ARCTIC
VOL. 64, NO. 3 (SEPTEMBER 2011) P. 302–306

Effects of an Arctic Fox Visit to a Low Arctic Seabird Colony

CHANTELLE M. BURKE,[1,2] APRIL HEDD,[1] WILLIAM A. MONTEVECCHI[1] and PAUL M. REGULAR[1]

(*Received 24 February 2010; accepted in revised form 25 November 2010*)

ABSTRACT. A visit by an arctic fox (*Alopex lagopus*) to Funk Island, Newfoundland, during 2009 had a negative impact on the breeding performance of five of the nine breeding seabird species. Species that nest in burrows (Atlantic puffin *Fratercula arctica*) or on the ground (northern fulmar *Fulmarus glacialis*, great black-backed *Larus marinus* and herring gulls *Larus argentatus*) did not fledge any offspring in 2009, and common murres (*Uria aalge*) at this colony, the largest for this species in North America, experienced an estimated 4.9% (~19 712.4 breeding pairs) reduction in the number of nesting birds. Later-than-normal persistence of Arctic sea ice on the Newfoundland-Labrador Shelf in 2009 likely provided the fox access to the colony up until late April, which coincided with the seabirds' return. The persistent predation threat near the onset of breeding likely resulted in large-scale abandonment of breeding attempts by vulnerable seabirds.

Key words: arctic fox, *Alopex lagopus*, climate change, Low Arctic, sea ice trends, murres, seabirds

RÉSUMÉ. La visite d'un renard arctique (*Alopex lagopus*) à l'île Funk, Terre-Neuve, en 2009 a eu des incidences négatives sur la reproduction de cinq des neuf espèces reproductrices d'oiseaux de mer. Les espèces qui nichent dans des terriers (macareux moine *Fratercula arctica*) ou sur le sol (fulmar boréal *Fulmarus glacialis*, goéland marin *Larus marinus* et goéland argenté *Larus argentatus*) n'ont pas eu de progéniture en 2009, et le guillemot marmette (*Uria aalge*) de cette colonie, soit la plus volumineuse colonie de cette espèce en Amérique du Nord, a enregistré une réduction du nombre d'oiseaux en nidification évaluée à 4,9 % (~19 712,4 paires de reproduction). En 2009, le renard a probablement réussi à se rendre à la colonie jusqu'à la fin avril en raison de la persistance plus tardive que la normale de la glace de mer de l'Arctique sur le plateau de Terre-Neuve-et-Labrador, ce qui coïncidait avec le retour des oiseaux de mer. La menace de prédation persistante au début de la période de reproduction s'est vraisemblablement traduite par l'abandon à grande échelle des tentatives de reproduction par les oiseaux de mer vulnérables.

Mots clés : renard arctique, *Alopex lagopus*, changement climatique, Bas-Arctique, tendances caractérisant la glace de mer, guillemots, oiseaux de mer

Traduit pour la revue *Arctic* par Nicole Giguère.

INTRODUCTION

Isolation from predators and proximity to food are key selective factors that determine the location of seabird breeding colonies (Lack, 1968). For seabirds that rely on colony isolation as a primary strategy for predator avoidance, natural or introduced invasions of mammalian predators can have devastating consequences (Petersen, 1982; Southern et al., 1985; Birkhead and Nettleship, 1995; Croll et al., 2005). Human introduction of arctic foxes (*Alopex lagopus*) and red foxes (*Vulpes vulpes*) to the isolated Aleutian Islands in the late 19th and early 20th century for the purpose of fox farming led to substantial reductions of native seabird populations, particularly of the more accessible, ground-nesting species (Bailey, 1993). Similarly, the natural invasions of foxes that periodically occur on low-latitude colonies can result in significant declines in breeding success (Petersen, 1982; Birkhead and Nettleship, 1995).

Arctic foxes are opportunistic predators that use both terrestrial and marine food resources. The arctic fox's main prey is lemmings (*Synaptomys* spp.), which exhibit well-documented population cycles (Audet et al., 2002). During years of low lemming abundance, marine foods, including ringed seal pups *Phoca hispida* (taken from birth lairs; Smith, 1976) can comprise up to 50% of the foxes' protein intake (Roth, 2002). Arctic foxes are also known to follow polar bears (*Ursus maritimus*) along the sea ice to scavenge on seal carrion (Andriashek et al., 1985; Gagnon and Berteaux, 2009). Satellite-tagging studies have shown that arctic foxes make extensive winter migrations over land-fast (Tarroux et al., 2010) and drifting sea ice (Pamperin et al., 2008). Foxes that encounter occupied seabird colonies at lower latitudes during these long migrations may prolong their stopovers to take advantage of the abundant food (Birkhead and Nettleship, 1995).

The Funk Island Ecological Reserve (49˚45′ N, 53˚11′ W) is a low-lying, offshore colony located on the

[1] Cognitive and Behavioural Ecology Program, Psychology Department, Memorial University, St. John's, Newfoundland and Labrador A1B 3X9, Canada
[2] Corresponding author: chantelb@mun.ca

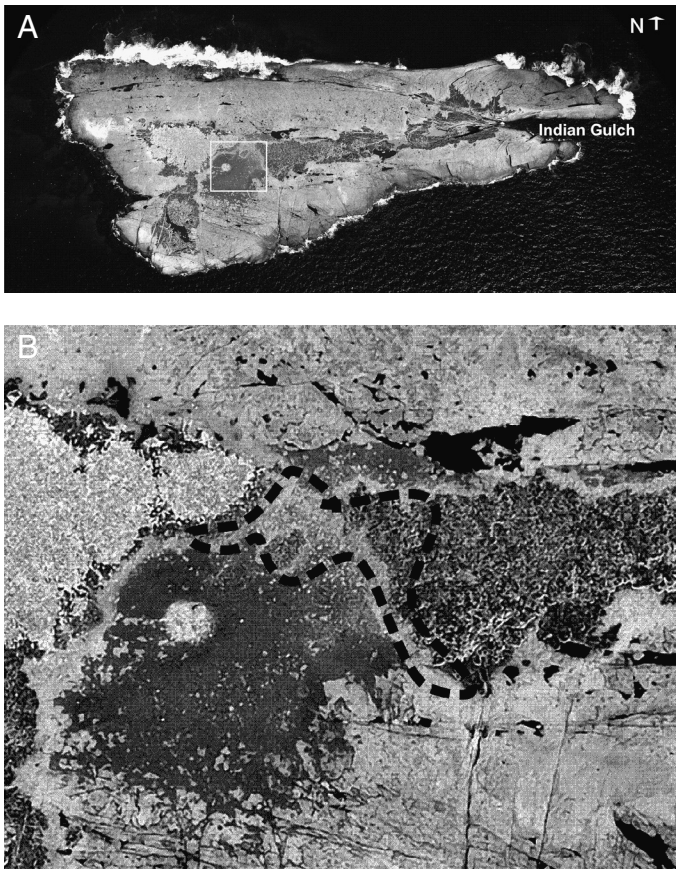

FIG. 1. A) Aerial photograph of Funk Island with black areas showing typical breeding murre distributions. Area used by fox is outlined in white and shown in B. The dashed line in B shows the area that murres abandoned in 2009.

Newfoundland-Labrador Shelf ca. 60 km from the mainland. The local climate is heavily influenced by the south-flowing Labrador Current, which transports Arctic water and ice along the coast and continental shelves (Petrie and Anderson, 1983). Seabirds on Funk Island nest over flat, exposed ground (Montevecchi and Tuck, 1987), which indicates that occurrences of mammalian predators are extremely rare. However, delayed breakup of offshore pack ice in the spring can provide opportunities for vagrant, ice-associated mammals to access the colony around the time when seabirds are returning to initiate breeding. We report on the effects of an arctic fox visit to Funk Island during 2009 and examine the sea-ice conditions that facilitated this rare occurrence. We also consider how climate-driven variability in sea-ice extent in Low Arctic waters might influence future occurrences of arctic foxes at seabird colonies in the Northwest Atlantic.

METHODS

Study Site

Funk Island supports the largest breeding colony of common murres (*Uria aalge*) in North America, with 412 524 breeding pairs (bp) (Chardine et al., 2003). The island also supports northern gannets (*Morus bassanus*; 9837 bp; Chardine, 2000), Atlantic puffins (*Fratercula arctica*; 2000 bp; Cairns et al., 1989), razorbills (*Alca torda*; ca. 200 bp), thick-billed murres (*Uria lomvia*; 250 bp; Montevecchi and Tuck, 1987), black-legged kittiwakes (*Rissa tridactyla*; ca. 200 bp; W.A. Montevecchi, unpubl. data) and about 225 bp of gulls, composed of herring gulls (*Larus argentatus*) and great black-backed gulls (*Larus marinus*). Funk Island is also the site of the largest colony of northern fulmars (*Fulmarus glacialis*) in Atlantic Canada, with 89 breeding pairs recorded during the last census in 2008 (W.A. Montevecchi, unpubl. data).

Data Collection

Information on seabird behaviour and breeding performance has been collected at Funk Island since around 1950 (Montevecchi and Tuck, 1987), and annual research visits have been conducted since 1977. During the 2009 research trip, we recorded information on the nature and magnitude of the effects of an arctic fox on seabirds and recorded observations of predation (carcasses and hunting), egg stealing, and caching. For common murres, the numerically dominant species on Funk Island, we used high-resolution photographs from the 2009 aerial survey, which were transferred into ArcGIS (ver 9.3) and geo-referenced using 18 reference locations (collected with a handheld GPS) on the island. We then quantified the total area where nest sites were abandoned in 2009, using the polygon area calculation tool in ArcGIS, and used density estimates from Birkhead and Nettleship (1980) to estimate the total number of birds that abandoned breeding sites in 2009.

Information on the timing and maximum extent of the sea ice on the Newfoundland-Labrador shelf during 2009 in relation to historical norms (1969–2000) is from the Archives of the Canadian Ice Service (2010).

RESULTS

The arctic fox discovered on Funk Island on 28 July 2009 had likely been there since late April, when late sea ice provided access to the colony. The fox had a greater negative impact on the seabird community than had been observed during any previous annual research visits (since 1977). The fox was seen daily (total of 11 days) on the southwestern and central areas of the colony (Fig. 1), where most birds nest over flat, exposed ground or in burrows, and where the majority of abandoned nesting sites were concentrated.

We frequently observed the fox carrying eggs, and we found chewed, broken eggshells (almost exclusively murre eggs) around the colony. We differentiated eggs preyed on by the fox (which were crushed) from those preyed on by gulls (which were punctured). Observations of egg stealing revealed that murre eggs were stolen along the colony perimeter as the adults flushed upon the fox's approach.

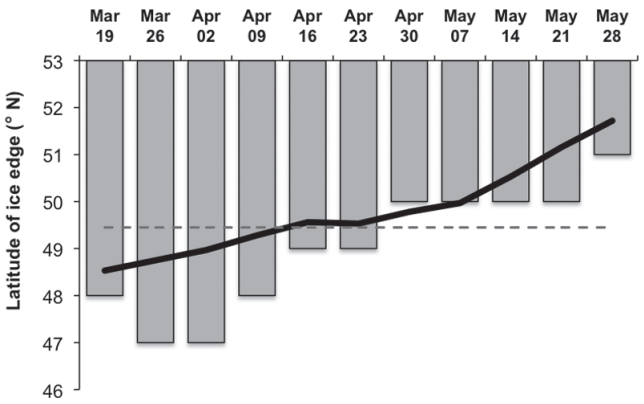

FIG. 2. Latitudinal progression of the ice edge along the Newfoundland-Labrador Shelf in 2009 (bars) relative to the historical mean for 1969–2000 (black line). Bars represent the latitude of the ice edge estimated to the nearest degree (source: Canadian Ice Service, 2010) and show the extent of sea ice cover for the corresponding dates on the horizontal axis. The dashed line shows the latitude of Funk Island (49°45′ N, 53°11′ W).

The fox was also observed stealing food from non-breeding and subadult gannets after repeated approaches and chases that caused the birds to regurgitate fish (herring, mackerel, and capelin). There were no observations of attempts to kill adult birds, but the carcasses of two gannets (one adult, one chick) and one adult puffin were found. No caches were found, though an exhaustive search of the colony was not conducted because of the added disturbance that this would have involved. The fox repeatedly hunted flightless murre fledglings as they walked to departure ledges after dusk, even though the fledglings were attended by adults. The fox chased fledglings over successive nights during peak fledging (4–6 August) in a ravine located on the north side of the colony that is the main departure route for adult-fledgling pairs. This departure strategy is usually very effective against the large predatory gulls, which are less active at night, but it provided a significant advantage to the crepuscular and nocturnal fox.

Atlantic puffins, the only burrow-nesting species on Funk Island, appeared to experience total breeding failure in 2009, since no adults were seen carrying food at the colony. Northern fulmars completely abandoned the colony, and nest-site inspections showed no signs of nest material (small pebbles) or egg shells, suggesting that breeding attempts were not initiated. Herring and great black-backed gulls did not raise any chicks in 2009, nor were there any signs of nesting material near nest sites used in previous years. There was no evidence of reduced breeding success by northern gannets or the cliff-nesting thick-billed murres and black-legged kittiwakes. Effects on crevice-nesting razorbills were difficult to assess because breeding pairs are distributed widely across the island, and not all locations are known.

Common murres experienced unprecedented reductions in breeding performance due to nest abandonment and fledgling mortality. Nest abandonment was confined to the southwestern area of the colony (Fig. 1) around the perimeter of the puffin colony, where the fox was most active and most frequently observed. There was no evidence of disturbance or abandonment in areas of the colony where common murres nest on cliffs (e.g., Indian Gulch). We estimated that approximately 8% of the southwestern breeding area and 4.8% of the central colony were abandoned in 2009. On the basis of density estimates available for the central and southwestern colonies (25.3 bp per m^2 and 23.5 bp per m^2 respectively; Birkhead and Nettleship, 1980), we estimated that approximately 19 712.4 bp (4.9%) abandoned breeding in 2009. More subtle behavioural effects undoubtedly had a cumulative effect on breeding failure for common murres. Site-holding failed breeders were often present on the island, and the persistent fox threat made these birds highly agitated and very easily disturbed. Regular flushing of what amounted to thousands of birds resulted in additional losses of eggs and chicks as these spooked birds stampeded out of the colony.

Sea-Ice Conditions

Typically, heavy sea ice of Arctic origin begins to break up and retreat northward around mid-April, after which the waters around Funk Island are ice-free and inaccessible to terrestrial mammalian predators. In 2009, Arctic sea ice penetrated farther south than normal during the last week of March and the first week of April (Fig. 2). Consequently, the northward retreat of sea ice was delayed, and sea ice was still present around the colony during the last week of April (23–30 April).

DISCUSSION

Mammalian predators can reduce seabird breeding success directly by killing adults and chicks, or indirectly by causing disturbances that alter seabird behaviour, or both (Burger and Gochfeld, 1994). The extensive impact of a single arctic fox on the breeding performance of the Funk Island seabird community in 2009 demonstrates a lack of effective defense strategies at this colony, where a shortage of nesting sites on the cliffs causes cliff-nesting species to nest on the ground.

Extensive breeding failures of burrow- and ground-nesting seabirds on Funk Island in 2009 occurred as a direct consequence of an arctic fox's presence during the early breeding season, when late spring sea ice provided access to an otherwise isolated offshore colony. Alternative explanations, including delays in the timing of breeding due to reduced food availability (Ganter and Boyd, 2000), do not explain the unique spatial and species-specific patterns of disturbance documented at Funk Island in 2009. For example, the abandoned nest sites of common murres were confined to those areas of the colony used by the fox, and murres (both common and thick-billed murres) nesting on the inaccessible cliff-nesting sites in Indian Gulch exhibited no signs of disturbance. Furthermore, undisturbed murres

in Indian Gulch were in the mid to late stages of chick-rearing, which was consistent with the timing of breeding observed at Funk Island in previous years.

Information from the 1972 and 2000 aerial surveys indicates that the murre population at Funk Island has remained relatively stable (389 097 in 1972 bp to 412 524 bp in 2000; Chardine et al., 2003), with only minor shifts in nest site distribution. Nonetheless, it is possible that the Funk Island murre population has increased since 2000 because enforcement of stricter hunting regulations in the Newfoundland murre hunt has reduced adult mortality (Chardine et al., 1999), oiling rates of seabirds have declined (Wilhelm et al., 2009), and a large-scale removal of gillnets took place following the eastern Canadian ground-fish moratorium in 1992 (Montevecchi et al., 2010). Increasing population trends at other major murre colonies in Newfoundland (e.g., Witless Bay; Robertson et al., 2004) support this line of reasoning. Consequently, our estimate of the numbers of breeding murres displaced by the fox in 2009, based on density estimates by Birkhead and Nettleship (1980), is likely a conservative one.

The highly accessible burrow-nesting puffins and ground-nesting gulls and northern fulmars that nest exclusively on the southwestern colony near the fox's territory did not rear any offspring in 2009, nor were there any signs of attempts at nest site establishment by gulls or fulmars (i.e., no nesting material on the usual sites). Gannets were the only ground-nesting species that did not exhibit signs of poor breeding performance in 2009 despite the fact that they nest near the area where the fox was most often observed. It is likely that the sheer size of the gannets (~ 3 kg; W.A. Montevecchi, unpubl. data) deterred the fox.

Natural periodic visits to low-latitude seabird colonies by arctic foxes are associated with ice movements into Low Arctic ocean regions (Birkhead and Nettleship, 1995). Anomalous sea ice in 2009 provided ideal conditions for the arctic fox to take advantage of the abundant food supply at Funk Island. The only other known occurrence of an arctic fox on Funk Island was documented in 1989 (Sklepkovych and Montevecchi, 1996), when spring sea ice similarly advanced farther south than normal (1962–87) and retreated north later in the spring (Prinsenberg and Peterson, 1992). In 1989, carcasses of adult seabirds were located in the den of a male fox. Other adult puffin carcasses were scattered around a temporary den, and some were partially buried (Sklepkovych and Montevecchi, 1996). The effects on seabirds at Funk Island in 1989 appeared less devastating than those in 2009, with no evidence of nest abandonment. Differences in the time when the foxes appeared on the colony (relative to egg laying) might account for interannual differences (e.g., Madsen et al., 2007).

Biological responses to climate change are predicted to involve distributional shifts of ice-associated Arctic animals. A warming Arctic climate is leading to a northward range expansion of red fox, a larger species, and this increased competition may result in a northward retraction of the arctic fox range (Walther et al., 2002). On the other hand, High Arctic glacial melt could increase the volumes of sea ice transported to southern latitudes via the Labrador Current, thereby increasing, at least initially, the occurrence of arctic foxes at isolated, southern seabird colonies. Increased frequency and abundance of natural invasions of ice-associated mammalian predators could have far-reaching negative consequences for seabird productivity at isolated colonies with limited defenses against these natural predators.

ADDENDUM

During the 2010 research trip to Funk Island, we discovered that the fox was still on the island. Milder-than-average winter temperatures (January–March) and below-average ice accumulation resulted in a lack of sea ice around Funk Island throughout the 2009–10 winter (Canadian Ice Service, 2010). This circumstance prevented the fox from leaving the island. Thus for the second consecutive year, the fox was present on the island when the birds returned in spring, and we observed very similar patterns of abandonment and disturbance for the most vulnerable ground-nesting and burrowing seabirds. For two consecutive years, the largest North American colony of common murres experienced an unprecedented reduction in nesting success, and the only breeding colony of northern fulmars in Atlantic Canada experienced complete breeding failure. In 2010, in contrast to 2009, hundreds of northern gannet nest-sites were also abandoned near the fox's main hunting area. Given the cumulative disturbance and the expansion of the fox into the gannet colony, the fox was removed in October 2010 to prevent long-term population consequences at this globally important seabird community.

ACKNOWLEDGEMENTS

We are grateful to John Chardine (Environment Canada, Atlantic Region) for providing aerial photographs of Funk Island from the 2009 population census. Thanks to Captain L. Easton and crew (especially Jeff Chaulk) for transport to and from Funk Island and for assistance in removing the fox during 2010. This manuscript benefited from comments provided by anonymous reviewers.

REFERENCES

Andriashek, D., Kiliaan, H.P., and Taylor, M.K. 1985. Observations on foxes, *Alopex lagopus* and *Vulpes vulpes*, and wolves, *Canis lupus*, on the off-shore sea ice of northern Labrador. Canadian Field-Naturalist 99:86–89.

Audet, A.M., Robbins, C.B., and Larivière, S. 2002. *Alopex lagopus*. Mammalian Species 713:1–10.

Bailey, E.P. 1993. Introduction of foxes to Alaskan islands: History, effects on avifauna, and eradication. U.S. Fish and

Wildlife Service Resource Publication 193. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service.

Birkhead, T.R., and Nettleship, D.N. 1980. Census methods for murres, *Uria* species: A unified approach. Canadian Wildlife Service Occasional Paper 43. Ottawa: CWS.

———. 1995. Arctic fox influence on a seabird community in Labrador: A natural experiment. Wilson Bulletin 107:397–412.

Burger, J., and Gochfeld, M. 1994. Predation and effects of humans on island-nesting seabirds. In: Nettleship, D.N., Burger, J., and Gochfeld, M., eds. Seabirds on islands: Threats, case studies and action plans. BirdLife Conservation Series 1. Cambridge: BirdLife International. 39–67.

Cairns, D.K., Threlfall, W., and Montevecchi, W.A. 1989. Researcher's guide to Newfoundland seabird colonies. Occasional Papers in Biology 14. St. John's: Memorial University of Newfoundland. 34 p.

Canadian Ice Service. 2010. Ice archive. http://ice-glaces.ec.gc.ca/WsvNjsQueryAction.jsp?Lang=eng&Inid=3&ScndLvl=no&ID=11715.

Chardine, J.W. 2000. Census of northern gannet in the Atlantic Region in 1999. Canadian Wildlife Service Technical Report 361. Sackville, New Brunswick: CWS, Atlantic Region. 16 p.

Chardine, J.W., Collins, B.T., Elliot, R.D., Levesque, H., and Ryan, P.C. 1999. Trends in the annual harvest of murres in Newfoundland and Labrador. Bird Trends 7:11–14.

Chardine, J.W., Robertson, G.J., Ryan, P.C., and Turner, B. 2003. Abundance and distribution of common murres breeding at Funk Island, Newfoundland, 1972 and 2000. Canadian Wildlife Service Technical Report 404. Sackville, New Brunswick: CWS, Atlantic Region. 26 p.

Croll, D.A., Maron, J.L., Estes, J.A., Danner, E.M., and Byrd, G.V. 2005. Introduced predators transform subarctic islands from grassland to tundra. Science 307:1959–1961.

Gagnon, C.A., and Berteaux, D. 2009. Integrating traditional ecological knowledge and ecological science: A question of scale. Ecology and Society 14:19, [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art19/.

Ganter, B., and Boyd, H. 2000. A tropical volcano, high predation pressure, and the breeding biology of Arctic waterbirds: A circumpolar review of breeding failure in the summer of 1992. Arctic 53:289–305.

Lack, D.L. 1968. Ecological adaptations for breeding in birds. London: Methuen.

Larson, S. 1960. On the influence of the arctic fox, *Alopex lagopus*, on the distribution of Arctic birds. Oikos 11:276–305.

Madsen, J., Bregnballe, T., and Hastrup, A. 2007. Impact of the arctic fox *Alopex lagopus* on nesting success of geese in southeast Svalbard, 1989. Polar Research 11(2):35–39.

Montevecchi, W.A. 2010. The eastern Canadian gill-net removal experiment: Tracking population responses of seabirds to the ground-fishery closure. First World Seabird Conference, 7–11 September 2010, Victoria, British Columbia.

Montevecchi, W.A., and Tuck, L.M. 1987. Newfoundland birds: Exploitation, study, conservation. Cambridge, Massachusetts: Nuttall Ornithological Club.

Pamperin, N.J., Follmann, E.H., and Person, B.T. Sea-ice use by arctic foxes in northern Alaska. Polar Biology 31:1421–1426, doi:10.1007/s00300-008-0481-5.

Petersen, M.R. 1982. Predation on seabirds by red foxes at Shaiak Island, Alaska. Canadian Field-Naturalist 96:41–45.

Petrie, B., and Anderson, C. 1983. Circulation on the Newfoundland continental shelf. Atmosphere-Ocean 21:207–226.

Prinsenberg, S.I., and Peterson, I.K. 1992. Sea-ice properties off Labrador and Newfoundland during LIMEX '89. Atmosphere-Ocean 30:207–222.

Robertson, G.J., Wilhelm, S.I., and Taylor, P.A. 2004. Population size and trends of seabirds breeding on Gull and Great Islands, Witless Bay Islands Ecological Reserve, Newfoundland, up to 2003. Canadian Wildlife Service Technical Report 418. Sackville, New Brunswick: CWS, Atlantic Region. 45 p.

Rolland, C., Danchin, E., and De Fraipont, M. 1998. The evolution of coloniality in birds in relation to food, habitat, predation, and life-history traits: A comparative analysis. American Naturalist 151:514–529.

Roth, J.D. 2002. Temporal variability in arctic fox diet as reflected in stable-carbon isotopes; the importance of sea ice. Oecologia 133:70–77, doi:10.1007/s00442-002-1004-7.

Sklepkovych, B.O., and Montevecchi, W.A. 1996. Food availability and food hoarding behaviour by red and arctic foxes. Arctic 49:228–234.

Smith, T.D. 1976. Predation of ringed seal pups (*Phoca hispida*) by the arctic fox (*Alopex lagopus*). Canadian Journal of Zoology 154:1610–1616.

Southern, W.E., Patton, S.R., Southern, L.K., and Hanners, L.A. 1985. Effects of nine years of fox predation on two species of breeding gulls. Auk 102:827–833.

Tarroux, A., Berteaux, D., and Bêty, J. 2010. Northern nomads: Ability for extensive movements in adult arctic foxes. Polar Biology 33(8):1021–1026.

Walther, G.-R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.-M., Hoegh-Guldberg, O., and Bairlein, F. 2002. Ecological responses to recent climate change. Nature 416:389–395, doi:10.1038/416389a.

Wilhelm, S.I., Robertson, G.J., Ryan, P.C., Tobin, S.F., and Elliot, R.D. 2009. Re-evaluating the use of beached bird oiling rates to assess long-term trends in chronic oil pollution. Marine Pollution Bulletin 58:249–255.