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ORIGINAL PAPER

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Local variation in arctic fox abundance on Svalbard, Norway

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Abstract Arctic fox (*Alopex lagopus*) numbers vary greatly, with cyclic fluctuations often associated with fluctuations in microtine rodents. However, in areas where small prey mammals are absent, such as Iceland and Svalbard, such cyclic fluctuations are lacking. Annual fluctuations in the density of the arctic fox population on the Brøggerhalvøya peninsula and Kongsfjorden region on Svalbard, Norway, were studied from 1990 to 2001 by using indices of fox abundance. All indices showed similar trends; fox numbers were low in 1990, increased until 1995 whereupon they decreased sharply, before increasing again and levelling off in 2001. Increasing numbers of foxes during the first part of the study paralleled increasing numbers of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) carcasses in winter and increasing numbers of nesting barnacle geese (*Branta leucopsis*) in summer. This study shows that the number of arctic foxes varies greatly even in areas without fluctuating microtine rodents.

Introduction

One of the factors controlling the density of arctic fox populations is the availability of food. Arctic fox prey populations fluctuate considerably both seasonally and annually. The close correlation between the 3–5 year cycles in the population density of Arctic microtine rodents and the population density of arctic foxes is well documented in most of the Arctic (Braestrup 1941; Chitty 1950; Macpherson 1969; Angerbjörn et al. 1995, 1999). When the numbers of Arctic microtine rodents peak, fox populations respond quickly due to increased food availability and a high reproductive potential. In a feeding experiment, Angerbjörn et al. (1991) showed that by providing extra food close to fox dens during winter and spring, the number of litters increased (see also Angerbjörn et al. 1995). The availability of a rich source of protein before the reproductive effort may also act to increase the reproductive potential of arctic fox populations (Smith 1976). Further, supplementing additional foods may also increase pup and juvenile survival and reduce dispersal (Bannikov 1970). In contrast, Tannerfeldt et al. (1994) found that supplementary summer feeding to arctic fox dens had no effect on juvenile survival.

In areas where naturally occurring small microtine rodents are absent, such as in Iceland and Svalbard, cyclic fluctuations in arctic fox populations are lacking and the populations appear to be more stable (Hersteinsson 1984; Prestrud 1992a). In Svalbard, food availability for arctic foxes varies considerably between the seasons; large numbers of migratory birds provide food during summer, whereas only the Svalbard ptarmigan (*Lagopus mutus*), Svalbard reindeer carcasses (*Rangifer tarandus platyrhynchus*), seals, and cached food are available during winter (Prestrud 1992b; Frafjord 1993). Prestrud (1992a) hypothesised that annual variation in number of reindeer carcasses or outbreak of rabies could affect arctic fox populations on Svalbard, but he found no correlation between annual changes in reindeer mortality, rabies and the dynamics of an arctic fox population in the central parts of Svalbard.

In the Kongsfjorden area in the northwestern part of Svalbard, the potential prey base of arctic foxes has increased significantly since 1978, when 12 Svalbard reindeer were reintroduced to the peninsula (Øritsland and Alendal 1986). The reindeer population increased to close to 400 animals in 1993/1994, when it crashed. It has since fluctuated around 100–200 individuals

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(N. Øritsland and T. Severinsen, unpublished; Aanes et al. 2000). In 1980, the first pairs of barnacle geese (*Branta leucopsis*) became established in the area (Prestrud et al. 1989), and the breeding population now amounts to 700–800 individuals (Loonen et al. 1998; Tombre et al. 1998). Both adult and gosling barnacle geese are preyed upon by arctic foxes (Loonen et al. 1998; Tombre et al. 1998).

This study aims to evaluate temporal variation in arctic fox numbers and their food resources at Kongsfjorden, Svalbard, from 1990 to 2001. We hypothesised that the large increase in potential prey may result in increasing numbers of arctic foxes. Our analysis was based on detailed knowledge of Svalbard reindeer and barnacle goose populations.

Materials and methods

This study was carried out in the region of Kongsfjorden, NW Svalbard, Norway (78°55′N, 11°56′E) in 1990/2001. The study area comprised the northern and eastern shores of Kongsfjorden, and the Brøggerhalvøya peninsula in the south (Fig. 1). The study area covers an area of 221 km^2, and has six known breeding arctic fox dens (Fig. 1). The landscape is mountainous and partly covered by glaciers. The Ny-Ålesund research station is located on the northern shore of the peninsula.

Twenty-four colonies of kittiwakes (*Rissa tridactyla*), Brünnich's guillemots (*Uria lomvia*), little auks (*Alle alle*) and fulmars (*Fulmaris glacialis*) are located in the study area (Bakken 2000) and provide a stable food supply to foxes during summer. The breeding seabird biomass during summer is estimated at 23,500 kg (F. Mehlum, personal communication). The establishment of a barnacle goose colony in the area in the early 1980s provides additional food (Prestrud et al. 1989). This colony increased and doubled in size from 246 in 1991 to 480 in 1992, stabilised around 600 individuals from 1993 to 1995, and increased to 783 individuals in 1996/1997 (Fig. 2; Loonen et al. 1998; Tombre et al. 1998). In addition, large numbers of arctic tern (*Sterna paradisaea*) and common eider (*Somateria mollissima*) breed in the study area (Bakken 2000).

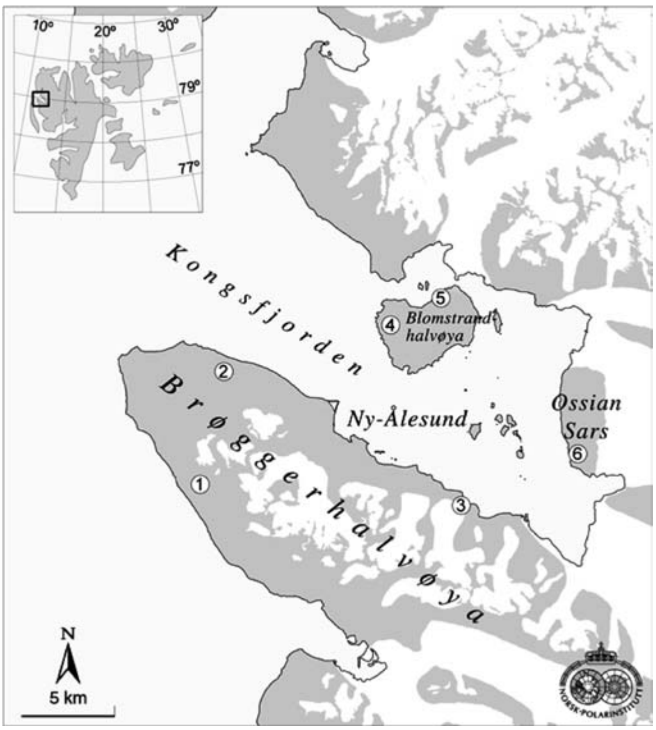

Fig. 1 Map of Brøggerhalvøya and Kongsfjorden on the Svalbard archipelago, Norway. Numbers (*1–6*) indicate den locations. Only 40% of the Svalbard archipelago becomes bare land in late summer, and the rest is covered by glaciers (indicated in white)

After an absence of at least 70–80 years, Svalbard reindeer were reintroduced to Brøggerhalvøya in 1978 as part of an ecological experiment (Øritsland and Alendal 1986). The initial 12 reindeer increased exponentially to 360 animals in the winter of 1993/1994, when the population collapsed (Fig. 2; N.A. Øritsland and T. Severinsen, unpublished; Aanes et al. 2000). The collapse was probably caused by a record rainfall of 278 mm in November 1993 followed by a cold period in the study area. This amount of rain in 1 month is extreme, since the mean annual rainfall in the study area is 370 mm (Førland 1993). The coincident cold period resulted in a thick layer of ice covering the vegetation, thereby making much of it unavailable to the reindeer. Only 78 animals were recorded in March/April 1994, a reduction of 80% (Fig. 2; N.A. Øritsland and T. Severinsen, unpublished). The decline appeared to have resulted from a combination of increased mortality and emigration, and 20 adults and calves were found dead in the study area the following spring (N.A. Øritsland and T. Severinsen, unpublished), a possible food source for foxes during winter. Annual registrations of the number of Svalbard reindeer in the study area have been carried out since 1978 (N.A. Øritsland and T. Severinsen, unpublished; Aanes et al. 2000, 2002).

Arctic foxes were captured in baited live-traps in 1990 and from 1993 to 1997. The number of traps used in this period varied from 5 to 25. The traps consisted of a wooden frame covered with wire mesh netting on all sides (1 m long ×0.32 m wide ×0.30 m high). The foxes triggered the trapdoor by pulling on a baited stick, thereby releasing the attached bar. Different baits, such as egg, sausage, Svalbard ptarmigan, Svalbard reindeer and seal blubber, were used. All traps were checked once every day. Each trapped fox was marked with plastic ear tags and released. Juvenile foxes captured between August and November/December were distinguished from adults by morphological differences and tooth

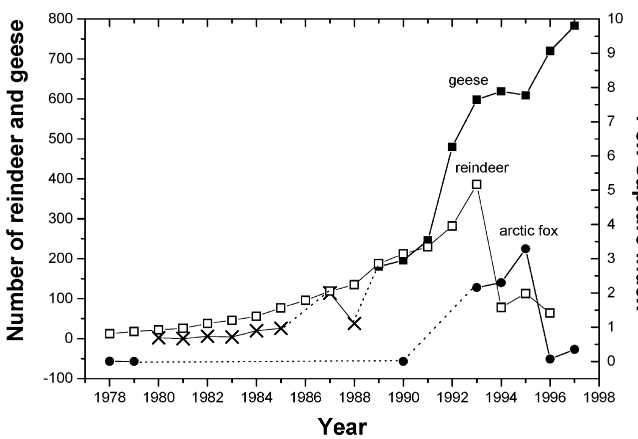

Fig. 2 Number of arctic foxes captured per 100 trap-days ("Fox Capture Index") on Brøggerhalvøya-Kongsfjorden in 1978/1979, 1990, and 1993–1997 (*solid circles*). Data from 1978/1979 are from Prestrud (1982). Values of Barnacle geese from 1980 to 1988 are number of adults estimated from observed nests (*crosses*), and values from 1989 to 1997 are the estimated number of adult Barnacle geese based on counting in Kongsfjorden (*solid squares*; Loonen et al. 1998). Values of Svalbard reindeer are the total number of animals counted each year on Brøggerhalvøya (*open squares*; N.A. Øritsland and T. Severinsen, unpublished)

wear. All animals captured between January and June were defined as adults. The number of foxes captured per 100 trap-days each year was used as an index of fox density termed "Fox Capture Index".

Extensive field work was carried out making observations of denning activity, i.e. observation of number of arctic fox litters and litter size at den. We have termed this "Fox Den Index" as a second index of fox abundance. A third index was termed "Fox Observation Index". This index was based both on observations of adult foxes seen away from breeding dens per 100 h field work and on reports received from scientists and local people on observations of adult foxes during summer. In addition, reports on observation of fox tracks in the study area were collected from 1990 to 2001 as a fourth index: "Fox Track Index". All observations were noted, and foxes seen and fox tracks were evaluated as few or many i.e. a subjective qualitative indication of fox abundance.

Results

We captured 39 foxes during 4,011 trap-days from 1990 to 1997 (we have no trap data from 1991 and 1992). The "Fox Capture Index" varied considerably between different years and the number of foxes captured increased from 0 to 34 from 1990 to summer 1995, decreased to 1 during autumn 1995 and winter 1995/1996, and increased again to 4 foxes captured in 1997 (Fig. 2). As an example, within 4 days in February 1995, we live-trapped 11 foxes, including four recaptures, while no foxes were captured in 25 traps distributed on Brøggerhalvøya in during the period February–April 1996. Of the 39 foxes live-trapped, 12 (7 adult males, 4 juvenile males, 1 juvenile female) were removed from the population for other studies (Fuglei and Øritsland 1999; Fuglei 2000; Fuglei et al. 2000; Fuglei and Øritsland 2001). The increase in the "Fox Capture Index" from 1990 to 1995 parallels the increase and stabilisation of the barnacle goose colony (Fig. 2; Loonen et al. 1998). Gosling survival in the study area from 1990 to 1997 (from Loonen et al. 1998) was negatively correlated with the fox index ($r = -0.83$; $P = 0.04$; Fig. 3). Similarly, the growth of the Svalbard reindeer population and the "Fox Capture Index" coincided until the decline in the reindeer population, with the decline in the fox population taking place 18 months after the reindeer population crash (Fig. 2).

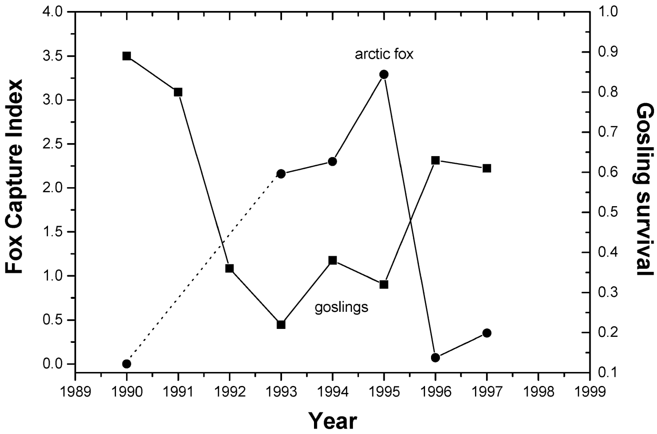

Fig. 3 The relationship between the "Fox Capture Index" (number of arctic foxes captured per 100 trap-days) on Brøggerhalvøya-Kongsfjorden (*solid circles*) and gosling survival in Kongsfjorden (*solid squares*). Gosling survival was negatively correlated with number of foxes captured per 100 trap-days ($r = -0.83$; $P = 0.04$) from Loonen et al. (1998)

Based on the "Fox Den Index", "Fox Observation Index" and "Fox Track Index" in the study area, fox abundance was low in 1990/1991, high from 1992 to 1995, very low in 1996, and then increased to high again in 1999/2001 (Table 1). By autumn 1995, foxes seemed to have disappeared from the study area, because no tracks or foxes were observed after the first snow fall in September or later that year, whereas foxes had been observed daily in summer 1995. Thereafter, fox tracks were not observed again until autumn 1996.

The observed number of litters in the study area increased from two in 1993 to six in 1995, declined to none in 1996 and 1997, and increased or leveled off again from 1998 to 2001 (Table 1). The highest litter size observed in the study area was eight (Table 1).

We found six dead foxes (five pups and one adult) in the study area in 1995 and seven dead adults in 1996.

Table 1 The "Fox Den Index" (observation of number of arctic fox litters and litter size at den), "Fox Observation Index" (foxes seen per 100 h spent in the field and a subjective index of foxes seen) and "Fox Tracks Index" in the study area from 1990 to 2001. *?* Pups registrated at den, but unknown number, + few foxes/tracks seen, + + many foxes/tracks seen, – unknown

Year	Number of litters	Litter size	Foxes seen/100 h	Foxes seen	Fox tracks
1990	–	–	–	+	+
1991	–	–	–	+	–
1992	–	–	–	+ +[a]	–
1993	2	2,8	–	+ +[a]	–
1994	4	3,4,8,?	–	+ +	+ +
1995	6	2,2,8,?,?,?	4.8	+ +	+ +
1996	0	0	0.7	0	+
1997	0	0	1.6	+	+
1998	1	4	2.7	+	+
1999	1	?	2.9	+ +	+ +
2000	4	2,4,5,?	–	+ +	+ +
2001	2	3,5	–	+ +	+ +

[a]From Tombre et al. 1998; Loonen et al. 1998

With the exception of two found in 1997, dead foxes have not, as far as we know, been found in the study area in any of the other years of this study. Nine of the dead foxes were autopsied even though the cause of death could not be established because the carcasses were too decomposed. However, the remaining four foxes were not autopsied because two of them were not brought in, and for the last two foxes only the heads were brought in. None of the foxes were infected by rabies and no other diseases could be detected (K. Handeland, personal communication).

The four indices [“Fox Capture Index”, “Fox Den Index” (observation of number of arctic fox litters), “Fox Observation Index” (foxes seen per 100 h spent in the field and a subjective index of foxes seen) and “Fox Track Index”], for which there were more than 4 years with data, were all highly positively correlated (Table 2).

Discussion

The four independent indices we used in this study to document changes in the density of the fox population in the Kongsfjorden area from 1990 to 2001 all showed similar trends (Table 2); the arctic fox population increased from 1990 to 1995, declined abruptly in the autumn of 1995 and winter of 1996, remained very low in 1996 and 1997 before it increased again. Our results are supported by observations made in the area from July to August by goose scientists (Tombre et al. 1998; Loonen et al. 1998), who defined 1990, 1991, 1996 and 1997 as “non-fox-years”, while 1992, 1993, 1994 and 1995 were defined as “fox-years” in the study area. High reproduction of arctic foxes before the decline in 1995, no reproduction the two following years, and the high number of dead foxes found in early autumn 1995 and the summer of 1996, suggest that the decline may have been caused both by failure in reproduction and adult mortality. The highest observed litter size in one den was 8 in the present study, which is within the range (2–11) previously found on Svalbard (Prestrud 1992a).

The 12 foxes live-trapped and removed from the population could not have affected the population dynamics in the study area significantly, as 9 of these foxes were captured before 1995, i.e. before the peak in fox abundance and the subsequent population crash.

Barnacle geese and reindeer carcasses are important foods for arctic foxes in Svalbard during summer and winter/spring, respectively (Prestrud 1992b; Frafjord 1993; N.E. Eide et al. unpublished). Consequently, the increase in the barnacle goose and reindeer populations (Loonen et al. 1998; Aanes et al. 2000), may explain the increase in the number of foxes during the first half of the 1990s. Low survival of barnacle goslings was correlated with high fox abundance (Fig. 3; Loonen et al. 1998). Only 2 goslings survived in 1994 because almost all nests were preyed upon by arctic foxes, while in 1996, when no foxes were observed, the estimated number of goslings at fledging was 620 (Loonen et al. 1998). Loonen et al. (1998), Stahl and Loonen (1998) and Tombre et al. (1998) concluded that the fox population may contribute to regulating the barnacle goose population in Kongsfjorden, which is in accordance with studies of arctic fox predation on goose colonies from other Arctic areas (Anthony et al. 1991, Samelius and Alisauskas 2001). Reindeer mortality was low on Brøggerhalvøya until winter 1993/1994 (N.A. Øritsland and T. Severinsen, unpublished), but possibly sufficient to provide an increasing supply of carcasses as food for the foxes.

The crash in the reindeer population in the winter of 1993/1994 undoubtedly provided extra food to the foxes for an extended time period because carcasses decompose slowly at this high latitude, and the only other scavenger of any significance in Svalbard in addition to foxes is the glaucous gull (*Larus hyperboreus*). Thus, this extra food may have contributed to the peak in fox numbers 18 months later. The decline in the fox population that followed shortly afterwards may be explained by a lack of food when reindeer carcasses from the population crash in 1993/1994 were consumed; few new carcasses were available as the population density of reindeer on Brøggerhalvøya was low. Emigration due to lack of food after the reindeer carcasses were consumed

Table 2 Spearman rank correlation coefficients between indices of arctic fox abundance (“Fox Capture Index”, “Fox Den Index”,“Fox Observation Index” and “Fox Tracks Index”) for which there were more than 4 years with data i.e. 1993–2001

	Fox den index	Fox observation index		Fox track index	Fox capture index
		Seen per 100 h	Foxes seen		
Fox den index	–	0.94868	0.79525	0.80329	0.97468
P		0.0138	0.0104	0.0163	0.0048
n		5	9	8	5
Seen per 100 h	–	–	0.94868	0.86603	1.00000
P			0.0138	0.0577	< .0001
n			5	5	3
Foxes seen	–	–	–	0.97590	0.89443
P				< .0001	0.0405
n				8	5
Fox track index	–	–	–	–	0.89443
P					0.1056
n					4
Fox capture index	–	–	–	–	–

may provide an explanation of the drastic decline in fox numbers in the study area. It has been reported that mass migrations can take place between north-east Canada and Greenland, and within the Russian Arctic as a response to low food abundance (Braestrup 1941; Bannikov 1970; Wrigley and Hatch 1976). The fact that none of the ear-tagged foxes were found dead or were observed in the study area, also supports the migration theory.

An alternative explanation to the drastic decline in the fox population in the study area in 1995/1996 is that it may have resulted from disease (Frafjord et al. 1997) in combination with reduced availability of reindeer carcasses. However, autopsies of fox carcasses were unable to establish the cause of death because of advanced decomposition. The rabies analysis was negative and no other diseases were detected.

Except for trapping data of foxes in 1978/1979 (Prestrud 1982), there is little information about the arctic fox population in the study area before 1990. However, diaries written by overwintering trappers in the Kongsfjorden area indicate that it was a good region for arctic fox trapping from 1908 to 1941 (Rossnes 1993), which suggests that foxes were present also on Brøggerhalvøya. Before 1973, arctic foxes also scavenged on polar bear carcasses abandoned by overwintering trappers in the study area; bear carcasses are considered to have been an important food supply for arctic foxes during winter (Larsen and Kjos-Hanssen 1983). However, after 1973, when polar bears were protected, polar bear carcasses were no longer available as fox food. Live trapping on Brøggerhalvøya by Prestrud (1982) gave low fox indices for 1978/1979 (Fig. 2). Frafjord and Prestrud (1992) reported low densities of foxes and few breeding pairs from 1985 to 1989, and no foxes were seen in Ny-Ålesund in summer 1987 (Tombre et al. 1998).

The factors regulating arctic fox populations are not well understood, even though availability of winter food is important for adult survival (Bannikov 1970; Smith 1976; Angerbjörn et al. 1991; Frafjord 1992). In areas where small rodents are present, abrupt declines in arctic fox densities are common and the number of litters born may vary considerably between years and between areas in the same year, in close correlation with rodent population densities (Angerbjörn et al. 1995, 1999). In contrast, arctic fox populations in central Svalbard, where small rodents are absent, were relatively stable even though reindeer mortality varied considerably between years (Prestrud 1992a). However, the present study shows that fox numbers in local arctic fox populations may fluctuate also on Svalbard.

In conclusion, our results shows that, in areas where small mammals are absent, considerable variations in arctic fox populations among years may occur, and influence the production in local prey species populations. A decline in the fox population of the same magnitude and significance as happened in 1995/1996 is similar to declines in arctic fox populations caused by crashes in small rodent populations in other parts of the Arctic. Failure in reproduction, adult mortality and migration as a result of reduced availability of food caused by the crash in the reindeer population in 1993/1994 are suggested as explanations of the abrupt decline in fox numbers in 1995/1996.

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References

Aanes R, Saether B-E, Øritsland NA (2000) Fluctuations of an introduced population of Svalbard reindeer: the effects of density dependence and climatic variation. Ecography 23:437–443

Aanes R, Saether B-E, Smith FM, Cooper EJ, Wookey PA, Øritsland NA (2002) The arctic oscillation predicts effects of climate change in two trophic levels in a high-arctic ecosystem. Ecol Lett 5:445–453

Angerbjörn A, Arvidson B, Norén E, Strömgren L (1991) The effect of winter food on reproduction in the arctic fox, *Alopex lagopus*: a field experiment. J Anim Ecol 60:705–714

Angerbjörn A, Tannerfeldt M, Bjärvall A, Ericson M, From J, Norén E (1995) Dynamics of the arctic fox population in Sweden. Ann Zool Fenn 32:55–68

Angerbjörn A, Tannerfeldt M, Erlinge S (1999) Predatory-prey relationships: arctic foxes and lemmings. J Anim Ecol 68:34–49

Anthony RM, Flint PL, Sedinger JS (1991) Arctic fox removal improves nest success of black brant. Wildl Soc Bull 19:176–184

Bakken V (2000) Seabird colony databases of the Barents Sea region and the Kara Sea. Report series no. 115, Norwegian Polar Institute, pp 78

Bannikov AG (1970) Arctic fox in the U.S.S.R.: biological premises of productivity. In: Fuller WA, Kevan PG (eds) Proceedings of the Conference on Productivity and Conservation in Northern Circumpolar Lands, Edmonton, Canada 1969. IUCN Publications new series 16, pp 121–130

Braestrup FW (1941) A study of the arctic fox in Greenland. Medd Groen 131:1–101

Chitty H (1950) Canadian arctic wildlife enquiry, 1943–49; with a summary of results since 1933. J Anim Ecol 19:180–193

Førland EJ (1993) Precipitation normals. Normal period 1961–1990. DNMI Report 39/93 Klima. Oslo, Norway

Frafjord K (1992) Behavioural ecology and behavioural energetics in the arctic fox (*Alopex lagopus*). PhD thesis, University of Bergen, Bergen, Norway

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

Frafjord K, Prestrud P (1992) Home range and movements of arctic foxes (*Alopex lagopus*) in Svalbard. Polar Biol 12:519–526

Frafjord K, Rofstad G, Fuglei E (1997) Døde fjellrev-valper på Svalbard av sykdom? (Did arctic fox pups die due to some kind of sickness?) Fauna 50:108–113

Fuglei E (2000) Physiological adaptation of the arctic fox to high Arctic conditions. Dr. Scient. dissertation, University of Oslo, Norway

Fuglei E, Øritsland NA (1999) Seasonal trends in body mass, food intake and resting metabolic rate, and induction of metabolic depression in arctic foxes (*Alopex lagopus*) at Svalbard. J Comp Physiol B 169:361–369

Fuglei E, Øritsland NA (2001) Energy cost of running in arctic fox (*Alopex lagopus*), on Svalbard, Norway. Poster presentation, First Canid Biology and Conversation Conference, Oxford University, 17–21 September 2001

Fuglei E, Aanestad M, Berg JP (2000) Hormones and metabolites of arctic foxes (*Alopex lagopus*) in response to season, starvation and re-feeding. Comp Biochem Physiol A 126:287–294

Hersteinsson P (1984) The behavioural ecology of the arctic fox (*Alopex lagopus*). PhD thesis. University of Oxford, Oxford, UK

Larsen T, Kjos-Hanssen B (1983) *Trichinella* sp. in polar bears from Svalbard, in relation to hide length and age. Polar Res 1:89–96

Loonen MJJE, Tombre IM, Mehlum F (1998) Development of an arctic barnacle goose colony: interactions between density and predation. In: Mehlum F, Black JM, Madsen J (eds) Research on arctic geese. Proceedings of the Svalbard Goose Symposium, Oslo, Norway, 23–26 September 1997. Norsk Polarinstitutt Skrifter 200, pp 67–79

Macpherson AH (1969) The dynamics of Canadian arctic fox populations. Can Wildl Serv Rep Ser no. 8

Øritsland NA, Alendal E (1986) Svalbardreinen. Bestandens størrelse og livshistorie (The Svalbard reindeer. Population size and life history). In: Øritsland NA (ed) Svalbardreinen og dens livsgrunnlag (The Svalbard reindeer and its resources). Oslo, Universitetsforlaget, pp 62–77

Prestrud P (1982) Årstidsvariasjoner i basalmetabolisme og fettlagring hos fjellreven (*Alopex lagopus*) på Svalbard (Seasonal variation in basal metabolic rate and fat deposition in the arctic fox (*Alopex lagopus*) on Svalbard). Cand Real Thesis, University of Oslo, Norway

Prestrud P (1992a) Arctic foxes in Svalbard: population ecology and rabies. PhD thesis, Norsk Polarinstitutt, Oslo

Prestrud P (1992b) Food habits and observations of the hunting behaviour of arctic foxes, (*Alopex lagopus*), in Svalbard. Can Field Nat 106:225–236

Prestrud P, Black JM, Owen M (1989) The relationship between an increasing Barnacle Goose (*Branta leucopsis*) population and the number and size of colonies in Svalbard. Wildfowl 40:32–38

Rossnes G (1993) Norsk overvintringsfangst på Svalbard 1895–1940. Meddelelser nr. 127, Norsk Polarinstitutt, Oslo

Samelius G, Alisauskas RT (2001) Deterring arctic fox predation: the role of parental nest attendance by lesser snow geese. Can J Zool 79:861–866

Smith TG (1976) Predation of ringed seal pups (*Phoca hispida*) by the arctic fox (*Alopex lagopus*). Can J Zool 54:1610–1616

Stahl J, Loonen MJJE (1998) Effects of predation risk on site \selection of barnacle geese during brood-rearing. In: Mehlum F, Black JM, Madsen J (eds) Research on arctic geese. Proceedings of the Svalbard Goose Symposium, Oslo, Norway, 23–26 September 1997. Norsk Polarinstitutt Skrifter 200, pp 57–65

Tannerfeldt M, Angerbjörn A, Arvidson B (1994) The effect of summer feeding on juvenile arctic fox survival—a field experiment. Ecography 17:88–96

Tombre IM, Mehlum F, Loonen MJJE (1998) The Kongsfjorden colony of barnacle geese: nest distribution and the use of breeding islands 1980–1997. In: Mehlum F, Black JM, Madsen J (eds) Research on arctic geese. Proceedings of the Svalbard Goose Symposium, Oslo, Norway, 23–26 September 1997. Norsk Polarinstitutt Skrifter 200, pp 57–65

Wrigley RE, Hatch DRM (1976) Arctic fox migrations in Manitoba. Arctic 29:147–158