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Microbial Ecology of Olympic Hot Springs

Abstract

The ecology of Olympic Hot Springs in Olympic National Park was studied through laboratory and field observations from September 1972 through October 1973. Olympic Hot Springs was found to be a meteoric-low salinity hot spring with a temperature maximum of 47°C and a pH of 9.2. The warm, alkaline waters supported a biological community similar to those of other alkaline hot springs.

Introduction

The hot spring environment provided an interesting system for study since it probably had existed throughout the time that life had been evolving on earth. The organisms found growing under these thermal conditions helped to reveal the extent to which evolution had been pushed. From an ecological point of view, studies were simplified by the limited speciation and short food chains found in these sites. Possible beneficial applications of hot spring research include potential for prediction and control of the effects of thermal pollution in aquatic environments.

The role of temperature as an environmental factor and the uniqueness of the hot springs ecosystem has been reviewed by Castenholz (1969) and Brock (1970). The limnology of Ohanapecosch Hot Springs in Mount Rainier National Park has been described by Stockner (1968). The studies described herein resulted from the monitoring of certain of the physical, chemical, and biological properties of Olympic Hot Springs from September 1972 through October 1973.

Olympic Hot Springs is located in the north-central portion (48° N) of Olympic National Park at an elevation of 900 m. The study area (Fig. 1) covered 50 m^2 and was isolated from the main hot springs area where human activity had had minimal effect on the ecosystem. The site was located on a north-facing slope and consisted of a narrow main stream 35 cm wide by 20 cm deep, fed by two springs (sites 1 & 2), and a pool located on the east side of a small island separating the pool from the stream. The pool was fed by a spring which flowed up from the bottom (site 5). The source at site 1 flowed from the hillside, falling 1 m to the head of the stream channel (site 3): the stream at site 2 flowed down a rocky slope for 3 m to the head of the channel. The stream and pool joined 8 m downstream from the hillside sources forming a circulating out-flow pool (site 10) which drained over a steep slope to the Elwah River.

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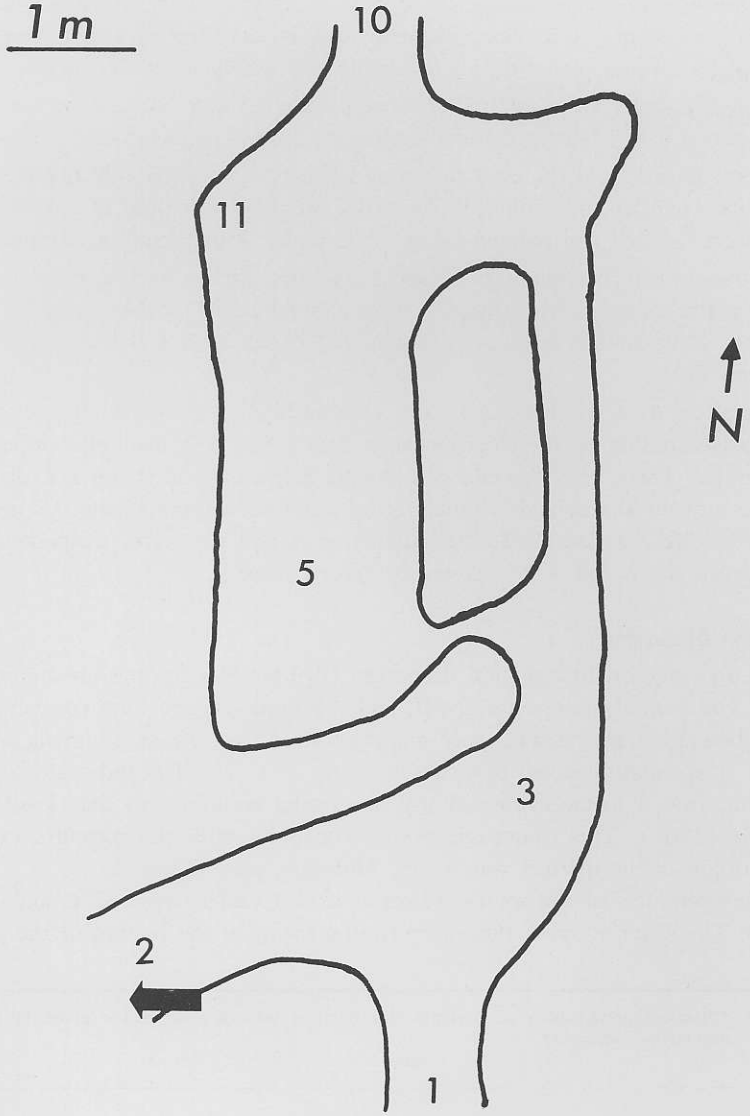

Figure 1. Olympic Hot Springs study area (numerals refer to sampling sites). The arrow indicates the location of the pipe used to divert the source water in the manipulation experiment.

Methods and Materials

Field observations and samples were taken monthly at designated sites marked by numbered wooden stakes. Temperature and dissolved measurements were made using a portable temperature, salinity, altitude compensated/oxygen meter (YSI model 51 A, Yellow Springs Instrument Co., Yellow Springs, Ohio). A Taylor pH comparator (VWR Scientific) was used for pH determinations.

Water samples for chemical analyses were collected in sterile 1 liter polyethylene bottles. One liter of water from each of sites 1, 2, and 10 was collected, fixed with chloroform, and stored on ice for phosphate analysis. One liter of water from the same sites was collected and placed on ice for use in the remainder of the chemical analyses.

Biological samples from selected sites were collected and stored in sterile glass jars and transported to the lab for cultural studies at ambient temperature.

The blue-greens from the algal mat were isolated in uni-algal culture for taxonomic classification on Allen's medium (1968) and Castenholz's Medium D (1969). The organisms were isolated and maintained at 40°C under 750 ft candles illumination.

A photosynthetic bacterium from site 5 and two filamentous bacterial types (one from site 2 and the other from site 11) were maintained in the laboratory by means of a modified "Winogradsky column" (Castenholz, 1972) with a thermal gradient from 32°C to 45°C.

In an effort to determine the in situ relationship between the algal mat and the filamentous bacterium on the slope between sites 2 and 3, a manipulation experiment was attempted. The source waters at site 2 were diverted by inserting a short length of PVC pipe into the source and channeling the water for approximately 0.5 m before it flowed from site 2 to site 3. This manipulation caused the water temperature on the slope between site 2 and 3 to decrease by several degrees.

Results and Discussion

Chemical and physical limnological data from Olympic Hot Springs are summarized in Table 1. The monthly temperature, pH, and dissolved oxygen were constant throughout the observation period with only minor seasonal fluctuations occurring in temperature (± 1°C) and dissolved oxygen (± 1 mg l^{-1}). The data indicate that Olympic Hot Springs was a meteoric-low salinity hot spring according to the classification of Castenholz (1969). This characterization is consistent with the meteoric rather than volcanic origin of the thermal waters (N. Anderson, pers. comm.).

The temperatures of the source waters at sites 1 and 2 were 42°C and 47°C, respectively. The water at site 5 flowed up from a spring at the bottom of the pool, with

TABLE 1. Chemical composition of Olympic Hot Springs waters (all values given in ppm unless otherwise indicated).

	Site 1	Site 2	Site 10
conductivity (μmhos cm^{-1})	290	300	290
turbidity (JTU)	0.49	1.50	0.68
NH_3	0.53	0.78	0.55
NO_3	0.12	0.12	0.16
PO_4	0.10	0.11	0.11
sulfates	32	25	30
Cd	0.004	0.004	0.004
Cr	0.006	0.006	0.006
Cu	0.01	0.01	0.01
Ni	0.008	0.008	0.017
Pb	0.10	0.10	0.10
Zn	0.001	0.019	0.001
Ca	1.20	1.80	1.44
Mg	0.07	0.06	0.06
pH	9.2	9.2	9.2
temperature (°C)	42	47	41

temperature measured at 47°C and a dissolved oxygen content of 0.5 mg l^{-1}. The condition of the pool was anoxic.

The microbial flora of Olympic Hot Springs was found to be similar to previously described alkaline hot springs (Stockner, 1968; Castenholz, 1969; Brock, 1970). The stream supported a mat of blue-green algae (also known as cyanobacteria [Stanier, 1974]) 3-4 cm thick which was made up of *Phormidium laminosum*, *Oscillatoria trebriformis*, and *Synechoccus lividus*. The underside of the mat lacked the heterotrophic flexibacteria found in algal mats of hot springs of higher temperatures (J. Bauld. pers. comm.). The rocky slope from site 2 to the head of the stream was covered by *Sphaerotilus natans*, a unicellular, rod-shaped bacterium enclosed in a sheath which gives the colony a white filamentous form.

In the pool area the algal mat was limited to the top centimeter of the pool's surface because of the anoxic conditions below. At the bottom of the pool, in areas not shaded by the algal mat, deep red patches of the photosynthetic purple sulfur bacterium *Chromatium violascens* were observed. The filamentous bacterium *Thiothrix nivea* was found along the margins of the pool where the water temperatures were cooler (30-35°C).

During April and May of 1973 it was noted that the flow from a cold spring which fed into the pool along its margin had diminished. This change resulted in a temperature increase from 33°C to 43°C. Accompanying this increase was a steady decline in the *Thiothrix* population until a level of approximately 40°C was reached; at this point, the organism disappeared from the system. Its thermal maximum had apparently been exceeded.

As a result of the manipulation of the source at site 2 the water temperature decreased from 47°C to 43°C with little effect on the overall flow rate. Accompanying the decrease in temperature was a change in the community structure between site 2 and the head of the stream channel. Within a month of the manipulation, the algal mat had spread up to the diversion point while *S. natans* had disappeared. Within a month after the flow pattern was restored to normal and the temperature increased to 47°C, the algal mat had receded to its original position in the stream and *S. natans* recolonized the slope below site 2.

These results suggest several alternative hypotheses: 1) growth of the algal mat was limited to temperatures below 47°C while that of *S. natans* is optimal at about 47°C; 2) increased competition by the blue-green algae may have lead to the demise of *S. natans* at the lower temperature; or 3) *S. natans* may excrete inhibitory factors which limit the growth of the blue-green algae, and it is only when *S. natans* is limited by the lower temperature that the blue-green can spread unchecked.

Apart from the microbial community described above, the only other major contributor to the hot springs community which was observed was the grazing fly *Paracoenia turbida* (Diptera: Ephyridae) which is common in hot springs with temperatures of 30-40°C (Brock, 1970; Collins *et al.*, 1976). These grazers contribute to the ecosystem through their feeding and excretory processes and their mechanical effects on the algal mat which allow greater gas and nutrient exchange (Brock, 1970).

These observations indicated that a biological community had developed which was typical of an ecosystem with the chemical and physical properties of Olympic Hot Springs. The members of the hot springs community were found to be living very near their thermal limits so that small changes in temperature led to rapid changes in the species diversity of the ecosystem. Community stability seemed to be dependent upon the constant physical and chemical properties found there.

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