WAIKITE WETLAND RESTORATION PROJECT: INITIAL RESULTS

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ABSTRACT

The Waikite Wetland occupies approximately nine hectares close to the centre of the Waikite Geothermal Area. Several geothermal springs discharge into the wetland in the southeast corner providing a source of hot water into the wetland and an opportunity for a geothermal ecosystem to develop.

The wetland area was developed in the 1930's, and has undergone changes that include land clearing, grazing and altering the path of waterways. The Department of Conservation (DoC) embarked on restoring the Waikite Wetland in 2009 which included a land exchange with farmers, fencing, restoring water courses, plantings and weeding.

This study presents the initial results of chemical, physical, microbiological and invertebrate monitoring at the wetland in response to the change in management of the wetland area.

INTRODUCTION

Rehabilitation of sensitive geothermal ecosystems that have been adversely impacted by development is an emerging area of research. Some forms of development (e.g. land that has been cleared for farming) may be amenable to remediation measures that attempt to restore at least some of the pre-development ecosystem over short to medium time frames (years to decades).

The Waikite Geothermal Field is located in the Waikite Valley, approximately 20 km south of Rotorua, New Zealand (Figure 1). The geothermal field is characterised by up to 47 identified surface features including hot springs, hot lakes, fumaroles, sinter deposits and streams, which range in temperature from 7.7°C to 98.4°C (Glover et al., 1992). The wetland is in the geothermal area and has thermal springs discharging into the southwest corner. This corner currently hosts a range of thermotolerant vegetation and thermophilic micro-organisms.

The wetland area has undergone major hydrological changes in the last 80 years due to development of the land for grazing. Land clearing, grassing, draining the wetland and diverting the Otamakokore Stream (Figure 1) around the wetland are some of the works carried out since the 1930's to increase the sheep grazing area.

Since 2009, the Department of Conservation (DoC) has embarked on restoring the wetland area. Actions to date include legal protection, invasive plant management, fencing, restorative plantings and restoring the Otamakokore Stream back through the wetland (June, 2009).

This study presents the initial results of physical, chemical and biological surveys in response to restoring the Waikite Wetland. Geothermal inputs into the wetland are also estimated. This study was developed to compliment the work been done by DoC.

METHODS

Ground Temperature survey

Ground temperature sites were selected to be in an approximate grid pattern inside and outside of the wetland. Hydrological conditions restricted site access in some parts of the wetland. A GPS location was taken at each site. Temperatures were measured at 1 m depths (where possible) at each site with a Yokogawa TX10 meter connected to type K thermocouple on 18/09/2009.

Physical measurements

Grab samples of water were collected from five sites (Figure 1) in August, September, November, and December 2009 and in, January, February, April, June and October 2010. Samples were collected following the procedures outlined by Rosen et al. (1999). Water samples were analysed at the Wairakei Analytical Facility. Only chloride (Cl) data will be presented in this paper. Chemistry data from Glover et al., (1992), Mahon (1965) and Waikato Regional Council (2010) was used to supplement the data collected. The electrical conductivity was measured at each site with a Hach HQ40D conductivity meter. The water temperature was measured using a K type thermocouple connected to either a Bontron or Yokogawa meter.

Flow gaugings at sites along the Otamakokore Stream used an OSS-PC1 current meter with measurements made every 10 cm across the stream (measurements were every 20 cm on 25/8/2010). Data were processed using gLog™ software. Flow gaugings at site WE1001 were taken from a small weir constructed with sandbags with a PVC pipe at the base of the dam. The amount of time taken to fill a 15 l bucket with the water flowing through the PVC pipe was recorded five times. An average of the five flow gaugings is reported.

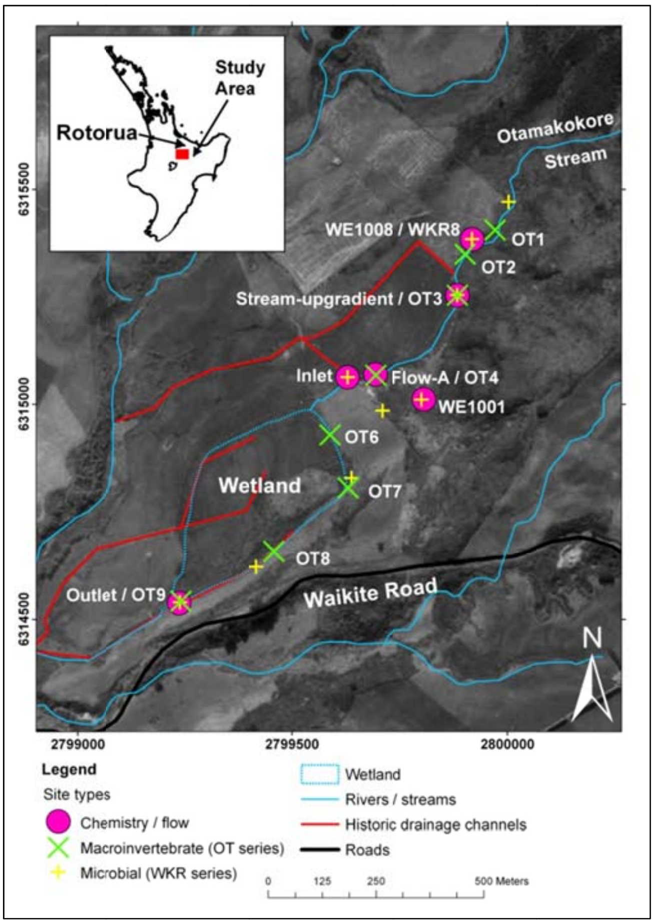

Figure 1. Waikite wetlands study area.

Table 1 PCR primers used for T-RFLP analyses

Primer	Specificity/Target	Sequence 5' to 3'	Reference
9F	*Bacteria*	GAGTTTGATCMTGGCTCAG	Lane et al. 1991
1492R	*Bacteria*	ACGGYTACCTTGTTACGACTT	Lane et al. 1991
109F	*Archaea*	ACKGCTCAGTAACACGT	Grosskopf et al. 1998
915R	*Archaea*	GTGCTCCCCCGCCAATTCCT	Grosskopf et al. 1998
106F	Cyanobacteria	CGGACGGGTGAGTAACGCGTGA	Nübel et al. 1997
781R(A)	Cyanobacteria	GACTACTGGGGTATCTAATCCCATT	Nübel et al. 1997

Microbiological

Water and/or soil samples were collected from nine sites (Figure 1) monthly between September 2009 and January 2010, and then in March, April and September 2010. Samples were collected in sterile falcon tubes (soil) or ethanol treated PPE water containers (water). Soil samples were centrifuged to remove excess water. Water samples were centrifuged to remove macro soil and sediment and then subsequently filtered through a 45µm membrane filter. Total environmental DNA was extracted from the processed soil and water samples using FastDNA Spin Kit for Soil (MP Bio). Samples were analysed using Terminal-Restriction Fragment Length Polymorphism (T-RFLP) (Liu et al., 1997; Marsh, 1999; Kitts, 2001) using selected primers (Table 1) for *Bacteria*, *Archaea* and Cyanobacteria.

Macroinvertebrates

Nine sites (Figure 1) were sampled for macroinvertebrates using the methodology and sampling sites of Duggan et al. (2007) using kick sampling along a 30 m reach for three minutes. Macroinvertebrates were identified to the lowest taxonomic level practical, generally using the keys of Winterbourn (1973) and Winterbourn et al. (2000). Data is compared to data collected from the same sites in 1999 (Duggan et al., 2007).

RESULTS AND DISCUSSION

Ground Temperature survey

Ground temperature measurements at 1 m depth range from 11.7°C to 80°C. Elevated temperatures (>20°C) occur along the southern boundary of the wetland and an area east of the wetland (Figure 2). Ambient (<20°C) temperatures occur for all other measurements. The highest measurement of 80°C occurs in the southeast corner of the

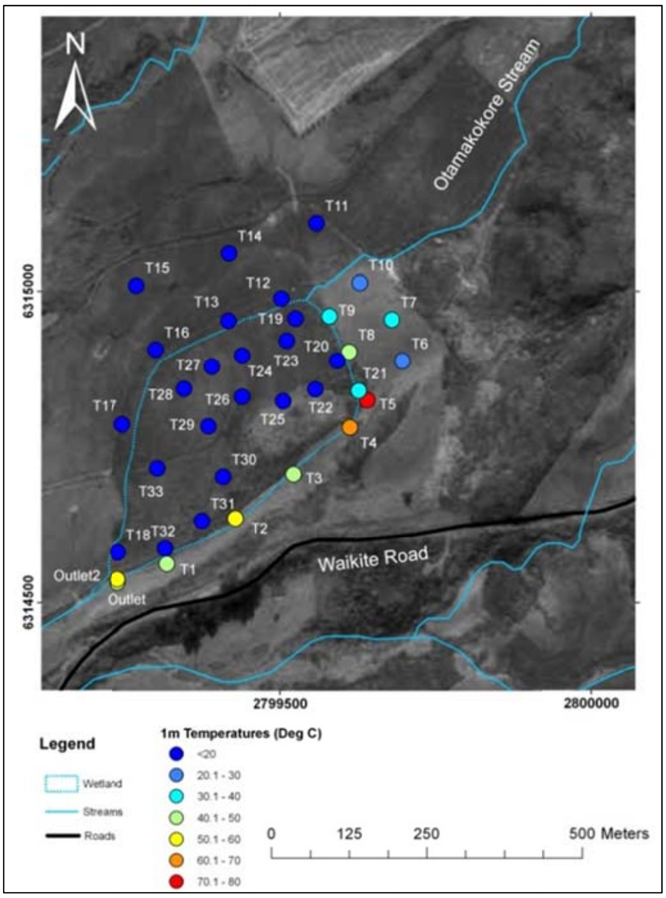

Figure 2. Spatial distribution of the 1 m ground temperature survey.

wetland where visible hot springs discharge into the wetland. Elevated ground temperatures along the southern boundary of the wetland are along the Paeroa Fault Scarp. This suggests that there may be subsurface hot seeps into the wetland along the southern boundary. Sinter deposits observed along this boundary show that hot fluids flowed in this area historically.

This data then suggests that there are three sources of geothermal fluids into the wetland; The Otamakokore Stream entering the wetland in the north eastern corner, which provides surface water at about 40°C, small springs in the south east corner of the wetland, and the subsurface flows along the southern and eastern margins of the wetland.

Physical measurements

Pre-development chemistry data are not available. Water chemistry of the wetland before the water course had been returned to the wetland in June 2009 was not obtained. This limits the interpretation of the data.

Water chemistry data between August 2009 and October 2010 is relatively stable and do not show any significant trends at any of the monitored sites. Cl is a useful parameter to discuss because it is a conservative tracer and therefore typically doesn't react with other parameters in solution. Cl trends over time (Figure 3) shows the following:

1. An increase in Cl (and most other parameters) at site WE1008 from 1964 to 1991.
2. Little change in the Cl concentration at the monitored sites between August 2009 and October 2010. At sites WE1001 and WE1008 little change has occurred since 1991.
3. Cl changes with time show a similar pattern at sites Inlet, Outlet (i.e., the wetland sites) and WE1001.
4. Cl concentrations at site Stream-upgradient have remained relatively constant over the monitoring period.

A lack of significant changes in Cl associated with diverting the stream flow may be due to the following factors; water chemistry could have changed quickly, and dissipated before monitoring began; there was no Cl change due to diverting the stream back through the wetland, or, the shallow groundwater/geothermal system are still equilibrating, and the change is yet to be observed.

Flow of the Otamakokore Stream increases between Stream-upgradient and Outlet by ~34 $l\ s^{-1}$ with ~ 14 $l\ s^{-1}$ (Figure 4) of this gained within the wetland (between sites Inlet and Outlet from surface and subsurface flows). The additional flow can be attributed to geothermal inputs using mass balance calculations using Cl. The mass balance calculations assume that the water composition at site WE1001 is representative of the additional geothermal fluids entering the Otamakokore Stream and the wetland.

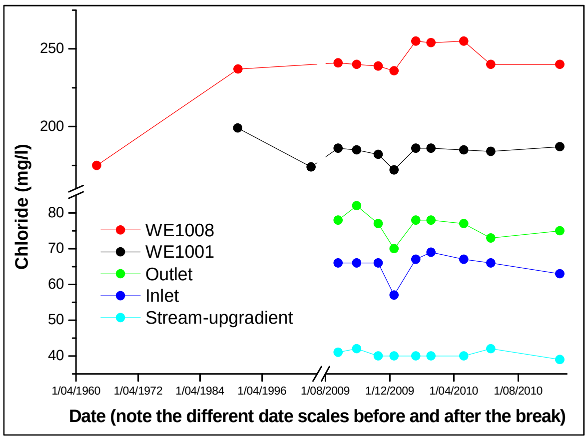

Figure 3. Chloride over time at the monitoring sites.

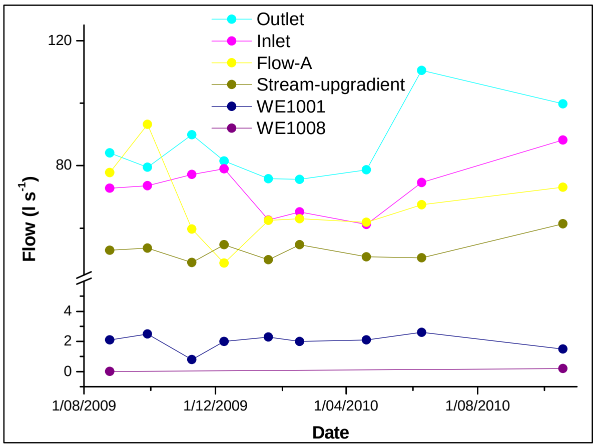

Figure 4. Flow rates over time at the monitor sites.

Microbiological

With the exception of WKR8 (Figures 1 and 5), no significant change in the microbial population was detected in any of the sampling sites. WKR8 was the only site that showed a major microbial population change across all types of analyses between 08/04/2010 and 28/09/2010. The soil samples at this site in particular showed a distinct reduction in species diversity over time (Figure 5). The change in the microbial population corresponded to an increase of 8°C in the water temperature measured at this site during this time period. The increase in water temperature at this site is probably caused by an increased water flow through a channel dug from the spring to the Otamakokore Stream between 10/06/2010 and 31/08/2010 which lowered the water level in the spring by approximately 5 cm.

Analyses of the water at WKR8 also showed significant decreases in microbial diversity and shifts in resident bacterial and archaeal species. Overall, the microbial population shifted from a community of thermophilic bacterial and archaeal species to a community dominated by archaeal species with the temperature increases. This observation is consistent with thermophilic microbial ecology that *Archaea* predominate over *Bacteria* at near-boiling temperatures. No cyanobacteria were detected at this site over the duration of the study. The average temperatures of this spring and associated soils (81.9°C and 85°C respectively) are too hot for photosynthetic

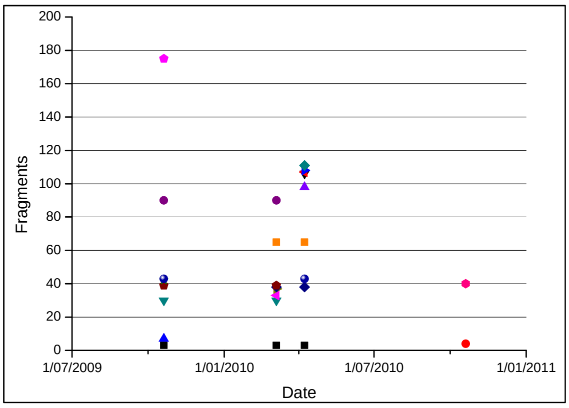

Figure 5. A scattergraph of all fragments recorded from amplification and subsequent digestion with MspI of total bacterial 16S rRNA genes found in soil at WKR8 over the study period.

microorganisms and therefore would not have supported cyanobacterial growth.

Macroinvertebrate

Macroinvertebrate abundance at sites sampled along the Otamakokore Stream is shown in Figure 6. Greatest abundance occurred at OT2 (7380/sample), OT3 (6240/sample) and OT6 (2698/sample) in 2009. In 1999 highest numbers occurred at OT1 (3592/sample) and OT2 (800/sample). At all sites the high numbers resulted from the occurrence of the chironomid midge *Tanytarsus*.

The macroinvertebrate fauna of the Otamakokore Stream was low in diversity, which is common with the macroinvertebrate fauna recorded from other geothermally-influenced water courses. The fauna comprised organisms that are common to non-geothermal waters as well as organisms found only in geothermal ecosystems.

The macroinvertebrate community sampled in 2009 comprised a greater proportion of species found commonly in geothermal waterways. This is largely explained by the loss of macroinvertebrates that are less well-adapted to the characteristics of geothermal waters, rather than an increase in species that occur more commonly in geothermal waters. In part this result is a reflection of the taxonomic penetration at each sampling period. However, it largely reflects the changing geothermal and habitat characteristics resulting from the stream reclamation.

The macroinvertebrate communities dominated by *Tanytarsus/Ephydrella* occurring at Otamakokore Stream are consistent with the alkali-chloride and bicarbonate geochemical characteristic occurring elsewhere in the Taupo Volcanic Zone (Hunt and Bibby 1992, Boothroyd 2009).

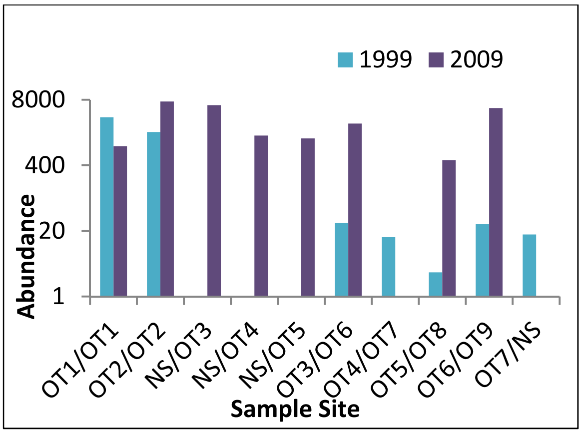

Figure 6. Macroinvertebrate abundance (number per sample) at sites within the Otamakokore Stream 1999 and 2009. Site notation is matched for the same location. NS = not sampled. NB. Log scale on y axis.

CONCLUSIONS

The three sources of water into the Waikite Wetland are identified; the Otamakokore Stream, small springs in the south east corner of the wetland, and the subsurface flows along the southern and eastern margins of the wetland. Geothermal water inputs from within the wetland are estimated to be ~ 14 l s^{-1}.

Monitoring data show that negligible changes in water chemistry and microbial populations have occurred in the wetland since monitoring began after management changes were implemented. Comparisons of the macroinvertebrate populations between 1999 and 2009 show that there were less taxa and also an increase in species that occur more commonly in geothermal waters in 2009. This is associated with redirecting the Otamakokore Stream back into the wetland.

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