Dynamics of alpine ranges and areas utilized by introduced caribou populations on the Kenai Peninsula, Alaska[1]

ABSTRACT

Alpine vegetation in the Kenai Peninsula, southcentral Alaska, was studied in relation to the winter grazing of introduced caribou populations. Vegetation structure differed more from area to area than did the measured environmental variables. Thus, biotic differences (including presence of caribou) may play a more important role in vegetation variation than does the physical environment. Lichens varied more from area to area than did vascular plants. Increased caribou density is associated with a decrease in preferred lichen species and increasing dominance of vascular plants. These results were also compared in a 10-year trends study involving a portion of these ranges.

Keywords: Caribou introduction, lichens, 10-year trends study, cover, macroplot, dominance.

INTRODUCTION

The Kenai Peninsula in southcentral Alaska (Fig.1) historically supported a population of caribou (Porter, 1893; SetonKarr, 1887; Schiefner, 1874; and Palmer, 1938); by the early 1900's caribou populations were eliminated from the peninsula (Palmer 1938). This extirpation has been attributed to both habitat change and human overharvest. Davis and Franzmann (1979) believes the latter is a "more proximate cause of extermination" than the former. To restore caribou populations on the peninsula, cooperative efforts between the Kenai National Wildlife Refuge (KNWR) and the Alaska Department of Fish and Game (ADF&G) have made several introductions on the peninsula. In 1965-1966 caribou *(Rangifer tarandus granti)* from the Nelchina herd, in southcentral Alaska, were introduced on the peninsula (Burns & McKnight, 1973). This population occupied the northern portions of the peninsula. During the month of April in 1985 and 1986, caribou from the same herd were captured and released on the southern portions of the Kenai Peninsula (Bailey, 1985; Bailey, et. al. 1990). These relocation efforts have currently resulted in the establishment of four herds, the Killey River, Fox River, Kenai Mountains, and Kenai Lowland Herds. There were five different herds at one time (i.e., Twin Lakes Herd), but currently there are four as this herd combined with the Killey River Herd. The

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Kenai Mountains population is increasing while the other three herds have all declined over the past 5-8 years. The details concerning the methods utilized for the caribou introductions, monitoring and spatial analysis, and population viability information is presented in Ernst, et. al. 2007 (in-prep).

Two environmental needs of caribou stand out above all others: 1) to escape or find relief from flying insects in the summer; and 2) to find food through deep snow in the winter (Bergerud, 1978). The winter survival of many caribou and reindeer populations living in sub-arctic or northern taiga areas depends on the availability of their preferred lichen food (mostly *Cladina* spp.) (Palmer & Rouse, 1945; Andreev, 1954; Pegau, 1968; Helle & Aspi, 1983). The slow rate of lichen growth is widely recognized. It has been standard practice to keep animal density at a level corresponding to the carrying capacity of the winter range. The winter range has typically been considered as the more limiting forage resource due to snow and other environmental variables that may reduce its availability. They are highly adapted to their environment and highly adaptable (Bergerud, 1978). The only other large mammal that may exhibit some interspecific competition for the caribou range resources is the Dall Sheep (*Ovis dalli*). Although, it has been recognized that the dominance of Dall's sheep diet in Alaska is prefer graminoids (66%) compared to other flora (Nichols Unpublished, <u>in</u> Schmidt and Gilbert, 1978) while the caribou specialize in lichens.

This study documents the vegetation composition, with special emphasis on lichens, of the winter ranges (December through March) utilized by the Killey River, Fox River, Kenai Mountains introduced caribou populations, and differences between these ranges with comparable areas without caribou presence. It provides an initial assessment of the condition of these ranges (1988 & 1989), as well as a 10-year revisit (1998) to a portion of these ranges. This information provides both baseline and trend information for the maintenance and management of these vegetation communities as a sustainable caribou forage resource. From it, some generalizations are made about the influence of both herbivores and the environmental factors (i.e., wind, elevation, aspect, etc.) on the structure of vegetation. Nomenclature for lichens follows Egan (1987) and for vascular plants follow Hultén (1968).

STUDY AREA

The Kenai Peninsula (26,000 km^2), hereafter referred to as the Peninsula, in southcentral Alaska is located in the sub-arctic zone (59°05'- 61°05' N., and 152°00'- 148°00' W.) flanked by Prince William Sound to the east, the Cook Inlet to the north and west, and the Pacific Ocean to the south (Fig. 1). The peninsula encompasses a total area of 26,000 km^2, with a 16-km connection to the mainland. This area is characterized as within the Cook Inlet Basin and Chugach-St. Elias Mountains Ecoregions (Nowacki, et. al. 2001). The narrow isthmus creates insular conditions from many of the biological resources on the Peninsula (Fig. 2). Climate is typically intermediate between the drier, continental type of the Alaskan interior and the wetter, mild maritime climate of southern, coastal areas (Karlstrom 1964). Major topographic features include the Kenai Mountains to the south and east, which rise to 1,600 m., the extensive Harding Icefield (approx 1,800 km^2) with associated glaciers, the Skilak-Tustumena benchlands averaging roughly 925 m. elevation, and the forested northern and western lowlands (<150 m.).

The alpine tundra vegetation community, where the caribou populations of this study winter, consists of short-stemmed perennial herbs, low growing or prostrate shrubs, lichens and mosses. Common in these areas are low mats of *Dryas octopetala, Empetrum nigrum,* and *Oxytropis nigrescens.* Much of the landscape consists of barren rock and rubble with scattered plants. The alpine tundra has low primary productivity, low decomposition rates, short growing seasons, and high susceptibility to physical disturbance (Miller, 1982; Klein & Lent, 1988). Lichen communities on alpine ranges change quickly with disturbance (e.g., trampling and grazing), and the time required for recovery is directly proportional to the degree of disturbance (Helle & Aspi, 1983; Pegau, 1975; Miller, 1982). The recovery of the lichen community is further complicated by competition with the vascular-plant community (Swanson & Barker, 1992). These processes are dynamic, and may express continued changes based on both the biotic influences, such as herbivory pressure or interspecific competition, and abiotic influences. In reference to the latter, the increasing temperatures that have been recorded on the Kenai Peninsula (National Climate Data Center, 2003) which may influence the vegetation growing period, as well as the movements of the caribou.

METHODS

Caribou Wintering Habitat Determination

The caribou winter-use areas were determined by radio-telemetry locations and visual caribou sightings. Personnel from the KNWR, ADF&G, and Chugach National Forest collected the movement data. In addition to movement information, observation on fecal pellets and vegetation damage provided supplementary determinations of caribou-use areas. A categorical herbivory index was developed using this information. A second herbivory index was generated from the movement locations in a program called Statistical Ecology Analysis System (J. Carey 1989, pers. comm.). This program uses harmonic means of animal activity areas (Dixon & Chapman, 1980) to create isopleths of "intensity of used surfaces". This information was used to both determine relative use of various sites and aid in determining appropriate caribou-use sampling sites.

Vegetation Sampling

During the summers of 1988 and 1989 permanent macroplots (100 m^2) were established and sampled using 20 quadrats (0.25 m^2) within (Fig. 3). Field sites included: 1) wintering areas utilized by the second caribou introduction (1985-86); 2) wintering areas utilized by the initial caribou introduction (1965-1966); and 3) four areas with similar general environmental indices as the caribou winter used areas, without caribou activity. The caribou winter-use sites and the control sites were as close as possible, with the average distances ranging from 16.5 km to 64.7 km. Vegetation was sampled during the summer because the snowfall precluded the primary interest in the study, namely acquisition of vegetation community data. While some information was lost, like vegetation conditions before caribou introductions and actual winter condition of the vegetation, these deficiencies were unavoidable.

Macroplots were placed along transects through each study area. A systematic sampling design (Braun-Blanquet, 1932; Greg-Smith, 1964; H.C. Hanson, 1950) was utilized to make relocation and re-sampling possible. Fig. 4 and Table 1 list the caribou wintering areas of the second introduction and locations of the vegetation sampling areas. There were 142-macroplots in seven different sampling areas, for a total of 2840 quadrates and a total vegetation sampling area of 710 m^2. The proportion of sites sampled are 43% in the wintering areas used by the second caribou introduction (Killey River and Fox River Herds), 42% in comparable areas without caribou, and 15% in areas utilized by the initial caribou introduction (Kenai Mountains

Herd) in the winter. At the time of the initial caribou range study (1988-89), the Twin Lakes area was not used by caribou. The 10-year revisit to a portion of the ranges included a reassessment of a total of 25 macroplots from the following sampling areas (# macroplots): Killey River Herd (14), Fox River Herd (8) and Mystery Hills (3) comparable area without presence of caribou. Note, these three macroplots visited in the Mystery Hills comparable area were originally sampled in 1989, therefore the revisit to these areas involved 9 years.

Information recorded included vegetation cover estimates (to the nearest 5%), vegetation heights, lichen biomass samples, herbivory evidence, physical environmental parameters (slope, aspect, elevation), and other groundcover values (exposed soil, rock, and dead vegetation). Evidence of herbivory was visually documented by 1) number of fecal pellets from caribou and other herbivores, 2) vegetation damage (vascular plant stripping and displacement of the lichen mat or “cratering”), and 3) other evidence of animal activity (e.g., trails, holes).

In the initial sampling period, a sample of lichens in the four 0.25 m^2 corner quadrants of a macroplot were collected in paper bags and the living portions were oven-dried (typically 60 hours), by species, until a constant weight was achieved at 37 C. Regression equations were then calculated to estimate biomass from cover values, and reduce lichen collecting. Macroplots that had quadrats with lichens previously harvested were not included in the determination of vegetation mean cover values in the 10-year revisit.

Snow Cover Information

Snow cover information (snow depth and snow-water equivalent) was obtained from the snow cover monitoring stations of the Natural Resource Conservation Service (NRCS) National Water and Climate Center (Clagett, 1990). The closest snow monitoring stations to the wintering ranges of the caribou populations are stations Middle Fork Bradley (59.76º N., - 150.76 º E.) for the Fox River Herd and Resurrection Pass (60.68º N., - 149.75º E.) for the Kenai Mountains Herd. For the winter of 1988-89, winter range photos were taken by 60-30 North Aviation Services (Nichols 1989, pers. comm.). Previous research has determined that the value at which snow density may limit caribou from acquiring forage is estimated at density > 32% (Pruitt, 1959).

Vegetation Analysis

In this assessment, vegetation quantities, heights, biomass, use and other obvious patterns among sampling areas, are compared. In a M.S. research project performed by the author, several multivariate techniques were used to detect other patterns and gradients in the vegetation information obtained from the 1988-89 field season (Paez, 1991).

The assessment of trend information for a subset of 25 macroplots was obtained in July 1998, ten years post the initial study. These results, referenced in the paper as 10-year trend study, yielded information concerning the differences in vegetation quantity, structure, and herbivory evidence compared to the initial assessment of the ranges.

RESULTS

Caribou Population Ranges

By the time of the initial range survey (1988-89), the second caribou introduction (1985-86) utilized two different wintering areas, the southern benchlands of Killey River (55 km^2) and Fox River (42 km^2) (Fig. 4). In the winter prior to vegetation sampling, 1987-88, there were 70 caribou for the Killey River population and 22 in Fox River population (Bailey, 1988). The average winter densities (i.e., # wintering caribou/area of wintering range) of caribou for these entire areas were 1.27 caribou/km^2 and 0.52 caribou/km^2, respectively. The initial caribou introduction (1965-66) utilized the habitats, by Big Indian Creek in the northern portion of the Kenai Peninsula (Kenai Mountains). This amount of caribou in this herd consisted of 243 (Bailey, 1990) to 280 (Spraker, 1992) in the winter prior to vegetation sampling, 1988-1989. The total winter range of this population was estimated at 520 km^2 (Fig. 4). The average winter density of this population was 0.47 km^2. These caribou density figures are averages and different parts of the ranges had different concentrations of caribou.

The potential winter-use areas without caribou were not devoid of herbivore evidence. The principle herbivore in these areas was the Dall Sheep (*Ovis dalli dalli*). Suitable foraging sites not used by either of the large herbivores, caribou or Dall Sheep, were few. A gradient of herbivore “evidence” (e.g., field fecal pellet and vegetation-use evidence) was observed from the least impacted areas, Mystery Hills and Russian Mountains, at one end to Kenai Mountains at the other. In the areas used by the initial caribou introduction (Kenai Mountains), areas with the entire vegetation mat was denuded with open patches and feeding craters was evident.

By the year 2001, the Killey River herd has increased substantially in size from the 1985-86 reintroductions to its peak in of 710 (Ernst, et. al. 2007 in-prep); however, in December 2001 or January 2002, an avalanche killed 143 individuals (23 Males, 103 females, 9 calves, and 8 unidentified). The Fox River group had grown from 16 animals in 1986 to 96 in 1997 (Ernst, et. al. 2007 in-prep); However by 2004, this population had declined to 25 in 2004. The Kenai Mountain Herd grew from 15 introduced animals in 1965 to approx 450 animals at its peak in 1996, and since then the population has appeared to decline slightly (Ernst, et. al. 2007 in-prep).

The ranges of these caribou populations through 2005 (Ernst, et. al. 2007 in-prep.) are represented in Figs. 5-7, with the ranges of the Killey River herd, in the 1990s and 2000s, were approx 550.30 and 884.12 km^2 respectively. Five collared caribou from the Killey River herd moved to nunataks within the Harding Icefield to calve in the summers of 2000-2003, and, subsequently, in the 2000s the estimate of the summer range was 749.24 km^2 at 0.46 caribou/km^2, which was larger than the winter range (554.89 km^2 at 0.63 caribou/km^2). The Fox River herd also appeared to increase their range from approx 104.05 km^2 (1990s) to 151.25 km^2 (2000s); The Fox River herd had the smallest seasonal ranges of the four herds on the Peninsula (summer, 118.27 km^2 at 0.24 caribou/km^2; winter, 95.97 km^2 at 0.29 caribou/km^2). The Kenai Mountains herd area increased from approx 321.47 km^2 in the 1990s to 710.79 km^2 in the 2000s. The summer and winter ranges from data in the 2000s were 626.48 (0.52 caribou/km^2, density) and 508.78 (0.64 caribou/km^2) km^2, respectively.

Vegetation Composition and Diversity

A total of 24 species of lichens, 39 species of vascular plants, brophytes, and fungus were recorded (Table 2, Fig. 8). In all seven sampling areas (Table 3), the most prevalent lichen species were *Stereocaulon alpinum, Cladina rangiferina, Cladina mitis,* and *Cladina stellaris.* The predominant vascular plants were *Empetrum nigrum*, *Diapensia lapponica*, *Dryas octopetala*, and *Vaccinium caespitosum.* Four groups of lichen species were not distinguished in the earlier field season; thus, these were grouped for comparative analysis (Table 4). Concerning caribou forage species, *Cladina rangiferina* and *Cladina mitis*, labelled as "*Cladina* group", were the most important of these combinations.

In reference to the characteristics of the vegetation in areas exposed to varying degrees of caribou herbivory pressure, as the grazing pressure increased, the preferred lichen species became less dominant with vascular plants, such as *Dryas octopetala*, *Empetrum nigrum*, *Diapensia lapponica* and *Vaccinium caespitosum* becoming the dominant species based on mean cover values. A similar relationship was found as in the study by Swanson & Barker (1992), which indicated that the recovery of the lichen community is further complicated by competition with the vascular-plant community. This trend of reduced lichen cover and increased vascular plant cover was also seen by Henry and Gunn (1991), Klein (1987), and Helle and Aspi (1983).

Assuming interspecific competition occurring between the vegetation species within the community, increases in these parameters may be due to reduction of the competitive abilities of plants by herbivory, and a consequent reduced tendency towards dominance. This gradient coincides with the relationship represented by the herbivory sign information. The amount of herbivory sign in the 10-year revisit increased with the inclusion of feeding craters (Figs. 9-10), which were previously only seen primarily in the Kenai Mountain Herd winter use areas.

In the 10-year trends study, the 14 macroplots visited from the Killey River Herd areas yielded a decrease in the average lichen cover values for 9 of the 19 lichens recorded (Fig. 11), most importantly in the preferred *Cladina* group (*C. mitis* & C. *rangiferina*) lichen species. The eight macroplots within the Fox River Herd 10-year trends study yielded decreases in the average lichen cover values for five of the 19 lichens recorded (Fig. 12). The differences in mean cover values for the three macroplots from the Mystery Hills comparable habitats without caribou were minor (Fig. 13). Large increases occurred in the White Sterile crust lichens (*Ochroleuca* spp.) for the Killey River & Fox River caribou use areas (Figs. 14-15). O*chroleuca* spp. has been associated with disturbance, possibly related to abiotic factors such as desiccation (wind stress) and biotic factors, such as herbivory. The Fox River Herd areas were noticeably windy areas. The Mystery Hills comparable habitat did not have any cover value for Ochroleuca spp. in 1989 and small amounts were present in 1998 (Fig. 16). This area is not along exhibiting the high herbivory or extreme wind pressure, but does have some possible disturbance from foot traffic, with a trail nearby.

The composition of the vascular plants exhibited similar changes as in the initial study, with a pronounced increase in vascular plant cover amounts in the caribou-use areas (Figs. 17-18). In the Fox River Herd caribou-winter use area, the dominant species that exhibited increases included *Dryas octopetalia*, *Diapensia lapponica* and *Empetrum nigrum*. The vascular plants within the Killey River area exhibited similar increases, particularly in *Dryas octopetalia*, *Diapensia lapponica* and *Emptrum nigrum*. These changes in both the lichen and vascular plant species composition and cover values were not that evident in the 10-year study of the Mystery Hill Comparable Caribou Habitat Areas (Fig. 19).

Vegetation Heights

The mean heights of vascular plants were ≤5 cm. for all macroplots in this windswept alpine tundra. Lichen live podetia heights differed most between the least impacted non-caribou use sites, Mystery Hills and Russian Mountains, with the rest of the areas. For the 10-year trends study, the differences in live lichen podetia heights from the Killey River, Fox River and Mystery Hills comparable caribou use areas mirrored the relationship evident in the mean cover values. The Killey River and Fox River caribou winter-use areas exhibited pronounced decreases in preferred lichen heights (Figs. 20-21), while the Mystery Hills comparable caribou habitat lichen live podentia lichen heights exhibited minor differences (Fig. 22).

Lichen Biomass Information

The regression of biomass against cover shows that biomass can be estimated well from its cover data. Half of the species analyzed had high correlation, with $r^2 > 0.80$ ($p < .01$) (Table 5). This information has potential for being extrapolated for estimating the amount of potential lichen biomass available within the caribou ranges. Such an extrapolation can be used for estimating carrying capacities. However, as stated earlier, with the free-ranging capability of the caribou, possibly a greater limitation would be the availability of quality forage, not necessarily quantity.

Abiotic Elements

The general environmental variables of slope, aspect, and elevation between caribou winter-use areas and comparable areas without caribou were similar in all sampled areas (Table 6). In addition to these variables, the bedrock type that occurs in the caribou winter-use areas and control areas is the Graywacke-Argillite and other consolidated rocks formations (Karlstrom, 1964). Multivariate techniques utilized in (Paez, 1991) to provide quantitative environmental values as variables (excluding slope and aspect which showed little variance between groups) to predict sampling area membership, 98% of the 82 cases (macroplots) from the caribou-use group were predicted correctly; and 92% of the 60 cases from the control areas were predicted correctly. There was virtually no correlation of any environmental variable (all $r < .16$) along this axis. Therefore, confidence occurred in that all caribou and control areas were indeed similar in terms of the physical environment.

Snow Cover Information

According to information from NRCS stations, the snow density values of 32% and greater were present in the later winter months of 1988-89, indicating that snow conditions were possibly limiting the caribou from acquiring forage. However, this is a general estimate since it does not provide information concerning possible "rain crusts" which could prevent foraging at lesser snow depths (Swanson 1989, pers. comm.). In the winter prior to sampling the reintroduced caribou-use areas, the snow characteristics at the Middle Fork Bradley station indicated density percentages at or greater than the value of 30%.

In the winter of 1988-89, information for the longer-established caribou population from the NRCS Resurrection Pass station was not complete; however, data from a 25-year average of that station indicated densities were greater than 30% in the late winter months. Winter photographic survey flights indicated complete snow cover with minimal exposed areas (Nichols 1989, pers. comm.). From 1961-1985, the northern, mountainous region averaged approx 270 cm of precipitation at 570 m while the southern region averaged 75 cm at 360 m (Soil Conservation Service 1988) although levels of precipitation can vary greatly from year to year.

DISCUSSION

The caribou pressure on the vegetation community may create or modify the spatial heterogeneity within the system. There are many components to which the vegetation responds, and only a few have been studied here. It is clear that the caribou do have a profound effect on the vegetation. Some changes, such as feeding craters in the areas used by caribou populations, are obvious; but others such as interspecific competition among plant communities and interaction with environmental elements, may be quite subtle.

Through these analyses, several similarities resulted which may allow the following suppositions. Compared to vascular plants, lichen species have provided more variance in the data set. This indicates the importance of lichens in the structure and pattern of these tundra communities, which are undergoing varied herbivory. In addition, when vegetation and environment information are analyzed together, the vegetation provides more variance in the data set. This suggests the areas chosen for this comparative study are comparable in their environments to the extent they were measured.

Other information for this tundra/caribou interaction lies in the index related to caribou densities associated with the ranges. Combining data from the densities of caribou winter-activity locations with associated macroplot information for these areas, a comparison on the effects of this presence can be made. In Figure 8, Mean Lichen % Cover Values per Sampling Area – Initial 1988-1989 Sampling Period, the mean cover amounts of the preferred lichen species, *Cladina* spp., and *Cladina stellaris*, between the assemblages of caribou-use areas and the least disturbed comparable areas without caribou, Mystery Hills and Russian Mountains, are the most impressive. Reductions in live lichen podetia heights between these areas (Figs. 19-20) coincide with this relationship. There is also a reduced lichen cover and increased vascular plant cover (Figs. 11-12, 16-17), a trend also seen by Henry and Gunn (1991), Klein (1987), and Helle and Aspi (1983). The increase in the White Crust lichen *Ochroleuca* spp. (Figs. 14-15) in the Killey River and Fox River caribou winter use areas is another indicator of the harsh environment present there, both in herbivory and desiccation for the vegetation. The Fox River Area is especially prevalent to extreme wind conditions.

As stated in the beginning of the paper, the caribou environmental needs of escape or finding relief from flying insects in the summer and acquiring food through deep snow in the winter can be major obstacles to their viability. The free-ranging capability of the caribou, affords them the possibly of seeking better habitats with less flying insects and better quality forage. Their wide-ranging movements on the Kenai Peninsula, particularly the Killey River Herd, have shown this capability. However, there are compounding factors on the Kenai Peninsula, such as the insular nature of the Peninsula, and the hazards present through glaciers and other difficult travel corridors, which may reduce their viability. In addition, the surmounting changes expressed by the changing climate may compound these limitations. Overall, the caribou and its habitat may stay viable on the Kenai Peninsula if the innate ability of the caribou to migrate is not limited. This study has documented some of the vegetation issues associated with caribou and their habitat, and provides comparative studies based upon on these findings.

MANAGEMENT RECOMMENDATIONS

Detailed assessments of caribou ranges, which include the acquisition of large sample sizes of field-derived information, are impractical for most management agencies. Unlike the reindeer populations, which are herded to various wintering areas, the movements of caribou are uncontrolled. With the insular characteristics of the Kenai Peninsula, the winter range is a serious concern since introduced caribou population can undergo nearly exponential growth while their food supply depends largely on slow growing lichens. In addition, some of the winter and summer ranges of these caribou herds are not distinct.

A feasible approach may be to utilize a methodology, which affords the possibility of forecasting what type of vegetation community is envisioned with a specific grazing pressure. This type of method which relates the effects of grazing pressure to the "ecological status or condition" has been utilized for reindeer management (Swanson et. al., 1983, 1992; Shiftlet, 1973; Dyksterhuis, 1958). This technique, briefly described, recognizes the concept of "climax communities" implies stability, which is questioned by some, but can serve as a guide to what type of community could be expected, under certain environmental conditions in the near future. Other types of rangeland assessments can be performed utilizing remotely sensed imagery for determining ecological site descriptions and rangeland evaluations (Maynard, et. al. 2007).

It has been demonstrated in this study and confirmed by other studies the changes that occur to the lichen and vascular plant community structure with prolonged grazing. This expectation can provide information concerning the limits of carrying capacity of rangelands for herbivorous predators.

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Figures & Tables:

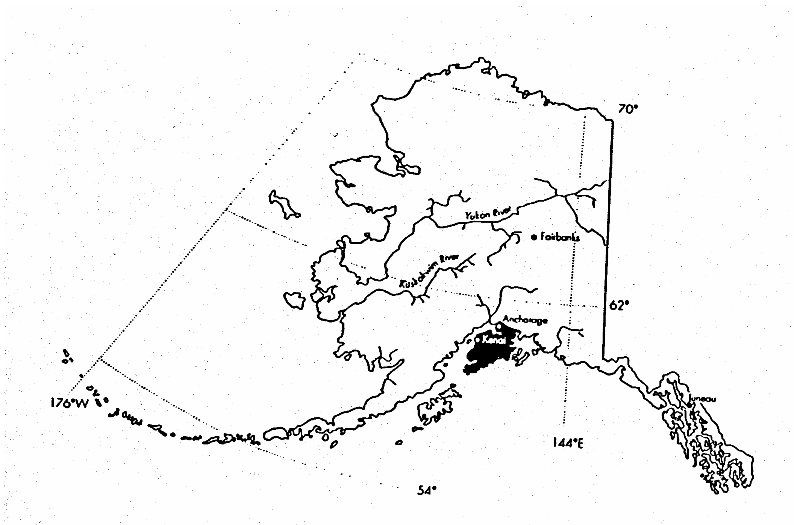


Fig. 1. Kenai Peninsula in Southcentral Alaska

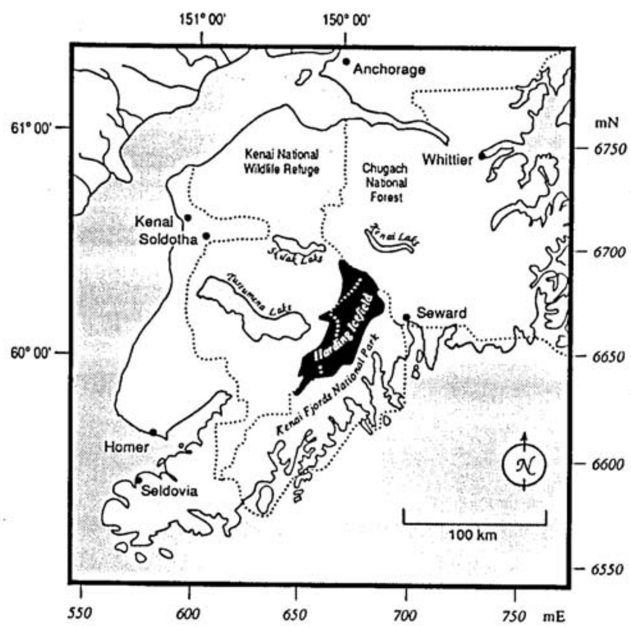


Fig. 2. Kenai Peninsula and the location of Federal Lands – Kenai National Wildlife Refuge, Chugach National Forest and Kenai Fjords National Park

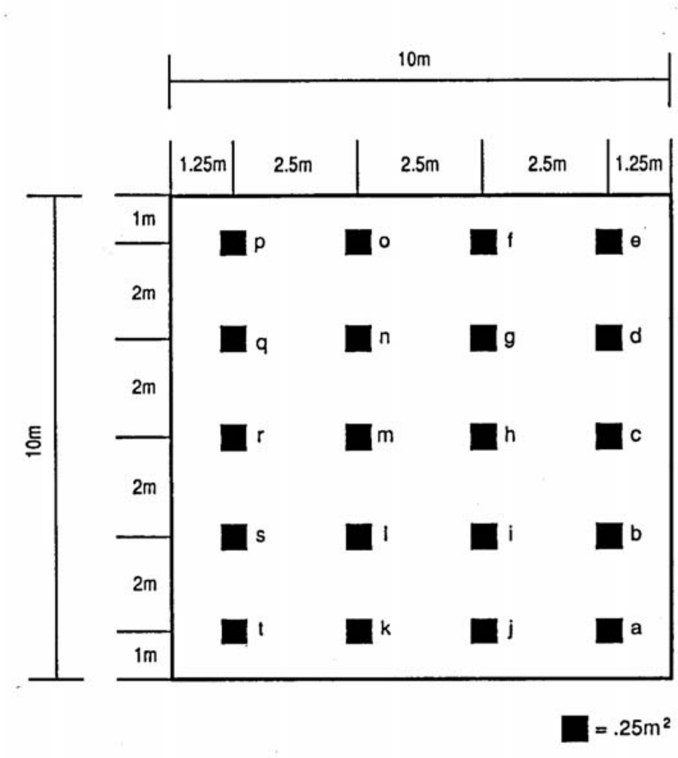
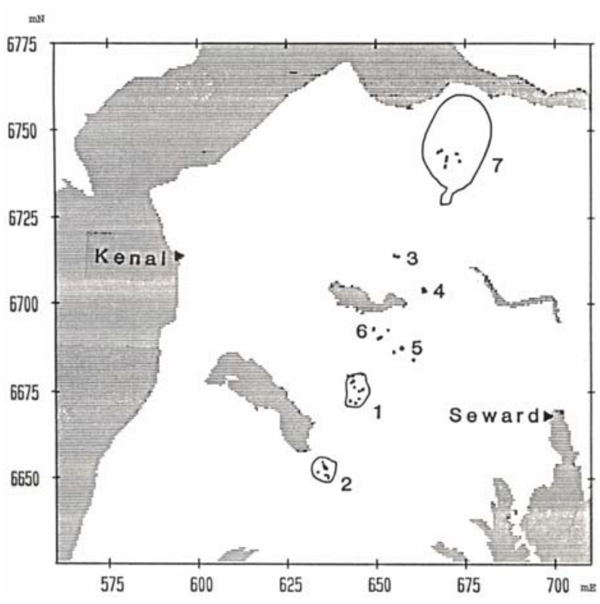


Fig. 3. Macroplot (100 m^2) with 20 – ¼ m^2 quadrats



Caribou-Use Areas (# Macroplots)	Comparable Areas without Caribou (# Macroplots)
1 – Killey River (41)	3 – Mystery Hills (13)
2 – Fox River (20)	4 – Russian Mountains (14)
7 – Kenai Mountains (21)	5 – Twin Lakes (20)
	6 – Cottonwood Creek (13)

Table 1. Macroplot (100 m^2) Sampling Areas

Fig. 4. Enlargened view of the Kenai Peninsula with Caribou Winter Ranges Outlines & Macroplot Locations.

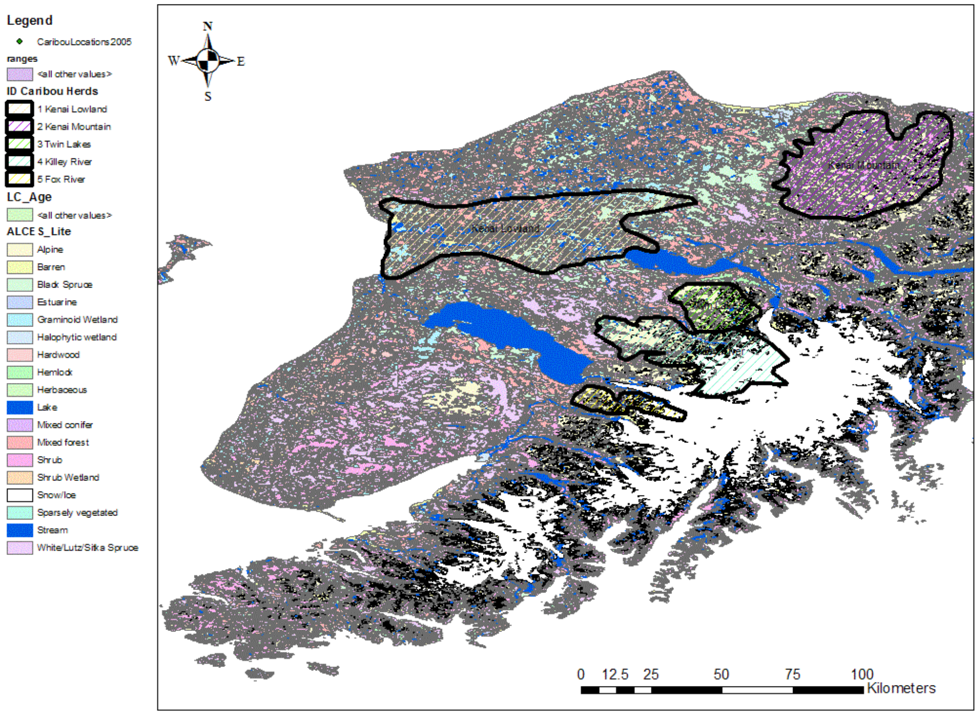


Fig. 5. Caribou Ranges (all herds) on the Kenai Peninsula (2005).

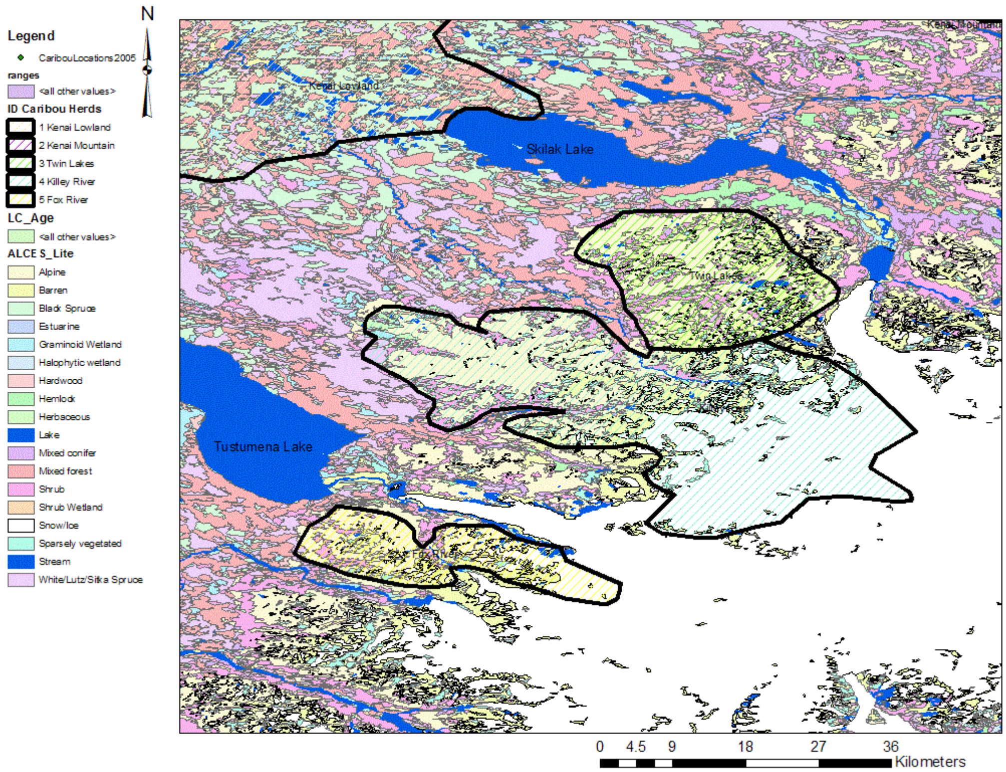


Fig. 6. Second Caribou Introduction (1985-86) Ranges on the Kenai Peninsula (2005).

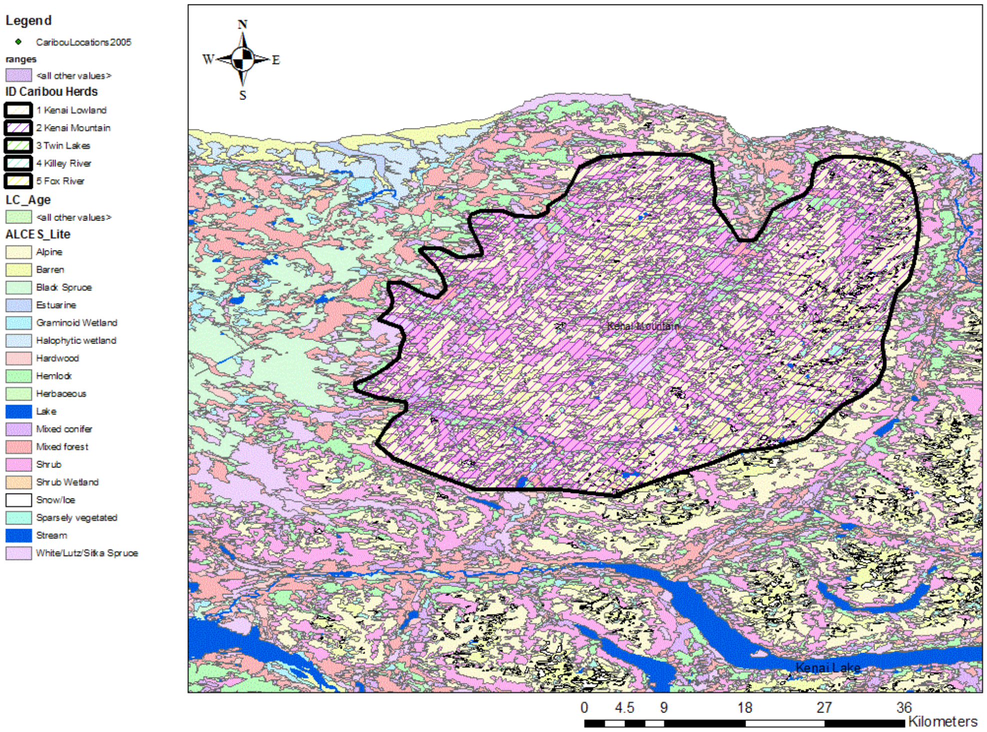


Fig. 7. First Caribou Introduction (1965-66) Kenai Mountains Herd Range on the Kenai Peninsula 2005.

Table 2. Species Composition for the Caribou Winter Range Analysis Project

	Scientific Name	Abbreviation		*Scientific Name*	Abbreviation
1	*Alectorica divergens*	Alec. div.	**31**	*Brophyta spp.*	moss
2	*Bryocaulon divergens*	Bry. div.	**32**	*Pedicularis spp.*	Ped. spp.
3	*Cetraria cucullata*	Cet. cuc.	**33**	*Cyperaceae spp.*	sedge
4	*Cetraria ericetorum*	Cet. eri.	**34**	*Gramineae spp.*	grass
5	*Cetraria islandica*	Cet. isl.	**35**	*Loiseleuria procumbens*	Lois. p.
6	*Cetraria nivalis*	Cet. niv.	**36**	*Saxifraga bronchialis*	Sax. br.
7	*Cladina mitis*	Cla. mit.	**37**	*Silene acaulis*	Sil. ac.
8	*Cladina rangiferina*	Cla. ran.	**38**	*Arnica frigidia*	Arn. fr.
9	*Cladina stellaris*	Cla. ste.	**39**	*Anemone narcissiflora*	Anem. n.
10	*Cladonia gracilis*	Cla.gr	**40**	*Astragalus umbellatus*	Ast. um.
11	*Cladonia amaurocraea*	Cla.am	**41**	*Oxytropis nigrescens*	Oxy. ni.
12	*Cladonia unicialis*	Cla.un	**42**	*Oxytropis campestris*	Oxy.ca.
13	*Dacylina arctica*	Dac.ar	**43**	*Diapensia lapponica*	Dia. la.
14	*Lobaria linita*	Lob.li	**44**	*Arctostaphylos alpina*	Arc. al.
15	*Umbilicaria proboscidea*	Umb.pr	**45**	*Pedicularis capitata*	Ped. ca.
16	*Pseudephebe pubescens*	Pse.pu	**46**	*Pedicularis lanata*	Ped. la.
17	*Sphaerophorus globosus*	Sph.gl	**47**	*Pedicularis oederi*	Ped. oe
18	*Stereocaulon alpinum*	Ste.al	**48**	*Lycopodium spp.*	Lyco.
19	*Thamnolina vermicularis/ subliformis group*	Tha.ve	**49**	*Ledum decumbens*	Led. de.
20	*Ochroleuca spp. (white crust lichen)*	Ochro. spp.	**50**	*Minuartia arctica*	Min. ar.
21	*Salix arctica*	Sal. ar.	**51**	*Gentiana glauca*	Gen. gl.
22	*Salix reticulata*	Sal. re.	**52**	*Geum rossii*	Geum r.
23	*Salix ovalifolia*	Sal. ov.	**53**	*Lloydia serotina*	Lloy. s.
24	*Dryas octopetalia*	Dry.oc.	**54**	*Primula cuneifolia*	Pri. cu.
25	*Betula nana*	Bet. na.	**55**	*Artemisia campestris*	Art. ca
26	*Betula glandulosa*	Bet. gl.	**56**	*Polygonum viviparum*	Poly. v.
27	*Betula nana X glandulosa hybrid*	Bet. hy.	**57**	*Tofieldia coccinea*	Tof. co.
28	*Vaccinium caespitosum*	Vac. ca.	**58**	*Antennaria monocephala*	Ant. mo.
29	*Empetrum nigrum*	Emp. ni.	**59**	*Spirea beauvardiana*	Spir. b.
30	*Vaccinium vitis-idaea L.*	Vac. vi.	**60**	*Campanula lasiocarpa*	Camp. l.
			61	*Fungi spp.*	Mushrm.

Table 3. Lichen Species % Cover Mean Values per Sampling Area[2]

Species[1]	**SKI**	**TRU**	**BIG**	MYS	RUS	TWI	COT
macroplots	**41**	**20**	**21**	13	14	20	13
Ale.och.	0.35	0.54	0.84	1.49	2.87	0.58	0.49
Bry.div.	0.58	0.19	2.03	2.04	1.89	0.26	0.35
Cet.cuc.	0.52	0.34	0.60	1.24	0.43	0.81	0.84
Cet.spp.	0.57	0.57	0.32	0.39	0.38	0.48	0.34
Cet.niv.	0.92	1.18	1.39	3.53	5.07	1.39	1.10
Cla.spp.	1.75	2.67	1.60	5.07	4.15	2.14	2.33
Cla.ste.	0.55	1.50	3.57	10.12	8.36	0.59	1.67
Cld.gra.	0.16	0.35	0.69	0.72	0.50	0.90	0.37
Cld.spp.	0.32	0.45	0.35	0.25	0.72	0.11	0.17
Dac.arc.	0.05	0.04	0.13	0.00	0.004	0.68	0.05
Lob.spp.	0.33	0.21	0.08	0.00	0.00	0.68	0.03
Pse.pub.	3.07	1.27	0.81	0.06	0.20	3.11	0.95
Sph.glo.	0.27	0.36	0.73	0.56	0.72	0.34	0.98
Ste.alp.	3.12	2.35	1.44	4.59	2.67	8.20	14.17
Tha.spp.	1.10	1.01	0.88	1.05	1.21	1.21	0.95

[1]refer to tables 2 & 4

[2] Initial 1988-1989 Sampling Period - Skilak Tustumena or Killey River Herd (SKI),Truuli Creek (TRU) or Fox River Herd, Big Indian or Kenai Mountain Herd (BIG),Mystery Hills (MYS),Russian Mountains (RUS),Twin Lakes (TWI),Cotton Hills (COT).
Caribou winter use areas in bold.

Table 4. Grouped Lichen Species

	Scientific Name	Abbreviation
1	*Cetraria ericetorum & Cet. islandica*	Cet. gp.
2	*Cladina mitis & Cl. rangiferina*	Cl. gp.
3	*Cladonia amaurocraea & Cla. unicialis*	Cla. gp.
4	*Lobaria linita & Umbilicaria proboscidea*	Lob. gp.
5	*Thamnolina vermicularis & T. subliformis*	Th. gp.

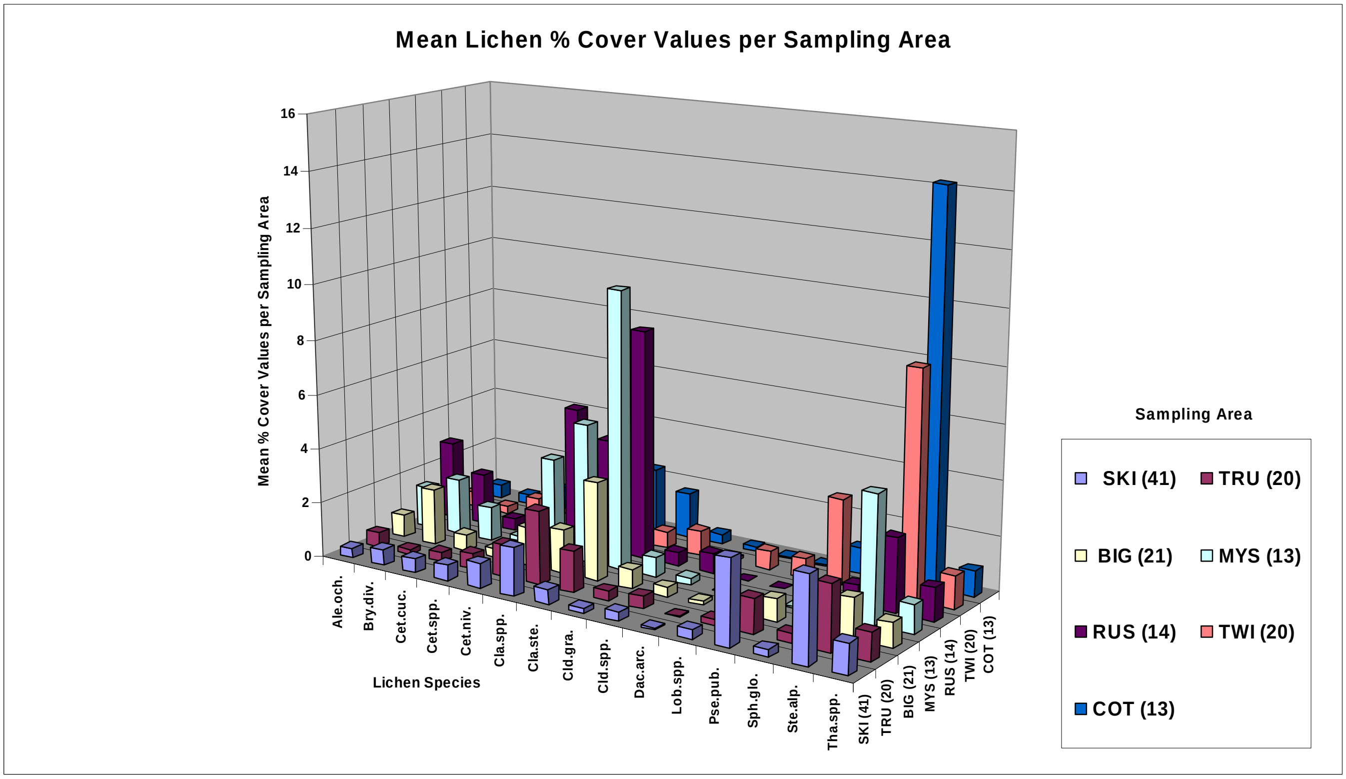


Fig. 8. Mean Lichen % Cover Values per Sampling Area – Initial 1988-1989 Sampling Period.
Skilak Tustumena (SKI) or Killey River Herd, Truuli Creek (TRU) or Fox River Herd, Big Indian (BIG) or Kenai Mountain Herd Mystery Hills (MYS), Russian Mountains (RUS), Twin Lakes (TWI),Cotton Hills (COT).

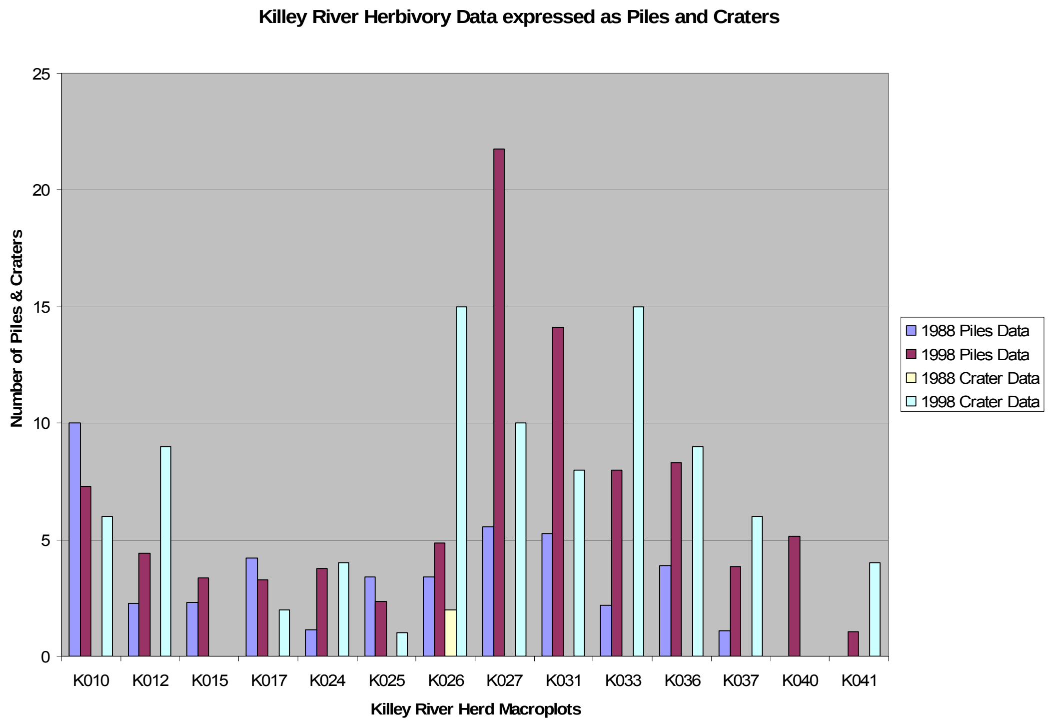


Fig. 9. Killey River Herd Caribou Piles & Cratering Trend Information

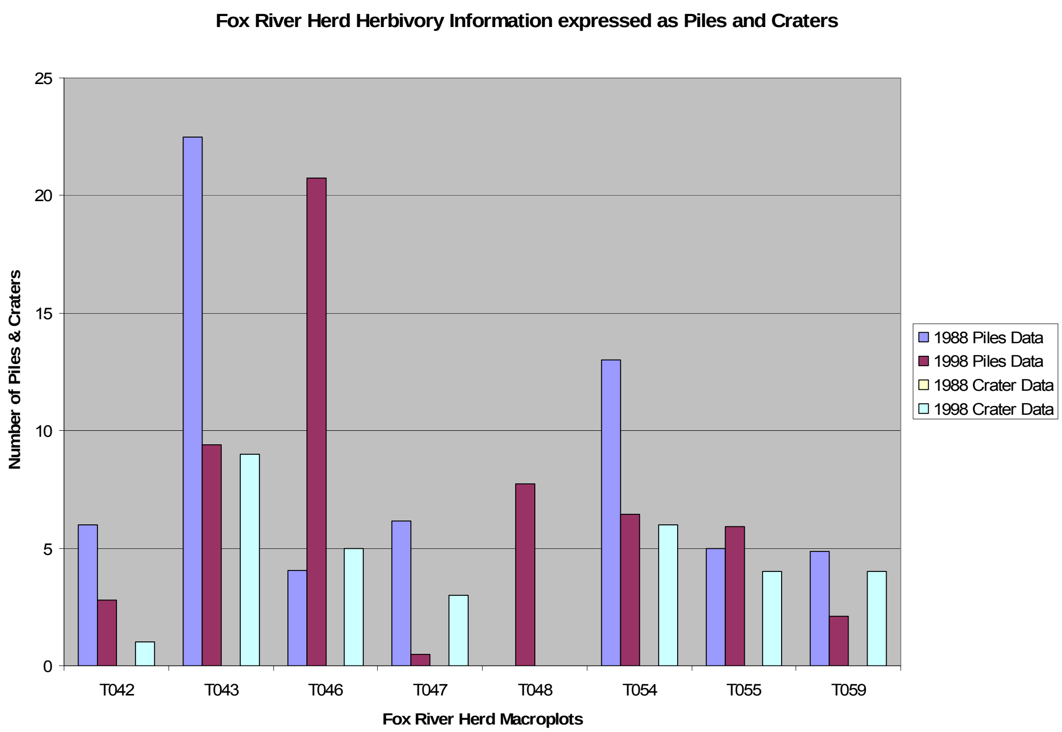


Fig. 10. Fox River Herd Caribou Piles & Cratering Trend Information

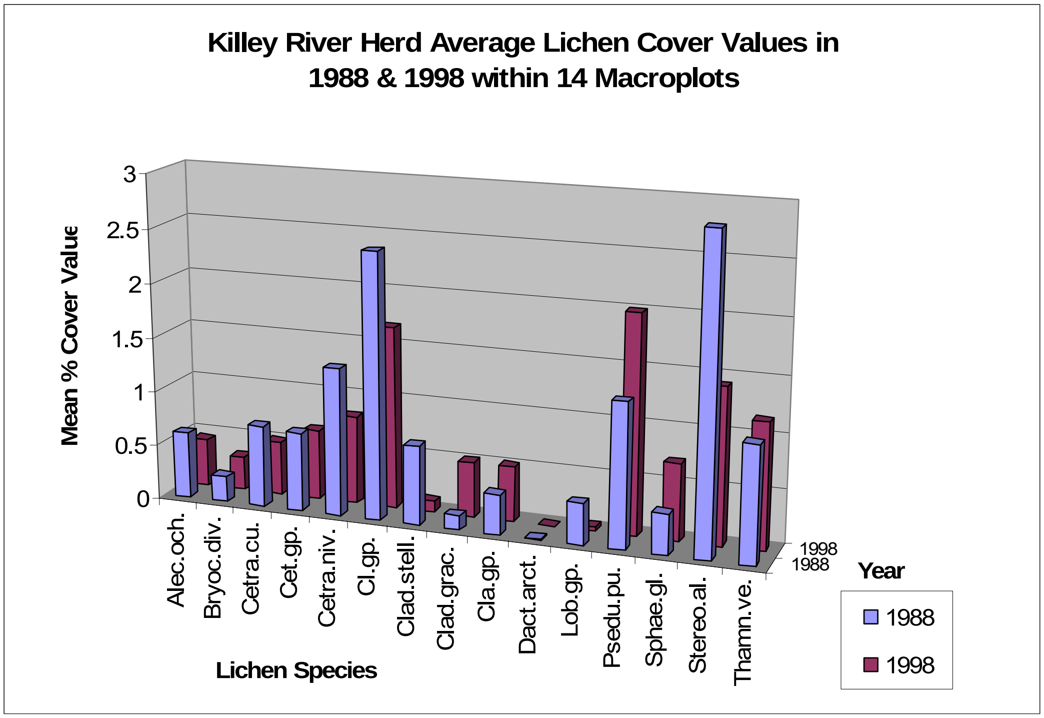


Fig. 11. Killey River Herd Average Lichen Cover Values Trend Information

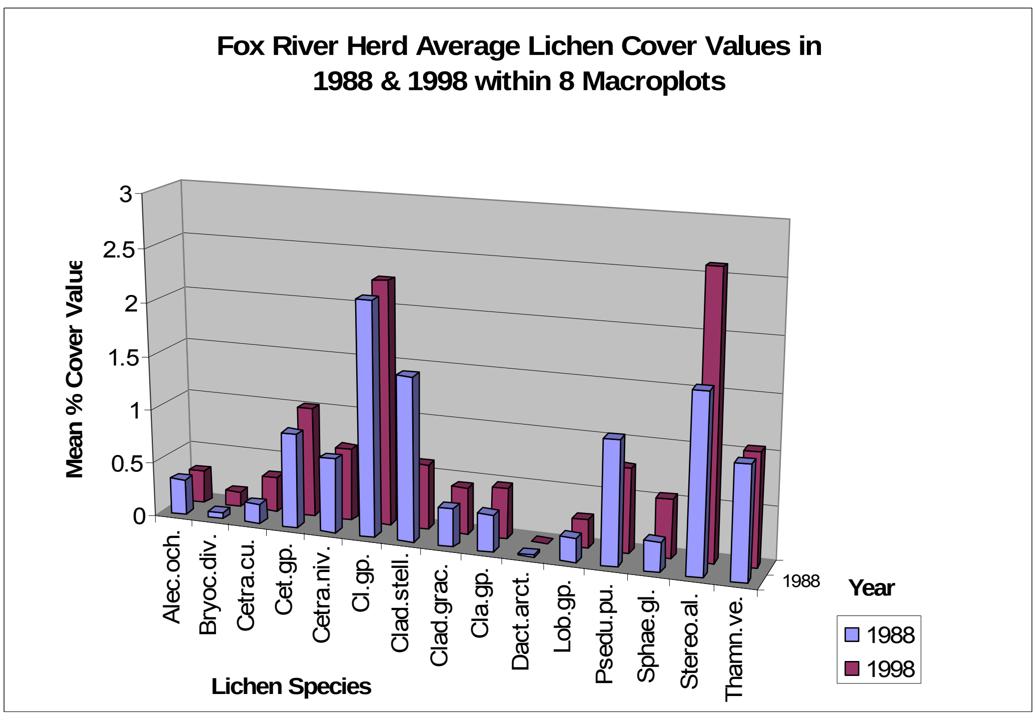


Fig. 12. Fox River Herd Average Lichen Cover Values Trend Information

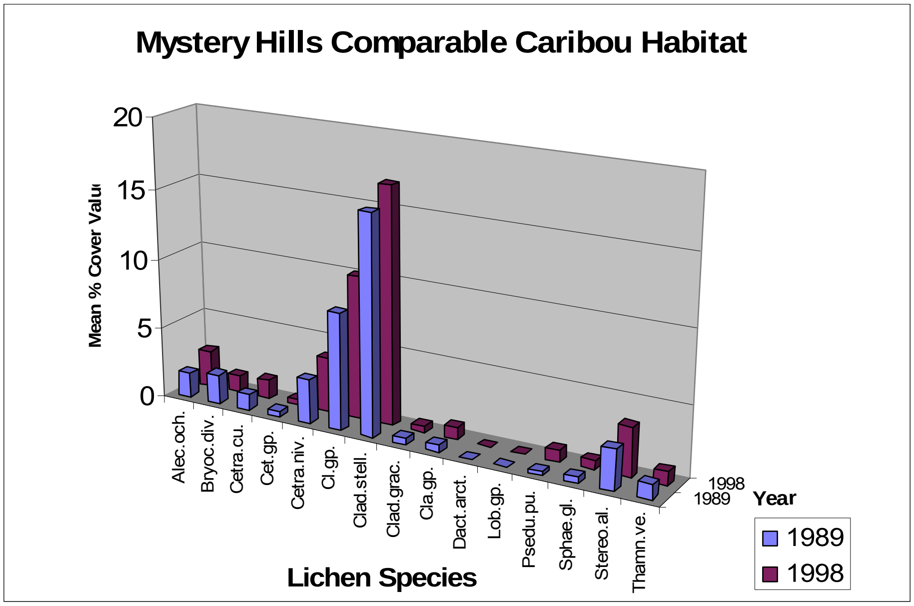


Fig. 13. Mystery Hills Comparable Caribou Habitat Average Lichen Cover Values Trend Information.

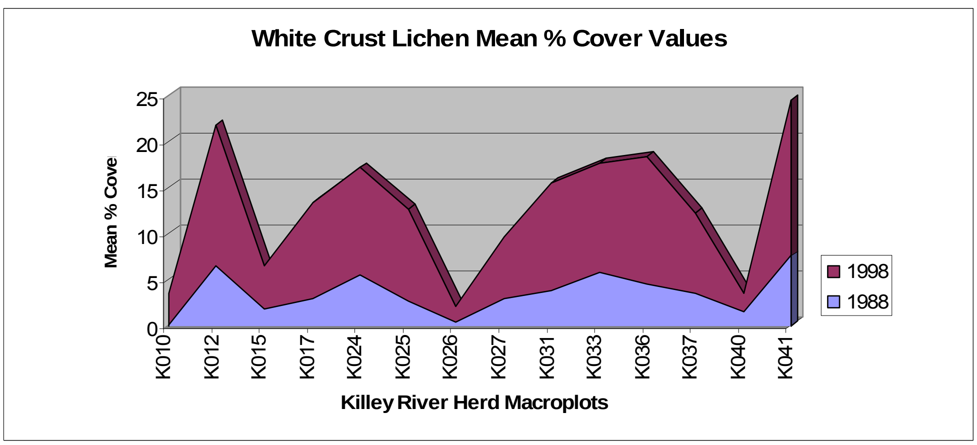


Fig. 14. Killey River Herd White Crust Lichen (*Ochroleuca* spp.) trend information.

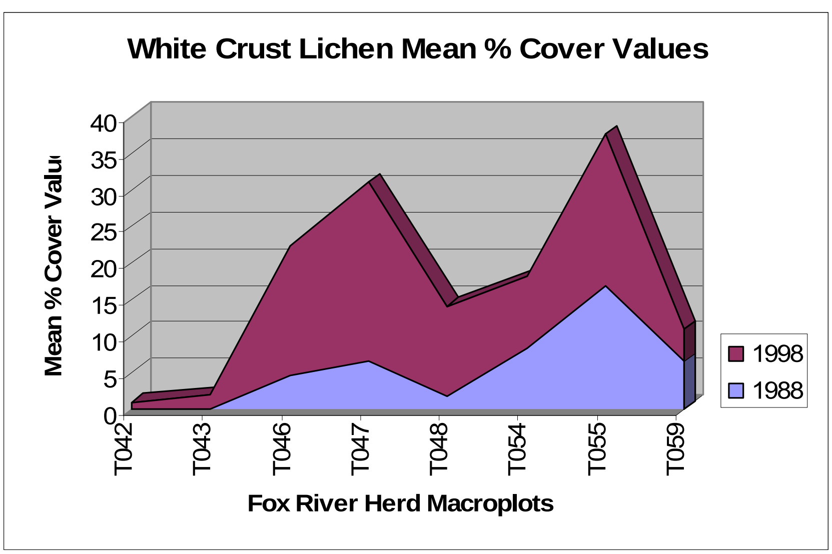


Fig. 15. Fox River Herd White Crust Lichen (*Ochroleuca* spp.) trend information.

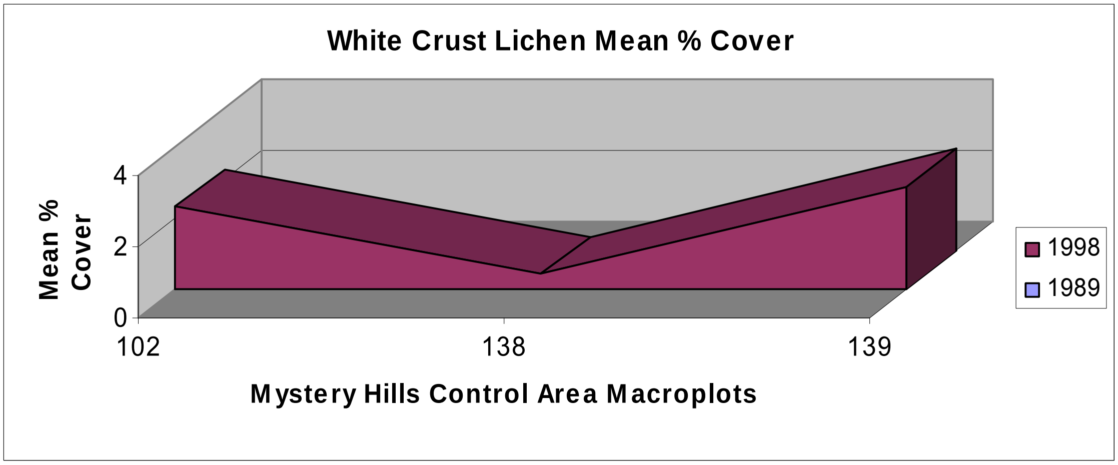


Fig. 16. Mystery Hills Comparable Caribou Habitat White Crust Lichen (*Ochroleuca* spp.) trend information.

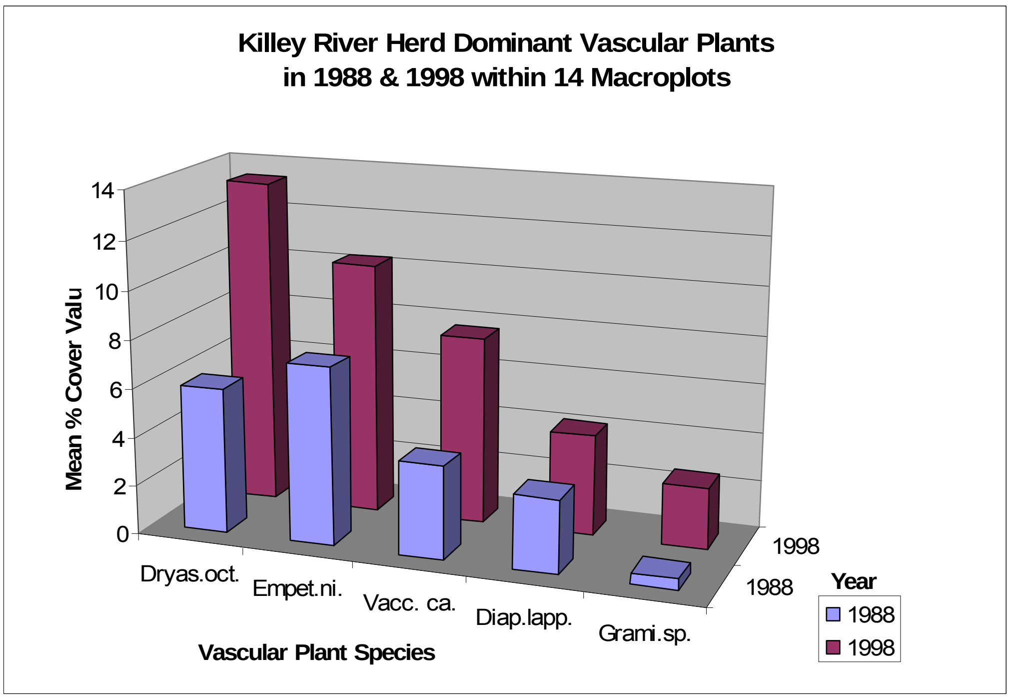


Fig. 17. Killey River Herd Dominant Vascular Plants trend information.

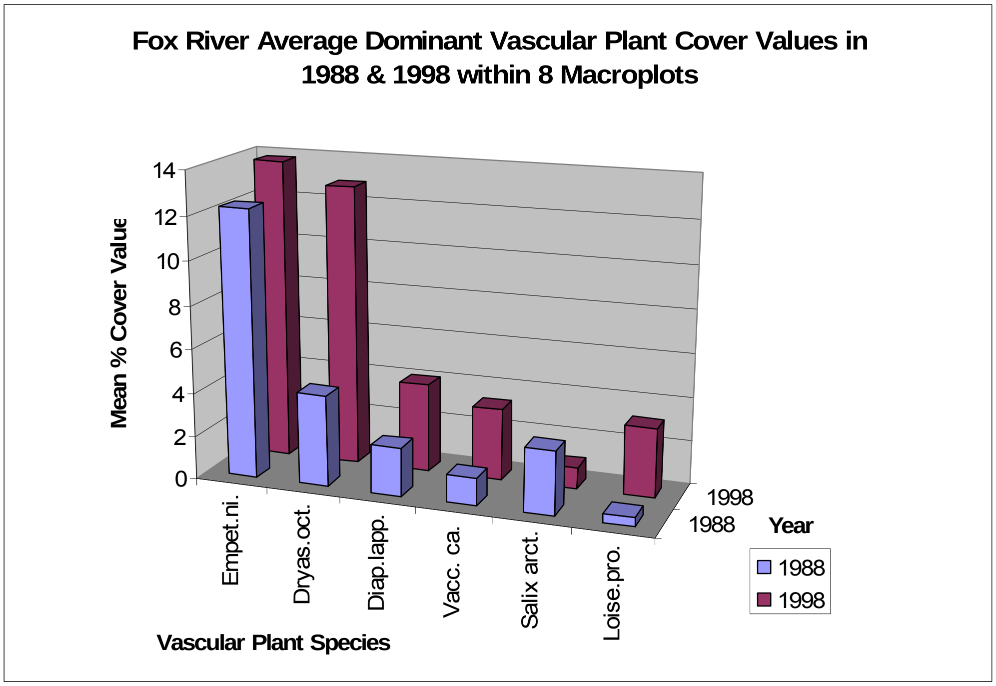


Fig. 18. Fox River Herd Dominant Vascular Plants trend information.

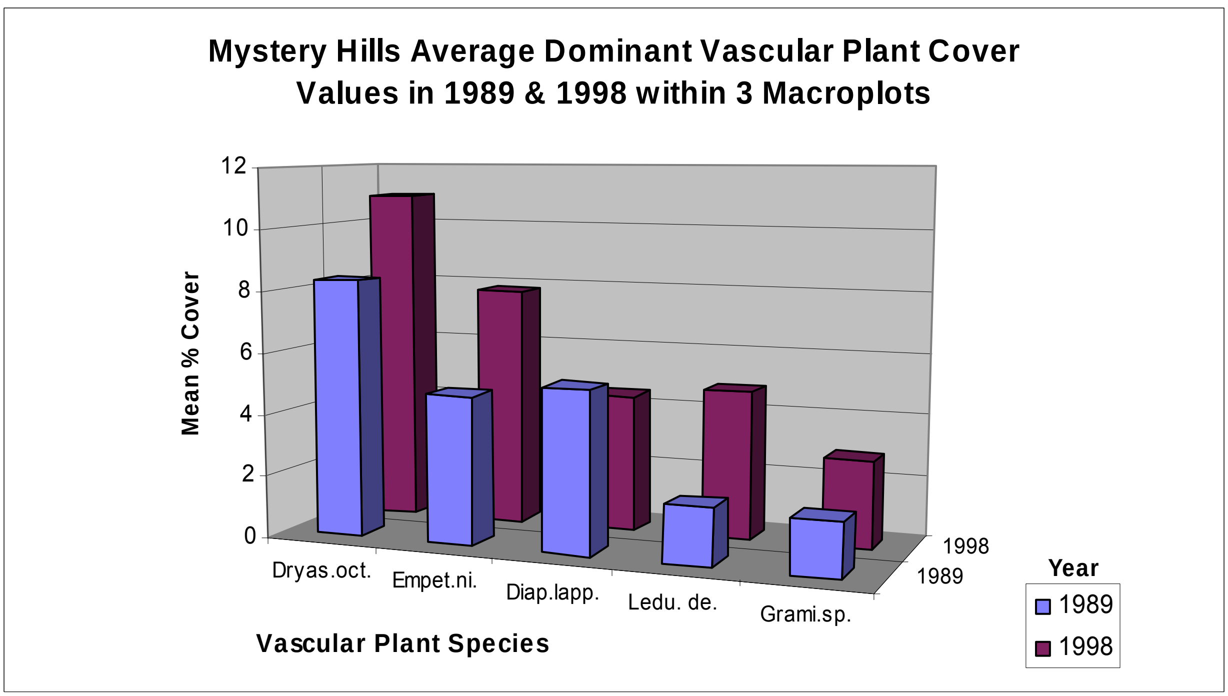


Fig. 19. Mystery Hill Comparable Caribou Habitat Dominant Vascular Plants trend information.

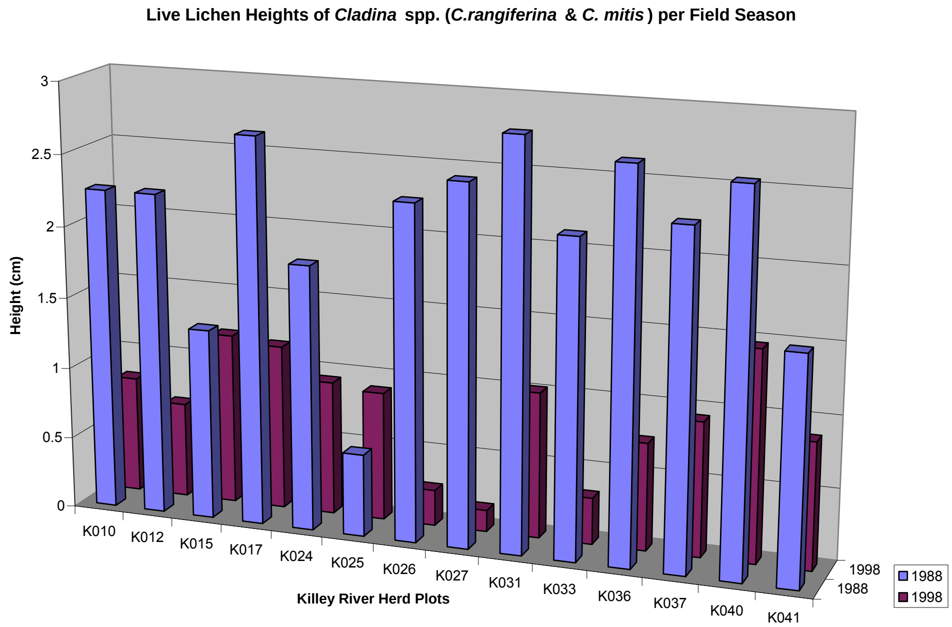


Fig. 20. Killey River Herd comparative *Cladina* spp. lichen live podetia heights.

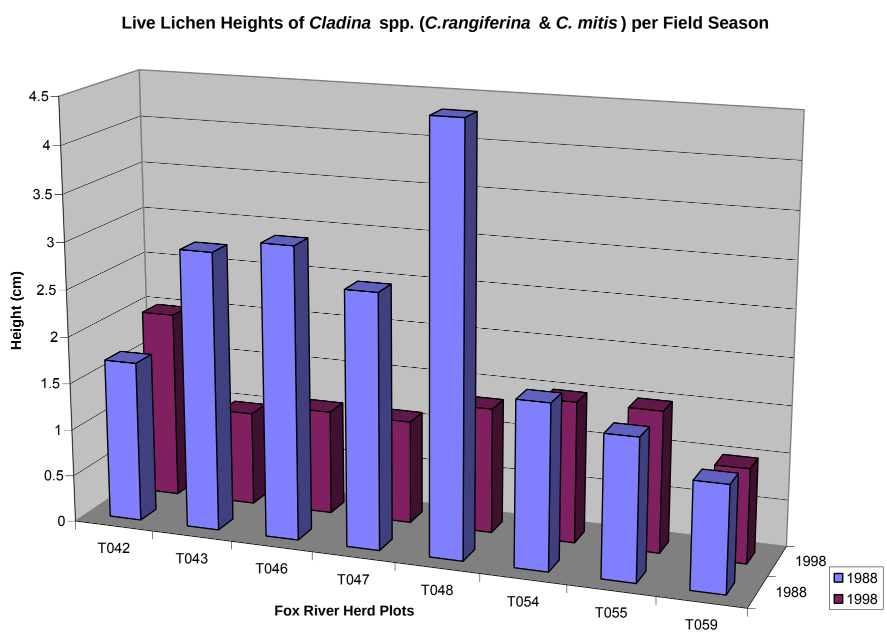


Fig. 21. Fox River Herd comparative *Cladina* spp. lichen live podetia heights.

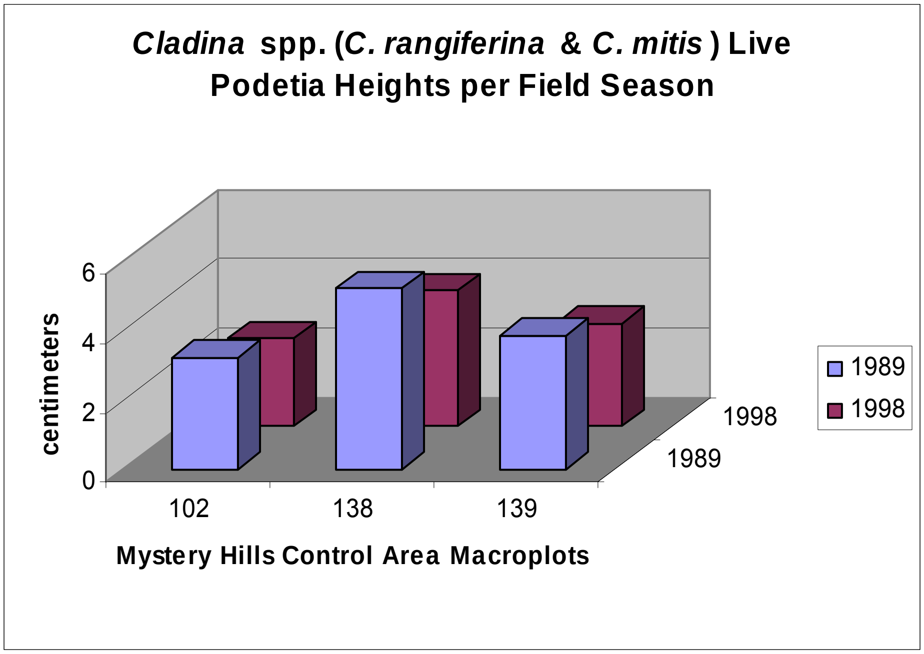


Fig. 22. Mystery Hill Comparative Caribou Habitat Lichen live podetia heights.

Table 5. Regression of Lichen Cover Values to Biomass

Lichen Species	**n**	**SE**	**R^2**
Alectoria ochroleuca	32	1.736	0.865
Bryocaulon divergens	34	1.833	0.831
Cetraria cucullata	29	1.919	0.893
Cetraria spp[2].	40	0.951	0.913
Cetraria nivalis	52	2.506	0.708
Cladina spp[3].	65	10.03	0.649
Cladina stellaris	37	9.191	0.726
Cladonia gracilis	30	3.351	0.801
Cladonia spp[4].	15	11.68	0.399
Sphaerophorus globosus	22	1.423	0.697
Stereocaulon alpinum	38	8.410	0.905
Thamnolia spp[5].	39	1.027	0.736

[2] *Cetraria ericetorium* & *islandica*
[3] *Cladina mitis* & *rangiferina*
[4] *Cladonia amaurocraea* & *unicialis*
[5] *Thamnolina vermicularis* or *subliformis*

Table 6. Mean Slope, Aspect, & Elevation Information per Sampling Area

Sampling Area[1]	Environmental Variables[2]		
	Slope	Aspect	Elevation
Killey River Herd (2)	0 - 4	135 - 224	321 - 338
Fox River Herd (2)	0 - 4	45 - 134	339 - 356
Mystery Hills (P)	0 - 4	45 - 134	268 - 285
Russian Mts. (P)	0 - 4	135 - 224	303 - 320
Twin Lakes (P)	0 - 4	45 - 134	321 - 338
Cottonwood Ck. (P)	0 - 4	135 - 224	303 - 320
Kenai Mountains Herd (1)	4 - 8	45 - 134	285 - 303

[1] Area Index: 2 = Second Caribou Introduction Winter-Use Area
1 = First Caribou Introduction Winter-Use Area
P = Potential Caribou Winter-Use Area

[2] Variables Index: Slope = in degrees, Aspect = in compass bearings
Elevation = in meters