Habitat mapping of Te Whanga Chatham Islands

A summary report of data collected in March 2009

by

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Background

Te Whanga is the body of water that occupies approximately 20% of the land mass of Chatham Island. It is 24 kilometres long and has an area of about 18,600 hectares. It has four compartments: a north basin that is separated from the remainder of Te Whanga by a shallow region that was used as a ford at one time; central and south basins that are separated by a shallow region; and a mouth region located on the coast between the central and south basins (Figure 1).

Figure 1 Map of Te Whanga, Chatham Island

Resource Management of Te Whanga

The Chatham Islands Council (CIC) is responsible for the management of Te Whanga with details for management provided in the Chatham Islands Resource Management Document (Chatham Islands Council, 2001). The following is an abridged version on Te Whanga management from this document.

Objective – Te Whanga

(i) The maintenance and enhancement of Te Whanga as a significant natural ecosystem and community resource in respect of:

- • food gathering and recreation
- • the functioning of ecosystems
- • Iwi values

Policies

(i) Te Whanga should be retained for community purposes such as food gathering and recreation unless it can be established that non community activities will not adversely effect community values.

(ii) Activities in or adjacent to Te Whanga should not adversely affect:

- iwi values
- community access
- water quality
- ecosystem values

Methods

(iii) Undertake studies on the functioning of the lagoon.

Anticipated Environmental Results

(iii) A better understanding of the functioning of the ecosystems of the lagoon.

In regard to studies on Te Whanga, there is existing information on its' hydrological regime, water depths and water quality (Goring, 2005; Hay *et al,* 1970; Meredith and Croucher, 2007). However, there is very little information on the lagoon ecosystem including habitats, ecosystem values and functioning of the ecosystem. Given that Te Whanga is a large and complex ecosystem it was determined that the starting point for a 'better understanding of the functioning of Te Whanga' would be a broad-scale approach. Hence, Environment Canterbury, which has the contract to carry out the Resource Management Act functions for CIC, began broad-scale habitat mapping of Te Whanga in March 2009.

Broad scale habitat mapping

The aim of broad-scale mapping of Te Whanga is to coarsely map shallow subtidal and shoreline habitats. This mapping is not designed to record detail. Broad-scale habitat mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: seagrass, macroalgae, rushland, etc) (Appendix I). These physical and biological habitats are integral to the structure and functioning of the ecosystem. This mapping, which follows the approach originally described for use in NZ estuaries by Robertson et al. (2002):

- provides baseline information on the spatial distribution of broad habitat groupings.
- helps provide a broad picture of the key productive components and ecological processes of the studied area.
- provides an overview of the habitats and their distribution as a framework for any subsequent detailed monitoring programmes and investigations.
- allows for the identification of ecological issues.
- allows similar habitats within different areas to be compared in general terms.

Method

The ideal method for broad-scale habitat mapping is to obtain aerial photos of the study area and then undertake on-site ground-truthing of the habitats shown on the aerial photos. Up to date aerial photos of Te Whanga were not available. However, there is satellite imagery of the Chatham Islands. While the imagery has been useful it does not provide the clear detail including delineation between vegetation types that aerial photos do. Thus broad-scale habitat mapping of Te Whanga was based on-site data collection.

The assessment of the habitats (see Appendix I for details) of the margin and shallow subtidal areas of the central basin (Figure 2) was carried out over 18-22 March 2009. In addition to habitat assessment the following data were collected:

- salinity at sites located in knee deep water
- presence of cockles at sites located in knee deep water
- presence and width of the band of rotting vegetation at the waters edge
- anything unusual or of note

Field observations were supported by photos and the collection of plant specimens for identification. Sites were accessed by boat and foot. Site details were recorded on specially prepared field sheets. These data were entered into excel files and then into GIS.

The broad-scale mapping of habitats in the other basins of Te Whanga will be undertaken over the next two years.

Results

Sediments of the central basin

Shorelines

The sediment of the shorelines is typically either sand, sand with shell or shellbed. The sand is typically firm, but there were areas where the sand was classified as soft. There were also areas of peat and rock.

There is a long stretch of sand and shell beach along the eastern margin of Te Whanga. This beach varied in total width as did the width of the bands of shell and bands of sand. The sand bands were either light or dark grey. The shell material was mostly cockle shell with occasional blue mussel shell. However, closer to the mouth there were also occasional pipi and tuatua shells. There were very occasional and small areas of peat exposed at the top of the shore.

Sand and shell beach,
northern end
eastern shoreline

Figure 2 Satellite image of the central basin (Projection: World Geodetic system 1984)

Shell bed, out from shore
southern end
eastern shoreline

Exposed peat
western shoreline

The sand and shell beaches of the western margin occurred in the embayments, with rocky headlands between embayments. The beaches varied in total width as did the width of the bands of shell and bands of sand. The sand bands were typically white/light grey but dark grey bands occurred on some beaches. The shell material was mostly cockle with occasional blue mussel. There were also small areas of rock beach and very occasional and small areas of peat exposed at the top of the shore. The rocky headlands typically consisted of lumps of rock interspersed on sand and shell.

Bed of cockle shell
western shoreline

Sand and shell beach
western shoreline

Sand and shell beach
western shoreline

Rock beach
western shoreline

Rocky headland between embayments
western shoreline

Shallow subtidal
Shallow subtidal sediments in knee deep water out from shore were assessed along with a few random sites in the shallow area at the northern end of the central basin (Figure 3). Observations were also made from the boat when travelling along the shore.

The sediment of the shallow subtidal was typically firm sand or firm mobile sand. There were rock reefs out from many of the embayment headlands of the western shore.

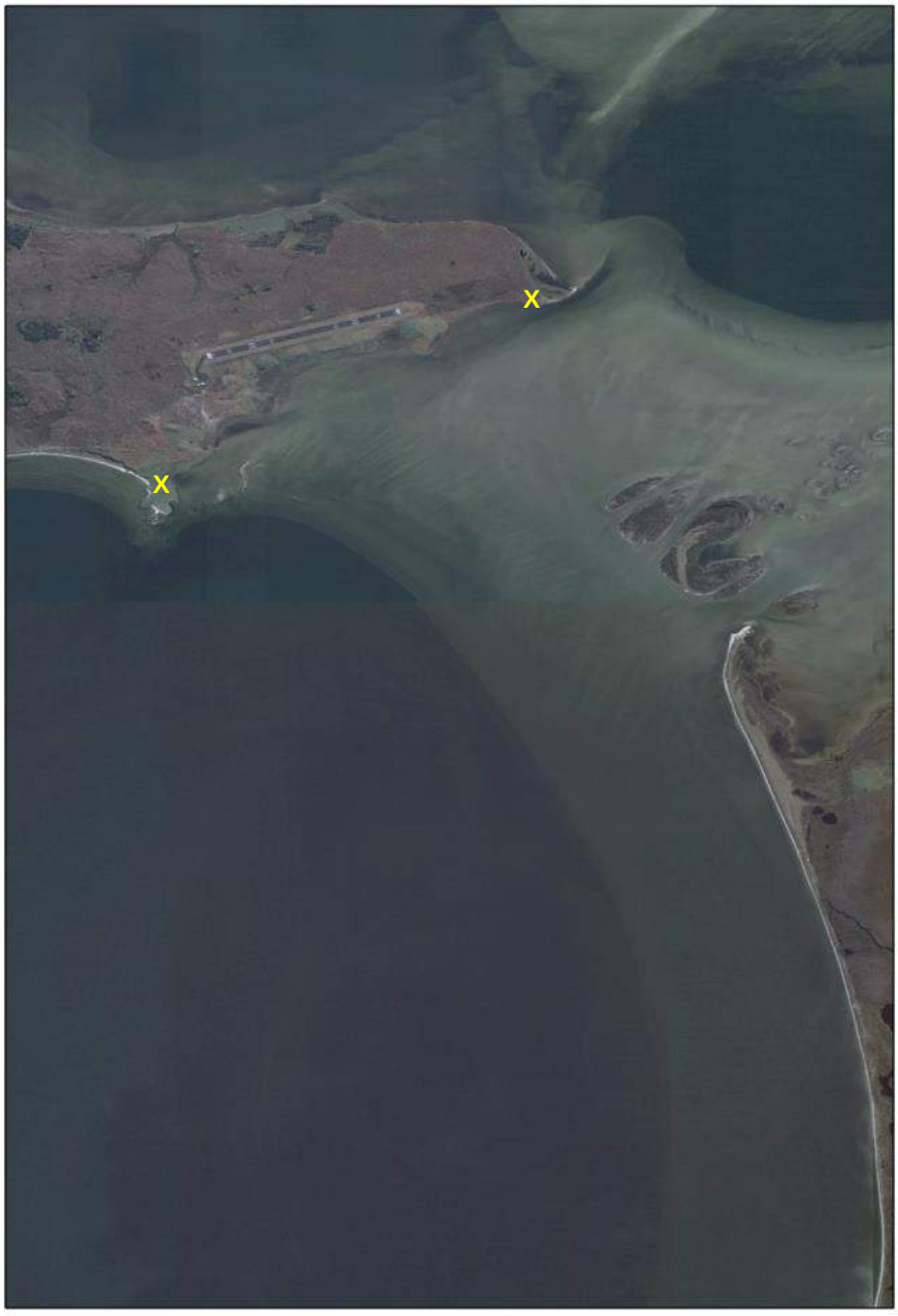
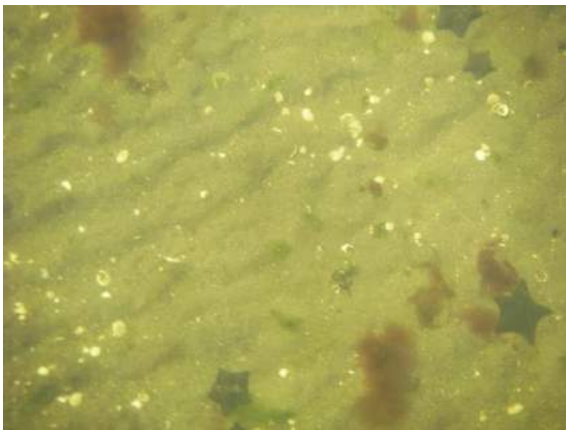


Figure 3 Satellite imagery of the northern half of the central basin. The extensive shallow area at the northern end of the basin is the lighter coloured area (Projection: World Geodetic system 1984)

Firm mobile sand
western shore

Firm mobile sand
Northern shallow subtidal area



Rocky reef
eastern shore

Vegetation types of the central basin

Shorelines

Herbfield
The herbfield species include sea primrose *Samolus repens,* remuremu *Selliera radicans,* buck's horn plantain *Plantago coronopus,* glasswort *Sarcocornia quinqueflora,* turf daisy *Leptinella dioica*, batchelors button *Cotula coronopifolia,* native celery *Apium prostratum*, orache *Atriplex prostrata,* glaucous goosefoot *Chenopodium glaucum.*

Sea primrose (bright green with white flower) and glasswort (red tinge)

glaucous goosefoot

native celery

batchelors button

Glasswort and sea primrose on sand with shell

The flats are sizeable flat areas typically populated by sea primrose with some glasswort. These flats occur on the eastern and western shore of the central basin. They occur on both sand and shell and flat rock.

Sea primrose dominated herbfield flat

Herbfield flat
eastern shoreline

Herbfield flat
western shoreline

Herbfield flat of sea primrose
with glasswort
western shoreline

The bands on sand and shell are populated by a variety of species including buck's horn plantain, native celery, orache, goosefoot, sea primrose and turf daisy. These bands occurred along both the eastern and western shorelines and on the shell banks out from shore. The percent cover of vegetation and width of the herbfield was highly variable.

Herbfield band along sand shell beach
western shoreline

Herbfield on sand shell beach
eastern shoreline

The shoreline south of the airport (between the yellow crosses in Figure 3) was populated by a mix of herbs including batchelors button, remuremu, sea primrose, bucks horn plantain, turf daisy with some goosefoot and orache. The sedge three-square occurred through the herbfield in this area.

Shoreline south of the airport

Sedgeland
The sedge three square *Schoenoplectus pungens* and knobby club rush *Ficinia nodulosa* were common around the central basin.

Along the western shore there were small patches of vegetation with three square the dominant plant. Three square was common within the herb bands and in the shoreline herb area south of the airport.

Three square patch and three square amongst native celery

Knobby club rush was abundant along the eastern shore. In the more northern part there were wide tracts of this plant landward of the marram grass while in the more southern part the club rush and marram were mixed together. In some areas of the eastern shore there was no marram with the knobby club rush extending to the edge of the sand shell beach. Occasional clumps of knobby club rush occurred all along the western shore.

Marram grass and knobby club rush
northern end
eastern shore

Mixed marram grass and knobby club rush
southern end
eastern shore

Knobby club rush and sand daphne towards southern end
eastern shore

Marram grass

Marram grass *Ammophilia arenaria* occurred along the western and eastern shore of the central basin. Along the western shore the vegetation behind the sand shell beaches was typically marram grass. The distribution of marram along the eastern shore is included in the description of the distribution of knobby club rush. Near the lagoon mouth the vegetation behind the sand shell beach was only marram grass.

Marram grass behind a sand shell beach
western shore

Rushland

A number of *Juncus* species occur on the shore of the central basin. These have yet to be identified. The Chatham Island bamboo rush *Sporadanthus traversii* was present in the southern part of the western shore. This bamboo rush covered an extensive area landward of the knobby club rush band and was eastward of the southern most adjacent waterbody.

Chatham Island bamboo rush

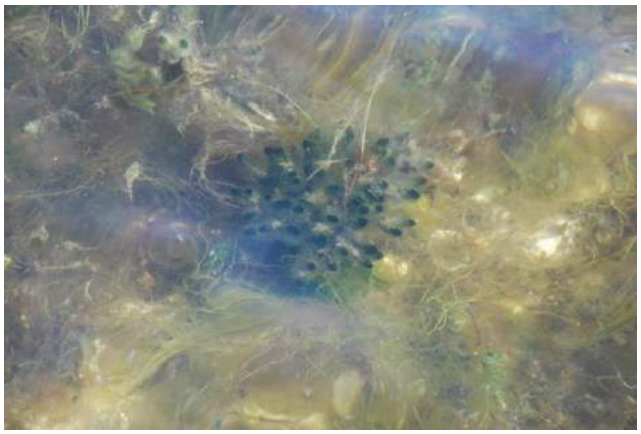
Area of Chatham Island bamboo rush

Only patch of a tall rush *Juncus pallidus*?

Shallow subtidal vegetation
There was a large bed of *Ruppia megacarpa* in the northern shallow subtidal area. There were also patches of this plant in shallow water areas of the central basin.

Fine red and green algae were living on the *Ruppia megacarpa* and also occurred at low density in the shallow water areas of the central basin (see photo of firm mobile sand northern shallow subtidal area). Green algae were abundant on the shallow subtidal rock substrate off the embayment headlands along the western shore. Of particular note was the large green algae *Codium* sp. There were localised small patches of lime green algae along the western shore. The algae species present in Te Whanga were not identified.

Codium sp.
western shore



Codium sp. and green filamentous algae
western shore

Lime green algae
western shore

Washed up vegetation

One of the notable features was the accumulation of rotting vegetation in the water at the waters edge. This rotting vegetation was present along both the eastern and western shorelines of the central basin. This vegetation was typically *Ruppia megacarpa.* However, there were small amounts of red and green algae including *Entermorpha* sp., *Codium* sp.and *Ulva* sp. Where present the width of the band of vegetation was estimated. The greatest recorded width was 20 metres on the eastern and 15 m on the western shoreline (Figure This rotting vegetation was typically anoxic and gave out a sulfur smell when disturbed.

Band of rotting vegetation
northern end
eastern shoreline

Rotting vegetation and dead swan
western shoreline

Rotting vegetation
western shoreline

Rotting vegetation interspersed with herbfield flats, southern end
eastern shoreline

In areas with extensive herbfield flats, for example, the south eastern embayment near the mouth, there was rotting vegetation along the shoreline and in the pockets of water within the herbfield.

On the western shore there were patches of rotting algae. In addition there were localised small patches of recently dislodged floating green scum (a seasonal blue-green algae?). Along the southern end of the eastern shore there was a band of recently dislodged green algae at the waters edge.

Rotting algae
western shoreline

Floating green scum
western shoreline

Recently dislodged green algae
and *Ruppia*
outhern end
eastern shoreline

The occurrence and the width of the band of rotting vegetation at the waters edge of the central basin are shown in Figure 4.

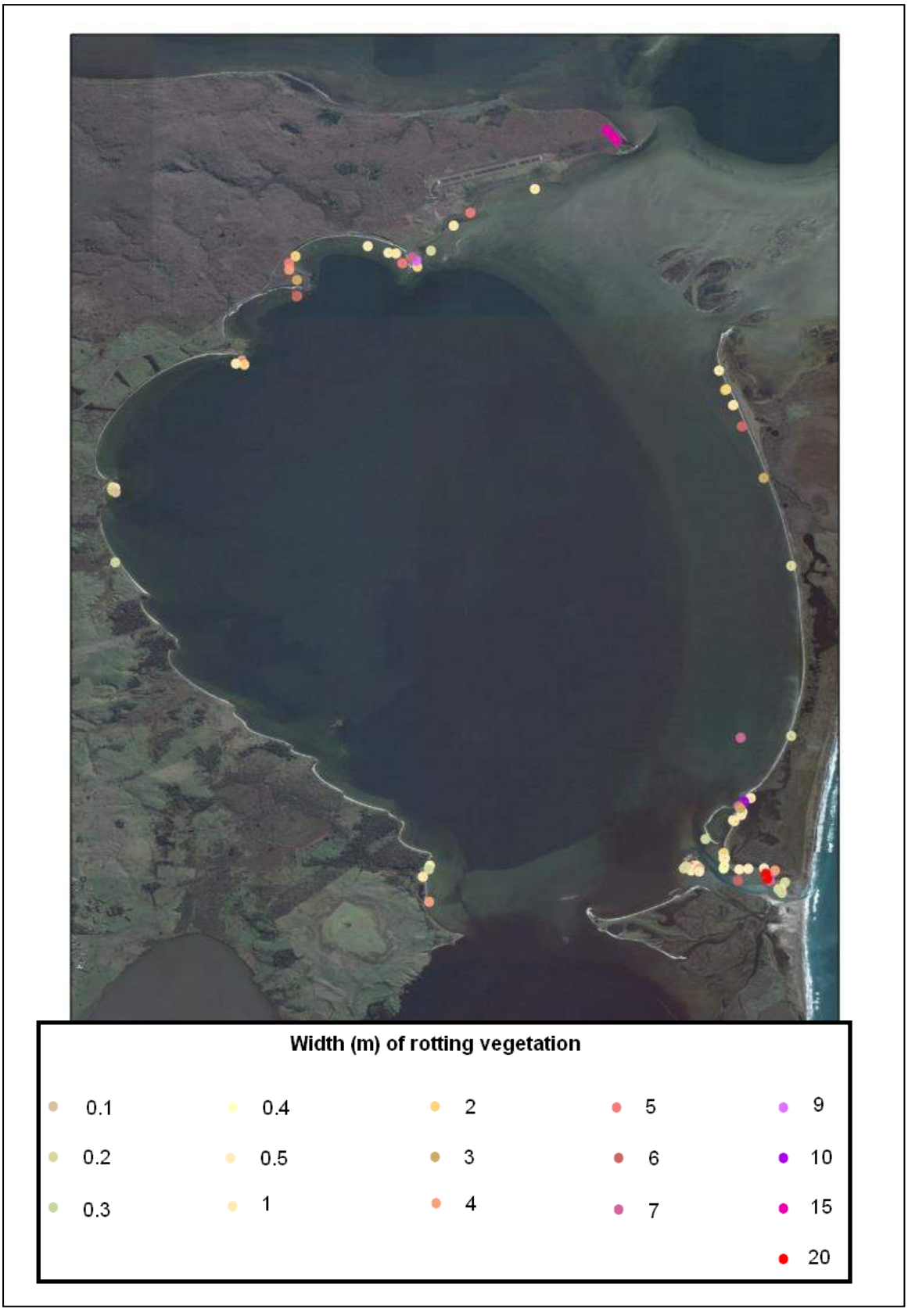


Figure 4 Mapping of the occurrence and band width of rotting vegetation at the waters Edge (Projection: World Geodetic system 1984)

Adjacent landuse

Eastern shore

There are numerous interconnecting waterbodies and expanses of rushes between the eastern margin of the central basin and the coastal dunes. There are occasional patches of grassland between the rushes.

Vegetation between the eastern margin and the coastal dunes

Western shore

On the western side of the central basin the land above the cliffs and behind the treed embayments is typically pasture land. Not all embayments have trees but many have camping areas that have been set up and are used by the land owner. East from where Airbase road skirts close to Te Whanga the land cover is typically scrub and in particular bracken. This vegetation appears as a pink colour in Figure 3. The proximity of the bracken to the shore can be seen is one of the photos above. East of the airport a fenceline is the demarcation between bracken and herbfield.

Trees to the waters edge western shore

Scrub covered cliff with farmed land and trees above the cliff western shore

Farmed land to the waters edge
western shore

A camping area
western shore

Fenceline demarcation
between bracken and herbfield
east of airport

The habitat at 512 sites in the central basin was evaluated. The habitat types at these locations are shown in Figure 5 with a closer view of the western shore and near the mouth habitats in Figure 6. There is a discrepancy between the satellite imagery and the on-the-ground GPS points. Hopefully this discrepancy can be fixed by GIS experts.

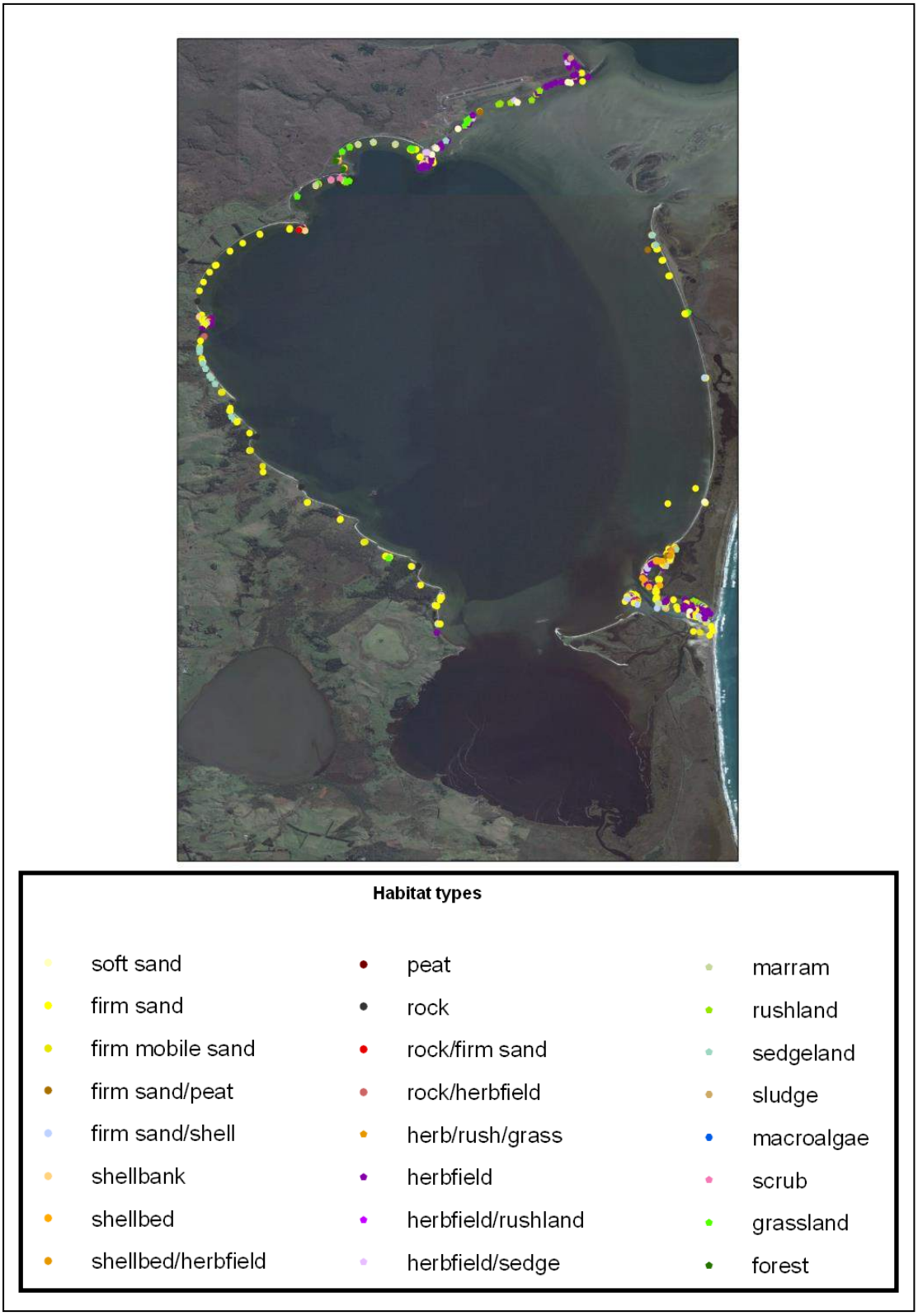


Figure 5 Mapping of the habitats of the central basin (Projection: World Geodetic system 1984)

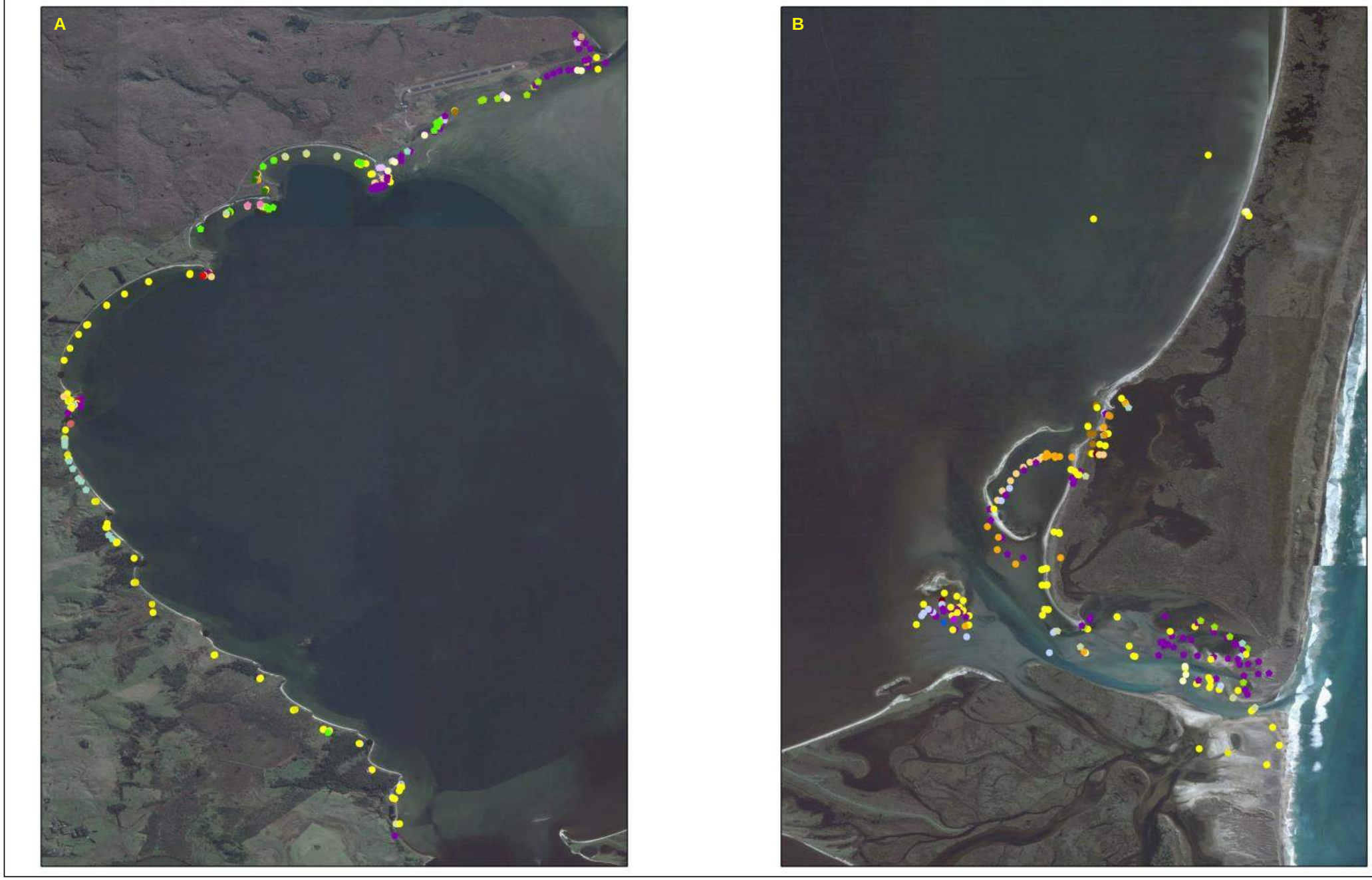


Figure 6 Mapping of the habitats of the central basin A – western shore B – southern eastern shore/Te Whanga mouth (Projection: World Geodetic system 1984)

Water quality of the central and south basins

Nutrient concentrations
A water sample was collected from each of six sites in the central basin (22A-C and 23A-C). The concentration of ammonia nitrogen (NH_3N), nitrate-nitrite nitrogen (NNN), total nitrogen (TN), dissolved reactive phosphorus (DRP) and total phosphorus (TP) was measured in each sample. The concentrations recorded are compared to those routinely collected from the western shore of the central basin at Waitamaki Creek, Airbase Road (Figures 7-11 below).

NH_3N concentrations at sites within the central basin are similar to those from the waters edge. NNN, TN, DRP and TP concentrations at sites within the central basin are at the lower end of those from the waters edge. These results suggest that general land runoff and waterways are a source of nutrients to the central basin.

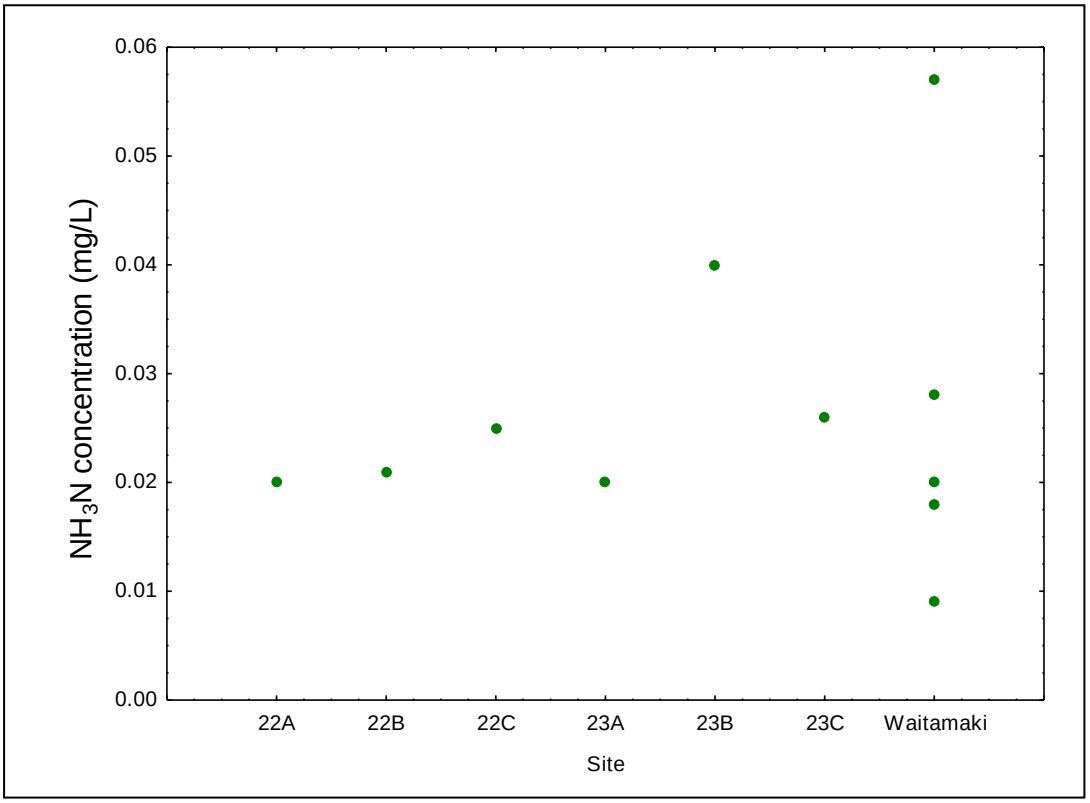


Figure 7 Ammonia nitrogen concentrations (mg/L) at central basin sites

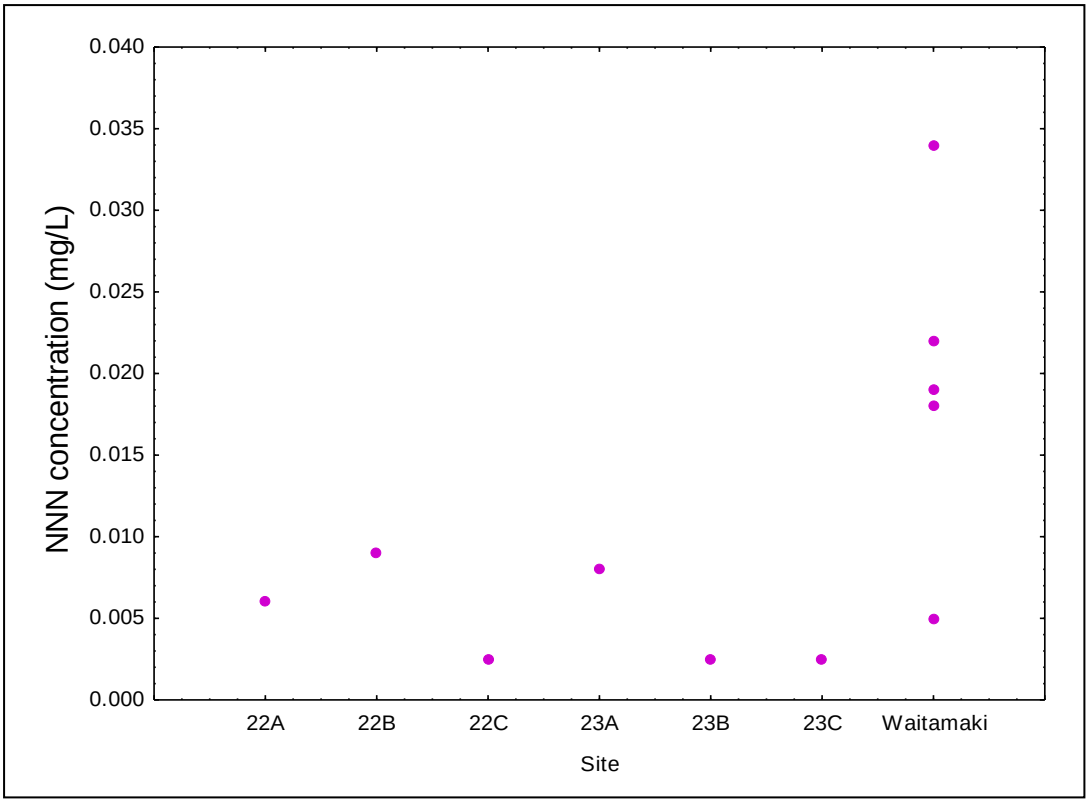


Figure 8 Nitrate-nitrite nitrogen concentrations (mg/L) at central basin sites

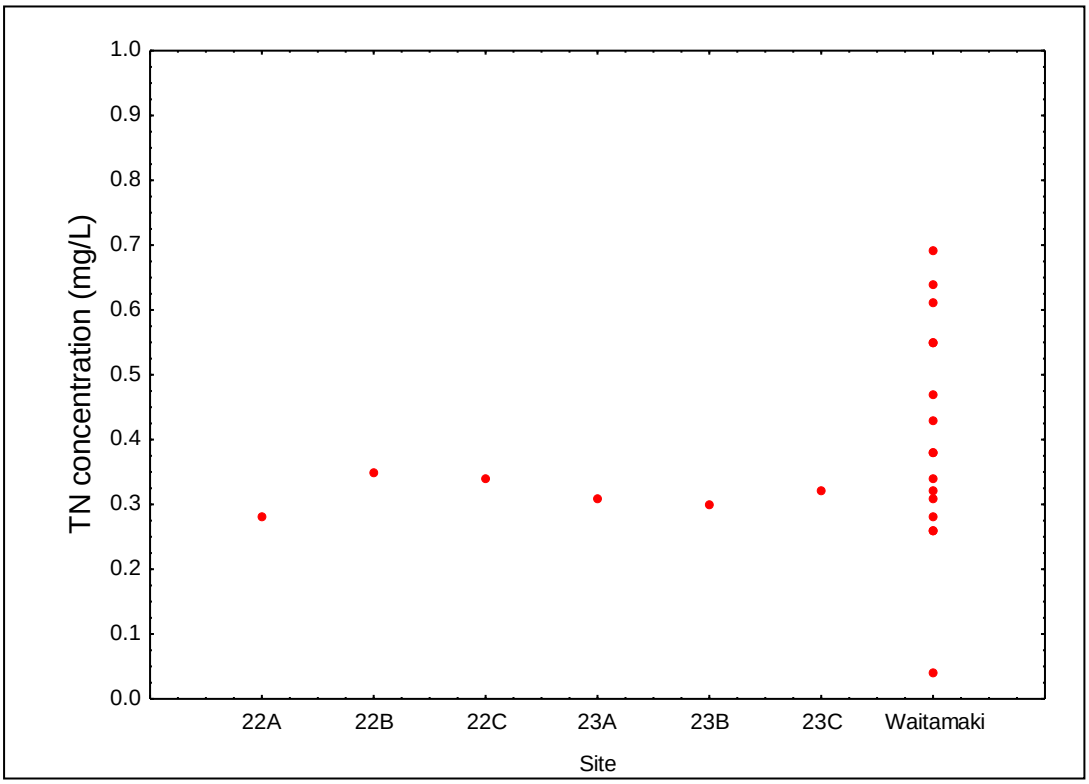


Figure 9 Total nitrogen concentrations (mg/L) at central basin sites

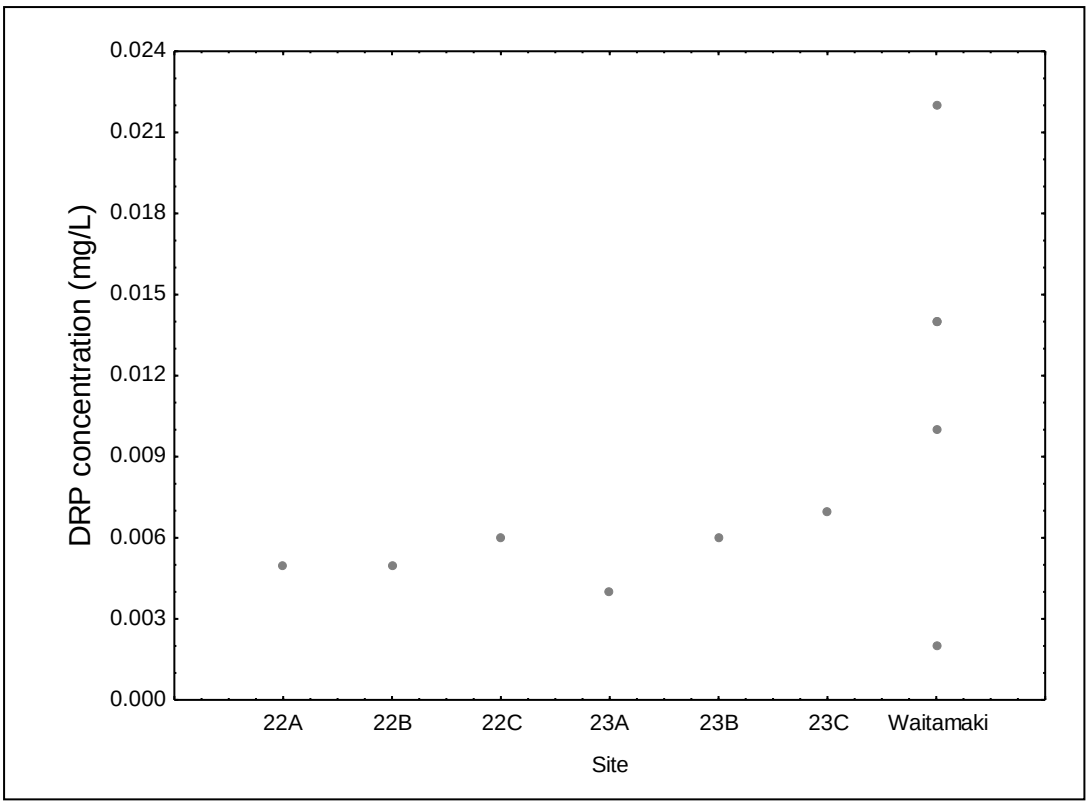


Figure 10 Dissolved reactive phosphorus concentrations (mg/L) at central basin sites

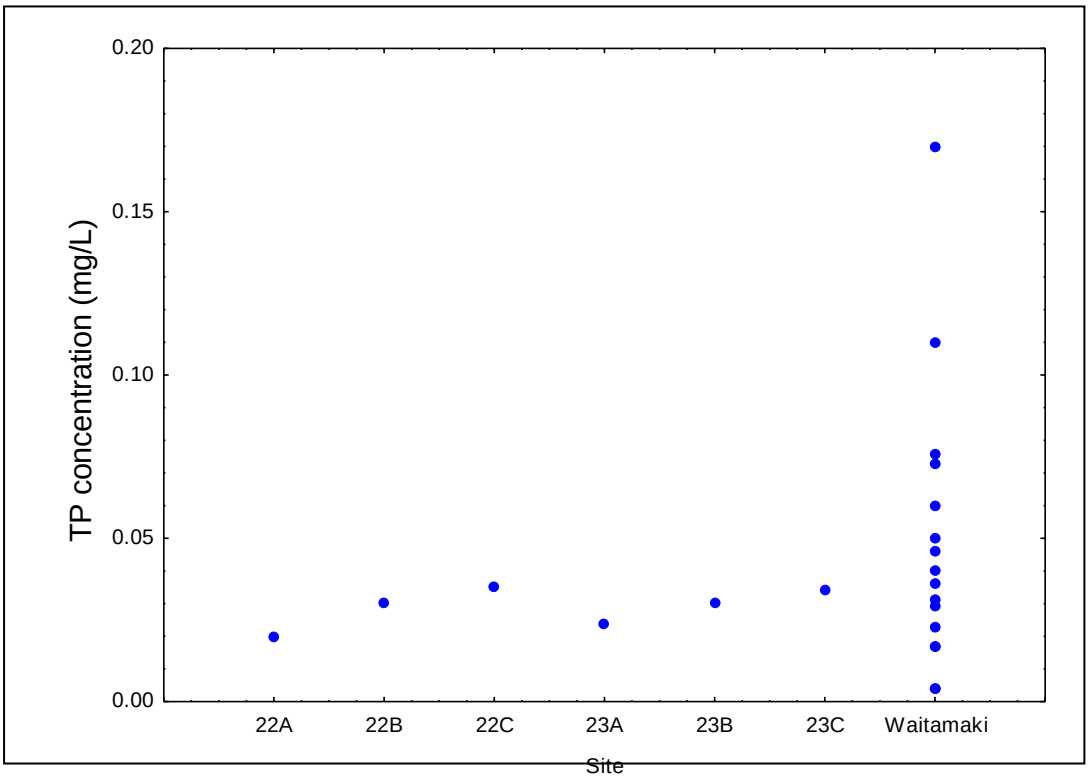


Figure 11 Total phosphorus concentrations (mg/L) at central basin sites

Salinity

Salinity was measured at many sites around the shore of the central basin. In addition salinity was measured at sites in the northern shallow subtidal area, sites in the middle of the central basin and at sites in the south basin. The salinity at a water depth of 20-30 cm was typically measured. However, where there was a distinct layering in the water column the salinity of both the surface and bottom water was measured. The salinity results for the central basin are shown in Figure 12. The data were grouped by site location, i.e. western shore, eastern shore and from the northern end and centre of the basin. In addition salinity data collected quarterly since 2005 from the western shore of the central basin at Waitamaki Creek, Airbase Road were plotted.

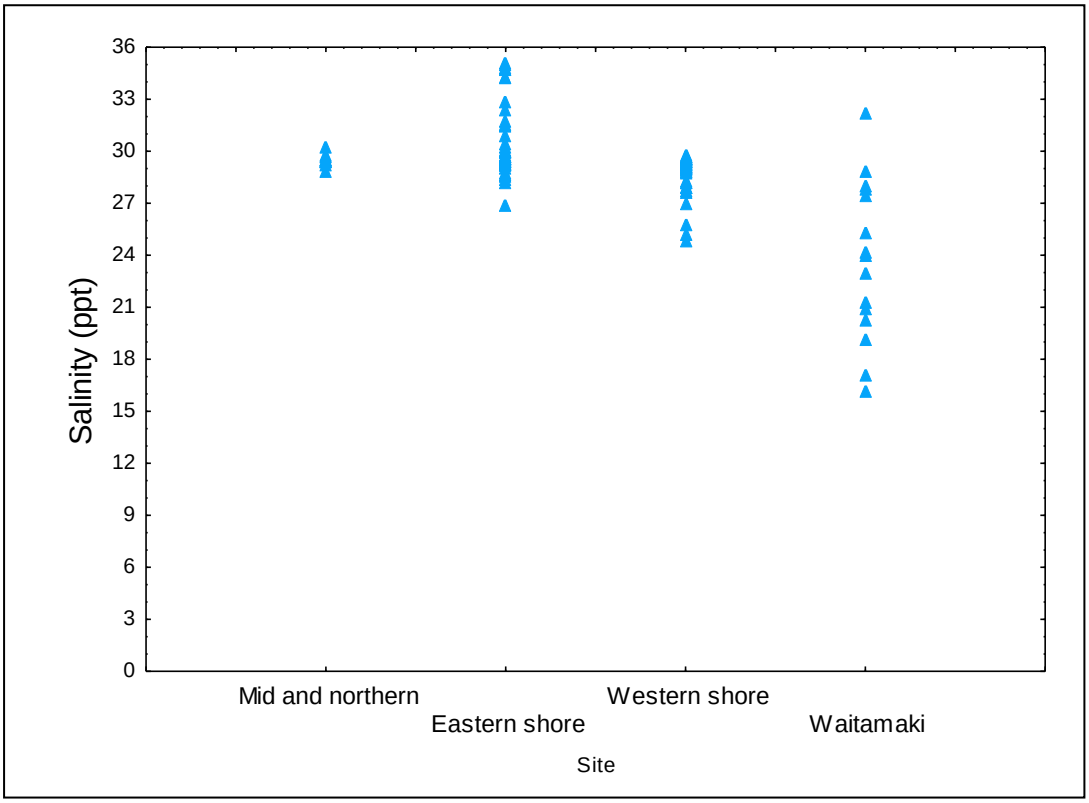


Figure 12 Salinity (ppt) in the central basin

The salinity of the central basin was around 28.5-30 ppt, with 72% of recorded values in this range (Figure 13). On the eastern shore the salinity increased as sites got closer to the mouth with the highest salinity recorded being 34.8 ppt. The salinity recorded over time at Waitamaki is variable and indicates the influence of freshwater flows into the basin on salinity.

At some sites between the central and south basin and in the south basin there was a difference in salinity between surface water and bottom water. Thus salinity was measured at both water depths (Figure 14). The results show that there was fresher water layer over a more saline layer. However, the fresher water layer did not have a salinity close to zero, that is it is still a mix of fresh and sea water.

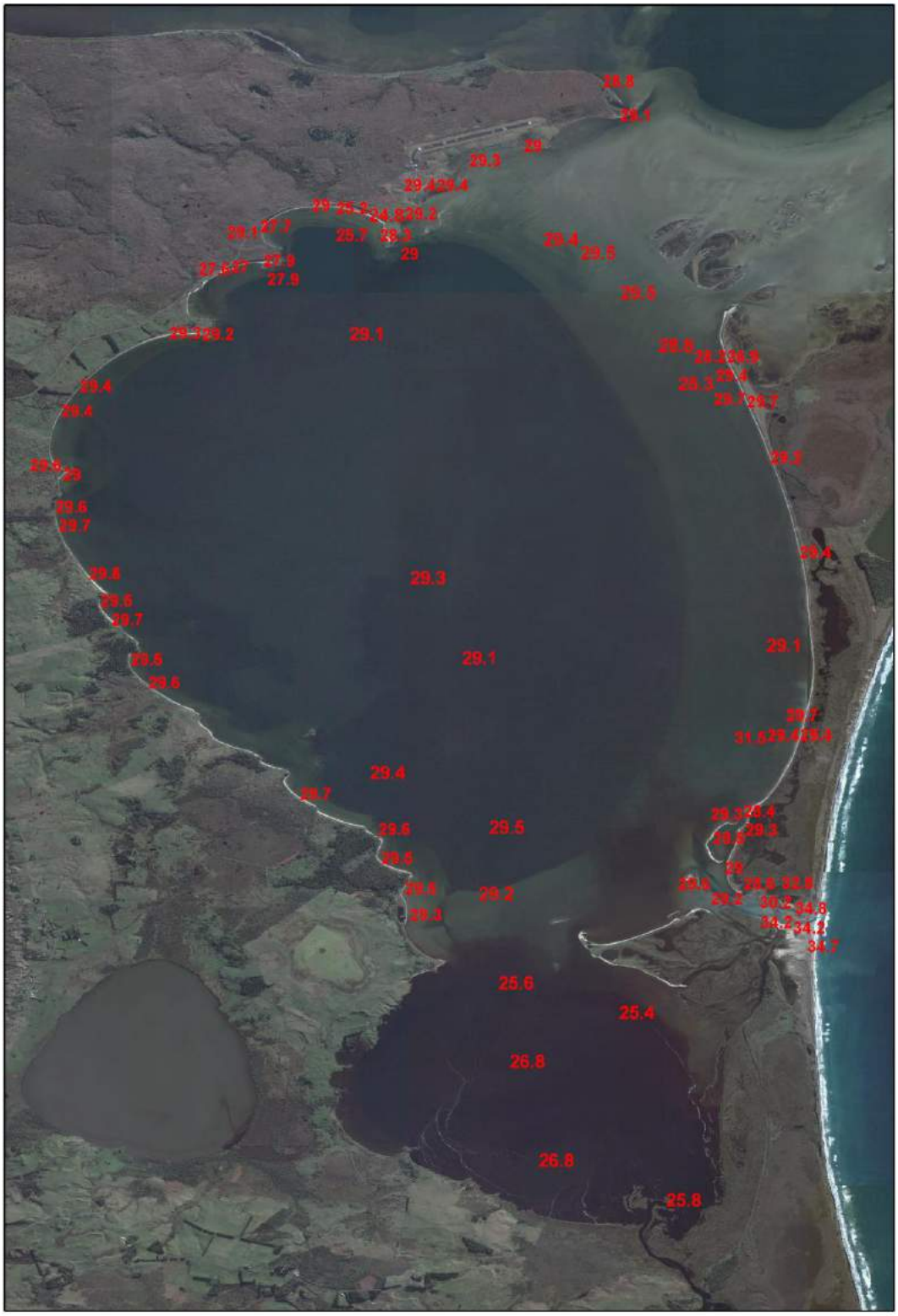


Figure 13 Salinity (ppt) at 20-30 cm below the surface (Projection: World Geodetic system 1984)

Figure Salinity (ppt) in surface water and bottom water at some sites

Marine macrobiota
The following marine/estuarine species were noted as being present and abundant in the central basin.

Blue mussels - *Mytilus galloprovincialis?*
Cockles - *Austrovenus stuchburyi*
Molluscs – *Cominella glandiformis*
Cushion starfish – *Pateriella regularis*
Marine Worms – including lugworms (family Arenicolidae)
Isopods
Triplefins (small fish)

A note on Te Whanga bathmetry
The boat that was used for the work had an onboard marine GIS map of the Chatham Islands including Te Whanga. The GIS map was very accurate for the shallow areas of the central and south basin.

Preliminary evaluation of the ecology of Te Whanga

A marine or freshwater system
Based on the biological and water quality observations and data collected in March 2009 Te Whanga has the characteristics of an estuarine/marine system. That is:

- Estuarine animals such as cockles, cushion starfish, blue mussels, marine algae, marine worms, isopods and triplefins
- Salt marsh plants around the margins
- Water with a salinity below that of seawater but not as low as that of freshwater

The central basin
The central basin has:

- a diversity of aquatic and margin habitats
- a diversity of aquatic and margin plants
- an abundance of cockles
- an abundance of cushion starfish
- scenic landscapes
- beautiful sand and shell beaches
- extensive areas of rotting vegetation at the waters edge

The rotting vegetation
The rotting vegetation is a significant detractor to the aesthetic and recreational value of the central basin. Within the rotting vegetation zone dissolved oxygen concentration is reduced (a reading of 0% saturation was recorded within the rotting weed). That is, the rotting weed affects the plant and animal life in the area where it accumulates through oxygen depletion of the water and smothering of the seabed.

The presence of rotting weed at any site is influenced by both proximity to the areas where the plants grow and the direction of the prevailing wind. The amount of live weed dislodged would be influenced by wind speeds. That is, the presence and amount of rotting weed is a consequence of the frequent high winds and general windy conditions of Chatham Island.

Aquatic plants need a supply of dissolved inorganic nitrogen and phosphorus and light penetration into the water to grow. The water around the margins of the central basin away from the influence of the large freshwater inflows, which are characterised by tanin stained water, allow for light penetration for plant growth. That is, there is a considerable area of the central basin where light penetration to the seabed would occur (Figure 1). Water quality results indicate that Te Whanga is moderately to highly nutrient enriched and is predominantly

nitrogen limited (Meredith and Croucher, 2007). Dissolved inorganic nitrogen concentrations in Te Whanga are low (Meredith and Croucher, 2007). Hence there will be more plant growth than already occurs if in the quantity of nitrogen into Te Whanga increases. Land runoff, stream inflows and groundwater seepage are sources of nitrogen. Another source of nutrients is faecal matter from the numerous black swans that inhabit Te Whanga.

Water level

The water level in Te Whanga can vary over time because the Hikurangi Channel can become naturally closed off from the sea. When the channel is closed water cannot leave Te Whanga and the water level rises over time. The Hikurangi Channel is manually opened from time to time and can remain open for years. At the time of sampling the Hikurangi Channel was open.

A rise in water level in the central basin will reduce the width of the sand shell beaches and inundate the marginal vegetation. Of the marginal vegetation types it is the herbfields that will be most impacted by water inundation. Salt marsh herb species are not tolerant to long periods of immersion in water.

Recommendations for future mapping and research

Mapping and water quality

1. Habitat mapping of the south and north basins and around the mouth
2. Identification of the salt marsh plant species of Te Whanga
3. Detailed mapping of the *Ruppia megacarpa* beds
4. Collection of algae for identification by experts at NIWA
5. Collect more water quality data from sites close to and away from the margin
6. Collect more salinity data at different water depths

Research

It is recommended that a detailed investigation be undertaken on the cockles of Te Whanga. Cockles are a very important resource of Te Whanga. Not only are they a valued food the shells are an important structural component of the margins. The ideal for such research would be as a Masters or Ph.D. thesis through Islay Marsden (an expert on cockles) at the University of Canterbury.

This research could involve:

1. Determination of the distribution and abundance of cockles in Te Whanga
2. Evaluation of the size and age distribution of the cockles
3. Settlement and growth rates in different areas if Te Whanga
4. Survival in different areas of Te Whanga
5. Food availability and uptake in different areas of Te Whanga

I would recommend that a student of Chatham Island origin or with affiliations to the island undertake this work. It would require access to a boat and the ideal would be for the student to be based on Chatham Island for much of the period of the study. However this would require the student to have a working space and access to equipment such as a drying oven and microscope.

Acknowledgements

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Appendix I
Broad-scale mapping Classification definitions

Lichenfield
Vegetation in which the cover of lichens in the canopy is 20-100% and in which the lichen cover exceeds that of any other growth form or bare ground.

Scrub
Woody vegetation in which the cover of shrubs and trees in the canopy is > 80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants < 10 cm diameter at breast height (dbh).

Tussockland
Vegetation in which the cover of tussocks in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussocks include all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and > 10 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium,* and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia.*

Forest
Woody vegetation in which the cover of trees and shrubs in the canopy is > 80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥ 10 cm dbh. Tree ferns ≥ 10cm dbh are treated as trees.

Sedgeland
Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia*, and *Scirpus*.

Rushland
Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.

Reedland
Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata*, and *Baumea articulata*.

Cushionfield
Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield
Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground.Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Seagrass meadow
Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive
underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

Macroalgal bed
Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions:

Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

Stonefield/gravelfield
Land in which the area of unconsolidated gravel (2-20 mm diameter) and/or bare stones (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. The appropriate name is given depending on whether stones or gravel form the greater area of ground surface. Stonefields and gravelfields are named from the leading plant species when plant cover of ≥ 1%.

Boulderfield
Land in which the area of unconsolidated bare boulders (> 200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover is ≥ 1%.

Rockland
Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover is ≥1%

Mobile sand
The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.

Firm sand
Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.

Soft sand
Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.

Firm mud/sand
A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.

Soft mud/sand
A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.

Very soft mud/sand
A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 cm.

Cockle bed
Area that is dominated by both live and dead cockle shells.

Musselreef
Area that is dominated by one or more mussel species.

Oysterreef
Area that is dominated by one or more oyster species.

Sabellid field
Area that is dominated by extensive raised beds of sabellid polychaete tubes.

Shell bank
Area that is dominated by dead shells.

Artificial structures
Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.