Geothermal Spring Biophysical Setting
Statewide

Conservation Status Rank: S4 (apparently secure)

Introduction
The Geothermal Spring Biophysical Setting are features where geothermally-heated groundwater emerges at the ground surface (Figure 1). Characteristics of geothermal springs vary widely and are largely dependent upon the subterranean thermal, physical and chemical conditions of origin. They are sensitive habitats that, in part due to diffuse geothermal heating of the ground and surface water, support rare and disjunct populations of plants and thermophilic microbial organisms. Only limited information is available on the plant associations and vegetation succession of Alaska's geothermal springs and thus threats and trends of the systems are not fully understood.

Figure 1. Granite Hotspring, Alaska (photo by M. Duffy).

Distribution

With small areas of occupancy and fewer than 150 known occurrences in Alaska, geothermal springs are an uncommon biophysical setting that is largely restricted to regions of current or historic volcanic activity (Figure 2; Miller 1994). Approximately half of the known geothermal springs in Alaska are associated with the Aleutian volcanic arc. The remaining springs are in interior and southeastern Alaska and have no apparent spatial or temporal association with recent volcanism. The geothermal springs distribution map (Figure 2) was developed from the occurrences mapped by Miller (1994) and from the regions of known or potential geothermal resources (Laney & Brizee 2003).

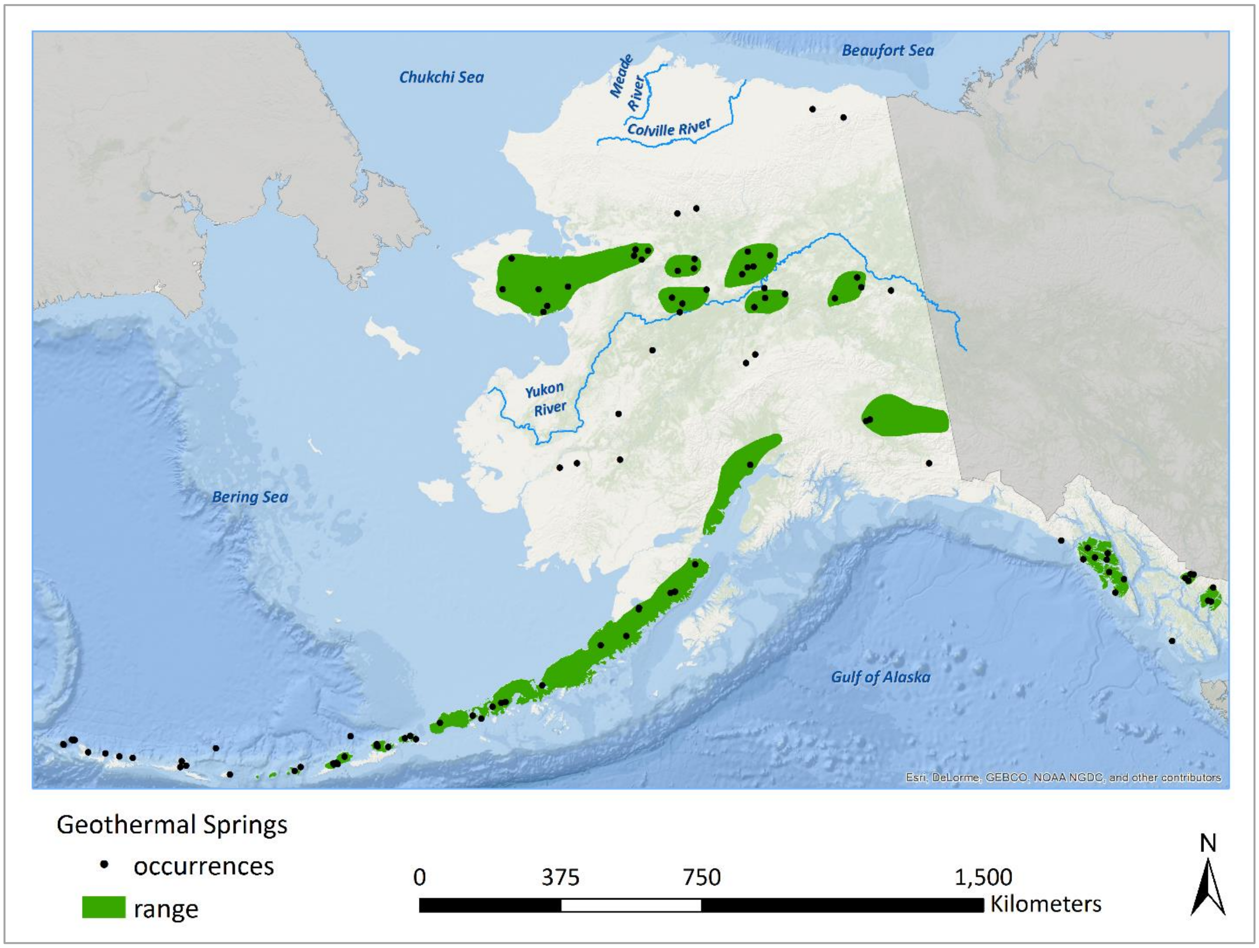

Figure 2. Distribution of the Geothermal Spring Biophysical Setting in Alaska. Note that the areas of occurrence in this map are buffered for greater visibility.

Climate

Geothermal springs are widely distributed across Alaska and are thus characterized by considerable range in the climatic factors of latitude, continentality, and elevation. Because these systems represent phenomena tied to areas of geothermal activity, they transcend the constraints of local climate and instead create small, isolated microclimates where soil, water and air temperatures are significantly warmer on more moderate than the surrounding macroclimate.

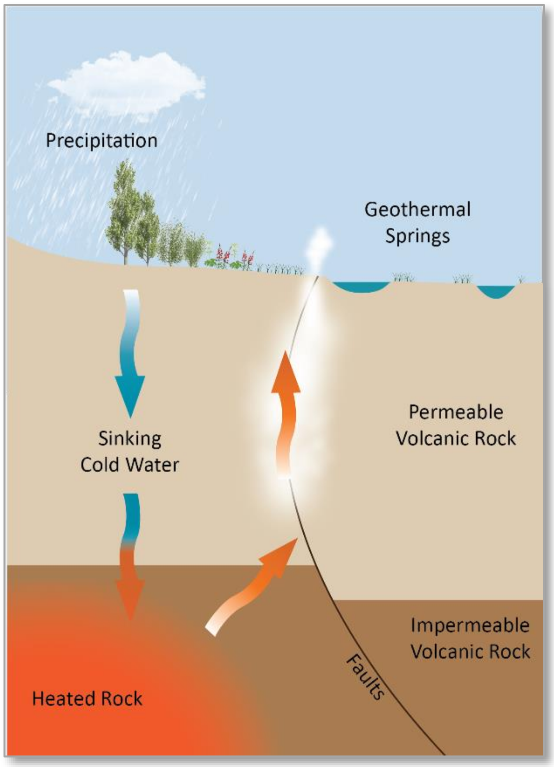

Figure 3. Geothermal springs water flow diagram.

Environmental Characteristics

Precipitation is the origin of almost all water emerging from geothermal springs. Below the ground surface, water infiltrates through faults or permeable layers to become heated by contact with hot rocks or magma before returning to the surface under hydrostatic pressure. In the Aleutian Islands and near the Wrangell Mountains, water can be heated by shallow magma, whereas geothermally-heated water emerging from the belt of springs across northcentral and within southeast Alaska is likely heated by still-warm rock at greater depth (Figure 3; Davis 1980).

The Aleutian volcanic arc extends some 2,500 km from the Hayes volcano (130 km west of Anchorage) to Buldir Island in the western Aleutians. Here springs are associated with major volcanic centers of Quaternary age, an association that is evidenced by the high surface temperatures of the spring water.

In the region north of the Alaska Range, 36 thermal springs have been reported, 32 of which are located in a 200 km wide east-west band extending across interior Alaska from the Seward Peninsula to within 160 km of the Canadian border. Additional, undocumented thermal springs may exist in this sparsely-populated area (Miller 1994). The majority of these geothermal springs are closely associated with the margins of granitic plutons and may be heated by these deep-seated intrusions of igneous rock. The origin of Pilgrim thermal springs on the Seward Peninsula is uncertain but may be related to a faulted margin of a Tertiary basin (Moll-Stalcup et al. 1994, Plafker and Berg 1994).

Several geothermal springs occurring in the Wrangell Mountains are associated with a thick layer of calcareous-alkaline rocks that underlie about 10,000 km^2 of the mountains. These rocks range from basalt to rhyolite, range in age from Miocene to Holocene, and appear to be related to a nearby subduction zone (Miller and Richter 1994, Stephens et al. 1984).

Eighteen geothermal springs occur in Southeast Alaska, 13 of which also appear to be associated with the fractured margins of granitic masses (Waring 1917, Miller et al. 1975, Motyka et al. 1980). The thermal waters which are alkali-sulfate to alkali chloride in character are likely derived from the interaction of deeply circulating meteoric waters with subterranean granitic rock (Motyka et al. 1980).

Vegetation and Biotic Communities

Thermophilic microorganisms including photosynthetic, autotrophic cyanobacteria and heterotrophic and chemotrophic bacteria and archaea, inhabit the bottom of warm spring ponds and their runoff channels. Hot spring outflows typically exhibit marked temperature gradients and brilliant colors that are the product of thermophilic microorganisms, especially the highly-pigmented cyanobacteria species. Colorful microbes are partitioned in thermal waters by temperature, with white-colored bacteria thriving in the hottest water (about 100 °C), then light greens (71–75 °C), yellows (63–71 °C), oranges (57–63 °C), dark browns (50–57 °C) and darker greens in the coolest water (<50 °C) (Rinehart 1980).

Thermophilic algae in hot springs are most abundant at temperatures of 55 °C or below. The optimum growth temperature for cyanobacteria (e.g. *Synechococcus*), which have high fidelity to hot spring habitats in temperate or colder climates, is over 45 °C. Chemotrophic and heterotrophic bacteria in the genera *Hydrogenobacter, Sulfolobus*, and *Thermocrins,* grow at higher temperatures. Chemotrophic organisms include hydrogen sulfide (H_2S) and sulfur oxidizers (e.g., *Sulfolobus acidocaldarius*, *Thiobacilus thiooxidans*) found in highly acidic geothermal springs, sulfate reducers (e.g. *Desulfovibrio thermophilus*), and methane oxidizers (e.g. *Methylococcus capsulatus*). Archaea bacteria, including methane-producing bacteria and sulfur-dependent bacteria, can survive at temperatures greater than 110 °C.

Figure 4. Pilgrim Hotspring, Alaska (photo by K. Walton).

Cold soils generally limit forest growth in many regions of Alaska (Van Cleve and Yarie 1986, Van Cleve et al. 1983). However, diffuse geothermal heating of the ground some distance from the immediate hot spring vents may promote lush growth of vegetation, often including plants typical of warmer soils and more southerly regions (Figure 4). In arctic Alaska, geothermal springs are often indicated by groves of *Populus balsamifera* (balsam poplar) surrounded by tundra (Bockheim et al. 2003).

Halophytic plants of coastal environments may also occur at geothermal springs. Plants in the immediate vicinity of the thermal springs generally include salt-tolerant graminoids in the *Carex*, *Eleocharis, Juncus* and *Puccinellia* genera (Figure 5). Mosses may be present but substrate salinity reduces their development. While not halophytic, the forb, *Epilobium hornemannii*, consistently occurs in the wet ground near hot spring vents in Alaska and throughout the Chukchi Peninsula (Vekhov 1996).

Figure 5. Lava Creek Hotspring, Seward Peninsula, Alaska (photo by J. Fulkerson).

Conservation Status

Rarity: Geothermal springs are uncommon both globally and within the state of Alaska. In Alaska, geothermal springs are of small extent with fewer than 150 known occurrences.

Threats: Geothermal springs may be developed for recreation, energy or agriculture (Miller 1994). In Alaska, the push to develop alternative energy sources, particularly geothermal, puts Alaska's geothermal springs at risk (K. Barrick pers. comm. 2013). For many geothermal springs, development threat is mitigated by their remote location.

Trend: Extent and condition of geothermal springs are not expected to change in the short- or long-term.

Species of Conservation Concern

The mammal and plant species listed below are designated critically imperiled or vulnerable either globally (G1-G3) or within Alaska (S1-S3) and are known or suspected to occur in this biophysical setting (Table 1, Table 2). Please visit the Alaska Center for Conservation Science website for species descriptions (ACCS 2016).

Table 1. Mammal species of conservation concern within the Geothermal Springs Biophysical Setting.

Common Name	Scientific Name	Global Rank	State Rank	Habitat Description
Keen's myotis	*Myotis keenii*	G2G3	S1S2	In southeast Alaska, this species occurs primarily in coniferous forests and also utilizes hot springs. On Hot Springs Island in the Queen Charlotte Islands, BC, bats roost among coastal boulders heated by runoff from local hot springs (Barclay, pers. com. 1992). This species has also been observed foraging over hot spring pools.

Table 2. Plant species of conservation concern within the Geothermal Springs Biophysical Setting.

Scientific Name	Global Rank	State Rank	Habitat Description
Botrychium pendunculosum	G2G/3	S1	Found near hotsprings in Northwestern, Alaska and the Alaska Peninsula.
Botrychium virginianum	G5	S3	Found in the thermal influence near Manley Hot Springs, could occur within the thermal influence of other hot springs elsewhere in the state.
Cardamine pensylvanica	G5	S1	Coast Mountains, Chief Shakes Hot Springs. Hot spring bank.
Carex deflexa var. deflexa	G5	S2S3	Dry herb meadows adjacent to hot springs in the Reed River valley of the Schwatka Mountains. The species is known from boreal North America and Greenland, and is found in the Yukon-Tanana uplands of interior Alaska. This record of C. deflexa is a northwestward range extension of over 400 km.
Chenopodium glaucum var. *salinum*	G5T5	S3S4	Found at several geothermal springs on the Seward Peninsula.
Crassula aquatica	G5	S1S2	Has a patchy, widespread distribution in North America, Europe, and eastern Asia. In Alaska, it is only known from warm springs on the Stikine River.
Cryptogramma stelleri	G5	S3S4	Grows at hot springs at Okpilak Lake.
Glyceria striata	G5	S3S4	Limited to isolated populations near two hot springs in interior Alaska, and several populations in coastal southeastern and southcentral Alaska.
Juncus nodosus	G5	S1S2	Obligate wetland plant along sandy shores of freshwater ponds/lakes and salt marshes.
Lycopus asper	G5	S1	Grows at hot springs at Circle.
Lycopus uniflorus	G5	S3S4	This species is widely distributed through North America and eastern Asia. In Alaska, it occurs in hot spring streams and margins and wet sedge meadow habitat at Shakes Hot Spring on the Stikine River and Granite Hotsprings in the Selawik Hills.
Polypodium sibiricum	G5?	S3	Boulder field adjacent to hot springs in the Reed River valley of the Schwatka Mountains.

Scientific Name	Global Rank	State Rank	Habitat Description
Ranunculus monophyllus	G5	S2	Collected at Serpentine Hotsprings.
Schizachne purpurascens	G5	S2	Found growing in a dry meadow adjacent to Reed Hot Springs in Gates of the Arctic NPP. This grass of boreal Asia and North America is known from south of the Alaska Range, hence this record documents a northward range extension of approximately 600 km.
Schoenoplectus pungens	G4G5	S1	Marshy borders of hot springs.

Plant Associations of Conservation Concern

No plant associations of conservation concern are known or suspected to occur within this biophysical setting. Additional study is required to evaluate whether this biophysical setting supports plant associations of conservation concern.

Classification Concept Source

This publication represents the first description of the Mud Volcano Biophysical Setting.

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