ARCTIC
VOL. 53, NO. 1 (MARCH 2000) P. 1–8

Arctic Fox (*Alopex lagopus*) Diet in Karupelv Valley, East Greenland, during a Summer with Low Lemming Density

FREDRIK DALERUM[1] and ANDERS ANGERBJÖRN[1,2]

(*Received 7 July 1998; accepted in revised form 9 June 1999*)

ABSTRACT. We investigated the diet of arctic foxes (*Alopex lagopus*) in the Karupelv valley, East Greenland, during the summer of 1997. Despite a low density, lemmings were the most utilized prey, comprising 65.3% of dry fecal weight in fresh feces. This demonstrates the importance of lemming species as prey for arctic foxes all through a lemming cycle. Birds, arctic hare (*Lepus arcticus*), and insects also contributed to the diet. Arctic fox remains suggested that the foxes had scavenged their own species. Vegetation, muskoxen (*Ovibos moschatus*), and seal (*Phocidae*) were found in small amounts. We compared estimates of prey availability and diets of arctic foxes for a coastal area (<10 km from the shore) and an inland area (>10 km from the shore). Abundance of avian prey tended to be higher in the coastal area. Fresh feces indicated a significant overall difference in arctic fox diets between the coastal and inland areas. Within prey categories, lemmings were significantly more represented in the inland area, while the coastal area had a more diverse diet overall. We also suggest that the existence of arctic foxes in East Greenland is dependent on regular peak years in lemming density.

Key words: Arctic fox, *Alopex lagopus*, diet, East Greenland, fecal analysis, lemming

RÉSUMÉ. Au cours de l'été de 1997, on a étudié le régime alimentaire du renard arctique (*Alopex lagopus*) dans la vallée de la Karupelv (Groenland oriental). Malgré sa faible densité, le lemming était la proie la plus courante, constituant 65,3 p. cent de poids fécal sec dans les excréments frais. Ce fait illustre l'importance de l'espèce du lemming comme proie pour le renard arctique durant un cycle complet de lemmings. Les oiseaux, le lièvre arctique (*Lepus arcticus*) et les insectes entraient aussi dans le régime alimentaire. Des restes de renard arctique donnent à penser que les renards se nourrissaient des charognes de leurs congénères. On a trouvé de petites quantités de plantes, de boeuf musqué (*Ovibos moschatus*) et de phoque (*Phocidae*). On a comparé les estimations de la disponibilité des proies et le régime des renards arctiques pour une région côtière (< 10 km du rivage) et pour une région à l'intérieur des terres (> 10 km du rivage). L'abondance des proies aviaires tendait à être plus grande dans la région côtière. Les excréments frais révélaient une différence globale importante dans le régime du renard arctique entre la région côtière et l'intérieur des terres. Si l'on considère les catégories de proies, le lemming se retrouvait en quantité relativement plus élevée dans la région située à l'intérieur des terres, alors que la région côtière avait dans l'ensemble un régime plus diversifié. On suggère également que l'existence du renard arctique dans l'est du Groenland est liée à la régularité des années d'abondance dans la densité de lemmings.

Mots clés: renard arctique, *Alopex lagopus*, régime alimentaire, Groenland oriental, analyse coproscopique, lemming

Traduit pour la revue *Arctic* par Nésida Loyer.

INTRODUCTION

Food utilization is an important factor for understanding carnivore ecology. The arctic fox (*Alopex lagopus* (L.)) is a small canid, regarded as having a semigeneralistic feeding strategy (Angerbjörn et al., 1994; Kaikusalo and Angerbjörn, 1995). Two arctic habitats with a high production of food for arctic foxes can be identified, and both fluctuate in productivity. In areas close to colonies of ground-breeding birds, such as seabirds or geese, prey abundance fluctuates on a yearly scale (Hersteinsson and Macdonald, 1996), while in areas with microtine rodents, prey abundance mostly fluctuates on a longer time scale (Elmhagen et al., in press). However, both habitats are characterized by a superabundance of prey during a restricted period. Therefore, the periods of food scarcity between these peaks in prey abundance may function as bottlenecks for fox populations. Most studies of carnivores exploring fluctuating food resources have presented data from periods of high food abundance. However, to understand the relationships between predators and their prey, it is important to study the diet at low food abundance. The arctic fox population in East Greenland appears to depend to a large extent on the cyclic population of the Greenland lemming (*Dicrostonyx groenlandicus* Traill), the only species of small rodent present (Manniche, 1910; Braestrup, 1941; Piantanida, 1979). In Greenland, foxes are confined to the coast and thus also to coastal food

---

[1] Department of Zoology, Stockholm University, S-106 91 Stockholm, Sweden
[2] Corresponding author: Fax: +46 8 16 77 15; angerbj@zoologi.su.se

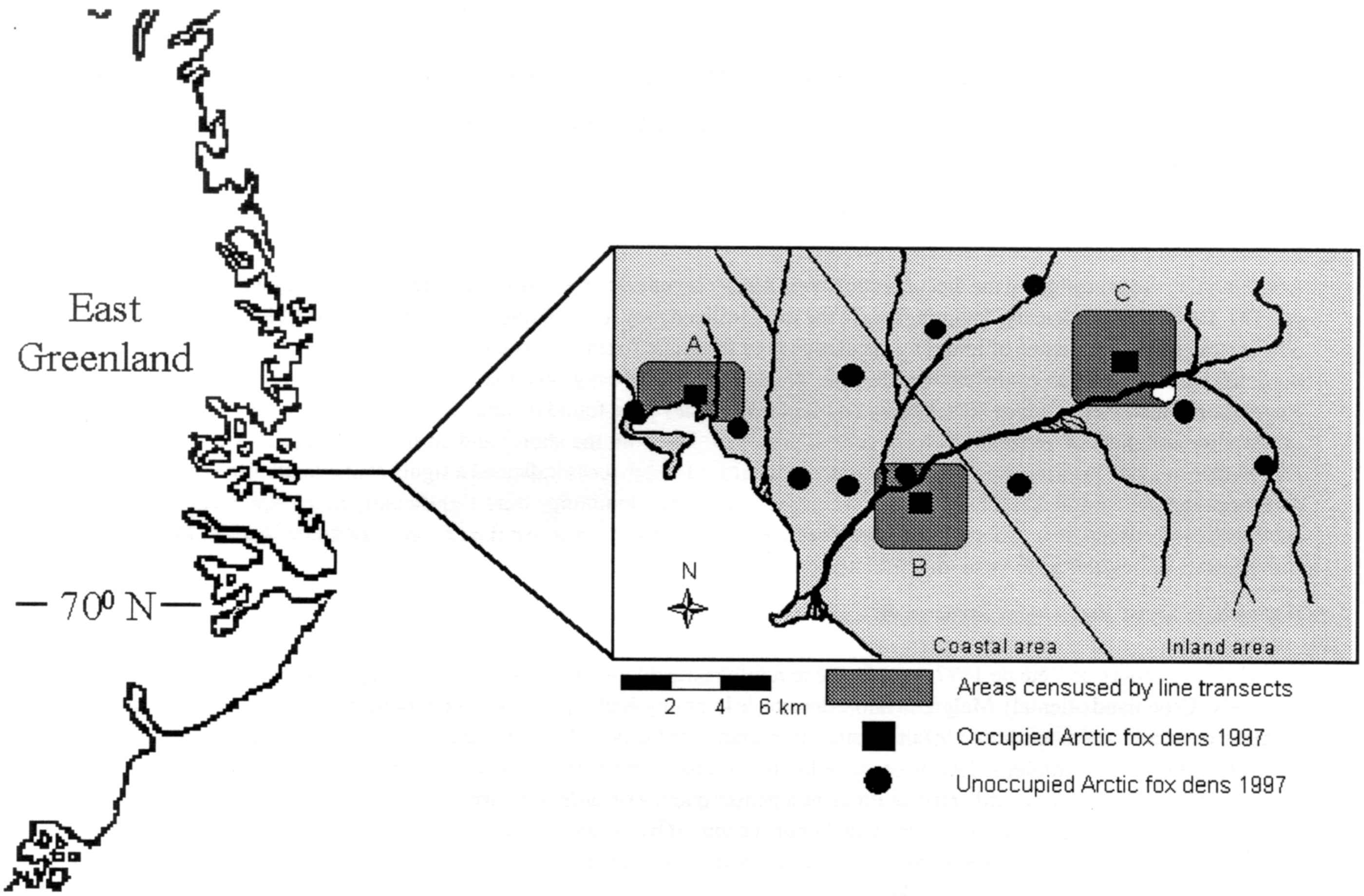

FIG. 1. Map of Karupelv valley, Traill Island, showing the inventoried arctic fox dens, the areas used for the bird census, and the border between the coastal and inland areas. The dens occupied by reproducing foxes in 1997 are marked A, B, and C.

resources (Angerbjörn et al., 1994). In East Greenland, this provides opportunities for exploring the food ecology of arctic foxes in an area with only one rodent species, but additional coastal food resources. In coastal areas in North America, arctic foxes sympatric with various rodent species have been shown to feed on alternative prey if it is available (Chesemore, 1968; Quinlan and Lehnhausen, 1982; Burgess, 1984; Fay and Stephenson, 1989). Also, coastal areas in Iceland appear to have a higher density of arctic foxes than do inland areas (Hersteinsson and Macdonald, 1996). However, no previous study has explored the arctic fox food utilization in East Greenland during a period with known lemming density.

In the present study, we investigated the diet of arctic foxes in the Karupelv valley, East Greenland, during the summer of 1997. A concurrent study in the area revealed a low lemming density, 10 times lower than in peak years (Sittler et al., 1998). With low density of lemmings, it is unclear whether the abundance of alternative prey species could be sufficient for arctic fox existence in these areas. We hypothesized that coastal areas should provide a greater food supply for arctic foxes during the summer than inland areas because alternative prey are more available. To investigate this hypothesis, we explored the following two predictions: 1) the abundance of alternative prey should be higher near the coast than inland, primarily because of higher prey diversity; 2) arctic foxes feeding on the coast should show a more diverse diet than foxes feeding inland. To test these predictions, coastal and inland areas were compared with regard to estimates of prey availability, principally bird abundance, and diets of arctic foxes.

STUDY AREA

The study was conducted in the Karupelv valley, on the western side of Traill Island (72˚30′N, 24˚W), East Greenland (Fig. 1). The study area comprises approximately 800 km^2, covering most of the valley. Altitude ranges from sea level up to 300 m, and the valley is bordered to the north and south by mountains up to 1700 m high. Apart from two rocky peninsulas, the study area consists of tundra dominated by dry grass heath and, in the lower parts, also moist meadow. This study was a part of a long-term field project that has been monitoring the population fluctuations of the Greenland lemming and related factors in the area since 1988 (Sittler, 1995).

Greenland lemming, the only species of small rodent in the study area, shows large fluctuations in density, with peaks every fifth year (Sittler, 1995; Sittler et al., 1998).

TABLE 1. Litter sizes estimated in the three occupied dens,[1] line transect census results in the three denning areas (number observed per 10 km transect), and the negative natural logarithm (-ln) of Simpson's corrected index of diversity,[2] counted for the bird community.

Den/ census area	Area	Initial litter size	Litter size in August	Muskoxen carcasses	Arctic hares	Anatids	Waders	Small passerines	Jaegers	Other bird taxa	Total birds	-ln of Simpson's index of species diversity
A	coastal	6	3	0.3	0.3	6.3	37.8	19.4	16.3	2.5	82.3	1.2
B	coastal	2	1	0	0	0	14.2	6.8	21.4	0.3	42.7	0.9
C	inland	3	0	0	0	2.8	21.4	2.3	16.5	1.0	44.0	0.9

[1] based on monitoring and (in dens B and C) remains of dead cubs.

[2] (Rosenzweig, 1995) This measure, which decreases as species diversity declines, gives a relative index of bird species diversity in each area.

Arctic hare (*Lepus arcticus* Ross) and muskoxen (*Ovibos moschatus* (Zimmermann)) are the other mammalian herbivores in the area. Stoat (*Mustela erminea* L.) and polar bear (*Ursus maritimus* Phipps), together with arctic fox, are the mammalian predators present, but wolves (*Canis lupus* L.) may occasionally pass through the valley. Carcasses of marine mammals are sometimes available along the coast and on the drift ice in the fjord. There is no permanent human activity in the area.

Migratory birds are common during the breeding period. Six species of arctic waders (Charadrii), a few species of passerines, rock ptarmigan (*Lagpous mutus* (Moutin)), king eider (*Somateria spectabilis* (L.)), oldsquaw (*Clangula hyemalis* (L.)) and red-throated diver (*Gavia stellata* (Pontoppidan)) breed in the valley. Eider (*Somateria mollissima* (L.)), arctic tern (*Sterna paradisaea* Pontoppidan) and glaucous gull (*Larus hyperboreus* Gunnerus) breed along the coast and on small islands in the fjord. Two colonies of barnacle geese (*Branta leucopsis* (Bechstein)) occur in cliffs along the coast and pink-footed geese (*Anser brachyrhynchus* Baillon) have formed a colony in the middle part of the valley. The avian predators consist of parasitic jaeger (*Stercorarius parasiticus* (L.)), longtailed jaeger (*S. longicaudus* Viellot), gyrfalcon (*Falco rusticolus* L.) and snowy owl (*Nyctea scandiaca* (L.)). A number of invertebrates are present; insects are the most important taxonomic group for the foxes.

METHODS

We divided the valley into coastal and inland areas by setting a distance of 10 km from the coast as the limit for the coastal area (Fig. 1). We based this distance on published home range estimates of coastal arctic foxes (Eberhardt et al., 1982, 8.5 – 33.5 km^2; Hersteinsson and Macdonald, 1982, 9 – 19 km^2; Burgess, 1984, 18 – 24 km^2; Birks and Penford, 1990, 10 – 14 km^2; Frafjord and Prestrud, 1992, 10 – 125 km^2; Prestrud 1992, 34 – 50 km^2; Anthony, 1997, 5 – 13 km^2).

Although ten dens were known, the study area was systematically searched to detect possible new den sites. A den was classified as occupied or non-occupied according to the presence and quantity of fresh feces and prey remains. Dens initially considered to be occupied were monitored from a distance of 300 – 400 m, to register adult and juvenile foxes. These observations lasted from one to 48 hours.

Sampling and Analysis of Arctic Fox Feces

A total of 689 feces was collected throughout the valley from June to August 1997. The feces were divided into fresh and old, with respect to the degree of bleaching, growth of algae, and position in the surrounding vegetation (Macpherson, 1969; Angerbjörn et al., 1999). Fresh feces were estimated to be from the spring and summer of 1997, and old feces from unknown previous years. Fresh feces were collected at den sites and opportunistically whenever noticed in the field. Old feces were collected only during the first visit to each den site.

Collected feces were air dried and stored in plastic bags until analysis. Each fecal unit was individually fragmented and washed in water over a sieve with a mesh size of 1.0 mm to separate the macro and micro fractions. Only the macro fraction was used in the analyses. Macro fractions were dried and weighed (± 0.01g), and the different food categories were separated when possible. Separated food categories were weighed (± 0.1 g) and relative dry weight was calculated by dividing the weight of each food category by the total weight of that fecal unit. In cases where the separation was impossible, the dry weight of each category was calculated by multiplying the estimated relative dry volume of each fecal unit by the total dry weight of the macro fraction of the same fecal unit. This relative dry volume was visually estimated to the nearest 5%. Prey remains were identified by comparisons with reference material and the keys and guides of Day (1966), Debrots et al. (1982), Brom (1986), and Teerink (1991). No attempt was made to identify egg remains because they were highly fragmented. Plant material was excluded from analyses if it contributed less than 10% of the dry weight of the macro fraction. In these small proportions, plants were probably ingested accidentally and did not contribute substantially to the arctic fox diet (Chesemore, 1968; Goszcynski, 1974; Garrott et al., 1983; West, 1987).

The dietary results are presented as percentage of dry fecal weight, since this is regarded as the most appropriate method for quantifying fecal data from foxes (Lockie,

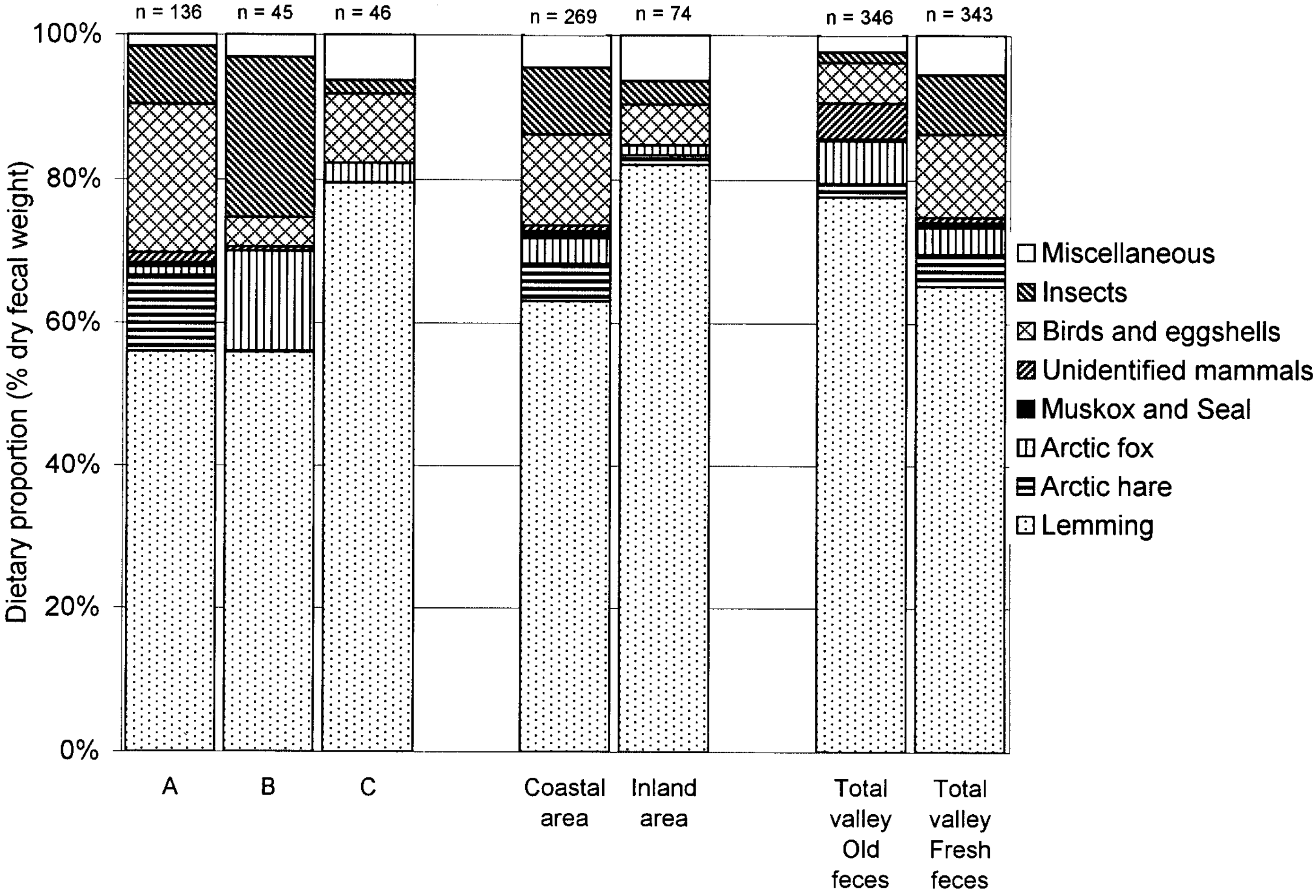

FIG. 2. Diets of arctic foxes in Karupelv valley, as indicated by percentage of dry fecal weight (n = number of fecal units). Total valley results = all samples pooled. Coastal area results include the feces from dens A and B, and inland area results include the feces from den C.

1959; Hersteinsson and Macdonald, 1996). However, we quantified bird taxa identified in feces as percentage of occurrences, with the total number of feces containing bird remains as total sample size rather than the total number of collected feces. We assumed that the fecal proportions approximate the proportions of different food categories in fox diets. Because of statistical difficulties with percentage of fecal weight (Reynolds and Aebisher, 1991), we used Whole Scat Equivalents (WSE) for the statistical calculations (except to compare identified bird taxa, for which frequency of occurrence was used). WSE is a modified frequency-of-occurrence measure that summarizes the relative dry volumes for a given prey category within a sample. It thus provides a frequency equivalent to the number of fecal units containing 100% of the current food category (Angerbjörn et al., 1999). We applied log-linear likelihood models (G-tests) on contingency tables for overall comparisons of diets and identified bird taxa. Comparisons within prey categories were made using chi-square statistics with Yates correction on 2 × 2 contingency tables (Zar, 1996). Level of statistical significance is set to $p \leq 0.05$, but the exact probabilities are given. All p-values are two-tailed.

Abundance of Alternative Prey

We recorded alternative prey species in quadrats of 16 km^2 around the occupied arctic fox dens (A, B and C, Fig. 1), except in area A, which was limited by the shoreline and covered only 10 km^2. We recorded birds, arctic hares, and carcasses of muskoxen while walking along parallel transects that were 4 km long and 300 m apart. The number of individuals was recorded for each observation, and the birds were identified by species if possible. Since there were extremely few observations of arctic hare and carcasses, and since line transect data may give rather unrealistic estimates of bird densities in poor arctic regions (Burnham et al., 1980), we only used the inventory data as relative density indices. Inventories were made during three periods for Area A (3–8 July, 12–17 July, 30 July–4 August), one period for Area B (7–28 July), and two periods for Area C (21–23 July and 7–8 August). To evaluate the diversity of bird species in three areas, we calculated the negative natural logarithm for Simpson's corrected index of diversity (Rosenzweig, 1995). We based these calculations on the number of observed individuals of each taxon, grouped as in Table 1, and not on the number of observed individuals of each species.

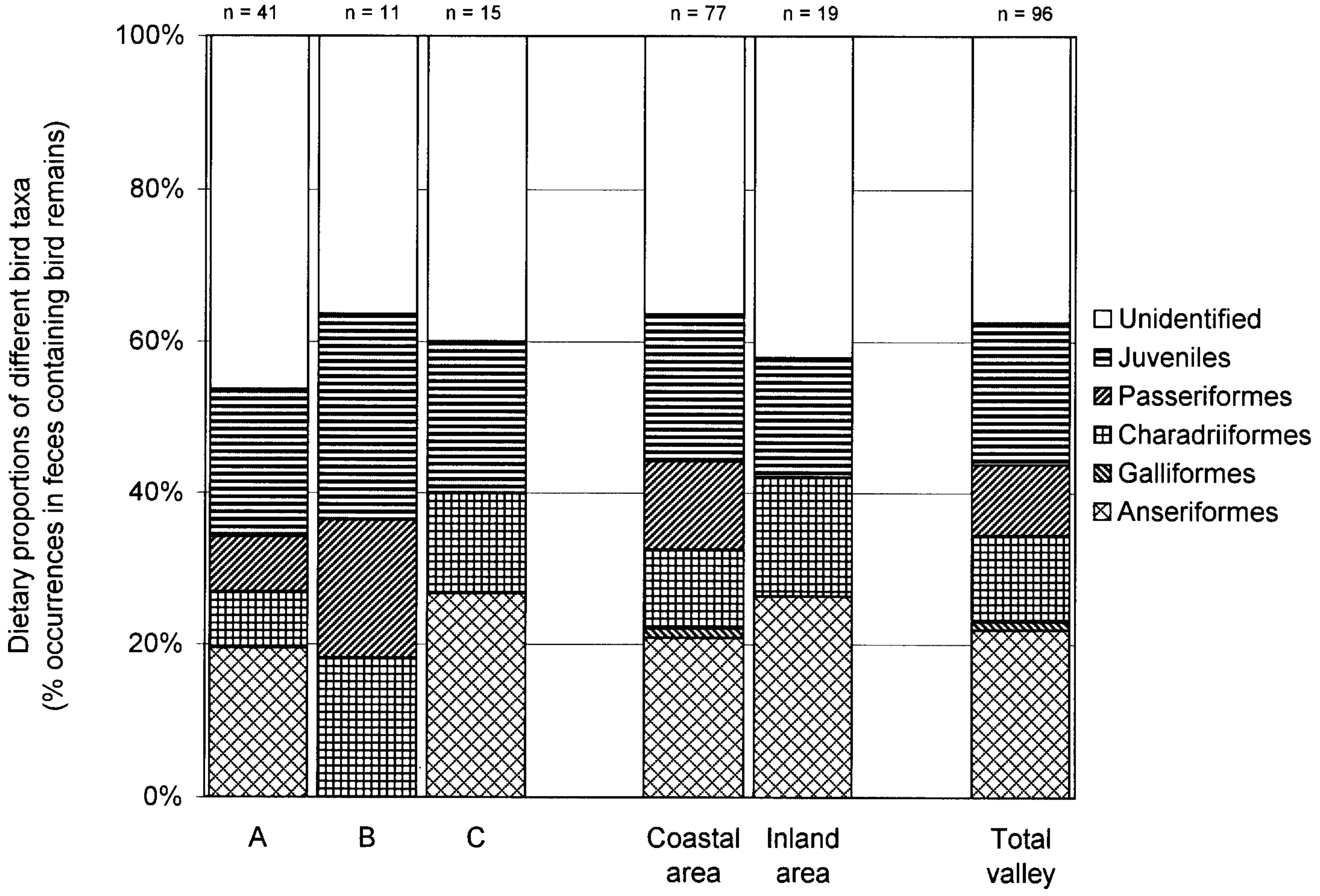

FIG. 3. Proportion of different bird taxa identified in fresh feces, expressed as percentage of occurrences of each taxon in relation to the total number of feces containing bird remains (n = total number of fecal units from each sample that contained bird remains). Total valley results = all samples pooled. Coastal area results include the feces from dens A and B, and inland area results include the feces from den C.

RESULTS

All together we found 14 dens in the area, but only three of these were occupied by reproducing foxes. Of these, dens A and B were within the coastal area, and den C was in the inland area (Fig. 1). Monitoring indicated an initial litter of six cubs in den A, of which at least three survived to early August (Table 1). Initial litter sizes in dens B and C were extrapolated from monitoring in mid-July, when they were visited for the first time during the season. Remains of one deceased cub at each of these dens gave a minimum number of two cubs born for den B and three for den C (Table 1).

Arctic Fox Diet

Although at low density, lemmings were the primary prey for arctic foxes in the Karupelv valley, contributing 65.3% of dry fecal weight in fresh feces and 76.8% of dry fecal weight in old feces (Fig. 2). Birds were the most important alternative prey category, contributing 11.5% of dry fecal weight in fresh feces and 5.5% of dry fecal weight in old feces. Further, birds were likely to be underestimated in feces, since only the macro fraction was analyzed (Reynolds and Aebisher, 1991). Eggshells were found only in trace amounts, but were also underestimated, since the quantities of undigested remains were small compared to the amount of digestible matter (Birks and Penford, 1990; Frafjord, 1993).

Comparing fresh scats, there was a significant overall difference in diet composition between the coastal and inland areas (Fig. 2; $G = 13.1$, $df = 4$, $p = 0.011$). Lemmings contributed to a significantly higher proportion of inland samples than of coastal samples ($\chi^2 = 10.19$, $df = 1$, $p = 0.014$). Both birds and insects (mainly bumblebees, *Bombus* sp.) tended to contribute to higher proportions of coastal samples (birds: $\chi^2 = 3.03$, $df = 1$, $p = 0.082$; insects: $\chi^2 = 2.31$, $df = 1$, $p = 0.129$). The proportions of bird taxa identified in feces did not differ significantly between the two areas ($G = 2.88$, $df = 5$, $p = 0.72$), but a greater diversity was indicated for bird remains from the coastal area (Fig. 3). We also found rather high proportions of arctic fox remains in the feces. Most of the feces that contained fox hair also contained bone fragments, suggesting that the foxes had been scavenging their own species.

There was a significant difference in overall diet composition between foxes occupying the three occupied dens (Fig. 2; $G = 19.2$, $df = 8$, $p = 0.013$). Lemmings contributed

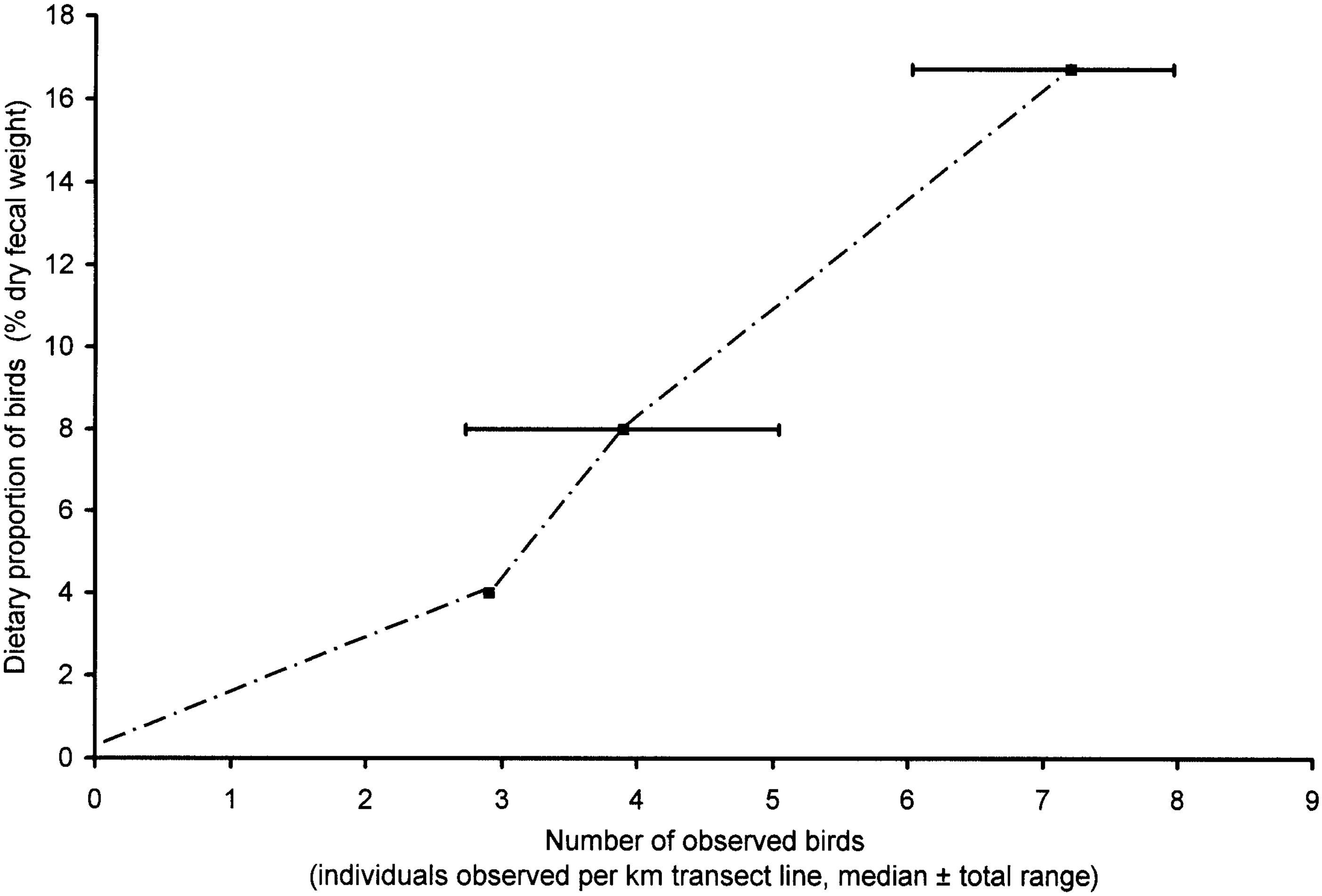

FIG. 4. Relationship between indices of bird abundance (individuals observed per kilometre transect, all bird taxa pooled) in 16 km^2 areas surrounding the three occupied arctic fox dens (A, B, and C, see Fig. 1) and the proportion of bird remains found in the feces from the corresponding dens, expressed as percentage of dry fecal weight.

a larger part of the diet in den C than in both den A ($\chi^2 = 4.36$, df = 1, $p = 0.037$) and den B ($\chi^2 = 4.11$, df = 1, $p = 0.042$). In feces from den B, a significantly higher proportion of insects compensated for the relatively low proportion of lemmings (den A: $\chi^2 = 6.17$, df = 1, $p = 0.013$; den C: $\chi^2 = 9.32$, df = 1, $p = 0.002$). In feces from den A, a more diverse diet overall compensated for the low proportion of lemmings. Furthermore, feces from this den had a higher diversity among identified bird taxa, although the sample size was too small for valid statistical analysis (Fig. 3). The dietary proportion of birds increased with the number of birds observed in corresponding census areas, indicating a functional response for birds (Fig. 4).

Abundance of Alternative Prey

Bird indices derived from the line transect census indicated a both more diverse and dense bird community in area A than in the other two census areas (Table 1). Long-tailed jaeger, ringed plover, and snow bunting were the most frequently observed species in all areas.

Only one recent muskox carcass and one arctic hare were observed, both in area A (Table 1). No carcasses of marine mammals were found along the shore. However we did not systematically search the entire shoreline for carcasses.

DISCUSSION

Only three of the 14 arctic fox dens were occupied during this year of low lemming density, illustrating the numerical response for arctic foxes preying on lemmings (e.g., Macpherson, 1969; Angerbjörn et al., 1999). The numbers also demonstrate the problems with low sample size in studies at such low lemming densities (Elmhagen et al., in press). The fecal analyses revealed lemmings as arctic foxes' main prey during summer 1997, even though the lemming population was reported to have been at low density (Sittler et al., 1998). This shows the importance of lemming species as prey for arctic foxes all through a lemming cycle. The higher proportion of lemming remains in old feces might be explained if a majority of the old feces are from lemming peak years, since arctic foxes are known to concentrate their feeding on lemmings at high density of lemmings (Macpherson, 1969; Ovsyanikov, 1993; Kaikusalo and Angerbjörn, 1995; Angerbjörn et al., 1999; Elmhagen et al., in press). Birds were found as an important alternative prey. Birds have also been noticed as important alternative summer prey for the arctic fox in other lemming areas (Chesemore, 1968; Macpherson, 1969; Riewe, 1977; Garrott et al., 1983; Burgess, 1984; Fay and Stephenson, 1989; Stickney, 1991; Elmhagen et al., in press). In Alaska, Burgess (1984) and Stickney (1991) found that birds and eggs dominated the arctic fox diet during the nesting period. Such a response was also indicated by the results of Summers and Underhill (1987) and Summers et al. (1998), implying that a generalistic feeding strategy toward birds might be general for arctic foxes in the presence of lemmings, with a corresponding type III response pattern (Taylor, 1984). This idea was supported by the pattern we found for bird utilization among the foxes inhabiting dens A, B, and C in this study, although the low sample size prevented us from drawing any specific conclusions concerning the functional response in this area. A local importance of insects and arctic hare could also be traced as reported in earlier studies (Riewe, 1977; Piantanida, 1979), further indicating the ability of the foxes to use a wide range of prey. Our dietary results suggest that scavenging of their own species had occurred among the foxes. Researchers in Canada (Macpherson, 1969), Scandinavia (Angerbjörn and Arvidsson, 1987; Sklepkovych, 1989), and Svalbard (Frafjord, 1993) have reported similar findings, indicating that such scavenging might be a widespread phenomenon in arctic fox populations during breeding seasons with shortages of food.

The results from the bird censuses partly supported our first prediction, i.e., a higher abundance of alternative prey in the coastal area. However, bird abundance appears to have been high only rather close to the coast. The 10 km limit for the coastal area seems to have been too great a distance for investigating coast-related spatial differences in bird abundance. Although the number of foxes in the valley was low, so that individual variation might bias the dietary results, the results from the fecal analyses indicated that the diets of foxes were more diverse in coastal areas, supporting our second prediction. The absence of seabirds, coupled with the fact that only trace amounts of remains from strictly maritime food categories were found in the feces, suggests that the sea has only minor importance as a direct food source. Instead, the greater availability of food near the coast might be caused by a higher terrestrial productivity, possibly due to moist soil conditions (Bliss, 1977), in combination with a higher habitat heterogeneity.

In an extended study of an Arctic community in northern Canada, Reid et al. (1997) revealed the importance of alternative prey species for potentially generalistic carnivores in arctic environments. The animal community in the Karupelv valley includes only a few species and lacks some principal food alternatives to lemmings, such as arctic ground squirrel (*Spermophilus parryii* (Richardson)) (Reid et al., 1997), sea birds (Fay and Stephenson, 1989), and human deposits (Garrott et al., 1983). This scarcity of alternative food sources appears to force the arctic fox to feed on lemmings even during years when these occur at low densities. This feeding might affect the fluctuations in lemming density and prolong the cycle length. As the coastal area appears to offer a slightly greater abundance of alternative prey, we predict that activity of arctic foxes in East Greenland will be concentrated in coastal areas during summers with low lemming densities, although the alternative prey might be too scarce to support extensive arctic fox reproduction. We also suggest that the existence of arctic foxes in East Greenland is dependent on regular peak years in lemming density.

ACKNOWLEDGEMENTS

We wish to thank Benoît Sittler and Marék Zakrzcewski, both participants in the 1997 expedition of the Karupelv valley project. Olivier Gilg and three anonymous reviewers gave valuable comments on the manuscript. We are also grateful to Grimsö Wildlife Research Station for the opportunity to use their laboratory facilities for the fecal analyses. The German Science Foundation is the main financial sponsor of the Karupelv valley project, and Fredrik Dalerum's participation in the 1997 field season was further financially supported by Kurt Belfrages Minnesfond.

REFERENCES

ANGERBJÖRN, A., and ARVIDSSON, B. 1987. Kannibalism bland fjällrävsvalpar? Viltnytt 24:27–33.

ANGERBJÖRN, A., HERSTEINSSON, P., LIDÉN, K., and NELSON, E. 1994. Dietary variation in arctic foxes (*Alopex lagopus*): An analysis of stable carbon isotopes. Oecologia 99:226–232.

ANGERBJÖRN, A., TANNERFELDT, M., and ERLINGE, S. 1999. Predator–prey relations: Arctic foxes and lemmings. Journal of Animal Ecology 68:34–49.

ANTHONY, R.M. 1997. Home ranges and movements of arctic fox (*Alopex lagopus*) in western Alaska. Arctic 50:147–157.

BIRKS, J.D.S., and PENFORD, N. 1990. Observations on the ecology of arctic foxes *Alopex lagopus* in Eqalummiut Nuunat, West Greenland. Meddelelser om Grønland, Bioscience 32. 28 p.

BLISS, L.C., ed. 1977. Truelove Lowland, Devon Island, Canada: A High Arctic ecosystem. Edmonton, Alberta: University of Alberta Press.

BRAESTRUP, F.W. 1941. A study on the arctic fox in Greenland. Meddelelser om Grønland 131(4). 101 p.

BROM, T.G. 1986. Microscopic identification of feathers and feather fragments of palearctic birds. Bijdragen tot de Dierkunde 56:181–204.

BURGESS, R.M. 1984. Investigations of patterns of vegetation, distribution and abundance of small mammals and nesting birds, and behavioral ecology of arctic foxes at Demarcon

Bay, Alaska. Unpublished M.Sc. thesis, University of Alaska, Fairbanks.

BURNHAM, K.P., ANDERSSON, D.R., and LAAKE, J.L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72. 202 p.

CHESEMORE, D.L. 1968. Notes on the food habits of arctic foxes in northern Alaska. Canadian Journal of Zoology 46: 1127–1130.

DAY, M.G. 1966. Identification of hair and feather remains in the gut and feces of stoats and weasels. Journal of Zoology 155: 485–497.

DEBROT, S.G., FIVAZ, C., MERMOD, J., and WEBER. M. 1982. Atlas des poils de mammifères d'Europe. Neuchâtel, Switzerland: Institute of Zoology, University of Neuchâtel.

EBERHARDT, L.E., HANSON, W.C., BENGTSON, J.L., GARROTT, R.A., and HANSON, E.E. 1982. Arctic fox home range characteristics in an oil-development area. Journal of Wildlife Management 46:183–190.

ELMHAGEN, B., TANNERFELDT, M., VERUCCI, P., and ANGERBJÖRN, A. In press. The arctic fox: An opportunistic specialist. Journal of Zoology.

FAY, F.H., and STEPHENSON, R.O. 1989. Annual, seasonal and habitat related variation in feeding habits of the arctic fox (*Alopex lagopus*) on St. Lawrence Island, Bering Sea. Canadian Journal of Zoology 67:1986–1994.

FRAFJORD, K. 1993. Food habits of arctic foxes (*Alopex lagopus*) on the western coast of Svalbard. Arctic 46:49–54.

FRAFJORD, K., and PRESTRUD, P. 1992. Home range and movements of arctic foxes *Alopex lagopus* in Svalbard. Polar Biology 12:519–526.

GARROTT, R.A., EBERHARDT, L.E., and HANSON, W.C. 1983. Summer food habits of juvenile arctic foxes in northern Alaska. Journal of Wildlife Management 47:540–545.

GOSZCYNSKI, J. 1974. Studies on the food of foxes. Acta Theriologica 19:1–18.

HERSTEINSSON, P., and MACDONALD, D.W. 1982. Some comparisons between red and arctic foxes, *Vulpes vulpes* and *Alopex lagopus*, as revealed by radio tracking. Symposium of the Zoology Society, London 49:259–289.

———. 1996. Diet of arctic foxes (*Alopex lagopus*) in Iceland. Journal of Zoology 240:457–474.

KAIKUSALO, A., and ANGERBJÖRN, A. 1995. The arctic fox population in Finnish Lapland during 30 years, 1964–93. Annales Zoologici Fennici 32:69–77.

LOCKIE, J.D. 1959. The estimations of the food of foxes. Journal of Wildlife Management 23:224–228.

MANNICHE, A.L.V. 1910. The terrestrial mammals and birds of North-East Greenland. Meddelelser om Grønland 45(1). 200 p.

MACPHERSON, A.H. 1969. The dynamics of Canadian arctic fox populations. Canadian Wildlife Service Report Series No. 8. Ottawa: Canadian Wildlife Service.

OVSYANIKOV, N.G. 1993. Behavior and social organization of the arctic fox (in Russian). Moscow: Isdatelctro Tsentralnoi Naushno—Issledovatelskoi Laboratori Ochotnichevo Chosjaistvoi Sapovednikov.

PIANTANIDA, A. 1979. Ecologie alimentaire du renard polaire (*Alopex lagopus*) dans quatre régions arctiques. Unpublished M.Sc. thesis, Université Louis Pasteur, Paris, France.

PRESTRUD, P. 1992. Denning and home range characteristics of breeding arctic foxes in Svalbard. Canadian Journal of Zoology 70:1276–1283.

QUINLAN, S.E., and LEHNHAUSEN, W.A. 1982. Arctic fox, *Alopex lagopus*, predation on nesting common eiders, *Somateria mollissima*, at Icy Cape, Alaska. Canadian Field-Naturalist 96:462–466.

REID, D.G., KREBS, C.J., and KENNEY, A.J. 1997. Patterns of predation on noncyclic lemmings. Ecological Monographs 67:89–108.

REYNOLDS, J.C., and AEBISHER, N.J. 1991. Comparison and quantification of carnivore diet by fecal analyses: A critique, with recommendations, based on a study on the fox *Vulpes vulpes*. Mammal Review 21:97–122.

RIEWE, R.R. 1977. Mammalian carnivores utilizing Truelove Lowland. In: Bliss, L.C., ed. Truelove Lowland, Devon Island, Canada: A High Arctic ecosystem. Edmonton: The University of Alberta Press. 493–501.

ROSENZWEIG, M.L. 1995. Species diversity in space and time. Cambridge: Cambridge University Press.

SITTLER, B. 1995. Response of stoats (*Mustela erminea*) to a fluctuating lemming (*Dicrostonyx groenlandicus*) population in North East Greenland: Preliminary results from a long-term study. Annales Zoologici Fennici 32:79–92.

SITTLER, B., LIESER, M., and ZAKRZEWSKI, M. 1998. Karupelv Valley Project: Overview on ongoing investigations. In: Berg, T.B., and Forchhammer, M.C., eds. Arktisk Biologisk Forskermøde 7 (Book of Abstracts). Copenhagen: Dansk Polarcenter. 6.

SKLEPKOVYCH, B.O. 1989. Kannibalism hos fjällrävar, *Alopex lagopus*, i de Svenska lappmarksfjällen (in Swedish with English summary). Fauna och Flora 84:145–150.

STICKNEY, A. 1991. Seasonal patterns of prey availability and the foraging behaviour of arctic foxes (*Alopex lagopus*) in a waterfowl nesting area. Canadian Journal of Zoology 69:2853–2859.

SUMMERS, R.W., and UNDERHILL, L.G. 1987. Factors related to breeding production of brent geese *Branta b. bernicla* and waders (*Charadrii*) on the Taimyr Peninsula. Bird Study 34: 161–172.

SUMMERS, R.W., UNDERHILL, L.G., and SYROECHKOVSKI, E.E., Jr. 1998. The breeding productivity of dark-bellied brent geese and curlew sandpipers in relation to changes in the number of arctic foxes and lemmings on the Taimyr Peninsula, Siberia. Ecography 21:573–580.

TAYLOR, R.J. 1984. Predation. New York: Chapman and Hall.

TEERINK, B.J. 1991. Hair of West-European mammals: Atlas and identification key. Cambridge: Cambridge University Press.

WEST, E.W. 1987. Food habits of Aleutian Island arctic foxes. The Murrelet 68:33–38.

ZAR, J.H. 1996. Biostatistical analyses. 3rd ed. Englewood Cliffs, New Jersey: Prentice Hall.