Vegetation and invertebrates in three geothermal areas in Iceland

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Abstract

The ecosystem of geothermal areas is poorly known both in Iceland and elsewhere. Information lack in general and studies that have been carried out in Iceland have mostly been descriptive. Knowledge about the ecosystem of these areas is an important consideration as these areas will be more and more important in the future, not only for energy extraction but also for recreation and conservation. A better understanding of these ecosystems is important as it may contribute to improved decisions in terms of utilization. The objective of this study was to demonstrate the distribution of vegetation and invertebrates in relation to physical and chemical parameters. Three geothermal areas in Iceland were selected for this study and the communities of vegetation and invertebrates and soil characteristics were studied along a soil temperature gradient. Results of this study indicate that soil temperature is a dominating environmental factor in explaining the distribution of different species at these sites, as well as soil characteristics. Species diversity and composition at warmer spots was different from the colder ones, but also there was a difference in pH and carbon content of the soil. Furthermore, a difference appeared among sites that are most likely due to different location, elevation and weather condition.

***Keywords**: geothermal areas, species/heat relationships, species diversity.*

1 Introduction

Geothermal activity is common in Iceland and in near future it is expected that utilization of geothermal energy will increase and more areas will be disturbed. It is evident that the activity will not only be important in the future for energy extraction, but also for tourism and nature conservation. However, today little is known about the ecosystem of these areas and the relationship of organisms with the unique environment. Therefore, it is vital to gather basic information about these areas, which can be used for management purpose and decisions of how and if these area should be utilized.

Previous studies on geothermal areas in Iceland have mostly been focused on utilization of the geothermal energy (e.g. Palmason *et al*. 1985; Bjornsson 1990). The ecosystems on the other hand have rarely been studied, and the studies that have been carried out are mostly descriptive (Tuxen 1944; Petursson 1958; Steindorsson 1964; Kristjansson and Alfredsson 1986). The situation is similar in other countries, where geothermal activity exists, with a major gap in the knowledge of the ecology of these areas.

An ecological study was carried out in three geothermal sites in Iceland during year 2001, on the request of the National Energy Authority. The aim of this project was to demonstrate the distribution of vegetation and invertebrates in relation to physical and chemical parameters in geothermal areas in Iceland. In this paper we will discuss the species diversity for vegetation and invertebrates found at the three sites, and how it changed along a soil temperature gradient.

2 Study sites and methods

Three geothermal sites were selected for the study, two in the Southwest (Reykjanes and Olkelduhals) and one in Northeast (Theistareykir) (Figure 1). Reykjanes is located about 20 m a.s.l. and near the seashore. The geothermal surface covers about 2 km² (Idnadarraduneytid 1994) and is characterized by fumaroles and solfataras. Olkelduhals belongs to the Hengill area, which is one of the biggest geothermal areas in Iceland and takes over 100 km² (Idnadarraduneytid 1994). The research area is located about 400 m a.s.l. and the active geothermal surface is hot steaming ground. Theistareykir is about 350 m a.s.l. The thermal area is about 19 km² and it is mostly on flat land where solfatara, steaming ground and sulphur sinter are present (Palmason *et al*. 1985: Idnadarraduneytid 1994).

Figure 1: Location of study sites in Iceland.

At each site two transects were extended from the hottest to the cool part. Within each transect 4–5 plots (10 x 10 m) were chosen subjectively to represent vegetation that was as homogeneous as possible within each plot, but encompassed what appeared to be differences in vegetation composition and soil temperature found at that site. Within each plot 8 subplots (33 x 100 cm) were placed randomly and within them all measurements were made. All data were collected in summer 2001.

Soil characteristics: Soil temperature was measured in July, two measurements in each subplot at 10 cm depth. For determination of pH and carbon content of the soil, two samples were collected with a soil core (5.2 cm in diameter) to a depth of 10 cm in each plot. Samples were dried at room temperature and samples from each plot were combined into one composite sample before analysis. Determination of pH was performed for samples that were rewetted with deionised water to a saturated paste and measured with a glass electrode (McLean 1982). The soil carbon content was analysed by means of a Leco–CR 12 Carbon Analyzer (Nelson and Sommers 1982).

Vegetation: Cover for vascular species and for mosses and lichens as a group was estimated visually in each subplot by using a percent scale. To obtain a comprehensive view of moss and lichen species, samples of mosses and lichens were taken within each plot. These sampling methods provide information about the species diversity within each study site.

Invertebrates: Three pitfall traps (7.5 cm in diameter) within a plot were used to catch invertebrates living on the ground. The trapping period was from beginning of July to the end of August in Theistareykir, and from end of June to beginning of September in Reykjanes and Olkelduhals. The traps were emptied twice over the period in Theistareykir and every other week in the other two sites. The traps contained ethylene glycol (antifreeze) to kill and preserve the catch. In some cases the liquid evaporated nearly or completely from traps at the warmest spots, which in those cases gave a minimum catch. All specimens were counted and identified to species when possible, but only those identified to species were used in analysis.

3 Results

3.1 Soil characteristics

In general, the soil temperature was higher in Reykjanes and Olkelduhals than in Theistareykir (Figure 2). The highest temperature within a plot was 79ºC in Olkelduhals, in Reykjanes it was 67ºC and 38ºC in Theistareykir. At the coolest part of each transect the soil temperature was measured around 14ºC in Reykjanes and 8–9ºC at the other two sites.

Carbon content of the soil was higher in cooler soil than warm soil, but same trend was not seen for pH (Figure 3). Great variability was within each site in carbon and pH. Smallest amount of carbon (0.1%) was measured in Theistareykir but highest in Olkelduhals (8.5%). The pH was lowest (1.9) in Theistareykir but highest (8.0) in Reykjanes.

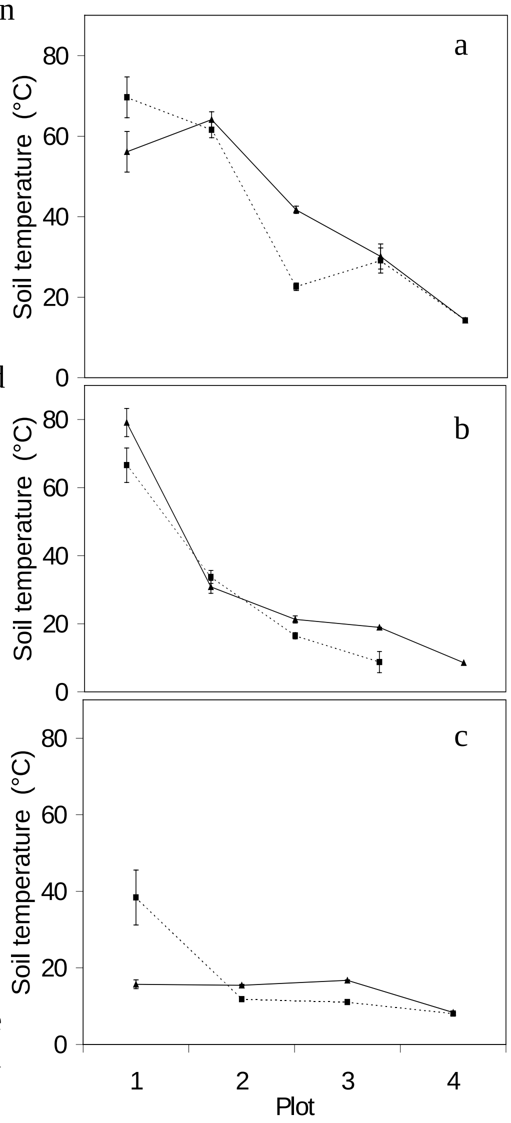

Figure 2: Soil temperature (ºC) at 10 cm depth (+/- SE) in plots at a) Reykjanes, b) Olkelduhals and c) Theistareykir. The two transects are shown.

3.2 Vegetation and invertebrates

Number of vascular plant species was 51 in Theistareykir, 44 in Olkelduhals and 39 in Reykjanes. Moss species found in Olkelduhals were 35, 30 in Reykjanes and 25 in Theistareykir. Lichen species were 18 in Theistareykir, but 12 and 13 in Olkelduhals and Reykjanes, respectively. In Theistareykir were 146 invertebrate species identified, 109 in Olkelduhals and 103 in Reykjanes.

Number of vascular species and invertebrates within a plot decreased as soil temperature increased (Figure 4.a and d). Lichens showed similar pattern, but on the other hand number of moss species did not show a clear respond to soil temperature (Figure 3.3.b and c). Within the hotter plots in Reykjanes and Olkelduhals, mosses (e.g. *Campylopus introflexus*, *Gymnocolea inflata* and *Archidium alternifolum*) were dominating in the vegetation but in Theistareykir these plots were almost barren. As the temperature decreased other moss species became dominant and in some cases replaced the ones that were abundant at hotter plots. Vascular plant species found at these hot plots were for example *Agrostis stolonifera*, *Thymus praecox*, *Alchemilla alpina* and *Ophioglossum azoricum*. Most of these species were also found at cooler plots, and their cover tended to increase as the temperature decreased. Lichens were rarely found within hot plots but the most common lichen species found, within both hot and cool plots, was *Peltigera canina*.

Dominating invertebrate species differed among the study sites. The spider *Erigone atra* dominated the hotter plots in Reykjanes, but beetles were most common in Olkelduhals and Theistareykir, such as *Bembidion bipunctatum* and *Nebria gyllenhali*. These species were not found at the colder plots. Species common at the colder plots (e.g. parasitic hymenopterans *Trimorus pedestris* and *T. ovata* and harvestman *Mitopus morio*) decreased in number as temperature increased and some were not found at the hottest plots at all.

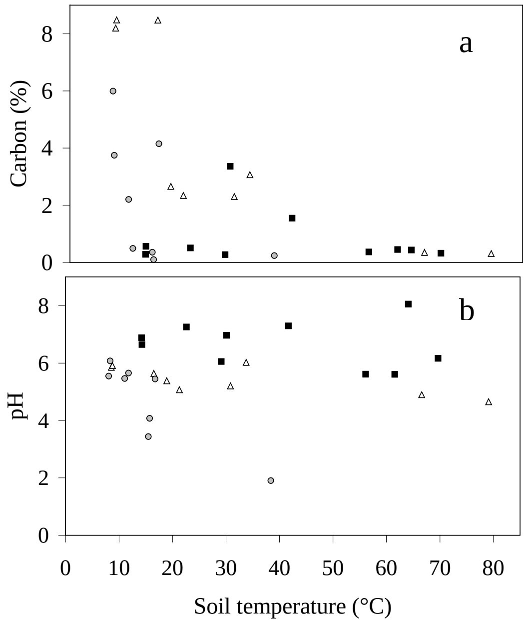

Figure 4: a) Soil carbon and b) pH of the upper 10 cm layer in plots within each site. Reykjanes is a box, Olkelduhals is a triangle and Theistareykir is a circle.

4 Discussion

The environment of geothermal sites are unique because of special conditions, which is usually characterized by steep gradients in soil temperature and humidity, high acidity and unusual concentration of minerals and elements (Burns 1997; Glime and Hong 1997). These conditions are likely to affect both flora and fauna that can be quite different from the surroundings (Halloy 1991, Burns 1997, Convey *et al.* 2000). In this study warm soils were in general characterized by low carbon values (<0.5% C), but it increased as the temperature decreased (Figure 3). The pH in soil was in most cases within the near neutral range (6–8), which favours nitrogen and phosphorus availability and microbiological activity for nitrogen fixation (Tucker *et al.* 1987). But as acidity becomes more extreme it strongly affects plants ability to take up certain nutrients and that might be the case within the barren plots at Theistareykir, where pH was measured as low as 1.9. Furthermore, at low acidity aluminium toxicity have shown to have a great influence on plants (Andersson 1988).

Our results indicated that soil temperature influence the species diversity in most cases (Figure 4). Number of vascular plant species showed a clear negative response to increased soil temperature and other researches have shown that vegetation at geothermal sites is closely related to soil temperature in the root zone (Given 1980; Glime and Iwatsuki 1994). The heat tolerance of normal plant cell activity has been shown to range from 45-55ºC, although some cells can survive at higher temperature (Konis 1949). Similar to other studies, this study showed that mosses can survive in the heat considerably well, which can be explained to some extent by lack of roots and that soil temperature is lower at the soil surface than for instance at 10 cm depth (Given 1980, Glime and Hong 1997). Some of these mosses (e.g. *Gymnocolea inflata*) were only found at high temperatures and therefore can be identified as geothermal species. Although soil temperature was somewhat lower at Theistareykir, compared with the other two sites, the hottest plots remained almost barren (Figure 4). This lack of vegetation might be explained by low soil pH within the plots (Figure 3). Unlike the mosses, few lichens were found at areas with soil temperature over 50ºC. Similar pattern have been found at other geothermal areas where lichens seemed to avoid hot humid areas (Kappen and Smith 1980, Glime and Iwatsuki 1990).

Unfortunately studies on the ecology of terrestrial invertebrates at geothermal areas are lacking generally so still we have little knowledge of the effects of geothermal heat on invertebrate species. This study showed that the number of invertebrate species decreased with Increase in temperature (Figure 4). Furthermore, agreeing with Olafsson (2000) many species living at high soil temperatures were not found in colder neighbouring areas and vice versa. The species that only were found at high temperatures in this study, e.g. *Bembidium bipunctatum* and *Nebria gyllenhali*, have been found in cold habitats further away (Sadler and Dugmore 1995, Olafsson 2000) so they are not restricted to geothermal areas. A study carried out at geothermal warm spots in the Andes at 6000 m a.s.l. similarly showed that most of the taxa found there were not found in neighbouring mountains. They were related to taxa from lower humid areas, hundreds or thousands of kilometres away (Halloy 1991).

The first results of this study indicated that soil temperature play a strong role in determining the distribution of species, it must however act in consort with other factors, e.g. pH and carbon content in soil. It is for example evident that location; weather conditions and elevation may influence the distribution of the organisms as well.

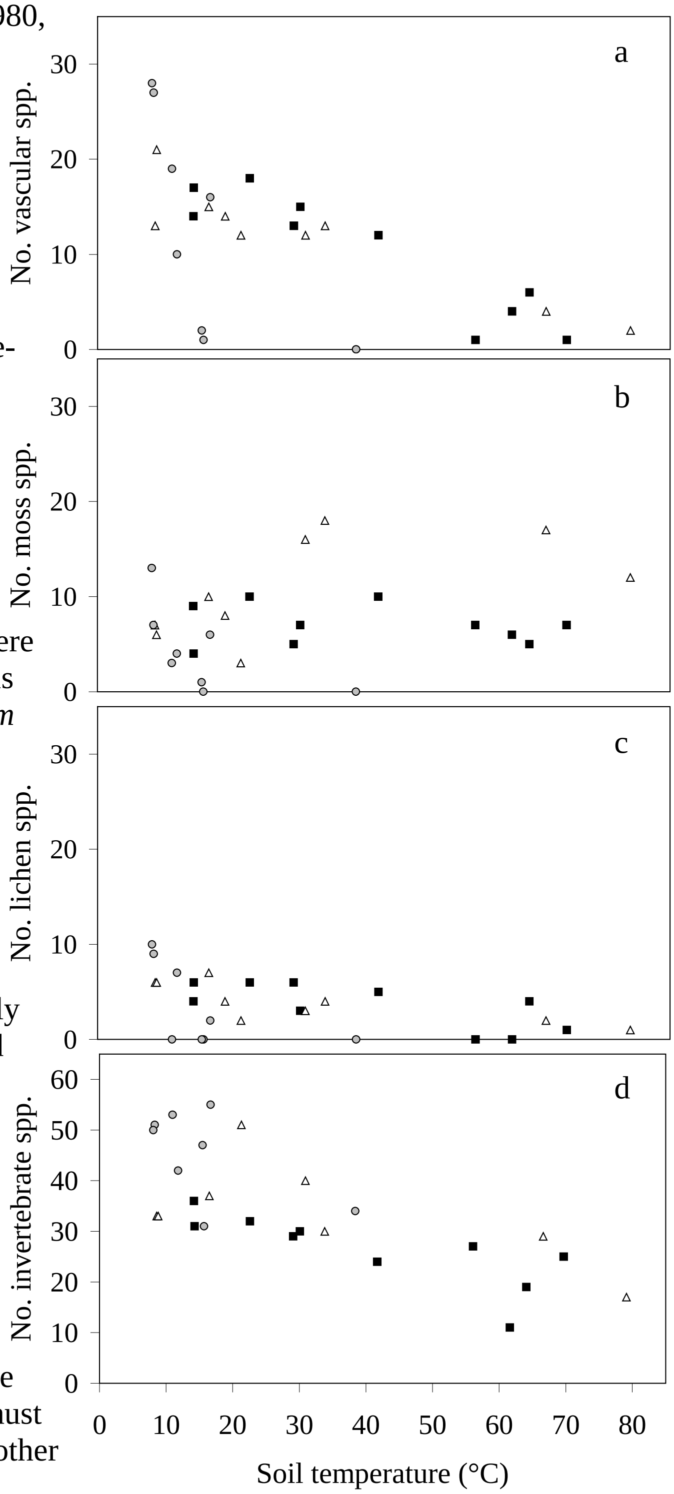

Figure 4: Species diversity; number of a) vascular plants, b) mosses, c) lichen and d) invertebrates within each plot. Reykjanes is a box, Olkelduhals is a triangle and Theistareykir is a circle.

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