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Physical Characteristics of Arctic Fox (*Alopex lagopus*) Dens in Svalbard

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ABSTRACT. Physical characteristics of 73 arctic fox (*Alopex lagopus*) dens in Svalbard are described. In a mountainous study area of 975 km^2, most dens were found below 200 m and none was found above 400 m. Most dens were located in slopes in valleys or along the coast, facing in a southerly direction (mean aspect 222°). Dens had an average of 9.8 entrances and a mean size of 52.1 m^2. Snow cover was less over dens than on adjacent areas in winter. Vegetation at dens was different than at adjacent areas. Of 56 dens found in the study area, 3 were burrows and the rest were situated under boulders, in screes or in bedrock. Dens were situated in dry localities, most often in protruding bedrock and ridges, where foxes had an unrestricted view.

Key words: arctic fox, *Alopex lagopus*, dens, Norway, Svalbard

RÉSUMÉ. On décrit les caractéristiques physiques des 73 repaires de renards arctiques (*Alopex lagopus*) situés dans le Svalbard. Dans une zone d'étude montagneuse de 975 km^2, la plupart des repaires ont été trouvés au-dessous de 200 m et aucun n'a été trouvé au-dessus de 400 m. La plupart des repaires étaient situés sur des pentes dans les vallées ou le long de la côte, et avaient une exposition méridionale (orientation moyenne de 222°). Les repaires avaient 9,8 entrées en moyenne et une superficie moyenne de 52,1 m^2. La couverture nivale était moindre sur les repaires que sur les zones adjacentes en hiver. La végétation sur les repaires était différente de celle de la zone adjacente. Des 56 repaires dénombrés dans la zone d'étude, 3 étaient des terriers et le reste se trouvait sous des rochers, dans des éboulis ou dans la roche en place. Les repaires étaient situés dans des endroits secs, la plupart du temps dans des affleurements du sous-sol rocheux ou sur des crêtes d'où les renards avaient une vue dégagée.

Mots clés: renard arctique, *Alopex lagopus*, repaires, Norvège, Svalbard

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INTRODUCTION

The arctic fox (*Alopex lagopus*) is distributed throughout the tundra of the circumpolar Arctic. During winter, it ranges widely over the polar pack ice as well. Arctic fox pups are born and reared in underground dens, a feature they share with all other canid species (Moehlmann, 1989). They are born in late spring and leave the den in late summer. For some foxes the dens may provide shelter year around, including winter (Eberhardt *et al.*, 1983). Garrott *et al.* (1983) and Smits *et al.* (1988) suggested that foxes are probably most susceptible to human disturbance while caring for the young in dens. It may also be possible that the availability of suitable denning habitat may limit fox numbers. Thus, suitable den habitat is crucial to survival and reproduction of arctic foxes. Dens should be identified and protected before major human activities are initiated in undisturbed areas.

Physical characteristics of arctic fox dens have been described in several parts of its range (Danilov, 1961; Chesemore, 1969; Macpherson, 1969; Østbye *et al.*, 1978; Garrott *et al.*, 1983; Smits *et al.*, 1988). According to these reports, dens are most often located on river banks, eskers, hummocks or moraines, where the soil is not too compacted to allow burrowing. In some areas, dens can be large, complex structures, which are reused and extended in subsequent years. Occasionally, dens have as many as 100 entrances (Macpherson, 1969).

Most descriptions of the characteristics of arctic fox dens originate from the tundra plains of Siberia, Alaska and Canada, a fairly uniform environment where arctic foxes have few alternatives to digging burrows in relatively unconsolidated substrate. Macpherson (1969) and Østbye *et al.* (1978) concluded that arctic foxes prefer such habitats, since they found few dens in scree or crevices in solid rock.

The High Arctic islands of Svalbard are predominantly mountainous, but there are also large land rims along the shore and broad, glaciated valleys, which contain habitat similar to the tundra plains of Canada, Alaska and Siberia. Arctic foxes are abundant on these islands. The objective of this study is to describe physical characteristics of dens used by arctic foxes in Svalbard, where they have the opportunity to locate dens in burrows, screes and crevices in bedrocks as well as in unconsolidated substrate.

STUDY AREA

The Svalbard archipelago (65 000 km^2) is located between 74°N and 80°N, and 10°E and 30°E. The islands are mainly mountainous and 60% covered by permanent snow and ice. A relatively warm climate results from the combined effects of the North Atlantic current and frequent low pressure systems, which bring warm air from the south during winter. The average temperatures in July and March are about +5°C and –15°C respectively.

Most of the data on fox dens were collected in a mountainous area of 975 km^2 on the northeast corner of Nordenskiöldland (hereafter called the "study area") (Fig. 1). It is dominated by two large glaciated valleys, and the highest mountain peaks are about 1000 m. It is naturally bounded in the north by Isfjorden and to the east, south and west by mountain ranges and glaciers. A mining town, Longyearbyen, with about 1000 residents is located in the northwest corner of the study area.

Sedimentary rocks, mainly limestones and sandstones from several geological periods, predominate throughout the study area (Major and Nagy, 1972). Small slate created by erosion of these sedimentary rocks cover most of the hills with scree where solifluction prevails. Unconsolidated substrate of marine, fluvial and glacial origin is deposited in valleys and along the coast. The term "unconsolidated substrate" in this report is defined as sand and gravel.

Vegetation in the study area occurs up to 400-500 m. There are about 1500 reindeer (*Rangifer tarandus*) but no other terrestrial mammals. Along the shore, there are 10 bird cliffs with

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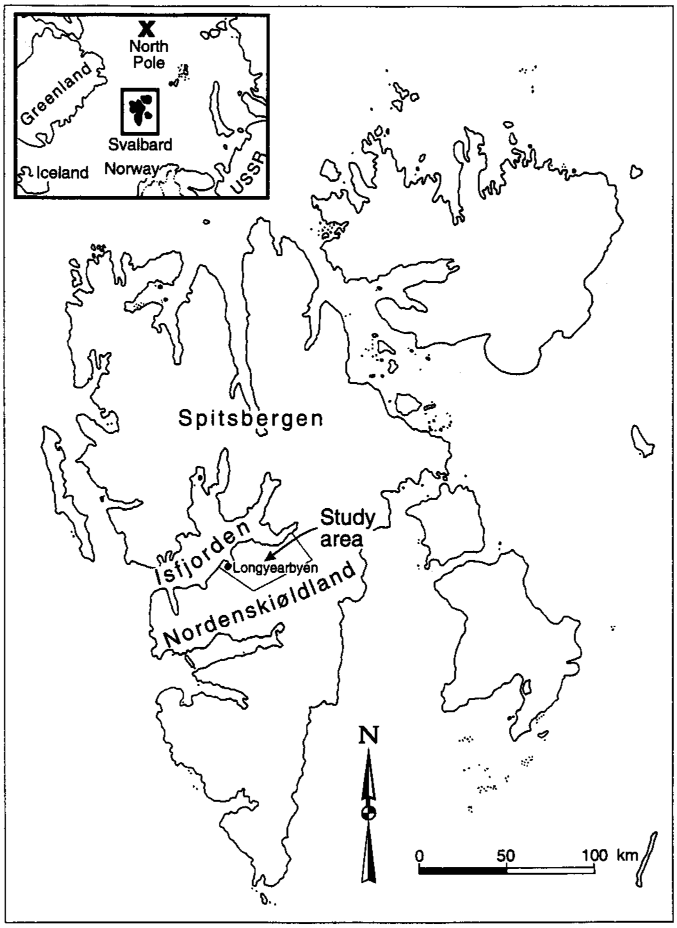

FIG. 1. Location of Svalbard and the study area (dotted line).

little auks (*Alle alle*), Brünnich's guillemots (*Uria lomvia*) and fulmar (*Fulmarus glacialis*). Ptarmigan (*Lagopus mutus*) breed throughout the study area. Pink-footed (*Anser brachyrhynchus*) and barnacle geese (*Branta leucopsis*) breed in the eastern part.

MATERIALS AND METHODS

Dens were located opportunistically all over Svalbard in 1977-79 and 1982-89 during various studies. Between 1000 and 1400 hours were spent searching for dens from the ground in the study area up to an altitude of 450-600 m during the summers of 1982-88.

Dens were plotted on a topographical map (scale 1:100 000), on a geological map (scale 1:100 000) (Major and Nagy, 1972) and on a vegetation map (scale 1:50 000) (Brattbakk, 1984). The aspect of the centre of dens was determined by a hand-held compass, and the gradient of the slope was measured with an inclinometer. The altitude of dens was determined from the topographical map. The area of each den (length × width of the area where entrances were found) that had clearly defined borders was measured, and the number of entrances were counted. Dens were classified as "dry" (usually no visible water in soil except during and immediately after rainfall), "moist" (soil usually damp) or "wet" (usually water on the soil).

Based on physical characteristics, dens were classified as: burrow — den dug out of unconsolidated substrate; combined — den under stones in combination with burrows in peat or in unconsolidated substrate; and scree — den in scree or in crevices in solid rock.

All parameters were not measured at each den. For example, it is not possible to determine an aspect for a den located in a flat area. This accounts for the small variability in sample sizes.

Snow cover was measured during late April and early May 1987 at 20 dens used most frequently during 1983-86. Because of logistic limitations, only 20 dens were surveyed one winter. Two 10 m transects, oriented N-S and E-W, were established with their midpoints in the centre of each den. Snow depth was recorded over the central den area and at one-metre intervals along the transects. From these measurements, the mean snow depth over each den was calculated inside a circle with a radius of 5 m around the den centre. The percentage of ground covered by snow on the den area was visually estimated to the nearest 10%. To compare the snow depth and snow cover inside and outside den areas, an average snow depth for the study area below 400 m was calculated by measuring the snow depth each 100 m along five transects measuring 10 km (2), 6 km (2) and 2.5 km (1) in length and located in different localities. The snow cover in these areas was visually estimated to the nearest 10%.

The vegetative cover at 10 dens used extensively during 1983-87 was analyzed by estimating the area of coverage of each plant species to the nearest 5% in 1-3 squares of 1 m × 1 m each placed on the central den area. The vegetation in a representative area adjacent to the den was also analyzed using the same method. Species present but not abundant enough to estimate coverage were also recorded (+ sign in the tables). Vascular plants and vegetation types were identified according to Rønning (1979). Bryophytes and lichens were recorded collectively. The dominant vegetation type of 47 dens in the study area was recorded. Due to logistic limitations only 10 dens were analyzed.

The central den area was defined as the area where pups and adults were observed being most active during the pupping season. The centre of dens where pups were not observed was determined on the basis of fresh burrowing, remains of fur in the entrances and the presence of prey remains.

Statistics

Statistical methods follow Zar (1984). The mean aspects of dens were analyzed using a Rayleigh test. Differences in snow depth and coverage between den areas and the rest of the study area were tested by Student's t-test after arcsin transformation of the percentage of snow coverage. Differences in percentage coverage of different plant species inside and outside den areas were tested with a nonparametric Mann-Whitney test. The significance level for all tests was set at $p < 0.05$.

RESULTS

Seventy-three dens were located during the survey, of which 56 were inside the study area. Dens were located on slopes between 0 and 45° (Fig. 2). The mean aspect of 60 dens located in slopes was 222°, and the distribution of aspects was significantly different from uniform (Rayleigh's test: $Z = 3.84$, $p < 0.05$) (Fig. 3). Dens were located at altitudes between 5 and 380 m (Fig. 4). The mean size (± SD) and the mean number (± SD) of entrances of dens having well-defined borders were 52.1 ± 75.7 m^2 (range 2 – 360 m^2, n = 59) and 9.8 ± 8.8 (range 1–35, n = 58) respectively.

Eight dens were classified as burrows, 31 as combined dens (under large stones or in crevices in rocks in combination with burrows in vegetation or sand) and 30 as scree dens (located solely in screes and/or in crevices in rocks). Four dens reported by inexperienced observers were not classified. Although at least 25% of the study area below 500 m consisted of unconsolidated substrate, only three dens (5%) were found there. Thirty-eight dens (68%) in the study area were associated with cracked solid rock, either in outcrops where the surrounding bed rock erodes more extensively or in ridges. Eight dens (14%) were associated with erratic boulders, and 8 (14%) were located in talus slopes. Forty-five (80%) of the dens were high on hillsides or on knolls, where the view was unobstructed. No dens were in depressions. Along the northern shore of the study area there are localized outcrops of intrusive bedrock (diabases), which constitute less than 1% of the entire study area. Here eroding bedrock forms large-stone screes, which create excellent denning habitat, and 5 of the 31 confirmed natal dens were located there. Only one den in the study area was located in a river bank. Of 66 dens surveyed, 61 were classified as dry, 5 as moist, and none as wet.

The mean (± SD) snow depth over 20 dens examined in late April to early May 1987 was 14 ± 14.6 cm, while the mean of samples elsewhere in the study area below 500 m was 17 ± 12.6 cm. In the same period, the average snow depth at the meteorological station in Longyearbyen (Fig. 1) was 17 cm. The difference in snow depth between areas with dens and the rest of the study area below 500 m was not significant ($t = 1.0$, $p = 0.32$). The mean (± SD) snow cover over the 20 dens, 48 ± 24.6%, was significantly less than the average snow cover elsewhere in the study area, estimated to be 70% ($t = 4.2$, $p < 0.001$). The central areas over 18 of 20 dens examined were either partly or completely free of snow.

The percentage cover of different plant species inside and outside 10 den areas is presented in Table 1. Species only present in trace amounts (+) in both areas are not included in the table. Shrubs such as *Cassiope tetragona*, *Dryas octopetala* and *Salix polaris* (lignified species) were more common outside den areas than inside, while plants more demanding of nutrition, such as grasses (graminoids), *Cerastium arcticum*, *Polygonum viviparum* and *Oxyria digyna*, were more common inside den areas. However, the variation in vegetation cover between different dens was large (coefficient of variation up to 300%; see Table 1), and few of the differences in percentage coverage for single species between inside and outside den areas were significant (Table 1). Of 47 dens where the vegetation type was recorded, 29 were dominated by *Polari-Dryadetum*, 11 by *Tetragono-Dryadetum*, 3 by *Cerastio-Saxifragion* (bird cliff vegetation), 2 by *Luzula confusa* and 2 by *Papaver dahlianum* vegetation types.

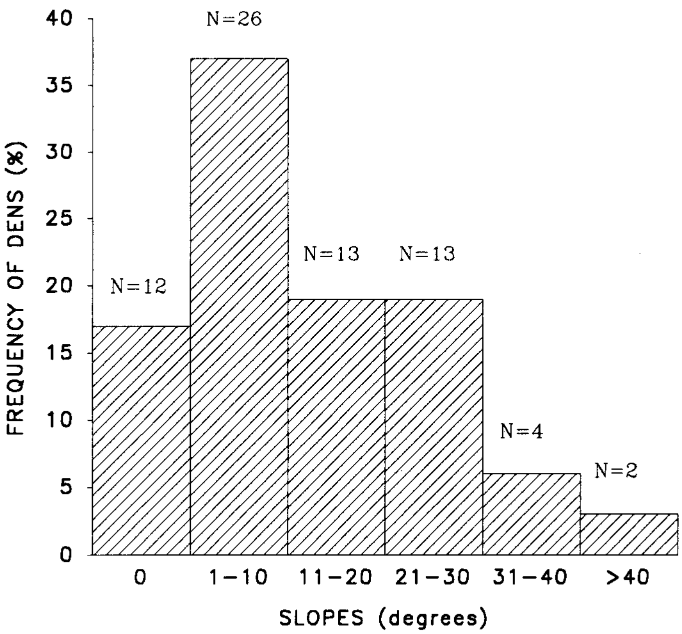

FIG. 2. Frequency of dens located on slopes of different gradients.

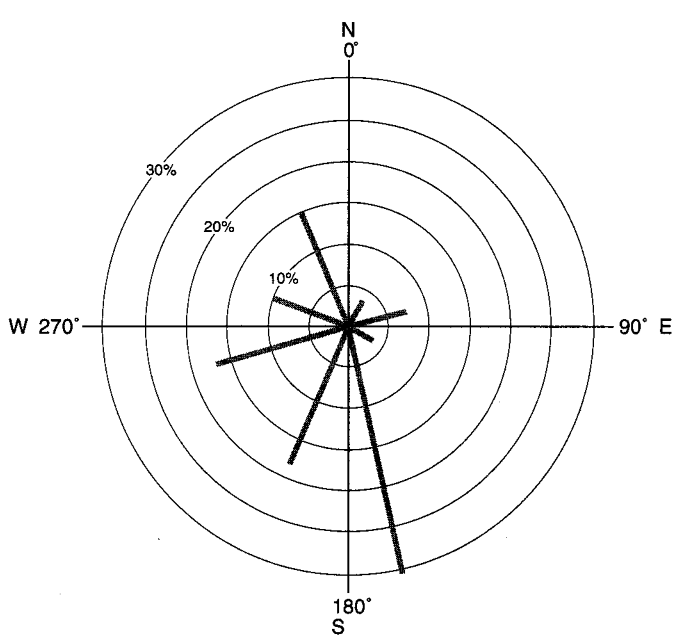

FIG. 3. Frequency (%) of dens at different aspects. Dens are pooled in 45° intervals. Concentric circles represent frequency increments of 5%. The mean aspect was 222°.

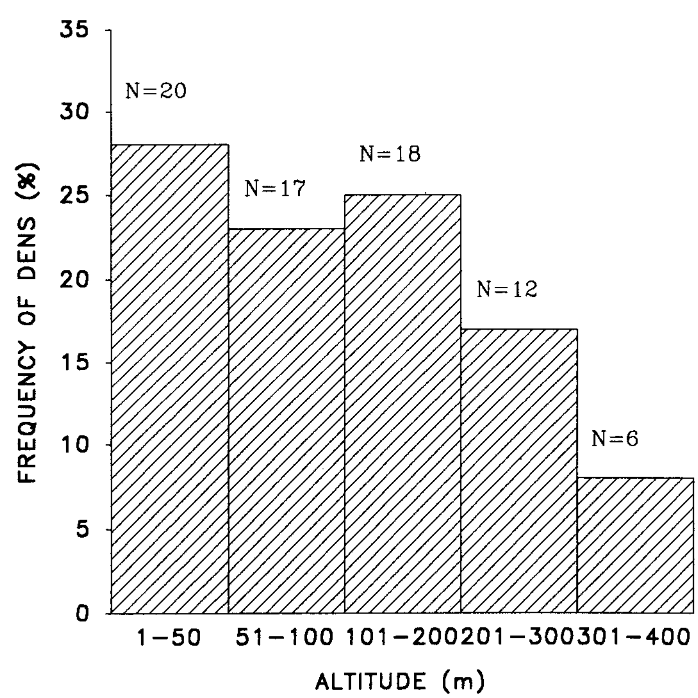

FIG. 4. The frequency of dens located at different altitudes.

TABLE 1. The mean coverage (± SD) of plant species inside and outside ten central den areas (the probability levels for Mann-Whitney tests of differences in coverage of different plant species inside and outside the den areas are given)

Species	Inside den (% coverage)	Outside den (% coverage)	Probability level Mann-Whitney test
Cassiope tetragona	0	8.7 ± 16.4	p = 0.14
Cerastium arcticum	14.4 ± 15.5	+	p < 0.05
Dryas octopetala	5.6 ± 7.3	21.2 ± 24.7	p = 0.21
Equisetum arvense	0	1.2 ± 3.5	
Oxyria digyna	11.2 ± 15.5	+	p < 0.05
Polemonium boreale	2.5 ± 7.1	0	
Polygonum viviparum	16.2 ± 17.7	7.5 ± 14.0	p = 0.48
Potentilla sp.	1.2 ± 3.5	+	
Ranunculus sulphureus	0	2.5 ± 4.1	
Salix polaris	5.0 ± 7.0	21.2 ± 19.5	p = 0.07
Saxifraga oppositifolia	0	1.2 ± 3.5	
Stellaria crassipes	2.5 ± 3.8	+	
Luzula confusa	10.0 ± 17.7	2.5 ± 7.7	p = 0.27
Alopecurus alpinus	1.2 ± 2.3	5.0 ± 14.1	
Festuca brachyphylla	5.0 ± 14.1	0	
F. rubra var. mutica	1.2 ± 3.5	0	
Poa alpina	6.2 ± 14.1	+	p = 0.14
Poa arctica	7.5 ± 17.5	+	p = 0.14
P. arctica var. vivipara	8.7 ± 17.2	+	p < 0.05
Trisetum spicatum	6.9 ± 11.6	+	p = 0.21
Mosses	19.0 ± 23.8	22.4 ± 27.8	
Lichens	3.1 ± 7.0	4.0 ± 5.0	
Soil/stone	36.2 ± 25.0	43.8 ± 20.7	p = 0.28

+ = present

DISCUSSION

Because of the intensity of the search for dens in the study area, few, if any, old dens would have gone undetected. Above 400-500 m the study area is quite barren, vegetation is almost absent, it is often very wet in summer, and snow does not disappear until July or August, if at all. Thus, biological productivity at this altitude is very low, and few arctic fox prey species are found there. Fox tracks encountered above this altitude usually passed through in a straight line, suggesting that foxes do not hunt or breed there. Although much of the area between 400 and 600 m was also surveyed for fox dens, none was found above 400 m (Fig. 4). Thus, it appears that suitable arctic fox denning habitat in the study area lies below 500 m.

The typical fox den in Svalbard is located on a hillside below 300 m with slope gradients of less than 30° and facing southwest (Figs. 2, 3, 4). A southerly orientation of the den entrances of arctic fox dens was also reported in other studies (Dementyeff, 1958; Danilov, 1961; Chesemore, 1969; Bannikov, 1970; Østbye *et al.*, 1978; Smits *et al.*, 1988). It is suggested that the preference for locating dens with a SW orientation reflects a warmer microclimate, which causes earlier melting of snow and thawing of the ground (Chesemore, 1969; Østbye *et al.*, 1978; Smits *et al.*, 1988). In agreement with this, Danilov (1961) and Smits *et al.* (1988) reported that the soil temperature outside den areas was lower than at den areas.

The size and number of den entrances were often difficult to measure because the boundaries of dens located in screes could not be determined precisely. There is considerable variation in the average den size and number of den entrances reported from Alaska, Siberia, Canada and Norway (mean number of den entrances in parentheses) from less than 30 m^2 (4) (Chesemore, 1969), through 63 m^2 (12.3) (Danilov, 1961) and about 130 m^2 (19.6) (Smits *et al.*, 1988) to a maximum of approximately 400-500 m^2 (>10) (Østbye *et al.*, 1978) respectively. Part of the large variation reported in surface area and number of entrances may result from methodological differences. For example, Østbye *et al.* (1978) mostly described old, well-known dens and included existing prey remains when defining den boundaries, so their results are not directly comparable to those from other regions, which are based on boundaries set by den entrances. Nevertheless, it appears there are substantial differences between regions as well.

Both Macpherson (1969) and Østbye *et al.* (1978) suggested that den sites were chosen in part for their small accumulation of snow during winter, but no studies were conducted to test this hypothesis. In Svalbard, the percentage of snow cover at the dens was significantly less than in surrounding areas. In 1987, most dens were partly free of snow by late April to early May. Since most dens were on knolls, ridges or other elevated landforms, and never in depressions, the wind usually kept them partially free of snow through most of the winter. Snow began to melt on south-facing hillsides in late April to early May. However, average snow depth over dens was not significantly different from the average snow depth in the surrounding area. This may be because dens in the study area were most often found under boulders, in screes or in crevices in rocks where snow can accumulate between or in the lee of stones. Consequently, snow depth in different parts of the dens showed great variability, from 0 to 2 m.

Danilov (1961) was the first to document how the vegetation at dens is lush and green because of fertilization by nutrients (both prey remains and faeces/urine) brought into the area by the foxes. The vegetation at dens examined in this study was dominated by grasses and other nutrition-demanding species such as *Cerastium arcticum* and *Oxyria digyna*, in contrast to the surrounding area where shrubs (lignified species) dominated. This is similar to results from heavily fertilized bird cliff vegetation in Svalbard (Eurola and Hakala, 1977) and confirmed by others (Chesemore, 1969; Garrott *et al.*, 1983). Even acknowledging differences in the methods used to analyze vegetation at den sites, some of my results appear to differ from areas where dens mainly are dug in sand. I did not find as marked differences in vegetation between den sites and adjacent areas as were reported by Chesemore (1969) and Garrott *et al.* (1983) in Alaska. This may be because dens in Svalbard are located in rocks and screes, where there is less soil for plants to grow in and the vegetation is much more scattered and scarce than it is where soils predominate in the substrate.

Land forms such as ridges and knolls have good drainage, and most dens were located at such sites. No dens were found in wet areas. The preference of arctic foxes for locating their dens in dry localities with good drainage has been noted by several studies (Danilov, 1961; Chesemore, 1969; Macpherson, 1969; Østbye *et al.*, 1978; Smits *et al.*, 1988). This is also reflected in the vegetation at dens in Svalbard; of five different vegetation types recorded at the dens, all are classified as dry and found in areas where little snow accumulates and melts early.

Dens in Svalbard were mainly found in association with large stones or crevices in bedrock, which differs markedly from dens described elsewhere. Macpherson (1969) and Østbye *et al.* (1978) reported few dens in bedrock and boulders in arctic Canada and southern Norway respectively. However, it appears they both put only minor effort into searching there, and there was little rocky habitat in Macpherson's (1969) study area. Bannikov (1970) noted that arctic fox "shelters" were sometimes found in rock crevices on some Siberian islands, but dens were usually located in eskers or in river banks. More than 25% of the study area is flat tundra below 50 m (Major and Nagy, 1972), consisting mainly of soil/sand of fluvial, marine or glacial origin. Some of the area is wetland, but there are also some dry moraines, elevated beaches and eskers, which should be excellent denning habitat for arctic foxes, at least according to the results of other studies. Consequently, it appears that even though habitat comparable to that used by arctic foxes in other areas was available in Svalbard, it was not preferred.

Dens in sand are easier to find than dens in rocks or under boulders because they are usually surrounded by lush vegetation, there is considerable disruption of the ground because of digging, and they are often situated in the top of raised hillocks. In this kind of habitat, dens are obvious enough that mapping from the air has been shown to be effective (Chesemore, 1969; Macpherson, 1969; Garrott *et al.*, 1983; Smits *et al.*, 1988). Dens in rocks or under boulders are difficult to detect from the air because they cause little visible change to surrounding vegetation and soil. In areas where a significant proportion of the dens may be in rocky habitat, a systematic ground survey will be needed. To date, no other detailed ground searches have been made for arctic fox dens in areas where a variety of den habitats are present in order to quantitatively evaluate preferences for denning habitat. Dens in scree and rocky habitat may give better shelter against predators than burrows in sand, gravel or soil. Red foxes (*Vulpes vulpes*) are considered a predator on arctic foxes in areas where the two species are sympatric (Macpherson, 1969; Østbye *et al.*, 1978; Frafjord *et al.*, 1989), and other predators are reported to kill arctic fox pups (Garrott and Eberhardt, 1982). Even though predatory species are not present in Svalbard, except for the Glaucous gull (*Larus hyperboreus*), that may kill fox pups, arctic foxes show a preference for locating their natal dens in rocky habitat.

Dens in unconsolidated material go through different stages with time until they finally collapse due to erosion (Macpherson, 1969; Østbye *et al.*, 1978). Many of the dens I examined in Svalbard were clearly quite old, as was indicated by an abundance of prey remains and the development of a complex den structure that would have required several years. Erosion damage to dens was not common in Svalbard, as most were in bedrocks or screes.

In conclusion, arctic foxes in Svalbard locate their dens in bedrock and scree in preference to constructed burrows. Dens in rocky areas are probably drier, provide better protection from predation and are less likely to collapse than dens dug in the ground. Most dens were located in rock outcrops or in ridges in hillsides of valleys or along the coast. It seems likely that preference of arctic foxes to den in the ground, as suggested by other studies, may result from a lack of rocky denning habitat.

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