

Effect of Rock Size, Distance and Age on the Biodiversity of
Lower Copper Creek Area Lichens:
A Test of the Theory of Island Biogeography

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Abstract

This study analyzed the species richness and abundance of lichens along Copper Creek, Gothic, CO., in relation to boulder size and distance from a source, in an attempt to illustrate the theory of island biogeography. Mine tailings were also sampled to determine the colonization and growth rates of lichens in the 120 years since they were created. Boulders of various ages, sizes and distances were measured for species richness and relative percent surface coverage. A slight relationship was found between size and number of lichen species present, but none between boulder distance and species. No significant difference was found at mine sites, either between tailings and bedrock, or between sites and the undisturbed scree slopes or boulder fields I analyzed for the body of my study. The general lack of statistical differences may simply be due to these hardy organisms' excellent ability to disperse, colonize and persist in their boulder 'island' habitats.

Introduction

Lichens are a fascinating group of organisms whose ubiquitous nature and colorful patterns on local geologic features makes them hard to miss and easy to appreciate. They are distributed worldwide in just about every habitat and microclimate. They are an obligate symbiotic association between a mycobiont; ~98% of which are ascomycete fungi, and a photobiont; ~90% of which are chlorophyte algae, 10% are cyanobacteria (St. Clair 1999). While there are about 15,000 species of lichen identified to date, most of this diversity comes from a wide variety of the fungal partner, there are only about 30 different types of photosynthetic partners. The mycobiont provides the physical thallus for the partnership which houses and protects the algae, and uptakes some minerals from its substrate. The photobiont provides sugars and vitamins through photosynthesis and amino acids through atmospheric nitrogen fixation. The association is not a perfectly equal mutualism as was previously thought. As Brodo et al (2001) puts it 'fungi have discovered agriculture' in that they are able to house and grow the algae and

harvest them as well. But the algae's life cycle reproduces their cells faster than they can be consumed by the fungi, so the association persists.

The fungal partner produces unique secondary chemical compounds thought to play important ecological roles (Ahmadjian, 1986) which may include microbial and grazing inhibition, both may be responsible for lichen's ability to live thousands of years. The 600 or so known compounds also aid in the chemical weathering of the substrate which not only allows the lichen to uptake certain minerals but also contributes to local soil formation. The pigments also serve to screen the algal partner from harmful U.V. rays and aid in temperature regulation.

Growth of most species is extremely slow, often only 1% annually, and is dependent upon sunlight, moisture, pH, temperature, stability and mineral nutrients (St. Clair 1999).

Lichen's economic importance goes back thousands of years, having been used by various cultures as antibiotics, expectorants, food, textile dyes, clothing, absorptive purposes, alcoholic beverages, perfume bases, fixatives, liquid thickeners and even in landscaping (Hale, 1969).

Lichens have important ecological roles as well. They serve as the primary winter food source for caribou, reindeer and the northern flying squirrel. Many birds use them as nesting material. Lichen serve as camouflage as well. They are important pioneers in the successional process, for they can colonize areas with little soil, water or nutrients and their tiny reproductive propagules can travel far and establish most anywhere they land (Brodo et al 2001)

During the last 150 years, researchers discovered that lichen growth and health is extremely sensitive to man-made air pollution, especially sulphuric and nitric acids, ozone, fluorides, copper, lead and zinc (Insarova et al, 1992) and this quality has been used successfully to monitor and improve air quality.

Previous studies on lichens at RMBL have been few and far between. Refsnider (2002), a geology student, used the ubiquitous, lime green *Rhizocarpon* to measure ages of local rock glaciers. It grows initially at a rate of 14 mm/year during first 100 years and 3.3 mm/year thereafter. He dated the rock glaciers in the area of Copper Creek, where I conducted my study, to be between 1,220-2,040 years old.

The current study aims to characterize the species richness and evenness of local lichens and relate their distribution patterns to the theory of island biogeography. This theory, set out by Mac Arthur and Wilson (1967), is one of the most familiar and oldest in the biological sciences. It proposed that the total number of species on an island was directly proportional to the island's age, size and distance from other similar islands. Two of the more familiar examples include the Galapagos and Hawaiian island groups. Since 1967, island biogeography theory has been applied to habitat islands as well, such as the isolated alpine zones of Nevada's basin and range lands. The habitat island I will be considering in this project are the isolated boulders in the Gothic region, inhabited by a rich diversity of native lichen species.

As Mac Arthur and Wilson (1967) did, I focused on the ability to predict the number of species based on boulder 'island' size and proximity to each other and to a scree slope, which I have determined is the largest and most stable lichen habitat in the area and thus will serve as my functional 'mainland'. My specific hypothesis asked whether the size of a boulder 'island' and its distance from boulders and the 'mainland' scree slope affect the number of species of lichen on it? My null hypotheses include: 1) No difference in number of species or relative percent cover in relation to boulder size, 2) No difference in number of species or relative percent cover in relation to their distance from each other and the mainland scree slope, 3) No relationship

between the area sampled on individual boulders and the number of species of lichen. This will demonstrate most directly the link between island size and species number.

My alternative Hypotheses include: 1) There will be a direct linear relationship of increasing numbers of species and relative percent cover as boulder size increases, 2) There will be a direct linear relationship of increasing numbers of species and relative percent cover as distance between boulders decreases, 3) There will be a direct linear relationship (on a log log scale) of increasing numbers of species as the sample area per boulder increases. Lastly, I hypothesize that there will be greater species diversity and percent coverage on mine site bedrock compared to mine site tailings.

Materials and Methods

My study site was located along the ridge northeast of Copper Creek Trail above the Rocky Mountain Biological Lab in the Maroon Bells Snowmass National Forest Wilderness Area of Gunnison County, Colorado (see attached map). The ridge forms the northern slope of the Copper Creek watershed and is vegetated Aspen and Spruce/Fir forests interspersed with rocky dry open meadows. This study was conducted from July 28-August 8, 2004 with a total of approximately 14 hours in the field.

First I surveyed two mine sites created in the 1880's. I ran a transect along the bedrock above the mines and the tailings below the mines and chose rocks at one meter intervals where I measured the size of the rock and identified the species and their percent coverage. This was done in an attempt to date the colonization and growth rates of the lichens and see which species

were able to colonize first. I chose to make the bedrock quadrats 100 cm² since they were continuous habitat, not individual rocks.

Next I visited a large boulder field, also known as scree slopes or rock glaciers to represent my 'mainland' habitat, which I presumed to be the largest continuous habitat as well as the most stable and oldest. I believe this is the site that Refsnider (2002) dated with lichonometry to be between 1,220-2,040 years old. I ran a 15 meter transect up the slope and again surveyed the species at one meter intervals. I chose to use 100 cm² quadrats again because even though the habitat did consist of individual boulders, from the biological standpoint they appeared to be so closely packed that it was as if they were one continuous habitat like the mine bedrock sites.

Next, I visited the large meadow along the jeep trail before it makes the first crossing of Copper Creek. Here, there are many boulders with a wide variety of sizes from several centimeters to several meters wide which I surveyed to represent my 'island habitats'. I randomly chose 10 boulders of varying sizes and surveyed them. In order to determine a species/area curve I chose two large boulders and ran 2 cm wide transects across them and took 10 4cm² samples. This was done not only to determine my minimum sample number to adequately characterize the community (as suggested by Brower et al 1990) but to make a connection between size and number of species as a second way to illustrate the idea of island size. In general, my replicate size was 10 boulders or quadrats. Replicates help to determine if there is more variation between replicates than between sites

Then, I sampled a scree slope above this site, where I ran a transect upslope, sampling 100 cm² quadrats every five meters for 150 meters. Lastly, I ran a transect downslope from the edge of the slope and sampled 30 boulder 'islands of various sizes for their species and their distances from this slope.

In general, for each boulder and slope location, I measured the area, identify the lichen species (using Corbridge, Hale and St. Clair), and measure each species' relative percent coverage. For my species/area curve transects, I kept track of the cumulative number of species vs. cumulative area samples so I could create a species-area curve as described in Brower et al. (1990).

I took digital photograph of each site and examples of the variety of boulders sampled and took close-ups of each lichen species. I also made a reference collection of each lichen species by finding examples of each lichen inhabiting rocks small enough to carry out.

On August 10-13 I conducted the analysis portion of my study and wrote the final draft of my paper. I subjected my data to statistical analyses to address my three main hypotheses : For my first two hypotheses, regression was used to relate species number to both boulder size and boulder distance. Then I made a species-area curve graph. I analyzed community similarity by using the Jaccard coefficient of community (Brower et al 1990), which is simply determining the percent similarity between sites.

Results

In total, I sampled 130 boulders at five sites, identifying 16 lichen 'morpho'species. Nine were the crustose thallus form and these had the highest coverage and frequency, while seven were foliose thallus form. In my 13 samples, I found an average of 7.3 species (sd=1.5). Figure 1 shows a graph of species found and their relative abundances, that is what percent of the 13 samples they were found in. Figure 2 shows the analysis of the relationship between number of species and size of boulder. Notice the F statistic is significant (0.0068). Figure 3 shows the

analysis of the relationship between number of species and distance of boulder from the 'mainland' . In this case, the F statistic is not significant (0.4467).

In conducting my transects to determine the species/area relationship, I found that very few samples were needed to adequately characterize the lichen species present. Usually a 10 cm² quadrat size was large enough to 'capture' 90% of the species on a boulder, regardless of whether that boulder was 10 cm² or 10,000 cm² size!

My historic mine sites did show some differences in diversity. The pair of sites each shared an average of just 56% of their species between the 120 year old tailing boulders and the undisturbed bedrock above. The overall lichen coverage was slightly different as well, with an average of 36% bare rock on the tailings vs. 18% bare rock on bedrock, which was to be expected.

There was little difference between diversity and coverage between my mainland scree slopes and my boulder fields. Each had a mean of 7.5 species , and nearly 100% of the species in common (just one boulder had Rust species- known to be found in nitrogen enriched environments like rodent burrow entrances.

Discussion

Although few of my results were statistically significant, they were not biologically insignificant, in fact quite the opposite is true. Lichens are the ultimate example of a group that has both excellent dispersal and colonization rates while having very low extinction rates. These are the deciding factors in Mac Arthur and Wilson theory of island biogeography.

Lichens have long distance dispersal mechanisms, being that both their sexual and asexual reproductive propagules are so tiny and easily carried in the wind. Once they settle on an

appropriate surface, of which they are not picky, they are quite hardy to extremes in temperature, wind, light and other environmental factors. They are the ultimate primary succession colonizers being that they do not need soil development, getting all their nutrients from the sun, air and from chemically weathering any geologic surface they attach to. Lichen islands can also be quite small and distant but still have richness because of the above characteristics. This differs from many species that inhabit true islands, and is one of the many reasons for the high extinction rates we see around the globe on oceanic island habitats.

In terms of species evenness, my lichen communities followed a common pattern found in nature, where a few species are the naturally dominant ones while the majority are uncommon or rare. For example, Lime, Smoke and Boots species were found at every site, while 5 other species were found at just one site each.

My species area curves demonstrated that I had more than enough samples to adequately characterize my sites, including surveying the rarest species. The fact that the lichens are quite evenly distributed over the rock surfaces show that they can establish and grow on top of one another are not limited by resources particularly.

Given that lichens are thought to have such slow growth rates, it was interesting to see their hardy development on the mine tailing sites, and their lower coverage there is probably just due to the small size of the 'islands' that no doubt get jostled about during the winter months.

Now that my project is finished, I have considered several ways I could have improved it. Of course identifying each morphospecies to a true species would be a good start. Adding more sites and samples is always a plus. I believe the best way I could have demonstrated the theory of island biogeography better would have been to expand my study area, so that my 'mainlands' would be entire mountain ranges, such as the West Elks or the San Juans, which, unfortunately

due to the limited scope and time of this assignment, was not realistic. Lastly, in order to get a better handle on the factors that contribute to their abundance in relation to island biogeography theory, one would have to explore lichen dispersal, colonization and extinction rates.

I believe there are many opportunities for future studies here at The RMBL on local lichen communities that have apparently been thus far ignored. The lichen flora in the Rocky Mountains is rich and diverse. One could explore the effects of geology, elevation, aspect, exposure and plant community on lichen diversity. Since lichens have traditionally been used as indicators of air quality, one could do some baseline studies of the occurrence and health of indicator species, especially since the Rockies are experiencing high population growth.

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