Vegetation Recovery Patterns Following Overgrazing by Reindeer on St. Matthew Island

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Abstract

Heavy grazing by extremely high densities of reindeer *(Rangifer tarandus)* on St. Matthew Island in the Bering Sea resulted in degradation of the lichen stands. Grasses, sedges, and other vascular plants initially increased in response to the removal of lichens under heavy grazing pressure by the reindeer. Twenty-two years following the crash die-off of the reindeer, mosses had invaded large portions of the ground area denuded of lichens, and lichens had recovered to only 10% of the standing crop of living lichen biomass occurring on adjacent Hall Island where there is no history of grazing. Lichen species dominating the recovering lichen stands on St. Matthew Island were those of relatively low preference as forage by reindeer in contrast to those in climax lichen stands.

Key Words: overgrazing, reindeer, lichens, range recovery

The first naturalists arriving at St. Matthew and adjacent Hall islands in the northern Bering Sea commented on the thick lichen mats that were present over much of the lower-lying areas of the 2 islands (Elliott 1882, Marriam 1901). Reindeer *(Rangifer tarandus)* were introduced to St. Matthew Island in 1944 and increased from 29 animals to 6,000 in the summer of 1963 (Klein 1968). They underwent a crash die-off the following winter. Lichens were greatly depleted as early as 1957 (Klein 1959) and strong winds that dominate the island weather were an important factor in removing lichen fragments from the damaged lichen mats. By 1963 lichens were no longer an important component of the winter diet of reindeer (Klein 1968). The degradation of the lichen mat released vascular plants that had been engulfed in it and exposed soil for new plant establishment. Sedges and grasses increased markedly. Palmer and Rouse (1945) in Alaska, Skuncke (1969) in Sweden, and Adreev (1954) in the Soviet Union investigated recovery rates of lichens following heavy grazing. They reported that 30-50 years may be required for recovery, depending on the amount of living tissue remaining after heavy grazing, the nature of the climate, and the influence of vascular plants in the areas affected.

On St. Matthew only a few female reindeer and one infertile male (shot for autopsy, Klein 1968) survived the die-off, and the last survivor is believed to have died in 1982 (A. Sowls viva voce). Since there had been essentially no grazing pressure on the vegetation of St. Matthew Island in the 22 years following the die-off, a unique opportunity existed to examine recovery rates of the vegetation of the island following the period of extremely heavy grazing. During July 1985 vegetation plots, established in 1957, were reexamined and comparative studies were made of lichen and other plant growth on St. Matthew Island. Hall Island was also visited and the ungrazed lichen stands were sampled to obtain estimates of lichen biomass for comparison with lichen regrowth on St. Matthew Island.

Study Area

St. Matthew and Hall islands (60° 15'N × 172° 30'W) in the Bering Sea are components of the Alaska Maritime National Wildlife refuge. They are uninhabited by humans and the vegetation is arctic-alpine with maritime influence, although winter weather is influenced by the surrounding pack ice. A detailed description of St. Matthew Island, its vegetation, and weather has been presented by Klein (1959). Reindeer were introduced to St. Matthew Island by the U.S. Coast Guard as an emergency food supply for personnel stationed there during the Second World War. At the end of the war the station was abandoned. Reindeer increased rapidly on the 332 km² island in the absence of other large herbivores, predators, and humans, reaching densities of 4/km² by 1957, thirteen years after their introduction, and 18/km² by 1963 immediately before their crash die-off. Adjacent Hall Island (23 km²) was not reached by the reindeer and the vegetation there has no history of use by large herbivores.

Methods

In July–August 1957, an investigation of the population dynamics and range relationships of the introduced reindeer was initiated (Klein 1959). Four 1-m² plots were established in each of 2 locations in the lowland areas dominated by lichens that showed evidence of heavy winter use by reindeer. Four additional 1-m² plots were laid out on a low, well-drained ridge dominated by dryas *(Dryas octopetalla)* and prostrate willow *(Salix crassijulis × ovalifolia)*. At each complex of 4 plots, 2 were protected from further reindeer grazing by a fenced enclosure. Vegetation within the plots was mapped in detail and percent ground cover recorded. St. Matthew Island was visited again by the author in July 1963, July 1966, and July 1985. During 1963 and 1985 vegetation in the plots was again mapped as a basis for determining changes that had taken place during the intervening periods. In 1985 all lichens were collected from randomly selected areas (1 m²) adjacent to the lowland complexes of established plots. Similar collections of lichens were made from randomly selected plots in lichen stands on Hall Island. The collected lichens were placed in plastic bags and transported to the University of Alaska, Fairbanks, where they were sorted by species and living versus dead portions, and oven dried until a constant weight was achieved at 40° C.

Results and Discussion

A detailed description of the changes in vegetation that had occurred from 1957, when the reindeer numbered 1,350, to 1963, when the population had peaked at 6,000, was made by Klein (1968). Vegetation plots established on St. Matthew Island in 1957 disclosed that by 1963, when the peak population of reindeer existed on the island, the lichen mat in sites favorable for the growth of lichens had been greatly reduced (Table 1). Only fragments of lichens remained on the ground surface. Although lichens had been largely eliminated as a forage source, sedges had increased substantially by 1963, apparently because previously the thick lichen mat had limited growth of vascular plants by restricting access to light, by limiting the availability of substrate for seedling germination, through insulative cooling of the soils, and possibly by chemical inhibition (Kershaw 1977, Brown and Mikola 1974). Grasses, willows, and forbs also increased in the plots from 1957 to 1963.

By 1985 moss had invaded much of the mineral soil areas left exposed by the removal of the lichens. Although lichen recovery, as

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Table 1. Changes in percent cover in eight 1 m² plots on St. Matthew Island from 1957 to 1985.

Plant Type	Plant cover (±SE$_m$)* 1957	1963	1957–1985	Percent Change 1963- 1963	1985
Grass	0.3 ± 0.10	1.6 ± 0.41	1.6 ± 0.85	+433	0
Sedge	11.2 ± 2.24	16.5 ± 2.04	6.8 ± 0.88	+40	-59
Willows	9.6 ± 2.75	12.4 ± 3.39	12.6 ± 2.48	+29	+2
Lichens	74.4 ± 2.92	12.7 ± 3.26	30.5 ± 7.53	-83	+140
Moss	0.5 ± 0.17	1.1 ± 0.61	35.3 ± 8.51	+120	+3109
Forbs	1.1 ± 0.31	1.8 ± 0.61	2.41 ± 0.58	+64	+33

*The remaining ground cover unaccounted for in these percentages was represented primarily by exposed mineral soil, with lesser amounts of *Vacciuium vitis-idea, Lycopodium selago* and *Luzula* spp.

represented by percent cover, had also increased substantially over the 1963 value, sedges had declined.

Some forbs appeared to have been reduced by the heavy grazing pressure of the reindeer. On plots established on a dry ridge 60 m above sea level *Oxytropis nigrescens* increased from 0.6% (±0.2 SE) ground cover in 1957 to 12.3% (±3.5 SE) in 1985. The purple color of flowers of *O. nigrescens* was particularly apparent on drier sites throughout St. Matthew Island in 1985 in contrast to the impression from previous years. Similarly, *Pedicularis sudetica,* which is known to be a preferred summer forage of reindeer (Wright 1979), appeared to be much more abundant on St. Matthew Island in 1985 than in 1957, 1963, and 1966. Reindeer and caribou select the floral parts of many forb species during early summer (Palmer 1934, White and Trudell 1980, Kuropat 1984) and under intensive grazing they presumably can reduce their occurrence by limiting seed production.

Even by 1957, when the reindeer had increased to 1,350 animals, lichen stands had become severely depleted. In the low dry flats on the southeastern portion of the island where lichens were most luxuriant prior to the introduction of the reindeer (Merriam 1901), broken portions of lichens remaining in 1957 indicated that the stands had been dominated by *Cladina stellaris* and *Cetraria cucullata.* In 1985, the lichen regrowth in these areas was dominated by the brown lichen *Cetraria delisei,* with lesser amounts of *Spharophorus globosus, Stereocaulon* spp., *Thamnolia* sp., and *Cetraria kamczatica.* The mean depth of the lichens was 18 mm in contrast to 75 mm in lichen stands on Hall Island. They were firmly attached to the substrate and consisted virtually entirely of living tissue, whereas on Hall Island 31% of the lichen podetia was dead tissue. Total lichen biomass on a dry weight basis was 35 g/m² (SD=±18), which is 8% of the living biomass or 6% of the total lichen biomass in climax lichen stands on Hall Island. *Cetraria delisei, Spharophorus globosus,* and *Stereocaulon* spp. are characteristically pioneering forms on mineral soil. Comparative species composition and lichen biomass by species are shown for St. Matthew and Hall islands in Figure 1. Climax lichen stands on Hall Island examined in 1985 were dominated by *Cladina stellaris* and *C. arbuscula.* Comparative measurements of the mean depth of the lichens and lichen biomass on St. Matthew and Hall islands are presented in Table 2.

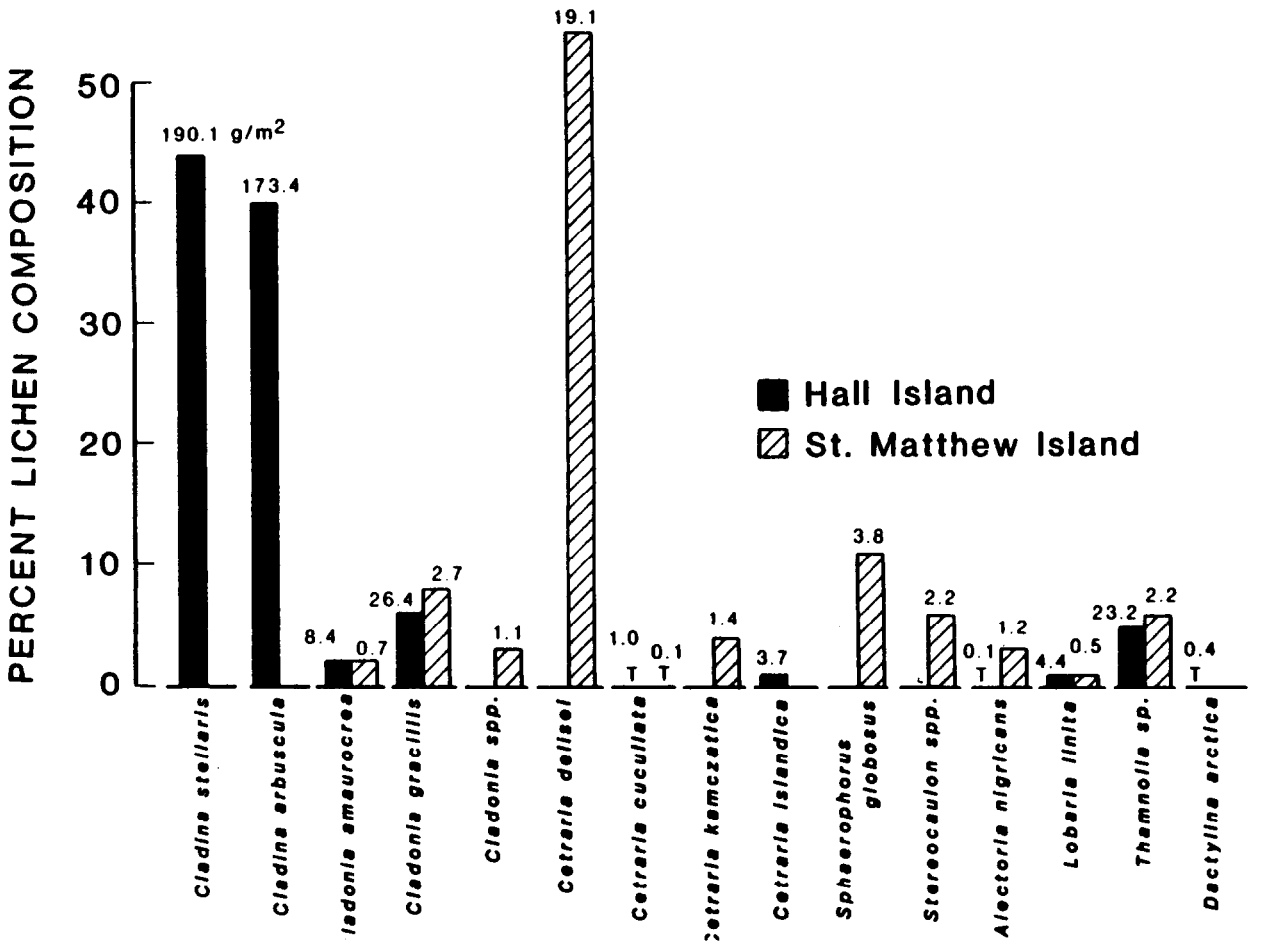

Fig. 1. *Lichen species composition (percent dry weight) and biomass on St. Matthew Island 22 years after extremely heavy grazing in comparison to adjacent and ungrazed Hall Island. Heights of bars are percent composition, values over the bars are dry weight of the living portion of each species in g/m².*

Table 2. Mean length (mm ± SD) and biomass (dry wt. ± SD) of lichens in 1985 on St. Matthew Island 22 years after depletion of lichens through heavy grazing, and in climax lichen stands on ungrazed Hall Island.

Species and location	Length of living podetia (n = 15)	Length of dead base (n = 15)	Lichen biomass (g/m²) (n = 3)
St. Matthew Island			
*Cetraria delisei**	18 ± 3		
All lichens			35 ± 18
Hall Island			
Cladina stellaris	49 ± 4	22 ± 3	
C. arbuscula	54 ± 6	25 ± 5	
All living lichens			431 ± 111
Dead lichen base			119 ± 34
Total lichens			550 ± 144

**Cetraria delisei* was the most abundant and tallest of the lichen regrowth on St. Matthew Island.

The rapid increase to extremely high density of reindeer on St. Matthew Island following their introduction was apparently made possible by the large standing crop of previously ungrazed lichens that existed there. The lichen biomass, however, represented accumulation over many years, through relatively slow growth and in the absence of grazing pressure. The expanding reindeer population was, therefore, exploiting a finite forage resource, only a fraction of which could be replaced through annual growth. This is a classic example of a species undergoing logistic or *r*-type growth while dependent upon plant forms characterized by K-selection.

Conclusions

Twenty-two years after extremely heavy grazing of climax lichen stands by reindeer on St. Matthew Island, lichen biomass had reached 35 g/m². This is less than 10% of the standing crop of living lichen biomass in climax stands on adjacent Hall Island, which has no history of reindeer grazing. Species composition of lichen regrowth following degration by heavy grazing on St. Matthew Island was dominated by *Cetraria delisei,* with lesser amounts of other dark colored lichens. In climax lichen stands on ungrazed Hall Island, *Cladina stellaris* and *C. arbuscula* were dominant species and total living lichen biomass exceeded 400 g/m². The ratio of living to dead tissue was 3.6 to 1. Other studies have shown that the *Cladina* species that dominate climax stands on Hall Island are more highly preferred by reindeer and caribou than the regrowth species that dominated lichen stands previously depleted by heavy grazing on St. Matthew Island (Larin 1937, Karaev 1961).

Among the vascular plants, sedges increased most notably during depletion of the lichen mats from reindeer grazing, but subsequently declined in the absence of grazing. Willows, grasses, and forbs also increased in response to the removal of lichens. An increase in sedges and grasses following heavy grazing of lichens by reindeer in northern Norway has also been reported (Oksanen 1978). Mosses expanded dramatically to occupy areas of mineral soil exposed through depletion of the lichens.

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