Water quality in Waikoko Wetland, Mana Island

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Abstract

Conductivity, pH and salinity were determined in the ponds of Waikoko Wetland and in Waikoko Stream, Mana Island, in July 1999. Water samples were also collected from selected ponds and analysed for nitrate, ammonium, phosphate, calcium, magnesium, potassium and sodium. This study shows that the water chemistry in Waikoko Wetland is controlled by both natural and anthropogenic factors, namely catchment runoff and disturbance, bird droppings, use of fertiliser and seepage of oxidation pond effluent. No evidence for tidal influence could be found in any of the ponds during the July sampling. Increased conductivity (pond 1) and high levels of cations (ponds 1 and 11), ammonium (ponds 3 and 11), phosphate (pond 3), nitrate (ponds 2, 3 and 4), have been identified and their effects on the establishment of threatened plants in Waikoko Wetland require further study.

1. Advice sought

1. What is the concentration of nitrate, ammonium, phosphate, Ca, Mg, K and Na in water samples collected from ponds 1, 2, 3, 4, 8, 9 and 11 in Waikoko Wetland, Mana Island?

2. What are pH, conductivity and salinity in each of the above ponds and in ponds 5, 6 and 7?

3. How significant might these water quality parameters be when considering threatened plant establishment?

2. Introduction

Waikoko Wetland, Mana Island, is a restored wetland that has been created on the site of a wetland that existed before Mana Island was developed as a farm in 1832. Although there is no record of the vegetation before farming, pollen samples indicate that sedges dominated the wetland. A network of drains and close grazing by sheep and cattle over the following 150 years obliterated most traces of the original wetland. The last farm stock was removed in 1986.

Mana Island was gazetted as a scientific reserve in 1987, and has been managed for conservation purposes since then. Major steps in the restoration of the island have included removal of farm stock, eradication of mice and the ongoing tree planting programme, and restoration of the wetland.

Wetland restoration aims to recreate appropriated habitats by controlling the hydrology and planting wetland plants and trees, to allow for the reintroduction of rare and threatened bird species. Over 20 threatened wetland plant species have been identified for planting in Waikoko Wetland. The purpose of this study was to assess the water quality in selected ponds in the wetland and evaluate its significance for the establishment of threatened plants (see Fig. 1 for schematic diagram of Waikoko Wetland).

3. Methods

3.1 SAMPLING

Water samples were collected into acid-washed polyethylene bottles from ponds 1, 2, 3, 4, 6, 7, 8, 9 and 11 in Waikoko Wetland, Mana Island, on 7 July 1999 (Fig. 1). Conductivity, salinity, total dissolved solids (TDS), pH and temperature were recorded at the time of sampling and in ponds 5, 5a, 5b, as well as in Waikoko Stream, both near the inlet (site WSI) and near the outlet (site WSO). In ponds 2, 8 and 11, these parameters were recorded both near the inlet (sites 21, 81, 111) and the outlet (sites 20, 80, 110) (Fig. 1).

3.2 ANALYTICAL

Samples were filtered using a 0.45 pm acetate membrane filter within a few hours of collection, and frozen. Samples from ponds 1, 2, 3, 4, 8 (sites 81 and 80), 9 and 11 were analysed for nitrate, ammonium, dissolved reactive phosphorus (phosphate) using an Autoanalyser and for potassium, magnesium, calcium and sodium by atomic absorption spectroscopy (AAS).

4. Results

4.1 pH

pH showed some variations between ponds, ranging from 6.2 (near inlet in pond 8, site 81) to 7.00 (pond 5a) (Table 1; Fig. 2). In the Waikoko Stream outlet by the beach (WSO), pH was 7.7, while it was close to 8.5 in seawater (Table 1). The pH values indicate that the water is near-neutral in the ponds, and is characteristic of nutrient-rich wetlands.

4.2 TEMPERATURE

Temperature ranged from 8.6°C (pond 5) to 11.1°C (pond 1 I , site 110) in the ponds, while it was 12.7°C in seawater (Table 1 ; Fig-3).

4.3 CONDUCTIVITY, TOTAL DISSOLVED SOLIDS (TDS) AND SALINITY

These three parameters are reported together, as they are strongly interrelated. The conductivity is an indicator of the ionic strength of the solution, which is in turn dependent on the concentration of total dissolved solids (mainly salts), that determine the salinity. Conductivity (in µS/cm) = total dissolved solids (TDS) (in mg/L) x 2. Here the salinity will be mainly given in terms of conductivity, as it gives a more accurate measure of the ionic strength.

The conductivity ranged from 280 µS/cm (0.2 ‰ salinity) (in pond 2, sites 21 and 20) to 1100 µS/cm (0.6 ‰ salinity) (in pond 1) (Table 1: Fig. 4). Field observations showed high levels of suspended fine matter in pond 1, as indicated by high turbidity, and high conductivity. Settling of suspended fine matter occurs downstream, as shown by a decrease in the conductivity in pond 5 (629 µS/cm) which is immediately downstream from pond 1 (see Fig. 1). The conductivity was similar in ponds 5a and 5b, with 639 µS/cm and 648 µS/cm, respectively (Fig. 1 and 4). Pond 5 also drains into pond 7, which is a large pond, where settling of fine particulate matter occurs, as indicated by a conductivity of 387 µS/cm. The conductivity was measured at two sites in pond 11, site 11 I, close to the inlet (692 µS/cm) and near the outlet of the pond at site 110 (656 µS/cm). The conductivity shows little variation between ponds 2, 3, 4, 6 and 8 (8I and 8()) (Table 1; Fig. 4).

4.4 NITRATE

Nitrate (NO_3^- - N) concentrations were below detection limit (0.02 g/m3) in pond l, and ranged from 0.05 g/m^3 in pond 9 to 0.93 g/m^3 in pond 3 (Table 1; Fig. 5). Nitrate concentrations of 0.22 g/m^3 and 0.25 g/m^3 were recorded in ponds 2 (site 20) and 3, respectively. In pond 11, nitrate concentration reached 0.06 g/m^3.

4.5 AMMONIUM

Ammonium (NH_4^+ -N) concentrations were below detection limit (0.02 g/m^3) near the outlet in pond 8 (site 80), and ranged from 0.05 g/m^3 in ponds 1,4 and site 81 (pond 8) to 0.44 g/m^3 in pond 11 and 0.45 g/m^3 in pond 3 (Table 1; Fig. 6).

4.6 DISSOLVED REACTIVE PHOSPHORUS

Dissolved reactive phosphorus (DRP) was below detection limit (0.02 g/m^3) in pond 1, and ranged from 0.03 g/m^3 (outlet pond 2) to 0.25 g/m^3 in pond 3 (Table l; Fig. 7).

4.7 CATIONS: CALCIUM, MAGNESIUM, SODIUM, POTASSIUM

Cation concentrations exhibited a similar distribution in the water samples measured. They were low in ponds 2 (site 20, 3, 4, 8 (sites 81 and 80) and 9, and high in ponds 1 and 11. Ca, Mg, Na and K concentrations ranged from 6.7 to 24.1 g/m^3, 8.6 to 25.6 g/m^3, 82.7 to 199.3 g/m^3, and 3.6 to 7.8 g/m^3, respectively (Table 1; Fig. 8, 9, 10, 11).

5. Discussion

Eight ponds of Waikoko Wetland were sampled and the water was analysed for nutrients and cations. Of these eight ponds, three had unusual chemical signatures: water in pond 3 had high nitrate, ammonium and phosphate concentrations, water in pond 11 (site 110) had high ammonium, relatively high phosphate, and high cation concentrations, whereas water in pond 1 had high conductivity and high cation levels.

The high nutrient levels in pond 3 can probably be attributed to a combination of bird droppings and fertiliser. Field observations have shown that a large number of shags live around the pond, and thus they are likely to contribute high levels of nitrogen and phosphorus. Furthermore, fertiliser use in the past (DOC, pers. comm. 1999) might have resulted in relatively high concentrations of nitrate in ponds 2 and 3 (Fig. 1). Nitrate concentration in pond 4 (0.25 g/ms) can be attributed to the mixing of the combined discharge from ponds 2 and 3. The decrease in concentration downstream from pond 4, at sites 81 and 80, suggests dilution and/or denitrification.

Ammonium concentrations are low in all other ponds, except pond 11 (site 110), which is located downstream of the oxidation pond. This therefore suggests that ammonium can be attributed to seepage of sewage from the oxidation pond. Previous studies (e.g. Rosen & Chague-Goff, 1997; Chague-Goff et al. 1999x, 19991)) have shown that discharge of oxidation pond effluent results in increased levels of ammonium in both surface and groundwater, whereas nitrate levels remained low. DRP spatial distribution also suggests seepage of oxidation pond effluent into pond 11. Further study is required to assess whether seepage of sewage effluent might have an adverse effect on the establishment of plants in this particular pond. Chague-Goff et al. (1999x) have shown that discharge of diluted oxidation pond effluent into a natural wetland has resulted in increased weed invasion, and a similar impact could be expected here.

The highest conductivity was measured in pond 1, which was characterised by high turbidity due to high suspended fine material. The observed decrease in turbidity downstream resulting from settling of the fine material, in ponds 5 and 7 in particular, is reflected in a decrease in conductivity. Pond 7 is a large pond, and the quiescent conditions probably allow for settling of particulates. At the time of sampling, surface water was flowing from pond 5 to ponds 5a and 5b, and the relatively high flow might not allow for settling of fine particulates, as indicated by similar conductivity levels in the three ponds.

Both pond 1 and pond 11 are characterised by a high conductivity and high cation concentrations. However, while the relatively high phosphate and ammonium concentrations in pond 11 probably reflect seepage of effluent from the oxidation pond, they remain low in pond 1, suggesting a different source for the cations. In pond 1, it is probably attributed to catchment runoff and possible catchment disturbance, as indicated by the high turbidity. Further study is required to assess the cause of catchment disturbance and whether it is a short-term event. It is also not known whether the high turbidity and high cation concentrations might have an adverse effect on the establishment of threatened plants.

The different chemical signatures in ponds 1 and 2 might also reflect differences in soil composition and landuse in the different catchments. Ca/Mg and Na/Ca ratios are fairly similar in ponds 1 and 2 (Table 1). However the Na/K ratio is significantly higher in pond 1, possibly reflecting variations in soil composition in this catchment (Weta Valley). However, further study is required to assess the influence of soil composition in the different catchments on Mana Island on water quality in Waikoko Wetland.

At the time of sampling (July 1999), no tidal influence could be detected in any of the ponds sampled. Seawater influence was only found near the sea outlet of Waikoko Stream, as shown by a higher pH.

6. Summary and Conclusions

This pilot study shows that water quality in Waikoko Wetland, Mana Island, varies between ponds and is controlled by natural and anthropogenic factors, namely catchment runoff, bird droppings, fertiliser and seepage from a sewage oxidation pond.

High turbidity, conductivity and cation concentration in pond 1 is probably attributed to catchment runoff (and possibly catchment disturbance) in Weta Valley. Whether the high levels of dissolved and suspended solids in pond 1 are the result of a short-term disturbance or are a long-term feature is not known and would require further study. The use of fertilisers (in the past) upstream of Astons Valley and Kaikomako Valley is the likely source of nitrate in pond 2, whereas both the use of fertilisers (in the past) upstream of House Valley and a high bird population in pond 3 have resulted in high nitrate, ammonium and phosphate levels.

Seepage of oxidation pond effluent is the probable source of ammonium, phosphate and high cations in pond 11, whereas no tidal influence could be detected in any of the ponds sampled at closest proximity to the sea during this sampling phase.

The identified increases in some of the measured water quality parameters (conductivity, nitrate, ammonium, phosphate, cations) in particular ponds might be significant when considering the establishment of threatened plants in Waikoko Wetland, and the assessment of their impact will require further study.

7. Recommendations

1. Undertake quarterly sampling and measurements of pH, temperature, and conductivity/salinity, nutrients and cations, in order to assess any seasonal changes. Previous studies (e.g. Boatman et al. 1975; Proctor 1994) have shown that water quality exhibits strong seasonal variations, depending on a number of parameters, such as temperature, rainfall and evaporation.

2. Assess the tidal influence on water quality in the ponds, in particular the ponds situated closest to the sea.

3. Assess the influence of effluent discharge from the oxidation ponds on water quality in pond 11, and its impact on the establishment of wetland plants.

4. Assess the influence of fertiliser (past) and bird population (present) on the water quality in the ponds and establishment of threatened plants.

5. Undertake a literature search to assess the nutrient and cation requirements for the establishment of wetland plants (in particular threatened plants).

8. References

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Table 1: pH, temperature M, conductivity (CD), total dissolved solids (TDS), salinity (Sal)
Nitrate, ammonium, phosphate (DRP), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) concentrations
and Ca/Mg, Na/K, Ca/K and Na/Ca In Walkoko Wetland, Mane Island (July 1999 sampling)

site	pH	T (°C)	CD (NS/cm)	TDS (mg/L)	Sal N)	N03-.N (g/m3)	NH4-N (g/m3)	DRP (g/m3)	Ca (g/m3)	Mg (g/m3)	Na (g/m3)	K (g/m3)	Ca/Mg	Na/K	Ca/K	Na/Ca
pond 21	6.70	9.7	284	155	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 20	6.73	10.4	280	153	0.2	0.22	0.08	0.03	6.7	8.6	82.7	3.6	0.8	23.0	1.9	12.3
pond 3	6.27	9.9	351	190	0.2	0.93	0.45	0.25	11.1	12.7	88.0	4.7	0.9	18.7	2.4	7.9
pond 4	6.58	10.0	348	190	0.2	0.25	0.05	0.08	9.6	12.8	106.4	4.7	0.8	22.6	2.0	11.1
pond 6	6.48	10.9	353	191	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 81	6.18	10.9	368	200	0.2	0.12	0.05	0.07	11.2	13.4	110.5	4.3	0.8	25.7	2.6	9.9
pond 80	6.50	10.2	358	194	0.2	0.08	<0.02	0.09	11.0	13.0	108.2	4.3	0.8	25.2	2.6	9.8
pond 1	6.94	8.9	1100	612	0.6	<0.02	0.05	<0.02	17.4	24.4	190.6	5.8	0.7	32.9	3.0	11.0
pond 5	6.72	8.6	629	346	0.3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 5a	6.70	10.4	639	352	0.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 5b	7.00	10.4	648	354	0.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 7	6.50	9.5	387	211	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 9	6.69	9.9	375	204	0.2	0.05	0.07	0.09	11.4	13.7	111.5	5.0	0.8	22.3	2.3	9.8
pond 111	6.79	11.0	692	379	0.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
pond 110	6.77	11.1	656	359	0.4	0.06	0.44	0.15	24.1	25.6	199.3	7.8	0.9	25.6	3.1	8.3
WSI	6.70	10.5	449	245	0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
WSO	7.70	10.4	460	250	0.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
seawater	8.46	12.7	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

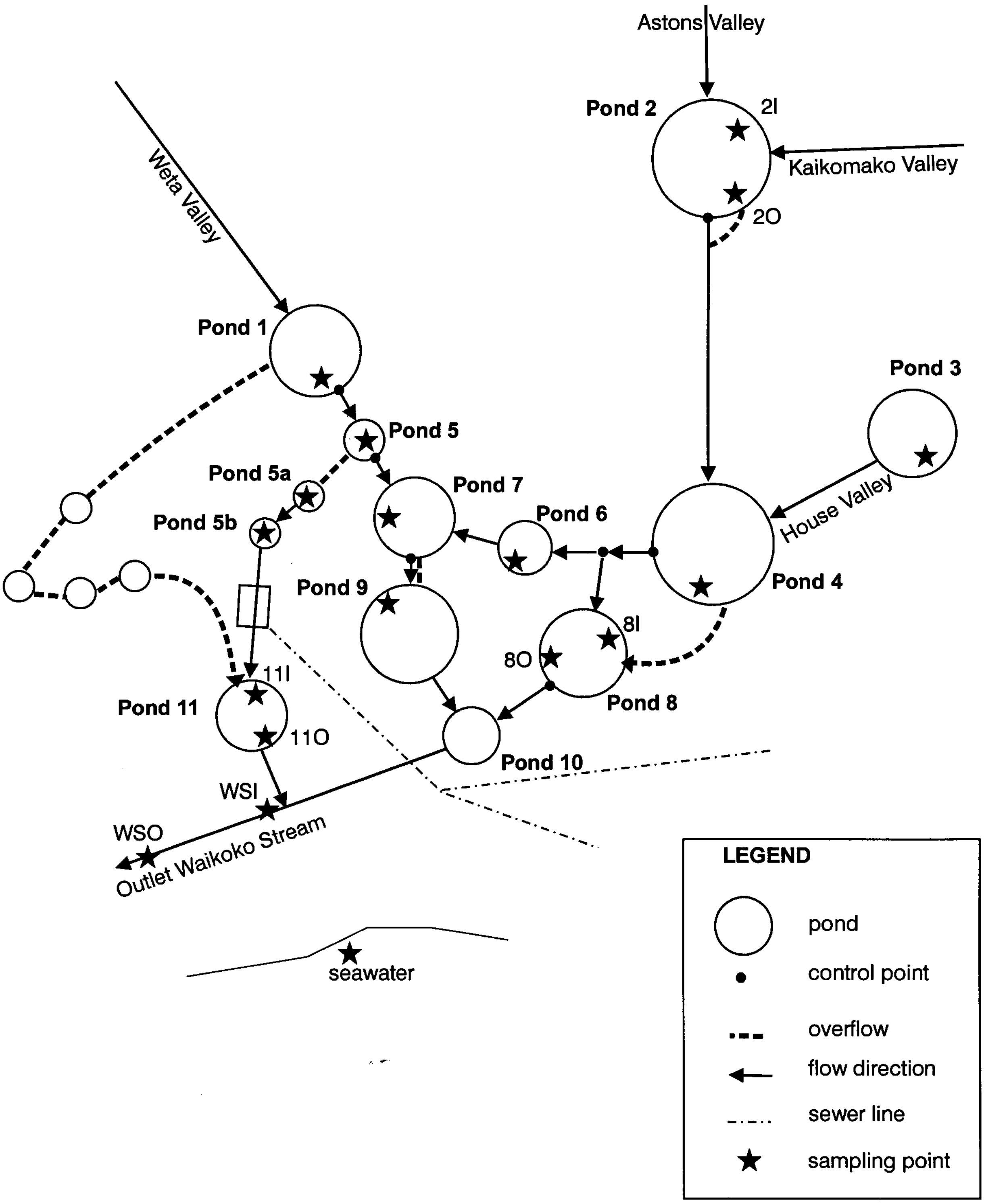

Figure 1. Waikoko Wetland, diagrammatic plan: water flow, storage-control, sampling sites.

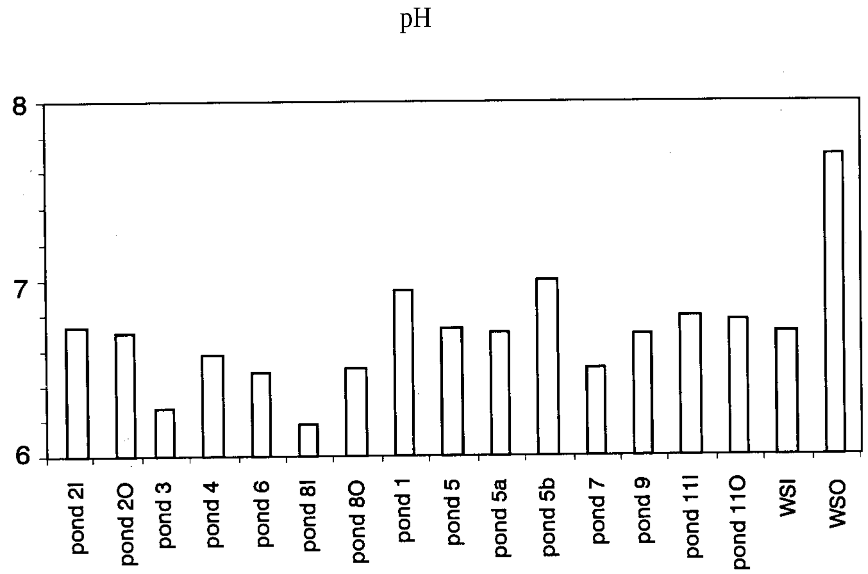

Figure 2. pH in ponds of Waikoko Wetland and in Waikoko Stream, Mana Island. See Figure I for sampling locations.

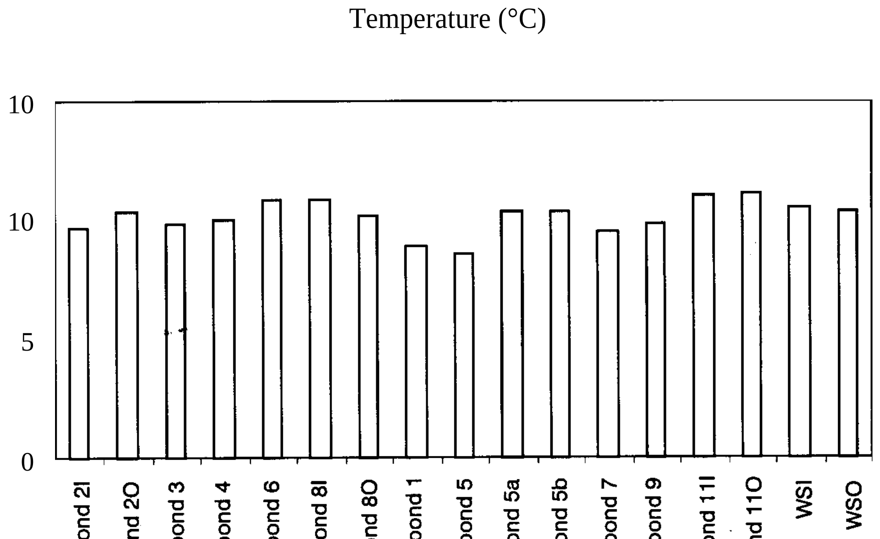

Figure 3. Temperature in ponds of Waikoko Wetland and in Waikoko Stream, Mana Island. See Figure 1 for sampling locations.

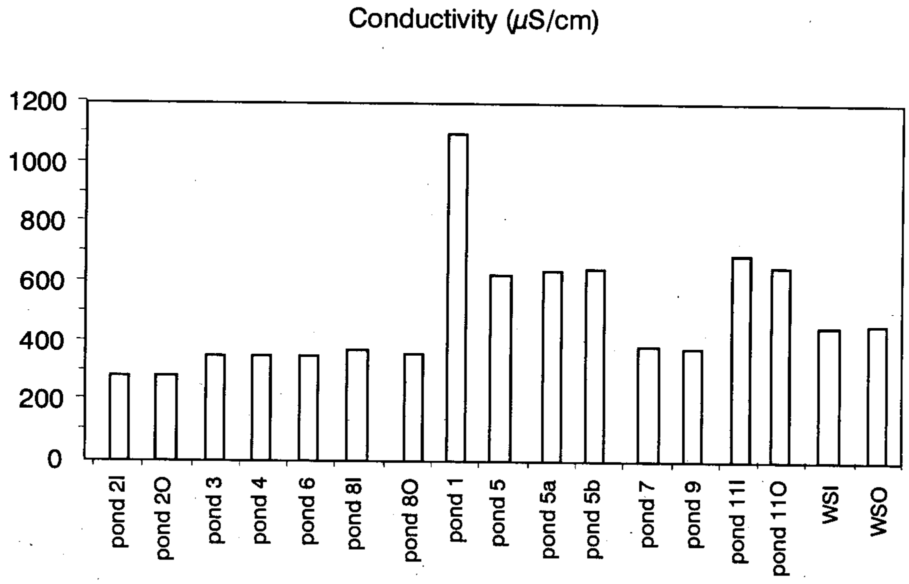

Figure 4. Conductivity (µS/cm) in ponds of Waikoko Wetland and in Waikoko Stream, Mana Island. See Figure 1 for sampling locations.

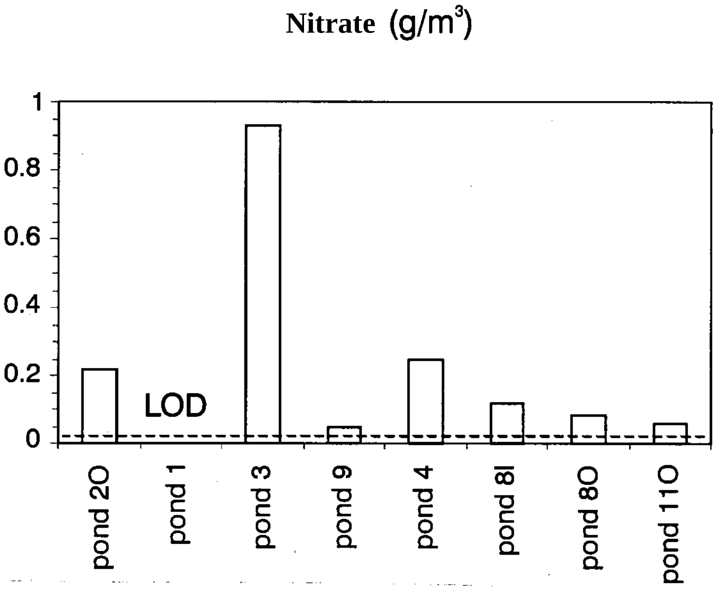

Figure 5. Nitrate (g/m^3) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations. LOD = limit of detection (0.02 g/m^3).

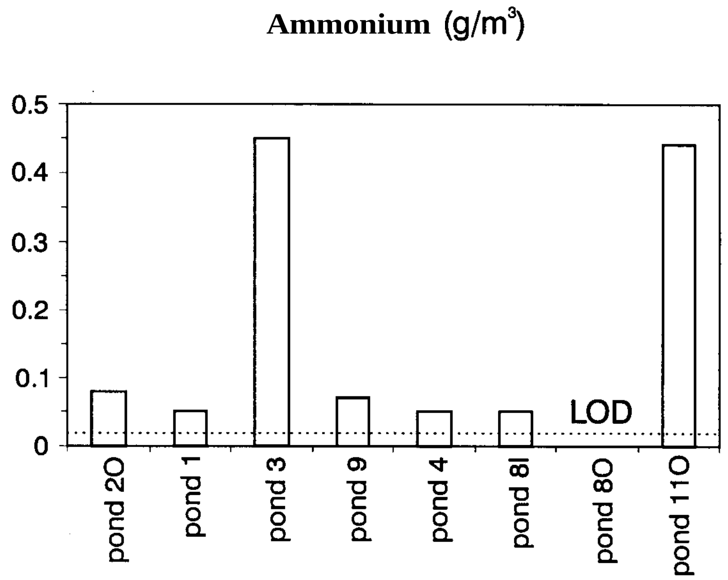

Figure 6. Ammonium (g/m^3) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations. LOD = limit of detection (0.02 g/m^3).

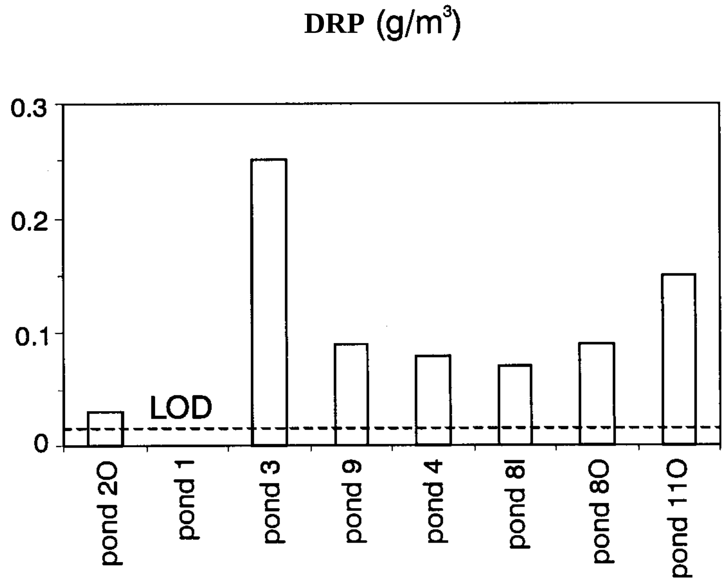

Figure 7. Dissolved reactive phosphorus (DRP) (g/m^3) at sampling locations 20, 1, 3, 9, 4, 8I, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations. LOD = limit of detection (0.02 g/m^3).

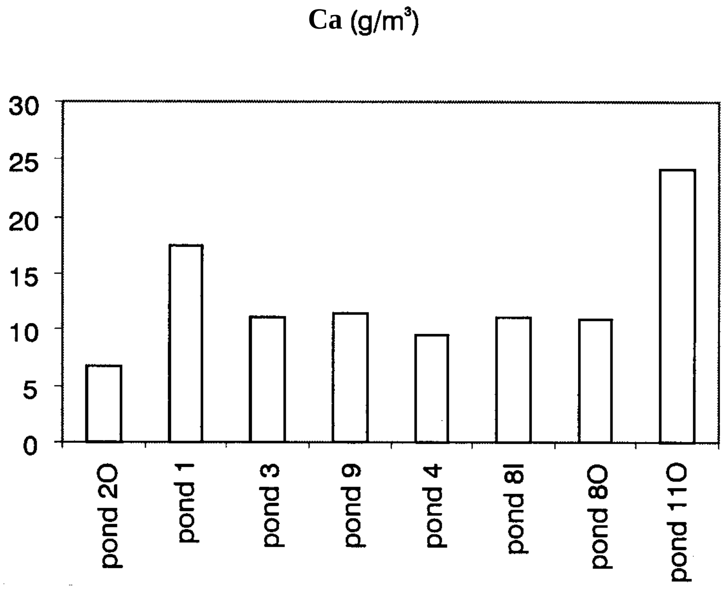

Figure 8. Calcium (Ca) concentrations (g/m^3) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations.

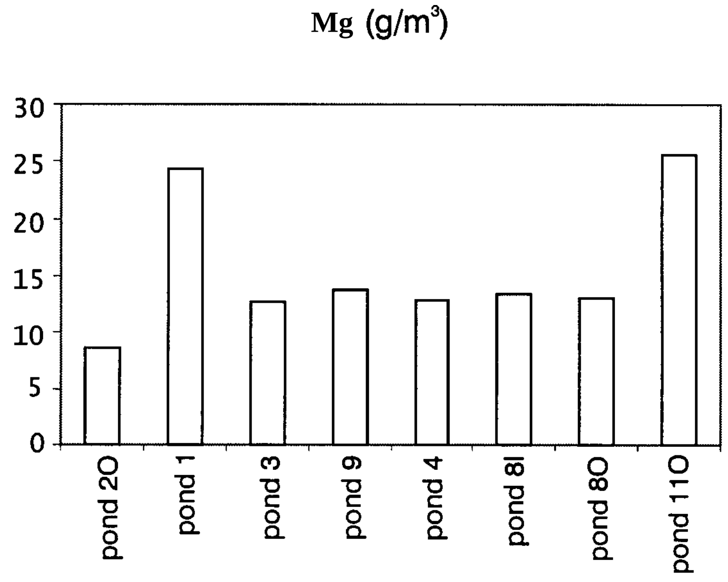

Figure 9. Magnesium (Mg) concentrations (g/m^3) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations.

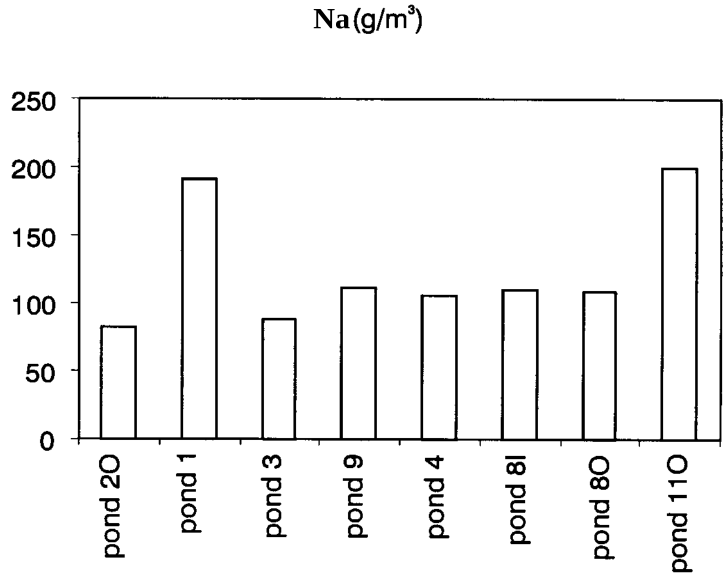

Figure 10. Sodium (Na) concentrations (g/m³) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations.

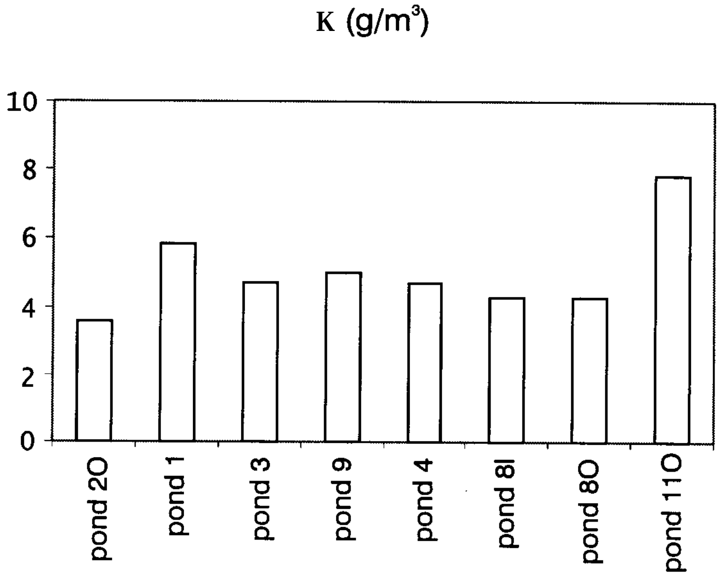

Figure 11. Potassium (K) concentrations (g/m³) at sampling locations 20, 1, 3, 9, 4, 81, 80 and 110 in Waikoko Wetland, Mana Island. See Figure 1 for sampling locations.