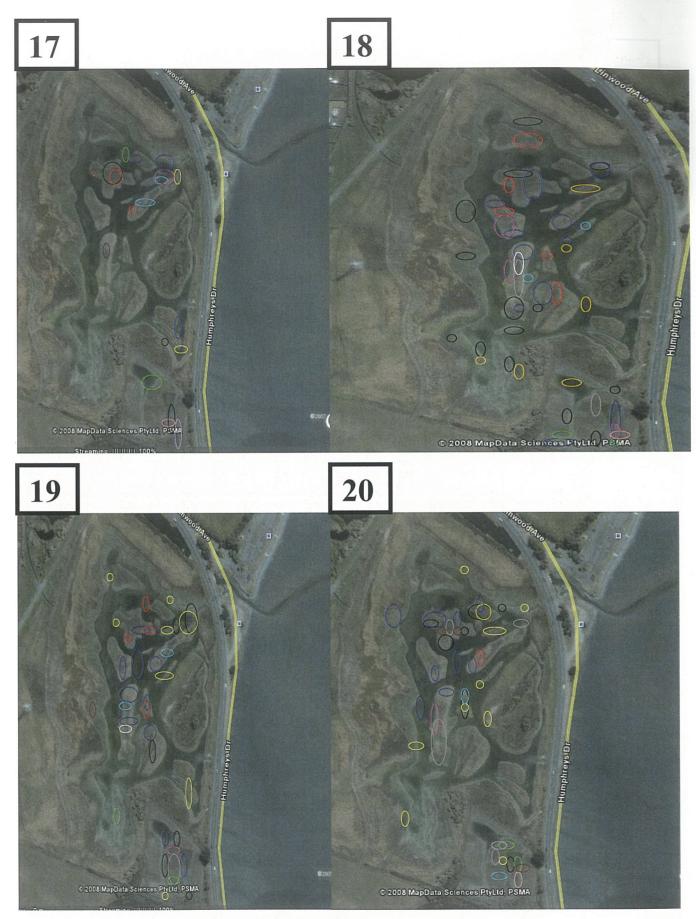


Figure 5: Bird distribution maps 17-20 from 08/12/08-26/01/09

Colour Code for bird species (common names)

Black - Pied Stilt

Blue - Grey Teal

YellowYellow - White-faced Heron

Purple - Eastern Bar-tailed Godwit

Green - Spur-winged Plover

Red – Paradise Shelduck

*Light Blue - Black-backed Gull

Lilac – Pukeko

Grey - South Island Pied Oystercatcher

Orange - Black-billed Gull

Dark Green - Mallard Duck

Sea Green - Pied Shag

Maroon - Starling

Pink - Red-billed Gull

White - Caspian Tern

Plum - Rock Pigeon

Table 1. Summary of bird distributions at Charlesworth at different stages of the tidal cycle. NM, new marsh; OM, Old marsh.

			Number Spp.	Spp.	Spp.
Code	Time	Tide	(Total)	NM	OM
1	8-Dec-08	Low	8	8	3
2	9-Dec-08	High	9	9	4
3	10-Dec-08	Low - High	10	10	2
4	11-Dec-08	High - Low	10	8	6
5	15-Dec-08	High	10	9	5
6	15-Dec-08	Low	10	10	5
8	17-Dec-08	High - Low	12	11	6
9	18-Dec-08	Low - High	9	8	5
10	6-Jan-09	Low - High	10	10	6
11	7-Jan-09	Low	7	7	3
12	7-Jan-09	High	12	10	6
13	15-Jan-09	Low	10	9	6
14	15-Jan-09	High	11	11	5
15	16-Jan-09	Low - High	10	9	5
16	16-Jan-09	High - Low	10	9	5
17	26-Jan-09	Low	10	8	4
18	26-Jan-09	High	10	8	8
19	28-Jan-09	High - Low	10	8	6
20	26-Jan-09	Low - High	12	8	8

Species List:

- 1) Pied Stilt (*Himantopus himantopus leucocephalis*)
- 2) Grey Teal (*Anas gracilis*)
- 3) White-faced Heron (Ardea novaehollandiae)
- 4) South Island Oystercatcher (*Haematopus ostralegus*)
- 5) Eastern Bar-tailed Godwit (*Limosa lapponica baueri*)
- 6) Royal Spoonbill (aerial sighting) (*Platalea regia*)
- 7) Paradise Shelduck (*Tadorna variegata*)
- 8) Spur-winged Plover (*Vanellus miles*)
- 9) Black-backed Gull (Larus dominicanus)
- 10) Pukeko (*Porphyrio porphyrio*)
- 11) Starling (*Sturnus vulgaris*)
- 12) Welcome Swallow (in scrub around wetland) (*Hirundo tahitica*)
- 13) Mallard Duck (*Anas platyrhynchos*)
- 14) Harrier Hawk (aerial sighting) (*Circus approximans*)
- 15) Black-billed Gull (*Larus bulleri*)
- 16) Pied Shag (*Phalacrocorax varius*)
- 17) Canada Geese (aerial sighting) (*Branta canadensis*)
- 18) Red-billed Gull (*Larus novaehollandiae*)
- 19) Variable Oystercatcher (*Haematopus unicolor*)
- 20) Yellow Hammer (only in surrounding vegetation) (*Emberiza citrinella*)
- 21) Caspian Tern (*Sterna caspia*)
- 22) Rock Pigeon (Columba livia)
- 23) Skylark (*Alauda arvensis*)
- 24) Chestnut Teal (Anas castanea)



Figure 6. Areas where the majority of South Island oystercatcher and eastern bar tailed godwit were observed while water was high (including high tide and the 3 hrs either side of it)

Table 2. Average number of birds counted at three high and low tide within the new and old Charlesworth marsh. HT. High tide; LT, low tide.

New Charlesworth Marsh

Species Pied Stilt	Site NM	HT1 43	LT1 27	HT2 65	LT2 11	HT3 103	LT3			
White faced Heron	NM	13	7	13	9	28	3			
Eastern Bar- tailed Godwit South Island Pied	NM	31	8	32	. 0	105	2			
Oystercatcher	NM	37	1	59	0	172	2			
Old Charlesworth Marsh										
Species	Site	HT1	LT1	HT2	LT2	НТ3	LT3			
Pied Stilt White faced	ОМ	17	9	5	0	11	5			
Heron Eastern Bar-	ОМ	28	3	8	5	11	5			
tailed Godwit South Island Pied	ОМ	12	2	2	0	0	2			
Oystercatcher	ОМ	. 7	0	1	0	42	0			

On average there were greater numbers of the four focal species counted within the new Charlesworth wetland than the old area. In both areas more birds were observed at high tide when the birds are pushed out of their low tide feeding grounds into the edges of the estuary to roost and at times continue feeding. The bird counts were conducted from December 2008-January 2009, South Island pied oystercatchers made up the largest numbers within the Charlesworth wetland complex in both the new and old areas. Followed by pied stilts, bartailed godwit then white faced heron (see Table 2). In the old wetland on average South Island Pied oystercatchers were the most abundant bird, followed by white faced heron, pied stilt and eastern bar-tailed godwit (see Table 2).

Benthic food resources and algal cover

The sediment within the wetland provided prey such as, mud snails, crabs and polychaetes for wading and shorebirds birds. *Helice crassa* were the most conspicuous members of the benthic fauna present within the wetlands.

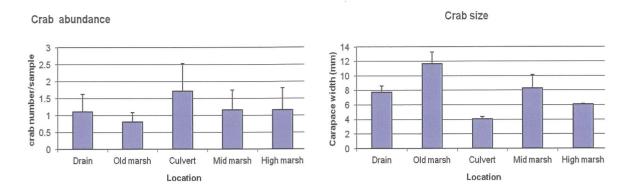


Figure 7. Density and carapace width of Helice crassa at Charlesworth wetland.

Helice crassa was widely distributed throughout the marsh with highest densities in the culvert areas closest to the sea (Fig.7). Similar densities were found in the other habitats such as, the drain, and the old marsh and in both the mid and upper levels of the new marsh. The largest crabs were found in the established parts of the marsh and the smallest individuals close to the culvert.

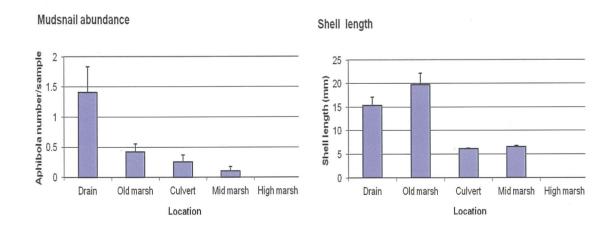


Figure 8. Density and size (shell length) of Amphibola crenata at Charlesworth wetland.

Amphibola crenata abundance varied amongst locations (Fig.8). The drain had the highest density with density decreasing in the old marsh, and was less from the culvert to highest marsh levels where there were no snails present. The largest individuals were recorded from the old marsh and the drain and the smallest (average shell length 6mm) from the culvert and mid marsh areas.

Polychaetes

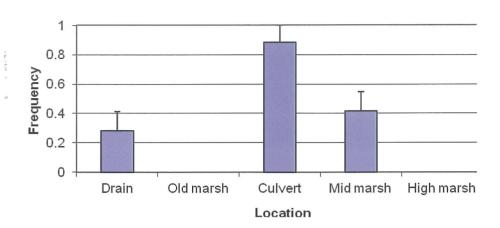


Figure 9. Frequency of polychaetes collected from different locations at Charlesworth wetland.

The diversity of species or groups of taxa within the Charlesworth marshes was relatively low compared with the estuarine mudflats. Polychaetes were found more in the culvert than the other habitats (Fig.9). No polychaetes were extracted from sediment samples collected from either the old marsh or the areas furthest away from the culverts in the new marsh.

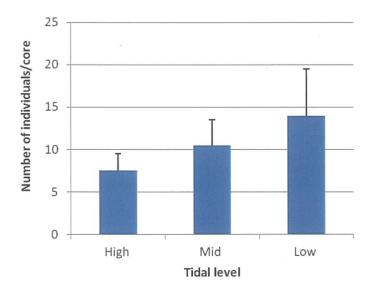


Figure 10. Effect of tidal level on the number of individuals (\pm SE) in benthic samples in cores in the new marsh culvert region.

In the region of the culverts marine invertebrates were divide into grouping or species where possible. Those species identified individualy included the polychaetes *Scolecolepides benhami*, *Nicon estuariensis*, the bivalve *Arthritica* and the mudsnail *Amphibola crenata*. Bivalves and gastropods were combined as molluscs and the other groups included Crustacea, and unidentified worms. The numbers of species was similar for all tidal levels but the density increased torwards the lower tide level (Fig.10).

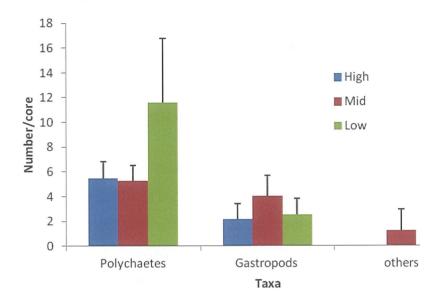


Figure 11. Numbers of polychaetes, gastropods and other taxa found at high, mid and low tide levels in the new Charlesworth wetland.

Polychaetes were the dominant faunal component in the benthic samples, especially at the low tide mark (Fig.11). Average *Scolecolepides* density ranged between 2.0 at the high and mid tide to 3.17 at the low tide. Densities of *Nicon* were similar ranging between 2.5 at the high tide, 1.0 at the mid tide and 2.2 at the low tide. Average *Arthritica* densities were between 1.7 and 3.5 and the most abundant polychaetes were small unidentified spionids in the low tide (6.5).

Algal cover

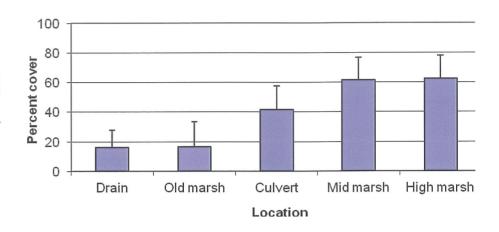


Figure 12. Percent cover of algae from different locations at Charlesworth wetland.

Several species of algae were found within the Charlesworth wetlands, macro algae *Ulva* and *Gracilaria* species were found some of which were partly decayed. There was also micro algae covering the sediment surface and from the variable colour this most likely comprised of a number of species. Overall algal density increased from about 20 % cover in the drain and the old marsh to about 60% cover in the mid and high parts of the new marsh (Fig. 12).

Organic levels and sediment contaminants

The sediment from different parts of the marsh differed in particle size distribution and the extent to which it was anoxic. Sandier substrates tended to be better aerated.

Water content

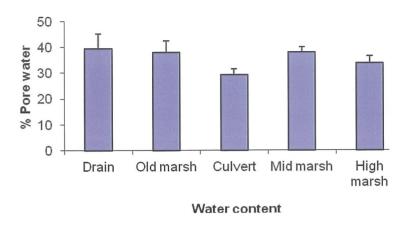


Figure 13. Percent pore water from sediment samples collected at Charlesworth wetland.

The pore water retention was similar in all samples with average values ranging between close to 30% and 40% (Fig. 13).

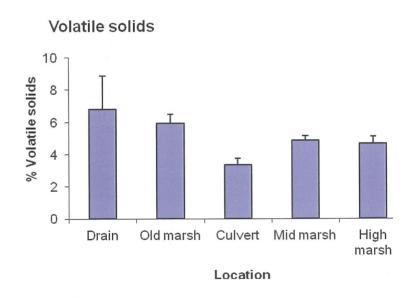
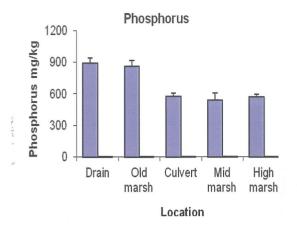


Figure 14. Percentage of volatile solids present in sediment from Charlesworth wetland.

The organic matter ranged from 7% in the drain, 6% in the old marsh to 5% in the higher levels of the new marsh (Fig.14). Lowest levels were found in the sediment close to the culvert.



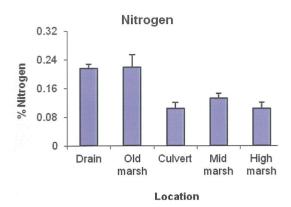


Figure 15. Phosphorus and nitrogen levels at Charlesworth wetlands.

Nitrogen values were more variable than phosphate levels within the marsh habitats but consistently high levels found in the drain and the old marsh (Fig.15). The trace metal concentrations were remarkably similar for all locations except the high levels of the new marsh where levels were elevated, up to 6 times the concentrations in the other sites.

Marsh sediments contained variable quantities of trace metals (Fig. 16.), with the highest levels found in the high marsh areas of the new Charlesworth wetland. Trace metal levels were within the low range and in similar to sediment from the estuary. Zinc was the trace metal found in the highest concentrations in the sediment samples; this may because the wetland site was built on reclaimed land.

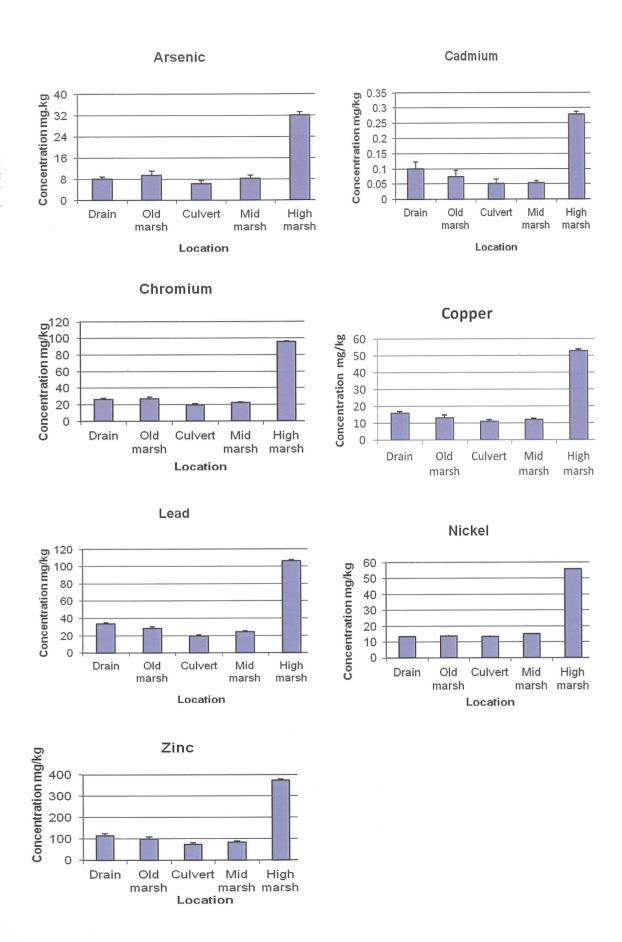
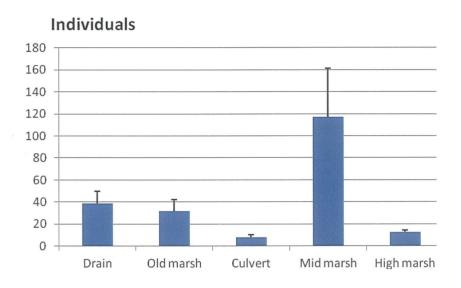


Figure 16. Trace metal concentrations from sediment samples taken at Charlesworth wetland.

Aquatic food resources

Incoming tides provide the wetland birds with food sources from the estuary. The fauna could be divided into terrestrial insects and larvae, semi terrestrial worm like organisms, marine polychaete worms, gastropods and bivalves, crustacean including amphipods, cumaceans, ostracods, crustacean larvae, nematodes and other worms. It was not possible to identify these to the species level. The species diversity was similar in each of the marsh habitats but the abundances were significantly different (Fig. 17). Numbers were greatest in the aquatic habitats in mid marsh area, similar in the drain and the old marsh and less abundant in the culvert and pools in the high marsh area.



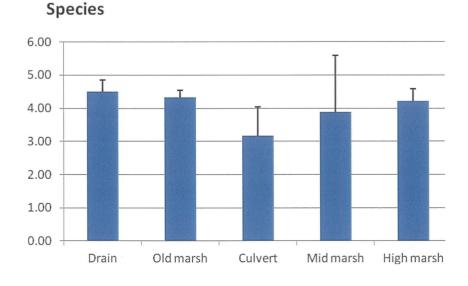


Figure 17. Abundance and diversity of invertebrates available in the water column at high tide in the Charlesworth wetlands.

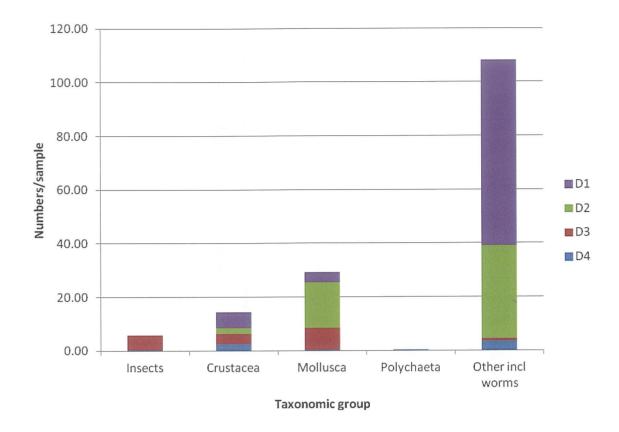


Figure 18. Pool water fauna in the drain running through the Charleswoth wetlands.D1 is water closest to the estuary and D4 further away (see Figure 3).

There was a distinct distribution pattern in the different tax of the drain with the total fauna was dominated by small worm like forms which were most abundant at sites closest to the estuary (Fig.18). There were similar numbers of crustaceans present in the water throughout the drain and the molluscs and insects dominated the intermediate distances. Few polychaetes were recorded in these samples.

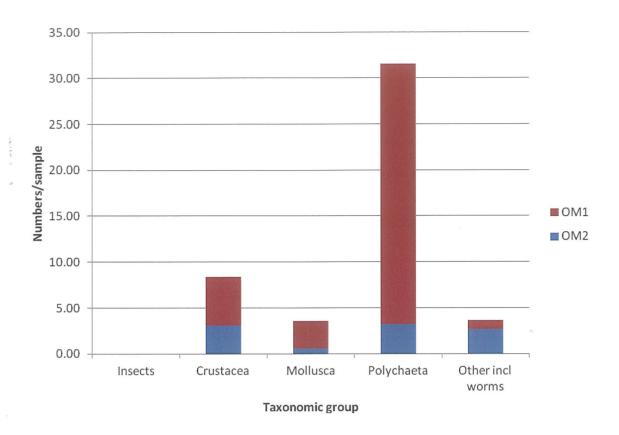


Figure 19. fauna of the pools in the old marsh, OM1 is closer to the road and estuary than OM2 (see Figure 3).

The fauna of the pools in the old marsh was broadly similar (Fig 19), however there were more polychaetes and molluscs in the pool closer to the estuary than on the pool which was more distant from the estuary.

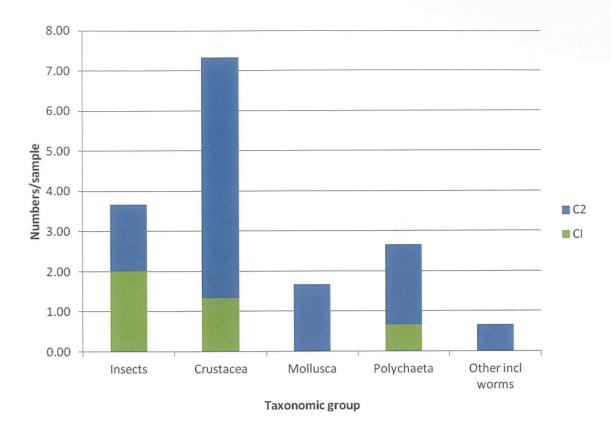


Figure 20. Fauna of the Culvert at high tide.C1 is the culvert in the central region of the new wetlands, C2 drains the eastern part of the marsh towards Linwood Avenue.

Differences were found in the abundances of the fauna in the two culvert regions, with the culvert on the eastern margin having higher numbers of crustaceans, polychaetes and molluscs (Fig. 20). At the time of sampling we also disturbed a large eel in the edge vegetation at that site.

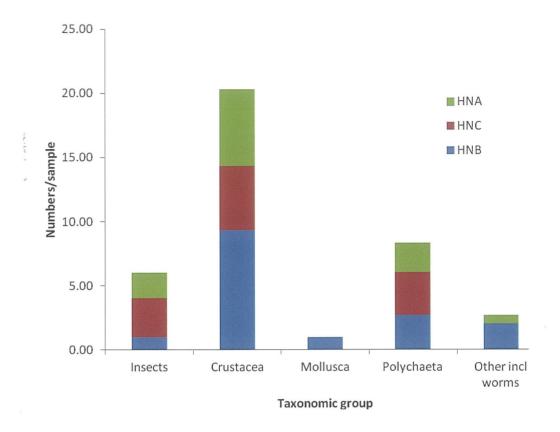


Figure 21. Pool water fauna collected from the high marsh area furthest away from the estuary (see Fig.3).

The pool water fauna in all three pools was similar and dominated by crustaceans, polychates and insects (Fig.21). However the densities were reduced compared with the older marsh area.

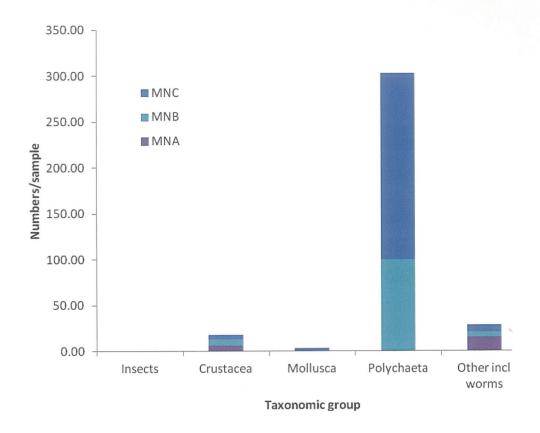


Figure 22. Pool fauna collected from the mid regions of the new wetland. Pool A was next to the drain directly behind the new wetland area, B was in the centre of the new wetland and C a pool located near to Linwood Avenue (see Fig.3).

The fauna of the pools in the mid region of the wetland was site specific with fewer invertebrates in the one closest to the drain (A) than the other two pools (Fig. 22). The fauna in these two pools was dominated by polychaetes worms, there were some crustaceans and other worms but few molluscs or insects and larvae.

Discussion

Salt marsh wetlands are threatened globally even though these ecotones provide essential ecosystem services for humans such as filtering pollutants, flood retention and acting as carbon sinks. To mitigate past and current destruction and degradation of these fragile ecosystems, local and regional councils have been working toward restoring these wetlands. Ecological restoration needs to be based on sound ecological theory and there is a real need for restoration projects to be monitored (Mitsch et al., 1998). Some see restoration as a true acid test of ecology theories or simply large scale experiments (Mitsch et al., 1998). Many scientists have now determined that restoring wetlands is far more complex than previously thought, with factors such as hydrological regime, invasive species and disturbance constraining ecological restoration (Zedler, 2000). The aim should not only be to restore a species or community but to restore the ecosystem function therefore there is a real need for ongoing monitoring of these restoration sites (Zedler, 2000).

Charlesworth wetland is one of the salt marsh wetlands currently being restored by the Christchurch City Council. Restoration of this site first took place in 1991, with the creation of pools and an island adjacent to a remnant of saltmarsh vegetation. The second stage took place in 2001, with the created of numerous islands differing in size, height and substrate, pools and channels. Charlesworth wetland provides the perfect opportunity for students and scientists to conduct research studying a range of things including restoration ecology, disturbance, wading birds and macroinvertebrates. We chose this site to conduct research over the summer of 2008-09 studying the abundance and distribution of wading and shore bird species and the availability of benthic food resources within the Charlesworth wetland complex. It was an opportunity to compare the effects of time on the restoration success of the marshes.

There was a range of wading and shore bird species present in Charlesworth wetland over the period of time that this research was conducted (December 2008-January 2009). In total there were twenty four bird species noted, this included wading, shore and passerine species. This research was purely observational in relation to the bird species utilising Charlesworth wetlands over the summer months. However we noted a wide range of behaviours from feeding to roosting during the tidal cycles. In addition we have mapped the distribution of bird species within Charlesworth wetland at high tide and low tide. On average more birds were counted at the new Charlesworth wetland perhaps because it

provides a larger habitat area, greater heterogeneity as well as a greater number of islands for roosting. The dominant species in both marsh areas was the South Island pied oystercatcher with many pied stilts and bar-tailed godwits. The white-faced heron however was seen more frequently in the old marsh areas which is less open and more densely vegetated at the edges. Some of the results of the present study can be compared with Love (1997) who recorded the abundances of pied stilts in the old wetland some 6 years after it had been established. Both the diversity and abundance of the key bird species were similar to the present study. He also highlighted the usefulness of the marsh areas for roosting and preening rather than feeding. Over the same time period of the current research, Gray (2009) compared the behaviour and feeding success of waders in the old marsh with similar areas in other parts of the estuary. She found that oyster catchers did not feed on the Charlesworth marsh most likely because of a lack of shellfish prey. In contrast, pied stilts were observed feeding in the old Charleswoth marsh where their feeding success rate (20%) was greater than at Heron St mudflats, but below the rate recorded for Estuary Rd mudflats where the success rate was 35%. This research confirms that the feeding behaviour and prey capture rate depends on prey availability and suitability. Thus, it would be expected that as the marsh food resources increase or change there would be an increase in the diversity of bird species feeding in the marshes and also improvement in the prey capture rate.

Helice crassa was the most conspicuous macroinvertebrate found within both the old and new Charlesworth wetlands. It is a common species which is widely distributed in the estuary (Marsden and Knox, 2008). This species was most abundant in the culverts closest to the sea (estuary) in the wetlands. The largest individual crabs were found in the oldest most established parts of the wetlands, with the smallest individuals found in closest to the culverts. These juvenile crabs may be from juveniles moving in the water column during high tide as proposed by Mitsch's (1998) self design concept. Amphibola crenata a common inhabitant of saltmarshes (Webster, 1997; Marsden and Knox, 2008) was also found in the Charlesworth marshes where individuals of a wide size range, including juveniles were recorded. The highest density of Amphibola crenata was found in the drain with the density decreasing in the old marsh and in the highest wetland zones. This may because of differences in salinity, with the areas closer to the drains being inundated first with seawater at high tide and may reflect tolerance levels. The largest individuals were found in the old Charlesworth wetland, with the smallest in the mid wetland zone. Polychaete density was very low in all wetland areas, with the highest densities found in the culvert area. Polychaetes were absent from sediment samples collected from the old Charlesworth wetland and areas

furthest away from culverts in the new wetland. This research has shown however that there were considerable food resources available for pied stilts in both the new and older marsh site.

The present research, which was undertaken in 2008, was not followed up subsequent to the 2010 earthquakes. Anecdotal evidence from 2009 and our own preliminary studies had indicated that benthic communities in the wetland mudflats especially close to the main culvert had continued to improve and cockles had established in the main culvert providing prey for oystercatchers. Also large polychaete worms were found regularly in the old marsh area. As a result of the earthquakes, marked changes were observed in the mudflat surface with large input of sediment and widening and flattening of the channels. Initially following the earthquake many of the birds disappeared but white-faced herons were seen in the marsh within 2 weeks of the February 2011earthquake, and other birds returned within the next month. Andrew Crossland, a local ornithologist is of the opinion that the Charlesworth wetland will be able to recover without large intervention methods. However, clearly it would be of benefit to try to increase water flow to continue the restoration of the mudflat areas. Our research was preliminary and given that the earthquake has significantly affected the marsh areas in many parts of the estuary, more rigorous scientific research needs to be conducted to assess the diversity and density of wading and shore birds over a longer time scale. Future research could focus on the change in diversity and abundance of species over space and time, wading bird roosting behaviour or compare the diversity, density and behaviours of wading and shore birds within these artificial wetlands with that of birds roosting and feeding in nature salt marsh wetlands. Questions which could be asked are; have bird behaviours changed over time since this previous research was conducted, how do food resources compare with the estuary proper? And, how do the birds use the marshes at different times of the day and evening or in spring and or neap tides?

In conclusion although in 2008, some of the Charlesworth wetlands contained high nutrients and levels trace metals in the sediment the wetlands provided vital habitat for high tide roosting and also for benthic invertebrates, therefore providing a supplementary food resource for wading and shore birds at high tide when the estuary is inundated with water. They therefore had achieved the aims that they were set up to do. The new wetland areas had similar macroinvertebrate fauna to that of the old Charlesworth wetland, confirming a successional pattern of natural recruitment of marine invertebrates. There is however a need for more extensive research to be carried out on the wetland over a longer time scale, to investigate temporal and spatial changes in biodiversity within the Charlesworth wetland

complex. There is also a need to understand the changing ecological status of all of the marshes both artificial and natural marshes in the Avon-Heathcote Estuary/ Ihutai following earthquake disturbance. With changed land designations there is also the opportunity for developing or encouraging the establishment of new marsh areas which can provide valuable roosting and feeding areas for wading and other birds to compensate for the lack of suitable natural resting sites along the estuary edge.

Acknowledgements

We would like to thank the Ihutai Trust, the Estuary Society and the Christchurch City Council without which this research would not have been possible. They provided funds for a summer scholarship for Ellena Soper and also covered the cost of the trace metal analysis of the sediments. We would also like to thank Andrew Crossland for the helpful information and the advice he provided. We would also like to thank Jan McKenzie for her help with a number of aspects of the project and a research assistant who helped with some of the sediment sampling. Juzah M. Zammit-Ross is also acknowledged for helping to write up parts of the report.

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Appendices



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REPORT

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SPv1

School of Biological Sciences Client: Contact: Marsden, Islay C/- School of Biological Sciences University of Canterbury Private Bag 4800 CHRISTCHURCH 8140

676746 Lab No: 28-Jan-2009 Date Registered: Date Reported: 02-Feb-2009 35122 Quote No: 151600 Order No:

Client Reference: Estuarine Sediments Marsden, Islay Submitted By:

Sample Type: Sediment						
	Sample Name:	D1H 08-Jan-2009	D1L 08-Jan-2009	D2H 23-Jan-2009	D2L 23-Jan-2009	D3H 23-Jan-200
	Lab Number:	676746.1	676746.2	676746.3	676746.4	676746.5
Individual Tests		-1-				
Total Recoverable Phosphorus	ma/ka dry wt	800	970	880	670	950
Total Nitrogen	g/100g dry wt	0.21	0.28	0.17	0.18	0.24
Heavy metal, trace level As,Cd				- 49540000		
Total Recoverable Arsenic	ma/ka dry wt	5.5	10	12	7.1	8.0
Total Recoverable Cadmium	ma/ka dry wt	0.22	0.13	0.077	0.17	0.047
Total Recoverable Chromium	mg/kg dry wt	25	24	27	32	22
Total Recoverable Copper	ma/ka dry wt	20	14	13	18	13
Total Recoverable Lead	ma/ka dry wt	34	35	31	34	29
Total Recoverable Nickel	mg/kg dry wt	11	12	14	14	13
Total Recoverable Zinc	mg/kg dry wt	160	120	100	140	92
	Sample Name:	D3L 23-Jan-2009	D4H 13-Jan-2009	D4L 13-Jan-2009	OM1H 14-Jan-2009	OM1M 14-Jan-2009
	Lab Number:	676746.6	676746.7	676746.8	676746.9	676746.10
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	1,100	890	900	990	1,000
Total Nitrogen	g/100g dry wt	0.20	0.21	0.23	0.36	0.11
Heavy metal, trace level As,Co				1	1	
Total Recoverable Arsenic	ma/kg dry wt	6.7	9.4	5.7	14	13
Total Recoverable Cadmium	ma/ka dry wt	0.054	0.043	0.060	0.037	0.035
Total Recoverable Chromium	ma/ka dry wt	29	24	28	21	23
Total Recoverable Copper	mg/kg dry wt	17	16	19	9.7	9.7
Total Recoverable Lead	mg/kg dry wt	36	32	41	24	26
Total Recoverable Nickel	mg/kg dry wt	14	15	14	13	12
Total Recoverable Zinc	mg/kg dry wt	110	96	110	67	77
Sample Name:		OM1L 14-Jan-2009	OM2H 14-Jan-2009	OM2M 14-Jan-2009	OM2L 14-Jan-2009	A3H 20-Jan-200
	Lab Number:	676746.11	676746.12	676746.13	676746.14	676746.15
Individual Tests					- +	
Total Recoverable Phosphorus	s mg/kg dry wt	860	890	800	630	770
Total Nitrogen	g/100g dry wt	0.16	0.19	0.25	0.24	0.15
Heavy metal, trace level As,Co	d,Cr,Cu,Ni,Pb,Zn			,	, , , , , , , , , , , , , , , , , , , ,	
Total Recoverable Arsenic	mg/kg dry wt	8.7	11	5.6	4.6	14
Total Recoverable Cadmium	mg/kg dry wt	0.044	0.052	0.13	0.15	0.029
Total Recoverable Chromium	mg/kg dry wt	31	26	31	31	24
Total Recoverable Copper	mg/kg dry wt	16	12	16	17	11
Total Recoverable Lead	mg/kg dry wt	29	29	31	32	30
Total Recoverable Nickel	mg/kg dry wt	14	14	15	15	15



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which

Sample Type: Sediment	Sample Name:	OM1L	OM2H	OM2M	OM2L	A3H 20-Jan-2009
	Sample Name.	14-Jan-2009	14-Jan-2009	14-Jan-2009	14-Jan-2009	71011 20 0011 2000
	Lab Number:	676746.11	676746.12	676746.13	676746.14	676746.15
Heavy metal, trace level As,Co	l,Cr,Cu,Ni,Pb,Zn			4		
Total Recoverable Zinc	mg/kg dry wt	96	95	130	130	82
	Sample Name:	A3M 20-Jan-2009	A3L 20-Jan-2009	A4H 20-Jan-2009	A4M 20-Jan-2009	A4L 20-Jan-2009
	Lab Number:	676746.16	676746.17	676746.18	676746.19	676746.20
Individual Tests	Lub Humber.	0.0.10.10	0.0.10.11			
Total Recoverable Phosphorus	mg/kg dry wt	560	690	490	570	590
Total Nitrogen	g/100g dry wt	0.13	0.18	0.092	0.11	0.064
Heavy metal, trace level As,Co		0.10	0.10	0.002		
Total Recoverable Arsenic	mg/kg dry wt	4.9	4.9	6.3	5.0	4.7
Total Recoverable Cadmium	mg/kg dry wt	0.047	0.079	0.029	0.040	0.024
Total Recoverable Chromium	mg/kg dry wt	23	24	21	22	20
Total Recoverable Copper	mg/kg dry wt	12	14	9.7	11	8.4
Total Recoverable Lead	mg/kg dry wt	24	26	23	22	21
Total Recoverable Nickel	mg/kg dry wt	15	15	15	16	15
Total Recoverable Zinc	mg/kg dry wt	81	96	75	77	63
		D411 24 1 2000	B1M 21-Jan-2009	D41 24 les 2000	D211.24 Jan 2000	D2M 24 Jan 2000
					676746.24	676746.25
	Lab Number:	676746.21	676746.22	676746.23	0/0/40.24	6/6/40.25
Individual Tests						
Total Recoverable Phosphorus		560	590	570	580	660
Total Nitrogen	g/100g dry wt	0.11	0.21	0.080	0.067	0.17
Heavy metal, trace level As,Co						
Total Recoverable Arsenic	mg/kg dry wt	9.0	3.8	4.9	14	6.2
Total Recoverable Cadmium	mg/kg dry wt	0.023	0.12	0.035	0.038	0.090
Total Recoverable Chromium	mg/kg dry wt	22	24	20	20	24 13
Total Recoverable Copper	mg/kg dry wt	10	15	12	8.7	23
Total Recoverable Lead	mg/kg dry wt	24	23	19	22	23 15
Total Recoverable Nickel	mg/kg dry wt	15 75	13	14 71	16 70	98
Total Recoverable Zinc	mg/kg dry wt					
	Sample Name:	B3L 21-Jan-2009	B4H 22-Jan-2009	B4M 22-Jan-2009	B4L 22-Jan-2009	
	Lab Number:	676746.26	676746.27	676746.28	676746.29	676746.30
Individual Tests						
Total Recoverable Phosphorus	s mg/kg dry wt	710	590	680	700	640
Total Nitrogen	g/100g dry wt	0.085	0.077	0.10	0.18	0.10
Heavy metal, trace level As,Co	d,Cr,Cu,Ni,Pb,Zn					
Total Recoverable Arsenic	mg/kg dry wt	7.9	13	4.4	3.9	11
Total Recoverable Cadmium	mg/kg dry wt	0.052	0.026	0.054	0.085	0.036
			20	22	24	19
Total Recoverable Chromium	mg/kg dry wt	21	20			10
Total Recoverable Chromium Total Recoverable Copper	mg/kg dry wt mg/kg dry wt	21	8.5	13	15	10
		11 19	8.5 19	21	24	20
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel	mg/kg dry wt	11 19 14	8.5 19 14	21 15	24 15	20 13
Total Recoverable Copper Total Recoverable Lead	mg/kg dry wt mg/kg dry wt	11 19	8.5 19	21	24	20
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc	mg/kg dry wt mg/kg dry wt mg/kg dry wt	11 19 14 79	8.5 19 14	21 15 82	24 15 100	20 13 70
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc	mg/kg dry wt mg/kg dry wt mg/kg dry wt mg/kg dry wt	11 19 14 79	8.5 19 14 67	21 15 82	24 15 100	20 13 70
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc	mg/kg dry wt mg/kg dry wt mg/kg dry wt mg/kg dry wt Sample Name:	11 19 14 79 C1M 22-Jan-2009	8.5 19 14 67 C1L 22-Jan-2009	21 15 82 C3H 23-Jan-2009	24 15 100 C3M 23-Jan-2009	20 13 70 C3L 23-Jan-2009
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc	mg/kg dry wt mg/kg dry wt mg/kg dry wt mg/kg dry wt Sample Name: Lab Number:	11 19 14 79 C1M 22-Jan-2009	8.5 19 14 67 C1L 22-Jan-2009	21 15 82 C3H 23-Jan-2009	24 15 100 C3M 23-Jan-2009	20 13 70 C3L 23-Jan-2009
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus	mg/kg dry wt Sample Name: Lab Number:	11 19 14 79 C1M 22-Jan-2009 676746.31	8.5 19 14 67 C1L 22-Jan-2009 676746.32	21 15 82 C3H 23-Jan-2009 676746.33	24 15 100 C3M 23-Jan-2009 676746.34	20 13 70 C3L 23-Jan-2009 676746.35
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen	mg/kg dry wt Sample Name: Lab Number: s mg/kg dry wt g/100g dry wt	11 19 14 79 C1M 22-Jan-2009 676746.31	8.5 19 14 67 C1L 22-Jan-2009 676746.32	21 15 82 C3H 23-Jan-2009 676746.33	24 15 100 C3M 23-Jan-2009 676746.34	20 13 70 C3L 23-Jan-2009 676746.35
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen Heavy metal, trace level As, Co	mg/kg dry wt Sample Name: Lab Number: s mg/kg dry wt g/100g dry wt d,Cr,Cu,Ni,Pb,Zn	11 19 14 79 C1M 22-Jan-2009 676746.31 480 0.087	8.5 19 14 67 C1L 22-Jan-2009 676746.32 510 0.059	21 15 82 C3H 23-Jan-2009 676746.33 560 0.14	24 15 100 C3M 23-Jan-2009 676746.34 490 0.16	20 13 70 C3L 23-Jan-2009 676746.35
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen	mg/kg dry wt Sample Name: Lab Number: s mg/kg dry wt g/100g dry wt d,Cr,Cu,Ni,Pb,Zn mg/kg dry wt	11 19 14 79 C1M 22-Jan-2009 676746.31 480 0.087	8.5 19 14 67 C1L 22-Jan-2009 676746.32	21 15 82 C3H 23-Jan-2009 676746.33	24 15 100 C3M 23-Jan-2009 676746.34	20 13 70 C3L 23-Jan-2009 676746.35 480 0.11
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen Heavy metal, trace level As, Co Total Recoverable Arsenic Total Recoverable Cadmium	mg/kg dry wt mg/kg dry wt mg/kg dry wt mg/kg dry wt sample Name: Lab Number: s mg/kg dry wt g/100g dry wt d,Cr,Cu,Ni,Pb,Zn mg/kg dry wt	11 19 14 79 C1M 22-Jan-2009 676746.31 480 0.087	8.5 19 14 67 C1L 22-Jan-2009 676746.32 510 0.059	21 15 82 C3H 23-Jan-2009 676746.33 560 0.14	24 15 100 C3M 23-Jan-2009 676746.34 490 0.16	20 13 70 C3L 23-Jan-2009 676746.35 480 0.11
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen Heavy metal, trace level As, Co Total Recoverable Arsenic Total Recoverable Cadmium Total Recoverable Chromium	mg/kg dry wt Sample Name: Lab Number: s mg/kg dry wt g/100g dry wt d/,Cr,Cu,Ni,Pb,Zn mg/kg dry wt mg/kg dry wt	11 19 14 79 C1M 22-Jan-2009 676746.31 480 0.087	8.5 19 14 67 C1L 22-Jan-2009 676746.32 510 0.059	21 15 82 C3H 23-Jan-2009 676746.33 560 0.14	24 15 100 C3M 23-Jan-2009 676746.34 490 0.16	20 13 70 C3L 23-Jan-2009 676746.35 480 0.11
Total Recoverable Copper Total Recoverable Lead Total Recoverable Nickel Total Recoverable Zinc Individual Tests Total Recoverable Phosphorus Total Nitrogen Heavy metal, trace level As, Co Total Recoverable Arsenic Total Recoverable Cadmium	mg/kg dry wt mg/kg dry wt mg/kg dry wt mg/kg dry wt sample Name: Lab Number: s mg/kg dry wt g/100g dry wt d,Cr,Cu,Ni,Pb,Zn mg/kg dry wt	11 19 14 79 C1M 22-Jan-2009 676746.31 480 0.087	8.5 19 14 67 C1L 22-Jan-2009 676746.32 510 0.059 4.0 0.037 16	21 15 82 C3H 23-Jan-2009 676746.33 560 0.14 9.3 0.064 22	24 15 100 C3M 23-Jan-2009 676746.34 490 0.16 8.3 0.032 23	20 13 70 C3L 23-Jan-2009 676746.35 480 0.11 4.7 0.049 23

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Sample Type: Sediment						
5	Sample Name:	C1M 22-Jan-2009	C1L 22-Jan-2009	C3H 23-Jan-2009	C3M 23-Jan-2009	C3L 23-Jan-2009
	Lab Number:	676746.31	676746.32	676746.33	676746.34	676746.35
Heavy metal, trace level As,Cd	,Cr,Cu,Ni,Pb,Zn					
Total Recoverable Zinc	mg/kg dry wt	63	54	85	89	90
5	Sample Name:	C4H 23-Jan-2009	C4M 23-Jan-2009	C4L 23-Jan-2009		
7 7	Lab Number:	676746.36	676746.37	676746.38		
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	470	570	440	-	-
Total Nitrogen	g/100g dry wt	0.15	0.22	0.11	-	-
Heavy metal, trace level As,Cd	,Cr,Cu,Ni,Pb,Zn					
Total Recoverable Arsenic	mg/kg dry wt	15	3.8	5.1	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.034	0.10	0.039	-	-
Total Recoverable Chromium	mg/kg dry wt	20	23	21	-	-
Total Recoverable Copper	mg/kg dry wt	9.0	15	11	-	-
Total Recoverable Lead	mg/kg dry wt	29	28	25	-	-
Total Recoverable Nickel	mg/kg dry wt	15	15	15	-	-
Total Recoverable Zinc	mg/kg dry wt	75	98	74	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Samples
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction.	-	1-38
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	-	1-38
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-38
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-38
Total Nitrogen	Catalytic Combustion (900°C, O ₂), separation, Thermal Conductivity Detector [Elementar Analyser].	0.050 g/100g dry wt	1-38

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client

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Peter Robinson MSc (Hons), PhD, FNZIC Client Services Manager - Environmental Division

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Hill Laboratories

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Notes Made to Accompany Bird Distributions:

<u>1 Bird Species Distribution – Monday 8th December, 7.00am-8.15am (Low Tide)</u> <u>Notes:</u>

- The two dominant species were Pied stilts and Grey teals
- Almost all birds observed were carrying out feeding related behaviour
- One White faced heron in new section was feeding briefly but stopped (was the only heron observed in new section).
- Pair of Black-backed Gulls on an island in new section became aggressive to another Black-backed Gull that flew in on its own
- Grey teal take off in flocks if spooked but land elsewhere in wetlands
- When a group of Grey teal were disturbed in old section (and subsequently took off), left old section relatively deserted

OBSERVATION OF PIED STILT FEEDING BEHAVIOUR:

- When feeding in water rapid side to side movement of head (~1 second frequency)
- On mud, slower, less frequent, no side to side action (more probing)
- No Pied stilts observed in the middle of wetlands while water was still relatively deep compared to margins

OBSERVATIONS OF GREY TEAL FEEDING:

- Bill immersed in water, swim along
- 'Sieve' water

OBSERVATION OF BAR-TAILED GODWIT FEEDING

- Probe substrate
- Rapid movement but less frequent compared to stilts

Bird Species List:

- Pied Stilt
- Grey Teal
- White-faced Heron
- Paradise Shelduck
- Bar-tailed Godwit
- Black-backed Gull
- Spur-winged Plover
- Pukeko

<u>2 Bird Species Distribution – Tuesday 9th December, 3.00pm-4.15pm (High Tide)</u> Notes:

New Area

- Observed both White faced Heron and Bar-tailed Godwit feeding in north eastern pool
- Water was relatively high/deep, so they were feeding on the margins

- Pied stilts restricted to margins also (or few areas of mud flat that remain)
- Many Grey teal were out in the middle of pools swimming
- Harrier hawk flew over and cause large amount of teals, stilts and heron to take off (however, they once again settled in wetland)
- Majority of Bar-tailed Godwits observed were sleeping in a large group on an island
- There was also a large group of South Island Pied Oystercatchers sleeping on this same large island
- While resting, birds tended to form distinct groups of own species
- More South Island Pied Oystercatchers flew in and settled down to sleep while observation was taking place
- Majority of White faced Heron observed have been feeding (all on water margins)
- Majority of all birds present are sleeping
- Pied Stilts were different to other species in that a large number were both feeding and sleeping
- Waders that are feeding are on pool margins
- Grey Teal are feeding on middle and margins
- Pair of Pukeko is regularly observed on South end of wetland near old part, possibly are or were nesting there?

Old Area

- Pied stilts feeding in middle of back pools (suspect that water is not so deep here)
- A lot of White faced Herons present (active), some of these are from the back pool in new area that I had to observe to access the old area
- Flock of Grey teal took off when I arrived
- Pied stilts alarm calling
- White faced Heron do not appear to be feeding on anything large (almost no handling time)
- Saw one White faced Heron pick up something large but it dropped it (inedible?)

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- Pukeko
- South Island Pied Oystercatcher
- Harrier Hawk

<u>3 Bird Species Distribution – Wednesday 10th December, 1.00pm-2.30pm (between Low/High tides)</u>

Notes:

New Area

- Not as many birds around
- Grey teal numbers were still high but the vast majority were sleeping

- A few Bar-tailed Godwit, Pied stilt and White faced Heron feeding
- Grey teal that were feeding were on mud flats (wetlands already were very drained, there was no water deep enough to swim in
- Hardly any Bar-tailed Godwit compared to the preceding high tide
- Not as many South Island Pied Oystercatcher compared to last high tide either (and none were feeding)
- Back pool (back from old area, in south west corner of wetlands) that had been so full of bird life at high tide was largely deserted

Old Area

- Many White faced Heron
- Some flew away when I arrived
- Most of the White faced Heron were resting rather than feeding
- One Pied stilt on arrival (and it was feeding)
- Four more Pied stilt flew in while I observed and started feeding
- Only area with any substantial amount of water left was the back left pool (when facing Humphreys Drive)
- This was where the Pied stilt focused their feeding

Bird Species List:

- Pied stilt
- Grey Teal
- White-faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- Pukeko
- South Island Pied Oystercatcher
- Black-billed Gull

4 Bird Species Distribution – Thursday 11th December, 7.40am-9.00am (between High/Low tides)

Notes:

New Area

- Water still high
- Mix between birds feeding and resting
- However, the majority are resting
- Majority of White faced Herons observed are feeding, except for individuals resting on two large logs near the south west pool.
- Grey teal that are active are able to swim
- A pair of Bar-tailed Godwit were observed feeding
- Unusually high number of Paradise ducks all on one island

Old Area

- Only Grey teals were feeding (they took off in a flock when I arrived)

- All other birds sleeping (with the exception of the odd individual heron or stilt)
- One lone South Island Pied Oystercatcher
- Two Mallard ducks (did not take off with the Grey teals
- Majority of Spur-winged Plover seen in the whole wetlands were in this area

Bird Species List:

- Pied Stilt
- Grey Teal
- White-faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- Pukeko
- South Island Pied Oystercatcher
- Mallard Duck

<u>5 Bird Species Distributions – Monday 15th December, 8.30am-9.30am (High Tide)</u> Notes:

New Area

- Unusually high tide
- Many islands almost completely submerged that are usually well clear of the water
- Therefore, while the distribution map may show many birds on the islands, most of these birds were actually feeding
- Water remained very high throughout observation
- White faced Heron were feeding in the deep water
- South Island Pied Oystercatcher and Bar-tailed Godwit were sleeping

Old Area

- High density of birds
- Many White faced Herons
- Was talking to Emily Gray (UC student) and she said that many of the main roosts were underwater, so may have contributed to this

Bird Species List:

- Pied Stilt
- Grey Teal
- White-faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- Pukeko
- South Island Pied Oystercatcher
- Shag (species unknown)

6 Bird Species Distribution - Monday 15th December, 2.40pm-3.50pm (Low Tide)

Notes:

New Area

- Water still unusually high
- As much water present as during an average high tide (at the start but did start to drain towards end of observation)
- Flock of brown unidentified passerines took off for no reason at start of observation
- Also group of Pied stilts were agitated (possibly Black-backed Gulls flying over head the cause?)
- Flock of Bar-tailed Godwits also restless
- A lot of alarm calling, flying etc. going on
- Starling feeding in actual wetland area rather than the vegetated fringes (which is usual)
- Even though water high, large numbers of Grey teal are resting (hardly any are swimming)
- Not as many White faced Heron present as in morning (despite high water)
- Many Pied stilts resting on islands in small groups

Old Area

- White faced Herons here but most are not feeding
- Many of the Pied stilt are also not feeding
- Water had drained quite a lot by this point (but was much later than predicted low tide)

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise duck
- Black-backed Gull
- Pukeko
- Red-billed Gull
- Starling
- Mallard Duck

8 Bird Species Distribution – Wednesday 17th December, 1.00pm-2.30pm (between High and Low tide)

Notes:

New Area

- Almost no birds were feeding, not even teals
- Water was still very high; many of the main islands were still submerged.
- Very quiet, only approximately 3-4 Grey teal, 2 White faced Heron and 3 Pied stilt feeding.
- Black-backed Gull pair now has a clearly visible fluffy chick on one of the large central islands.

Old Area

- A large number of White faced Heron have congregated in this part
- However, majority are simply standing around (not feeding)
- Also, there are a decent number of South Island Pied Oystercatchers

Bird Species List:

- Pied Stilt
- White-faced Heron
- Grey Teal
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- Pukeko
- South Island Pied Oystercatcher
- Variable Oystercatcher
- Mallard Duck
- Starling
- Black-billed Gull

<u>9 Bird Species Distributions – Thursday 18th December, 7.47am-9.00am (Between Low and High tide)</u>

Notes:

New Area

- Many Grey teal were out feeding
- Only a few South Island Pied Oystercatchers and Bar-tailed Godwit were present and were mostly sleeping
- Many of the Pied stilt were sleeping
- Many White faced Heron were also resting
- Halfway through the observation I scared a flock of Grey teal, caused a chain reaction, all Grey teal took off from new area before settling far down the end I had come from
- This is the reason Grey teal a missing from one half of the map

Old Area

- Most birds were on the middle island
- Many White faced Heron, only some were feeding
- Majority of birds were sleeping

Bird Species List:

- Pied Stilt
- Grey Teal
- White-faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck

- Black-backed Gull
- South Island Pied Oystercatcher
- Red-billed Gull

<u>10 Bird Species Distribution – Tuesday 6th January, 11.30am – 12.40pm (Between Low and High tide)</u>

Notes:

New Area

- Northern end largely empty
- No Grey teal present
- Almost no feeding occurring among any of the bird species present, most are sleeping
- Nothing in the back south pool
- Met Andrew Crossland: Banded Dotterels should arrive in the next 1-2 weeks (have finished breeding, islands to low (why they became submerged in spring tides)
- Emptiness may have been due to Andrew Crossland (CCC) disturbing the birds?

Old Area

- Many White faced Heron, most were resting on central island
- Stilts all resting
- One South Island Pied Oystercatcher feeding
- Overall, there were very few birds present in entire wetland

Bird Species List:

- Pied Stilt
- White-faced Heron
- Bar-tailed Godwit
- Spur-winged Plover
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Black-billed Gull
- Pukeko

11 Bird Species Distributions — Wednesday 7th January, 9.15am-10.30am (Low Tide) Notes:

New Area

- Again no Grey teal
- Very quiet, bird numbers depleted in general
- All White faced Heron observed were feeding for at least some of the time
- Majority of the Pied stilts were in large groups, roosting on islands
- Basically no birds out feeding on the mud
- Tides still neap

^{*}Old Area*

- Only White faced Heron and Spur-winged Plover present (no Pied stilts)
- Some White faced Heron feeding but most in group on central island
- Red-billed Gull flew in during observation period

Bird Species List:

- Pied Stilt
- White faced Heron
- Spur-winged Plover
- Black-backed Gull
- South Island Pied Oystercatcher
- Red-billed Gull
- Starling

12 Bird Species Distribution – Wednesday 7th January, 3.30pm-4.45pm (High Tide) Notes:

New Area

- Majority of birds resting
- Exception being White faced Heron
- A number of Pied stilts are feeding (but majority of this species resting)
- A minimal number of South Island Pied Oystercatcher and Bar-tailed Godwit feeding
- Grey teal have returned but in very small numbers

Old Area

- Grey teal also present (only a few)
- Many White faced Heron congregated in this area

Bird Species List:

- Pied Stilt
- Grey Teal
- Bar-tailed Godwit
- White faced Heron
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Black-billed Gull
- Pukeko
- Red-billed Gull
- Starling

13 Bird Species Distribution – Thursday 15th January, 4.00pm – 5.10 pm (Low Tide) **Notes:**

New Area

- Hardly any birds roosting apart from a flock of Pied stilts. 2^{nd} observation section dominated by Grey teals.

Old Area

- No birds resting.
- Bar-tailed Godwits probing (polychaetes).
- All White faced Heron feeding.

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Spur-winged Plover
- Red-billed Gull
- Black-billed Gull

<u>14 Bird Species Distribution – Thursday 15th January, 9.45am-11.45am (High Tide)</u> Notes:

New Area

- Caspian Terns present (have actually landed on islands to rest), previously have only ever sighted one flying over wetlands.
- Birds very flighty, saw flocks of Grey teal, Pied stilt, Bar-tailed Godwit and South Island Pied Oystercatcher take off on separate occasions, in both the old and new area.
- Met some English photographers who were pretty certain that they had sighted a Chestnut teal among the birds on one of the islands, however they had lost it when a flock of teals had randomly taken off.
- Some islands were partially submerged.
- Birds not in such defined groups as they usually are, more intermingling of species.
- Majority of birds observed were resting.

Old Area

- Large number of oystercatchers roosting took off near start of observation with some Grey teal, circled overhead before resettling.
- No Bar-tailed Godwit in this part.
- White faced Heron feed for short bursts then rest.
- White faced Heron that are feeding are on pool margins (note this is the case for back anoxic pool that I sampled).

Bird Species List:

- Pied Stilt
- Grey Teal
- White-faced Heron
- Bar-tailed Godwit
- Paradise Shelduck

- Black-backed Gull
- South Island Pied Oystercatcher
- Variable Oystercatcher
- Spur-winged Plover
- Caspian Tern
- Black-billed Gull
- Starling
- Chestnut Teal??

<u>15 Bird Species Distributions – Friday 16th January, 7.30am – 8.45am (Between Low and High tide)</u>

Notes:

New Area

- Mix of birds feeding and roosting
- Grey teal generally feeding
- Groups of Pied stilt resting & feeding
- White faced herons resting
- Bar-tailed Godwits & South Island Pied Oystercatchers resting
- Quite empty apart from teals

Old Areas

- No Grey teal (saw a lot across road on estuary).
- All birds feeding except the South Island Pied Oystercatchers and one Pied stilt.

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- Spur-winged Plover
- Red-billed Gull
- Black-backed Gull

$\frac{16\ Bird\ Species\ Distributions-Friday\ 16^{th}\ January, 1.30pm-2.30pm\ (Between\ High\ and\ Low\ tide)}{}$

Notes:

New Area

- Massive influx of Pied stilt, Grey teal, Caspian terns and White faced heron shortly after arrival.

Old Area

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Spur-winged Plover
- Black-billed Gull
- Caspian Tern

<u>17 Bird Species Distributions – Monday 26th January (Low Tide)</u> <u>Notes:</u>

New Area

- Very empty
- Only birds feeding are Paradise shelducks

Old Area

- Very empty
- Only waders present were Pied stilt
- Pukeko chick grown up

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- South Island Pied Oystercatcher
- Paradise Shelduck
- Black-backed Gull
- Spur-winged Plover
- Red-billed Gull
- Pukeko
- Rock Pigeon
- Starling

<u>18 Bird Species Distribution – 28th January (High Tide)</u> Notes:

New Area

- Many birds roosting
- Most of the birds that were feeding were teals, but took off in a flock
- Terns present again
- Many South Island Pied Oystercatcher and Bar-tailed Godwit roosting

^{*}Old Area*

- Most birds were feeding including South Island Pied Oystercatcher and Bar-tailed Godwit
- Suspect polychaetes in middle pool (fed well by drain), Bar-tailed Godwits are probing.

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Spur-winged Plover
- Red-billed Gull
- Caspian Tern

<u>19 Bird Species Distribution – Wednesday 26th January (between High/Low tide)</u> <u>Notes:</u>

New Area

- Is empty of vast majority of Bar-tailed Godwit and South Island Pied Oystercatcher that are usually present at high tide.
- Grey teal are still flighty (taking off in flocks before resettling etc.)

Old Area

- Most of the birds present are roosting on the central island
- Still a large group of South Island Pied Oystercatcher roosting

Bird Species List:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- South Island Pied Oystercatcher
- Spur-winged Plover
- Caspian Tern
- Starling

20 Bird Species Distribution – Wednesday 26th January (between Low/High tide) Notes:

New Area

- Not as empty compared to between HT & LT earlier on in the day

- Juvenile Black-backed Gull now as large as parents, moves around wetland frequently (is no longer restricted to the island that its parents nested on).

Old Area

- Have noticed additional Black-backed Gulls have been frequenting wetlands, particularly in this area

Bird Species Distribution:

- Pied Stilt
- Grey Teal
- White faced Heron
- Bar-tailed Godwit
- Paradise Shelduck
- Black-backed Gull
- Spur-winged Plover
- South Island Pied Oystercatcher
- Starling
- Pukeko
- Red-billed Gull
- Black-billed Gull