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Sustainable management of geothermal vegetation in the Waikato Region, New Zealand, including application of ecological indicators and new monitoring technology trials

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ABSTRACT

Geothermal vegetation – influenced by surface expressions of heat from the Earth's interior – is naturally rare both in New Zealand and internationally. The varied nature of geothermal manifestations, due to varying combinations of temperature, chemistry, hydrology, and localised protection from frosts, results in rare and unusual habitats for plants. These naturally uncommon ecosystems are classed as threatened and critically endangered, and include habitats for species occurring outside 'normal' latitudinal and altitudinal ranges. The varied nature of geothermal vegetation, one of the most threatened ecosystems in New Zealand, has important implications for management, including retention of existing areas and the maintenance and enhancement of ecological values. Most geothermal vegetation in New Zealand occurs in the central North Island in the Taupo Volcanic Zone, with c.74% of the total extent of New Zealand's geothermal vegetation located within the Waikato Region, and the remaining 26% located within the Bay of Plenty Region. Inventories of geothermal vegetation and identifications of management priorities have been undertaken regularly in the Waikato Region since 2000, with the latest having been undertaken in 2014, covering over 863 ha of geothermal habitat within 15 geothermal systems. Energy production (thermal and hydro-electricity, heating, and industrial uses) and land use changes such as mining, farming, forestry, urban development, tourism, fire, and herbicide and/or fertilizer drift have resulted in the loss of significant geothermal areas in the past, and such activities continue to threaten geothermal vegetation. Invasion of pest plants, particularly introduced conifers and other woody plant species, continues to be a major threat at many sites. Threats at each site, vulnerability to those threats, actions required to address threats, and the benefits and priorities of ecological management have been identified. Active restoration management is being undertaken by the Department of Conservation, tangata whenua, regional and local government, private landowners, and forestry companies. There are considerable opportunities for further restoration initiatives, at sites where work has already been undertaken and at all other sites. New threats have also been recognised, showing the importance of regular monitoring and inventory assessments. Continued monitoring and appropriate planning is a key requirement to improve management of this nationally rare ecosystem. Monitoring, protection, and restoration, where possible, are essential requirements to halt the decline of these fragile and unique ecosystems. To assist with management, a set of ecological indicators for geothermal systems was developed and applied across geothermal habitat within the Waikato Region. These indicators provide a measurable benchmark against which loss can be measured. Scores can be used to assess site condition and overall change within and across sites. In addition, new technology for undertaking monitoring was explored at one geothermal site as a case study. A drone was used to capture a range of imagery, as drones may be an ideal solution for geothermal site monitoring given the hazards to field surveys in geothermal areas.

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1. Introduction

Geothermal vegetation[1] and habitats are naturally rare both in New Zealand (Williams et al., 2007) and internationally. In New Zealand, four types of geothermal habitat have been ranked as Critically Endangered (fumaroles, geothermal stream sides, geothermal heated ground, and geothermal hydrothermally altered ground) (Holdaway et al., 2012). Most geothermal vegetation in New Zealand occurs in the central North Island, in the Taupō Volcanic Zone (see Fig. 1), with approximately 74% of the total extent of New Zealand's geothermal vegetation located within the Waikato Region, and the remaining 26% located within the Bay of Plenty Region. Although geothermal features are present elsewhere in New Zealand (in Northland, the Hauraki Gulf, and scattered hot springs in the North and South Islands), there is little to no associated geothermal vegetation at these localities. The varied nature of geothermal surface manifestations, due to varying combinations of temperature (Burns, 1997; Given, 1980, 1989; Wildland Consultants, 2011a,b), chemistry, hydrology, and localised protection from frosts, produces rare and unusual habitats for plants. These include plants capable of surviving high soil temperatures, disjunct populations found a considerable distance from other sites of the same species and which are usually confined to warmer climates, and local endemic species and distinct genetic forms arising where ground temperatures are sufficiently stable (Given, 1989). Many geothermal sites are dynamic and unstable, and changes in surface geothermal activity are reflected in relatively rapid changes in the extent and composition of geothermal vegetation, while changes in geothermal vegetation can indicate the reverse situation of changes in geothermal activity. Geothermal vegetation includes populations of several plant species which have a national threat ranking in New Zealand.

2. Material and methods

The Waikato Regional Council has been undertaking inventory studies of geothermal vegetation in the Waikato Region since 2000 with regular updates during this period. In 2014, a further update was undertaken, using 2012 colour digital aerial photographs as the base map. This study mapped, described, assessed, and ranked 64 sites (including four areas newly identified in 2014) supporting geothermal vegetation covering *c.*750 ha (including geothermally influenced bare ground). An additional *c.*113 ha is mapped as geothermal water, where it is an integral part of a site containing geothermal vegetation. Vegetation type boundaries were digitised and the extent of each type was calculated. Topographical maps and vegetation maps were prepared for each site. At each site, the vegetation was described and classified using predefined vegetation structural classes and a protocol for assigning vegetation type names based on the dominant plant species. Site condition, current threats, modifications and vulnerability were assessed, and management requirements were identified. Each site was assessed for ecological significance and assigned a relative significance level of International, National, Regional, or Local. Significance and relative significance were assessed using criteria in the Waikato Regional Policy Statement (2016).

Geothermal vegetation was assessed within geothermal systems. A geothermal system is an individual body of geothermal energy (including geothermal water) not believed to have any other connection in the upper few kilometres of the earth crust (Luketina, 2012). Geothermal system boundaries of all known high temperature systems have been mapped previously. There are 15 known high temperature, and approximately 31 low temperature, geothermal systems in the Waikato Region (Luketina, 2012). Some of these have surface expressions of geothermal energy that provide habitat for geothermal vegetation, while others do not.

A simple set of indicators was developed for objectively assessing the extent, condition and protection level of geothermal vegetation in the Waikato Region, and applied to all surveyed sites. Each indicator was scored in one of five classes, being 'very good', 'good', 'moderate', 'low', and 'very low'. The scoring system can be used in the future to identify changes in the condition and values of each geothermal site, threats to the sites and overall change over all sites in the Region.

One site, Craters of the Moon was selected as the basis for a case study of the use of drone-captured aerial imagery for assessing geothermal vegetation and habitats, because it was good example of a range of terrestrial geothermal vegetation and habitats present in the Waikato Region and is easily accessible, allowing verification of the drone-captured imagery to be made.

3. Vegetation and habitats

Vegetation assemblages at geothermal sites include lichenfield, mossfield, herbfield, fernland, scrub, shrubland, rushland, sedgeland, reedland, forest, wetland, open water habitats, and geothermally-influenced bare ground. Vegetation composition is highly variable, reflecting soil temperatures, the presence/absence of permanent water and ephemeral wetlands, acidity and other chemical aspects of soil and water, altitude, and the age of the geothermal activity at a particular site. Sites occur over a wide range of altitudes, from sea level to the summits of the central North Island volcanoes. Soil chemistry and temperature (environmental gradients) strongly influence vegetation at geothermal sites (c.f. Given, 1980; Burns and Leathwick, 1995).

The 750.3 ha of geothermal vegetation and habitats were mapped in three broad categories: geothermally influenced bare ground – *c.*89.8 ha, terrestrial vegetation – *c.*574.7 ha, and emergent wetland – *c.*85.8 ha. Terrestrial vegetation is all vegetation that was not mapped as geothermal wetland and non-vegetated raw-soilfield and includes (but is not limited to) forest, scrub, shrubland, fernland, and mossfield.

The largest single area of geothermal vegetation (*c.*221 ha) occurs in the Waiotapu-Waikiti-Waimangu Geothermal System.[2] Three systems (Horohoro, Atiamuri, and Whangairorohea) have less than 1 ha of geothermal vegetation (see Table 1), and two systems (Mangakino and Horomatangi) have no known geothermal vegetation.

Most geothermal vegetation in the Waikato Region occurs in Atiamuri Ecological District (*c.*81%) (Fig. 1), while Taupō and Tongariro Ecological Districts contain *c.*13% and *c.*7% respectively.

3.1. Changes in extent of geothermal sites over time

Using a combination of historical photographs and existing literature, we determined that the extent of geothermal vegetation has decreased at 23 of the geothermal sites in the Waikato since the 1940s. At six sites, the extent of geothermal vegetation has increased. For example, the eruption of Te Maari Craters in 2012 has increased the extent of this site by *c.*3.5 ha, and geothermal vegetation at Wairakei Borefield has increased by 36% since 2007. Eight sites had no discernible change. Causes of a reduction in geothermal vegetation cover include an increase in ground temperature beyond the capacity to support vegetation, vegetation clearance (e.g., for roading, pasture), weed encroachment, and more recently, overspray of aerial herbicide application to neighboring land. At Broadlands Road, two very small areas of geothermal vegetation (< 0.1 ha total) were destroyed by

[1] Geothermal vegetation is defined as "… terrestrial and emergent wetland vegetation … communities that have compositional, structural, and/or growth rate characteristics determined by current and former inputs of geothermally-derived energy (heat) or material (solid, fluid, or gas)" (Merrett and Clarkson, 1999).

[2] Note that Waimangu is outside of the Waikato Region and thus was not surveyed as part of this study. Geothermal systems are defined by the Waikato Regional Council 2017: www.waikatoregion.govt.nz/environment/natural-resources/geothermal/geothermal-systems-map/.