Epilithic stages of chasmoendolithic lichens were found southwest of Lake Vida (77°23'S 161°38'E, altitude 580 to 600 meters) on a slope which, like Linnaeus Terrace, is exposed to the north and is protected from southern winds. Chasmoendolithic lichens growing here occasionally form epilithic thalli when they become exposed by the crumbling of the weathering substrate. The areolate thalli have apothecia and pycnidia.

On the basis of their reproductive structures, the epilithic stages of crypto- and chasmoendolithic lichens could be identified tentatively as species of the genus *Buellia*, the largest lichen genus on the Antarctic Continent (Dodge 1973). For some of the specimens collected, this identification has been confirmed by Mason E. Hale, Jr. (Smithsonian Institution, Washington, D.C.).

The dark and nonporous Ferrar dolerite is generally not a suitable substrate for endolithic microbial colonization (Friedmann 1977). However, we found lichens on dolerite boulders both on Linnaeus Terrace and on the top of Finger Mountain (77°45'S 160°41'E, altitude 1,880 meters). These lichens grow in coarse fissures of rocks, about 10 to 15 millimeters below the surface where they form small, areolate, fertile thalli. Because the fissures are wide, the upper surface of the thalli is exposed (figure 2) and, therefore, this growth form may be regarded as an intermediate between the chasmoendolithic and the epilithic types. The lichens also apparently belong to the genus *Buellia*.

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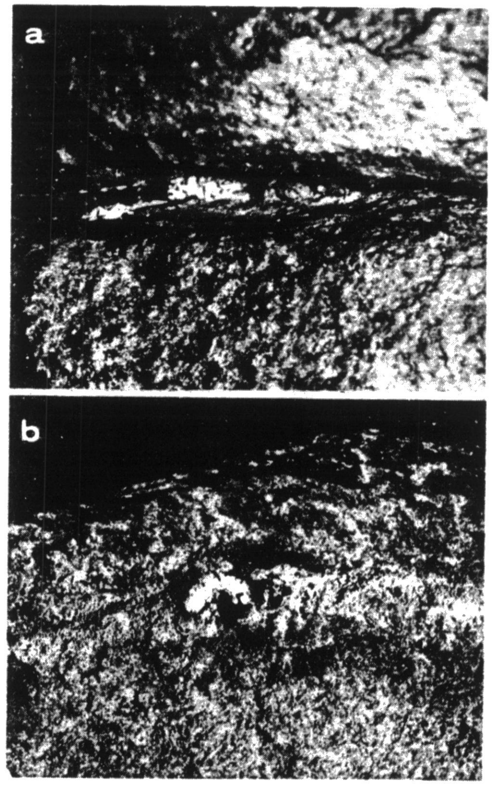


**Figure 2. *Buellia* sp. growing in coarse crack of a Ferrar dolerite boulder. a) surface view, b) lateral view, after splitting open the rock. Top of Finger Mountain. X 1.5.**

# Ecosystem comparisons of oasis lakes and soils

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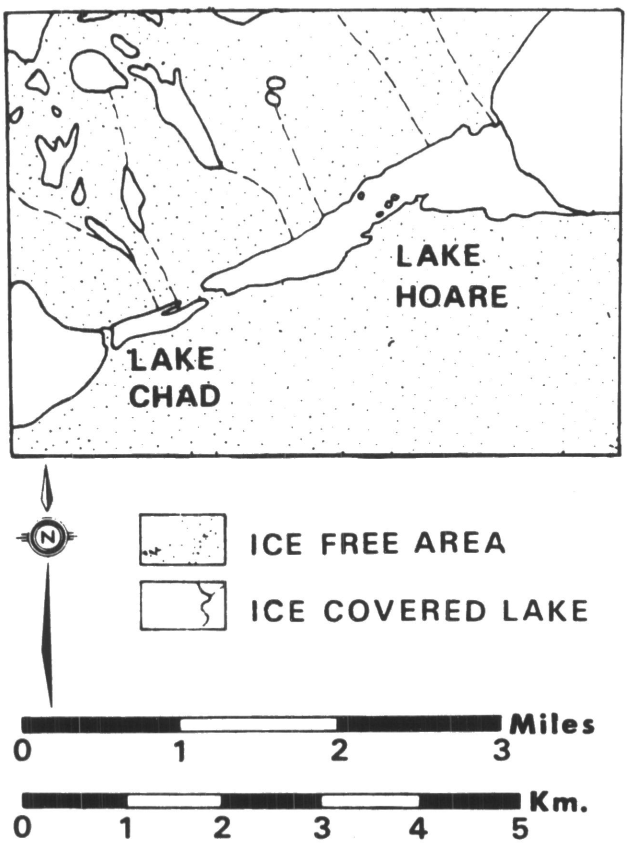
The major objectives of Project ECOLS (Ecosystem Comparisons of Oasis Lakes and Soils), now completing its third and final year, were (1) to assess the trophic status of southern Victoria Land lakes and their associated soils and glacial meltstreams, all located within a small geographic area, and (2) to identify some of the ecological causes for any trophic differences. During the first year (1977–78), 11 aquatic ecosystems were examined (Parker and Simmons 1978) and found to have strikingly different trophic states.

During the second year (1978–79), we focused on two adjacent lakes in the lower Taylor Valley, Fryxell and Hoare (77°38'S 162°53'E), separated only by the width of the Canada Glacier (Simmons, Parker, Allnutt, Brown, Cathey, and Seaburg 1980). SCUBA diving beneath the 5- to 6-meter permanent ice covers of these lakes revealed that the lake bottoms were extensively covered by thick blue-green algal mats.

During the third year (1979–80) all research was concentrated on Lake Hoare, a small (approximately 1.8 square kilometers), but deep (maximum depth = 31 meters) lake located just west of the Canada Glacier in Taylor Valley (see figure). The permanent ice cover of Lake Hoare averages 5.5 meters in thickness and the lake surface is approximately 58 meters above sea level. Unlike several of the more intensively studied lakes (e.g., Vanda, Bonney, Fryxell) of the southern Victoria Land oasis, Lake Hoare is not saline, nor is it chemically, thermally, or biologically stratified throughout much of its depth. It contains no hypersaline monimolimnion and is supersaturated with dissolved oxygen down to approximately 27 meters, below which there is an anaerobic bottom zone rich in hydrogen sulfide ($H_2S$). The two basic types of biotic communities in Lake Hoare are the plankton, consisting of algae, bacteria, and a few protozoans, and the benthic, attached algal mats. The dominant taxon in the sparse phytoplankton community is the cryptophyte, *Chroomonas lacustris*. Planktonic diatoms are noticeably absent (Seaburg, Parker, Prescott, and Whitford 1979), though dissolved silicic acid is abundant. The under-ice benthic algal mats contain numerous pennate diatoms and are dominated by the blue-green alga, *Phormidium frigidum*. Only in the glacial meltstreams or shallow ice-free moat areas around the edge of Lake Hoare are several species of heterocystous blue-green algae (Seaburg et al. 1979) important. SCUBA diving has confirmed that these attached algal mats extend from the lake surface into the anaerobic $H_2S$-rich ooze at 31 meters.




**Lake Hoare, west of the Canada Glacier, in Taylor Valley, South Victoria Land, Antarctica (77°38′S 162°53′E).**

Several factors that limit and/or probably control community structure and function in the lake have now been studied in some detail. The ice surface of Lake Hoare is covered with soil, rocks, and algal mat pieces; this reduces the light transmission through the 5.5-meter-thick ice cover. Only 0.3–0.5 percent of incident surface photosynthetically available radiation (PAR) reaches the water. Nonetheless, the eukaryote phytoplankton and algal mats occur at least to depths of 25–27 meters, at which the PAR is 0.01–0.02 percent of surface light. Therefore, a maximum of approximately 0.13–0.38 micro-Einstein per square meter per second reaches these depths for short diurnal periods during the 10-week austral summer. Thus, this depth of 25–27 meters apparently approximates closely the compensation point depth for net photosynthetic oxygen production.

Obviously, photosynthesis is limited by available light, as $^{14}C$ (carbon-14) primary productivity values decreased with increasing depth below 12 meters in both the plankton and benthic communities. In one experiment, algal mat collected at a depth of 9 meters was then incubated at various depths in the lake. At 10 times the normal light, productivity was 8 times that at 9 meters; at 100–200 times the normal light, productivity ceased, presumably because of photoinhibition; at greater than 9 meters, mat pieces exhibited little or no photosynthesis.

In laboratory growth experiments with unialgal cultures isolated from this and other lakes of the area, Seaburg (1979) has shown that a high proportion of the plankton algal species are either obligately cold-adapted (i.e., growing well at 5°C, dying at 20°C) or facultatively cold-adapted (i.e., growing well at 5°C but also growing at 20°C or greater). In contrast, the proportion of obligately cold-adapted algae from algal mats, littoral water edge, lake edge soil, and meltstream communities is significantly lower than that collected in the plankton.

One $^{14}C$ primary productivity experiment on benthic algal mat material from Lake Hoare showed that after freezing at −20°C and then thawing, mats were immediately capable of photosynthetic incorporation of $^{14}C$ into organic matter at a rate at least 10 percent that of the normal rate. This result adds to earlier findings (Holm-Hansen 1967) that algal isolates from this region generally display a greater viability following freezing than similar taxa isolated from Wisconsin habitats.

*In situ* $^{33}P$ (phosphorus-33) uptake studies of plankton and algal mats at Lake Hoare have confirmed that phosphorus is one of the more severely limiting nutrients in these ecosystems. The calculated half-saturation constants ($K_s + P_o$) are consistently greater than 5 times the measured dissolved $P_o$ values (i.e., 1–3 micrograms of phosphorus per liter). Since the maximum uptake rate of phosphorus ($V_m$ax) is suboptimal in Lake Hoare, phosphorus is limiting. However, in the anaerobic bottom layers below 27 meters, much higher $P_o$ values have been found.

As in 1977–78 and 1978–79, *in situ* acetylene reduction was detectable in glacial meltstreams and lake-associated pool and moat areas where ammonia Nitrogen ($NH_4^+$-N) levels are usually 0–6 micrograms per liter and the heterocystous blue-green algae *Anabaena* and *Nostoc* are found (Allnutt 1979). As shown earlier, no detectable acetylene reduction occurred in the plankton or the under-ice benthic algal mats (Allnutt 1979) which are bathed in water containing about 40 micrograms $NH_4^+$-N per liter.

Experiments during the 1979–80 austral summer verify that seiches do not occur in Lake Hoare, indicating that the permanent ice cover nullifies wind-generated water turbulence. Therefore, the absence of diatoms in the plankton may be a result of their inability to remain buoyant without the passive upward movement created by wind-generated turbulence, as has been shown for marine plankton diatoms (Smayda 1970). In contrast, the dominant phytoplankter, *Chroomonas lacustris*, is a flagellate that may be a strong swimmer.

In all but the few meters of anaerobic bottom water, the lake water is supersaturated with $O_2$ (24–51 milligrams per liter), contains little available $CO_2$ (0–30 milligrams per liter), and has a pH range from 7.7 to 9.2. High $O_2$, low $CO_2$, high pH, nutrient limitation, and bright light favor ribulose bisphosphate oxygenase activity and inhibit RuBP (ribulose bisphosphate) carboxylase activity (Tolbert 1974). Except for the lack of bright light, this environment should favor the inhibition of photosynthetic $CO_2$ fixation and stimulate the glycolate pathway. In all *in situ* and laboratory primary productivity experiments during the 1979–80 field season, samples were processed for both sestonic (cellular) and extracellular (dissolved) organic carbon. In all studies, less than 50 percent of the total organic photosynthate occurred in the sestonic fraction, comparing favorably with data for Lake Bonney which once had about 90 percent of its labeled photosynthate in the dissolved fraction (Parker, Hoehn, Paterson, Craft, Lane, Stavros, Sugg, Whitehurst, Fortner, and Weand 1977). Although the $^{14}C$ extracellular products have not been identified, $^3H$ (hydrogen-3) -labeled glycolate, as well as certain other dissolved organic substrates at low *in situ* concentrations, are assimilated by plankton and benthic mat organisms.

As Wilson (1979) has noted, "the salt and lake geochemistry of the McMurdo dry valley area . . . is far from being understood and there is a lot of apparently conflicting evidence . . . . " (pp. 205–206). Possible causes of salt inputs and outputs to the lakes include seawater incursions, sea spray, glacial meltwater, precipitation, groundwater, weathering of rocks, and precipitation of salts. Also, Wilson has described the relative deliquescence of various salts or the fractionation of salts in soils of the dry valleys in response to different relative humidities as a major salt input mechanism.

An important, biologically mediated output mechanism is the loss of select ions and chemical constituents when the benthic algal mats, which have incorporated chemicals through active uptake or through sediment binding, escape annually from the lakes through the ice covers. During the 1979–80 austral summer studies at Lake Hoare, an estimated 10 percent of the lake's benthic algal mat, the portion located in the shallower, brightly lit area under permanent ice, developed entrapped gas, determined to be mostly oxygen. This gas causes the mat to lift off and, by the mechanisms mentioned earlier, passively move through the ice cover, eventually to be blown away. In this way salts and nutrients are lost from the lake; the confinement of this process largely to the shallower sub-ice aras may even contribute to chemical stratification over long periods. Analyses of various elements in mats collected from Lakes Chad, Fryxell, and Hoare during 1978–79 show that the potentially escaping mat pieces contain large amounts of many elements (e.g., silicon, carbon, oxygen, hydrogen, aluminum, calcium, iron, magnesium, nitrogen, potassium, sodium, phosphorus, sulfur, chlorine). Such an apparently insignificant mechanism takes on added importance for many of the lakes of southern Victoria Land because of the restrictions placed on nutrient movement by the permanent ice covers.

The benthic algal mats may be described as "organosedimentary structures produced by sediment trapping, binding, and/or precipitation as a result of the growth and metabolic activity of microorganisms, principally cyanophytes" (p. 1). This is Walter's (1976) definition for stromatolites, those curious fossilized remnants of Precambrian times. Therefore, a unique assemblage of living, cold, freshwater stromatolites has been found in Lake Hoare; further study of these is currently underway.

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# Environmental "homeothermy" in an antarctic insect

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While the evolutionary basis of insect freezing adaptations remains unknown, we now know that temperate, alpine, and polar species demonstrate similar mechanisms (Baust and Edwards 1979; Baust and Morrissey 1977). Three basic survival strategies have evolved. First, insects may be tolerant to the presence of extracellular ice for prolonged periods (Salt 1961) and simultaneously accumulate high levels of cryoprotective agents (i.e., polyols and/or low molecular weight saccharides). Second, some species avoid extracellular ice formation by extended supercooling (SCP) (Baust, Grandee, Condon, and Morrissey 1979). The extension of SCP is also accomplished by the accumulation of antifreeze compounds identical in nature to cryoprotectants. The third mechanism has an ontogenetic component and involves a sequencing of the first two strategies. During certain larval and adult stages, a species may be capable of extended SCP as an avoidance mechanism, while during other stages it may be freezing-tolerant (Baust and Morrissey 1977).

The antarctic insects would be expected to utilize one of these basic mechanisms to ensure survival. Annual ambient air temperatures fluctuate between austral summer highs of 10°C to winter lows of −40°C (Palmer Station, 64°46′S 64°03′W). Resident terrestrial ectotherms must therefore develop under continual "winter" conditions. One species, *Cryptopygus antarcticus* (Collembola), uses the avoidance mechanism (Sømme 1979). However, a second species, *Belgica antarctica* (Diptera), only partially conforms to these strategies. *Belgica antarctica*, the only free-living, holometabolous insect of the antarctic continent, does not demonstrate the adaptative capacity necessary for survival following predicted low temperature extremes (−30°C).

During the course of a three-season study, supercooling points (SCP) were observed not to vary (−5.4° ± 0.20°C) (figure 1). Attempts to induce changes in SCP by thermal

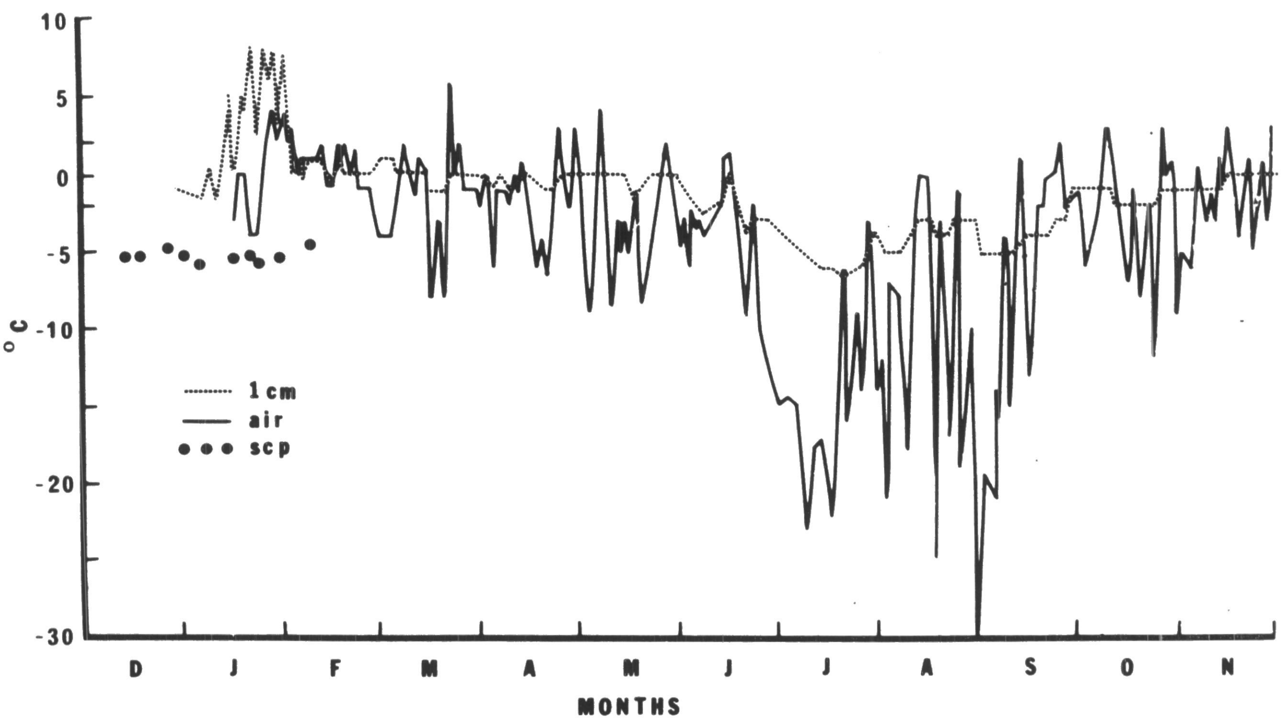


**Figure 1. Annual variations in air and microhabitat temperatures and supercooling points (SCP) of larval *Belgica antarctica* (1978–79).**