Soil Ecology of a Lichen Heath at Spitsbergen, Svalbard: Effects of Artificial Removal of the Lichen Plant Cover.

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Abstract

The Norwegian MAB project conducted research on the possible effects of overgrazing in winter pastures of the Spitsbergen reindeer (*R. tarandus playtyrhyncus*, Vrolik). In a 25-m² area of a lichen heath at Svalbard, (79° N, 12° E), the lichen plant cover was artificially removed. This was done to simulate the effects of heavy grazing, resulting in the disappearance of the lichens. The experiment resulted in a significant decrease in total soil respiration. A corresponding effect was found on the population development of the *Collembola* species *Hypogastrura tullbergi* (Schaffer). This species may, therefore, be a good indicator as to the long-term effects on soil microflora. It is also shown that the population development of the different *Collembola* species is not regulated through *Aranea* predation. The removal of the lichen plant cover did effect a decrease in the soil content of organic matter and macronutrients.

The lichen heaths of Spitsbergen (Brattbakk and Rønning 1978) represent important pastures for the Spitsbergen reindeer. Ruminant grazing has, however, in many areas of marginal rangeland, resulted in overgrazing, and consequently in increased run-off and ultimately in soil erosion and loss of nutrients (Lusby 1970, Rauzi and Hanson 1966). In areas where the potential of plant production exceeds the rate of decomposition, plant production will be regulated through the availability of essential nutrients. In such systems, it is the activity of the decomposers that regulates the whole system's productivity (Macfayden 1962 a).

In relation to these statements, it has been shown that reindeer, through their total grazing effect, i.e. ingestion and trampling, dislodged 68% of the lichens present during one summer season (Peagu 1970). In this case after one summer of grazing, 15% of the lichens were considered unusable because of trampling by reindeer (Pegau 1970). Trampling may further result in increased bulk density and consequently in decreased porosity of the soil (Smeins 1975). This may result in a reduced ability of water to penetrate into the soil. Consequently the surface run-off is increased (Rauzi et al. 1968).

These changes in the properties of vegetation and soil are also reflected in the decomposer activity in the soil. It has been shown that heavy grazing may cause a decline in soil respiration (Howard and Howard 1976) and also a reduced abundance of microbial grazers such as the *Collembola* (Willard 1973). It has also been recorded that changes in rates of decomposition affect the litter layer (Welch and Raws 1964).

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These general statements may be of considerable concern to the management of the reindeer population on an arctic island such as Spitsbergen. This population relies during the winter on pastures that are extremely vulnerable, both as a consequence of the lichen plant cover and the concentrated run-off of melt water in the spring.

A subproject of the Norwegian "Man and the Biosphere" (MAB) programme has, therefore, been concerned with the immediate effects on soil ecology caused by an artificial removal of the lichen heath.

Methods

The lichen heath tested is located close to Ny Alesund in Spitsbergen (79° N, 12° E). The lichen cover is dominated by *Cetraria delisei*; this range type is described by Brattbakk and Rønning (1978) from the point of view of plant sociology.

On this site an area 25 m² was cleared of lichens. The effects on total soil respiration were registered by an infra red gas analyser. The respiration studies were conducted at +5° C and 32% water content of the soil samples, in a static experimental procedure. The respiration rates are calculated as mg CO₂/m²hr and concern the total respiration of soil samples with a diameter of 5.5 cm and 3 cm deep.

From corresponding samples, soil arthropods were extracted in a high gradient extractor (MacFayden 1962 b). Data are here given as mean estimates based on twelve replicas in each sample.

The experiment started in the summer 1976 and has been recorded up until the end of the summer 1979.

Fig. 1. Rates of respiration in the natural lichen heath and in a test site where the lichens were removed in 1976. Respiration data is from the summer, 1978. Respiration temperature +5° C.

Fig. 2. Number of Collembola ($\pm$ SE) in the control and the test site. Test site; the lichen cover removed.

Results

Soil respiration in a natural (control) site of the lichen heath, during summer 1978, is estimated to have been between 40–96 mg CO₂/m²/hr at 5° C and 32% H₂O. This estimate gives the limits of the 95% confidence interval. This estimate is comparable to data given by Billings et al. (1977). There, total soil respiration in more humid soils in Alaska was estimated to produce 75–300 mg CO₂/m²/hr over the summer season.

The effect on soil respiration of removing the lichens is shown in Figure 1.

Figure 1 shows a significant decrease in total soil respiration (significant at the 10% level). The mean estimate declined from 68 mg CO₂/m²/hr in the control area to 35 mg CO₂/m²/hr in the treatment area.

As an indication of the effects on the soil zoological community, the results from the study of *Collembola* are shown in Figure 2. It can be seen that initially there was a decrease in *Collembola* abundance. From the end of the 1977 summer, an increased *Collembola* abundance was found, however.

When the data in Figure 2 are divided into individual species, it is demonstrated (Fig. 3) that the removal of the lichens has produced different effects for each of the two dominating *Collembola* species at the site: *Folsomia quadrioculata* (Tullberg) and *Hypogastriura tullbergi* (Schäffer). These two species account for about 95% of total *Collembola* abundance at the site.

The total effect of removing the lichen plant cover on soil erosion are shown in Table 1. A decrease in the content of organic matter and macronutrients after 4 years is demonstrated.

Discussion

These results clearly demonstrate that a severe grazing intensity

that totally alters the plant cover may also severely affect the ecology of the soil. It is shown that the removal of the lichens resulted in a 50% decrease in soil respiration. This, I am inclined to conclude, will affect the rates of release of essential nutrients for further plant production.

The effects of the experiment on the two *Collembola* species (Fig. 3) might also have a reasonable explanation. The decreasing species, *H. tullbergi*, is known to be a fungi grazing animal (Addison 1977). While the representatives of the genus *Folsomia* are reported to be primary decomposers (Whittaker 1974).

The results therefore indicate that the soil biota live together in complex relationships. It may be concluded that, while *F. quadrioculata* in many ways may be unaffected or even negatively affected by an actively growing soil microflora, the other species *H. tullbergi* may turn out to be a relatively good indicator of the long-term activity of the soil microflora in these areas. These kinds of indicators in connection with soil ecology might be useful because the measurement of long term microbial activity is difficult and extremely time consuming.

Table 1. Chemical content of soil. Data after 4 years of exposure. Data are mean estimates, each based on a mixed sample from five replicas.

Parameters	Dry matter (%)	Loss of ignition (%)	N (Kjeldal) (%)	P (%)
Test site				
Control	64.9	16.3	0.72	0.063
Lichen cover removed	66.8	12.8	0.32	0.056

Fig. 3. Relative effects of an artificial removal of the plant cover for two dominating *Collembola* species of the lichen heath.

The use of biological indicators is, however, a complex matter. It may be argued that the results merely are a consequence of different responses to predation, or changes in the abiotic environment.

As to the effect of predation on soil animals, a theoretical predation pressure by *Aranea* has been calculated for the test site (Hegstad 1978). Here, it is shown that *Aranea* is only able to utilize 1% of the standing crop of *Collembola*. It therefore seems reasonable to conclude that the population development of the *Collembola* is not influenced by *Aranea* predation.

As to the question whether the variation in *Colembola* abundance in this experiment is a direct result of alterations in the abiotic environment, some data pertinent to the problem are shown in Table 2.

As can be seen, the water content does not vary significantly. There is however a slight decrease in the soil water content at the test site. Further, there are some differences in the mean temperature for the summer season. The temperatures have increased on the ground level where the lichens were removed, that is, on the test site. On the other hand, temperatures deeper in the soil profile have decreased. These results probably reflect the variations in the total heat flux on the black soil surface on the test site, in contrast to the insulated surface on the control site. It is unlikely that these relatively small changes in the abiotic environment directly should

affect the population development of the *Collembola* species. If, however, the slight decrease in the water content nevertheless affects the *Collembola* abundance, the two dominating species should respond in the same way. Correspondingly, if the variations in soil temperature directly affect the population development of the different *Collembola* species, the variations should be most beneficial for the more typical surface dweller, *H. tullbergi*. Since the two dominating *Collembola* species respond to the changes in the abiotic environment in the opposite way, I am apt to conclude that the explanation may be found in their biotic environment.

In this context it is of interest to understand the functional relationship within the soil detritus food chain. Based on biomass estimates (Sendstad 1977, 1978), it is possible to calculate the energy the *Collembola* need to consume, in order to maintain their biomass (Reichle 1969). The food consumption of the *Collembola* community is calculated according to the formula:

$$y = a \cdot x^b$$

where:

y = cal. consumed/specimen/day.

x = cal. content/specimen

a = 0.071

b = 0.725 (Reichele 1969).

The results corrected for a temperature range between +5 and +15°C, $Q_{10} = 1.60$ (Harding and Stuttard 1974) are shown in Table 3.

These estimates of microbial grazing may be compared to data for the microbial biomass at the site. Based on the assumption that 1 Kcal is needed to produce 0.12×10^{-3} kg microbial mass (Odum 1971), it is possible to calculate the microbial production of the site during the active growing season. Soil respiration of the lichen heath is estimated or to be approximately 432 Kcal/m²/year

Table 2. Mean temperatures and water content of the soil in the lichen heath, summer season 1978.

Climatic factors	Control site	Test site
Water content %±S.E.	35.5±2.3	32.9±3.2
Mean temperature at ground level (°C)	6.8	8.0
Mean temperature at -2 cm level in the soil (°C)	9.3	8.4

Table 3. Food consumption in the *Collembola* community of an unaffected lichen heath at the Brøgger peninsula, Spitsbergen. Data given for +5 and +150° C.

Species	Food consumed
<i>F. Quadrioculata</i>	12.0 – 19.1 Kcal M ⁻² year ⁻¹
<i>H. tullbergi</i>	0.7 – 1.1 Kcal m ⁻² year ⁻¹
Other <i>Collembola</i>	1.2 – 2.0 Kcal m ⁻² year ⁻¹
Σ <i>Collembola</i>	13.3 – 22.2 Kcal M ⁻² year ⁻¹

(Sendstad 1978). If a root respiration of approximately 50% is assumed, then 216 Kcal/m²/yr is liberated by the heterotrophic food chain each year. This implies that approximately 26 g microbial mass have been produced on this site. In energy terms this means approximately 130 Kcal. Compared to the data given in Table 3, it can thus be seen that the *Collembola* ingests between 11% and 17% of the microflora production.

The *Collembola* community is estimated to represent about 70% of the total detritovores/fungivores invertebrate biomass of the unaffected lichen heath (Sendstad 1978). If the data for *Collembola* consumption are extrapolated to the whole fungivores/detritovores biota, the total ingestion of these invertebrates may be estimated to be between 16% and 24% of the microbial production. It is still an open question whether this grazing intensity has any regulating effect on the activity of the soil microflora. These results do, however, show that the heterotrophic foodchain in the soil, in a complicated way, may be affected by artificial changes in the plant cover.

It is finally demonstrated that a removal of the plant cover does promote an overall, loss of organic matter and macronutrients from the pastures (Table 1). Whatever the reasons for these effects, these losses will eventually decrease the potential for plant production. A comprehension of the total effects caused by a destruction of the lichen plant cover must consequently be based on a long-term understanding of soil erosion, combined with an understanding of soil ecology at the site.

The long-term goal of this kind of research will be to see at what level of ruminant grazing intensity, an abnormal rate in the release of nutrients may be experienced, and at what corresponding state we then find the soil heterotrophic food chain. The state of art of soil ecology does not permit us to make any firm statement about the effects of reindeer overgrazing in the arctic tundra. The present data do indicate, however, that we have to be aware of the possibility of a whole spectrum of interactions between the reindeer and its environment.

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Authors Omitted

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