Long-distance migratory movements and habitat selection of Snowy Owls in Nunavut

Jean-François Therrien, Gilles Gauthier

Département de biologie & Centre d'études nordiques, Université Laval, Québec

Joël Bêty

Département de biologie & Centre d’études nordiques, Université du Québec à Rimouski

Gary Mouland

Parks Canada - Nunavut Field Unit, Iqaluit

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Project Leader

Gary Mouland — Parks Canada - Nunavut Field Unit, PO Box 278, Iqaluit, NU X0A 0H0
Tel: 867-975-4672; email: Gary.Mouland@pc.gc.ca.

Collaborators

Jean-François Therrien — Department of biology and Centre d'études nordiques, Université Laval, Québec (Québec) G1K 7P4
Tel: 418-656-2131 ext 6327; e-mail: jean-francois.therrien.3@ulaval.ca

Gilles Gauthier — Department of biology and Centre d'études nordiques, Université Laval, Québec (Québec) G1K 7P4
Tel: 418-656-5507; e-mail: gilles.gauthier@bio.ulaval.ca

Joël Bêty — Department of biology, Université du Québec à Rimouski (UQAR), Rimouski (Québec) G5L 3A1
Tel: 418-656-5507; e-mail: joel_bety@uqar.qc.ca

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Cover picture: This picture of a Snowy Owl marked with a satellite transmitter on Bylot Island in July 2007 was taken in Abernethy, Saskatchewan, on 10 April 2008, 2750 km from the marking site.

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SUMMARY

Snowy Owls are a top predator of the Arctic tundra and one of the least known species of birds in Nunavut, in part due to their erratic migratory movements. The primary goals of this project were to study the long-distance migration of Snowy Owls breeding in Nunavut by tracking animals using satellite telemetry and to organize a workshop in the community of Pond Inlet to allow a two-way transfer of knowledge between scientists and northerners on the biology and movements of the species. During the summer 2007, 12 adult female snowy owls were marked with satellite transmitters on Bylot Island, Nunavut, and their movements were tracked since then. In summer 2008, the sites where most birds had settled were visited to resight them. Three transmitters became stationary during the winter but only one bird could be confirmed dead in summer 2008. Annual survival of radio-marked owls was thus at least 75% and perhaps as high as 92%. No negative effect of the marking was observed on the survival, movements or reproduction of the birds. Owls showed enormous variability in their migration patterns: although 2 birds moved to temperate areas for the winter (Newfoundland and North Dakota), most spent the winter at high latitudes (south Baffin Island and west Hudson Bay) and one even spent the winter further north, on Ellesmere Island. The average distance between the breeding and the wintering site was 1727 km (range: 410-3245 km). All birds wintering in the north but one (n = 7) spent a significant amount of time on the sea ice (from 1 to 2.5 months), suggesting that it is an important wintering habitat for owls in Nunavut. Birds started migrating north in late March and settled on a summer range in early May. Birds showed no breeding site fidelity between years as none returned to Bylot Island to breed. In summer 2008, marked birds settled throughout Baffin Island except for one that moved to Prince Patrick Island in the western Arctic. The mean distance between the summer range of birds in 2007 and 2008 was 733 km (range: 235-1228 km). All 8 birds that had settled throughout Baffin Island were resighted and we found nests for 7 of them, thus confirming for the first time that Snowy Owls can breed in two consecutive years in sites very far apart. Qualitative observations reported by participants from the community during the workshop confirmed some of the scientific results although it appears that people of Pond Inlet have very little information on the wintering ecology of owls. Overall, this project was highly successful and provided new and unique information on the long-distance movements and space use of Snowy Owls breeding in Nunavut.

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ᐅᐸᒌᑦ ᓂᕿᑦᓴᖅᓯᐅᓂᖅᐸᐅᕗᑦ ᐅᑭᐅᖅᑕᖅᑑᑉ ᓇᑎᕐᓇᖓᓂᒃ ᐊᒻᒪᓗ ᖃᐅᔨᒪᔭᐅᓗᐊᖕᖏᓂᖅᐸᐅᑦᓱᑎᒃ ᑎᒻᒥᐊᓂ ᓄᓇᕗᒻᒥ, ᐃᓚᖓ ᐱᔾᔪᑕᐅᔪᖅ ᓇᒨᐃᓐᓇᑦᓱᐊᖅ ᓄᑦᑕᕐᕝᒧᑕ. ᑐᕌᓪᓗᐊᑕᐅᓯᒪᔪᑦ ᐆᒨᓚ ᐊᐅᓚᓂᐅᔪᒧᑦ ᖃᐅᔨᓴᕐᓂᐅᔪᖅ ᐅᖓᓯᑦᑐᒧᑦ ᑎᒻᒥᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐅᑭᐅᖅᑕᖅᑐᒥᐅᑦ ᐅᐸᒌᑦ ᕿᑐᕐᖏᐅᓇᐊᖅᑐᖅᓯᑎᒃ ᓄᓇᕗᒻᒥ ᒪᓕᑦᓯᖏᑦ ᐅᐸᒌᑦ ᖃᖓᑦᑕᖅᑎᑕᐅᓯᒪᔪᒃᑯᑦ ᐊᒻᒪᓗ ᐸᕐᓇᐃᖅᓯᑎᒃ ᐃᓕᓐᓂᐊᕐᓂᕐᒥᒃ ᓄᓇᓕᖓᓐᓂ ᒥᑦᓯᒪᑕᓕᐅᐸ ᒪᕿᓕᖓᖅᑲᖓᔪᒥᒃ ᖃᐅᔨᒪᓂᖅᑕᕐᑲᕐᑯᓪᓗᒍ ᖃᐅᔨᓴᖅᑎᒻᒪᓇᓐᓂᒃ ᐊᒻᒪᓗ ᐅᑭᐅᖅᑕᖅᑐᒥᐅᓂᒃ ᖃᓄᐃᑦᑑᓂᖏᓐᓄᑦ ᐊᐅᓚᓂᖏᓐᓄᓪᓗ ᐅᐸᒌᑦ. ᐊᐅᔭᖓᓂ 2007, 12 ᐊᕐᓇᐃᑦ ᐅᐸᒌᑦ ᓂᕕᖓᐃᕕᐅᓯᒪᔪᑦ ᖃᖓᑦᑕᖅᑎᑕᐅᓯᒪᔫᖓᔪᓂᒃ Bylot Island-ᒥ, ᓄᓇᕗᒻᒥ, ᐊᒻᒪᓗ ᐊᐅᓚᓂᓇᔭᖏᑦ ᒪᓕᑦᑕᐅᑦᓯᑎᒃ ᑕᐃᒪᓐᖓᓂᓪ. ᐊᐅᔭᖓᓂ 2008, ᐃᓂᑭᔭᖏᑦ ᐅᐸᒌᑦ ᐃᓂᓪᓚᕝᕕᑭᔭᖏᑦ ᐅᐸᑦᑕᐅᔪᑦ ᑕᑯᑭᐊᖅᑕᐅᒃᑲᓐᓂᖅᓯᑎᒃ. ᐱᖓᓱᑦ ᓂᕕᖓᑖᑦ ᐊᑐᕈᓐᓃᔪᑦ ᐅᑭᐅᒃᑯᑦ ᑭᓯᐊᓂ ᐊᑕᐅᓯᑐᐊᖅ ᐅᐸᒃ ᓇᓗᓇᐃᖅᑕᐅᒍᓇᖅᓯᓂ ᑐᕐᑯᓐᓂᓇᐊᖓ. ᐊᕐᕌᒍᒥ ᐊᓐᓇᒍᓐᓇᕐᓂᖏᑦ ᓂᕕᖓᑖᓕᖅᑕᐅᓯᒪᔪᑦ ᐅᐸᒌᑦ ᐃᒻᒪᖃ 75%-ᖑᔪᖅ ᐊᒻᒪᓗ ᐃᒻᒪᖃ ᕐᑯᑦᓯᓂᖅᐹᖓ 92%. ᐊᑦᑐᐃᓂᕐᓗᑦᑐᒥᒃ ᖃᐅᔮᔪᖃᔪᖕᖏᑦᑐᖅ ᓂᕕᖓᑖᖃᕐᓂᕐᒧᑦ, ᐊᐅᓚᓂᖏᓐᓄᑦ ᕿᑐᕐᖏᐅᕐᓂᖏᓐᓄᓅᓐᓃᑦ ᐅᐸᒌᑦ. ᐅᐸᒌᑦ ᑕᑯᑦᓴᐅᑎᑦᓯᔪᔪᑦ ᖃᓄᐃᑦᑐᑐᐃᓐᓇᕐᓂᒃ ᐃᖏᕐᕋᓂᕆᔭᒥᓂ: ᒪᕐᕿᒃ ᐅᐸᒃ ᐃᖏᕐᕋᓯᒪᒐᓗᐊᖅᓯᑎᒃ ᐅᖅᑰᓂᖅᓴᒧᑦ ᐅᑭᐅᒥ (ᓂᐅᕙᓐᓃᓐ ᐊᒻᒪᓗ ᒥᐊᓕᒐᐃᑦ ᓄᓇᖓᓐᓂ ᓄᐊᕐ ᑕᑰᑕ), ᐊᒥᓰᓂᖅᓴᐃᑦ ᐅᕿᔪᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ (ᓂᒋᐊᓂ ᕿᑭᖅᑖᓅᑉ ᐊᒻᒪᓗ ᐱᖓᓐᓇᖓᓂ ᑕᓯᐅᔭᕐᔪᐊᑉ) ᐊᒻᒪᓗ ᐊᓪᓛᑦ ᐊᑕᐅᓯᖅ ᐅᕿᔪᖅ ᕐᑯᑦᓯᓂᖅᓴᕆᐊᓪᓚᒻᒥ, Ellesmere Island, ᐊᐅᔪᐃᑦᑑᑉ ᕿᑭᑦᑕᖓᓂ. ᐅᖓᓯᓐᓂᖓ ᒥᑦᓴᐅᓯᔪᖅ ᕿᑐᕐᖏᐅᕐᕕᖏᓐᓄᑦ ᐅᕿᕕᖏᓐᓄᓪᓗ 1727km (ᐊᖏᓂᖓ: 410-3245 km). ᐅᐸᒌᑦ ᐅᕿᔪᓕᒫᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐋᒻᒐᑐᐊᖅ ᐊᑕᐅᓯᖅ (n=7) ᐊᑯᓂᐊᓗᒃ ᑕᓇᐅᑉ ᓯᑯᖓᓃᔪᑦ (ᑕᖅᑭᓕᒫᖅ ᑎᑭᑦᓯᒍ ᑕᖅᕿᒃ ᒪᕐᕿᒃ ᓇᐸᐸᕐᓗ), ᓇᓗᓇᐃᕈᑎᒋᑦᓯᒍ ᐱᒻᒪᕆᐹᓘᒋᐊᖓ ᐅᕿᕕᐅᔪᖅ ᐅᐸᓐᓄᑦ ᓄᓇᕗᒻᒥ. ᐅᐸᒌᑦ ᐃᖏᕐᕋᕙᓪᓚᐊᓯᓰᑦ ᐅᐊᓐᓇᒧᑦ ᒫᑦᓯᐅᐸ ᓄᓐᖑᖅᐸᓯᐊᓂ ᐊᒻᒪᓗ ᐊᐅᔭᓚᕕᕆᓂᐊᖅᑕᒥᓄᑦ ᐃᓂᓪᓚᑦᓯᑎᒃ ᒪᐃᒥ. ᐅᐸᒌᑦ ᑕᑯᑦᓴᐅᑎᑦᓯᔪᓐᖏᑦᑐᑦ ᕿᑐᕐᖏᐅᕐᕕᒻᒥᓄᑦ ᐅᑎᓲᖑᓂᕐᒥᓂᒃ ᐅᑎᖅᑐᖅᑲᔪᓐᖏᒻᒪᑦ Bylot Island-ᒧᑦ ᕿᑐᕐᖏᐅᓇᐊᖅᑐᖅᑐᓂᒃ. ᐊᐅᔭᖓᓂ 2008, ᓇᓗᓇᐃᒃᑯᓯᖅᓯᒪᔪᑦ ᐅᐸᒌᑦ ᐃᓂᓪᓚᔪᑦ ᕿᑭᖅᑖᓗᒻᒥ ᐊᑕᐅᓯᖅ ᓅᓚᓗᐊᖅᓯᓂ Prince Patrick Island-ᒧᑦ ᐱᖓᓐᓇᖓᓄᑦ ᐅᑭᐅᖅᑕᖅᑑᑉ. ᐅᖓᓯᑦᑐᓂᕆᓂᕆᔭᖓᑦ ᐊᐅᔭᖓᓂ 2007 ᐊᒻᒪᓗ 2008 ᐅᐸᒌᑦ 733 km-ᖑᔪᔪᖅ (ᐊᖏᓂᖓ: 235-1228 km). ᐃᓅᓇᑎᒃ 8 ᐅᐸᒌᑦ ᐃᓂᓪᓚᑦᓯᒪᔪᑦ ᕿᑭᖅᑖᓗᒻᒥ ᑕᑯᔭᐅᒃᑲᓐᓂᖅᓯᒪᔪᑦ ᓇᓂᑦᓯᑎᒍᓗ 7 ᐅᓪᓗᖏᑦ, ᓇᓗᓇᐃᕈᑕᐅᑦᓯᓂ ᓯᕗᓪᓕᖅᐹᒥ ᐅᐸᒌᑦ ᕿᑐᕐᖏᐅᕈᓐᓇᓇᐊᖏᑦ ᐊᕐᕌᒎᓐᓂ ᑭᖑᓕᕇᓐᓂ ᐅᖓᓯᒌᑦᑐᐹᓗᓐᓂ ᐅᓪᓗᖃᕐᕕᓐᓂ. ᐊᒥᓱᓐᖑᐸᓪᓕᐊᓂᖏᓐᓄᑦ ᐅᖃᐅᓯᐅᔪᑦ ᐃᓚᐅᔪᓄᑦ ᓄᓇᓕᓐᓂᒃ ᐃᓕᓐᓂᐊᕐᓂᖃᖅᓯᑎᒃ ᓇᓗᓇᐃᖅᓯᔪᔪᖅ ᖃᐅᔨᔭᐅᔪᓂᒃ ᐃᓚᖏᑦ ᒥᑦᓯᒪᑕᓕᒥᐅᑦ ᖃᐅᔨᒪᓗᐊᖕᖏᒃᑲᓗᐊᖅᑎᓪᓗᒋᑦ ᐅᐸᒌᑦ ᒥᑦᓴᐃᓐᓄᑦ ᐅᕿᓂᕙᑦᑕᖏᑦᑕ. ᐃᓅᓈᒍᑦ ᐊᐅᓚᓂᐅᔪᖅ ᑲᔪᓯᑦᓯᐊᖅᑐᐹᓅᔪᖅ ᐊᒻᒪᓗ ᐊᑐᐃᓐᓇᐅᑎᑦᓯᕕᐅᑦᓯᓂ ᓄᑖᓂᒃ ᐊᔾᔨᐅᖏᑦᑐᓂᓪᓗ ᑐᓴᕋᕐᓴᓂᒃ ᐅᖓᓯᑦᑐᒧᑦ ᓄᑦᑕᕐᓂᖏᓐᓂᒃ ᐊᒻᒪᓗ ᐃᓂᒥᒃ ᐊᑐᕐᓂᖏᓐᓂᒃ ᐅᐸᒌᑦ ᕿᑐᕐᖏᐅᖅᑐᑦ ᓄᓇᕗᑦᒥ.

1. INTRODUCTION

Observations reported by the Inuit people (Krupnik and Jolly 2002) and western science (ACIA 2005) both indicate that the Arctic environment is changing and in particular that climate is warming rapidly. These changes could have a considerable impact on Nunavut wildlife species in future years, most of which are well adapted to the cold and harsh environment of the arctic tundra. However, our understanding of the impact of these changes on wildlife species and on the functioning of the tundra ecosystem remains very limited because some basic information is still lacking for several species. This is especially true for top predators in arctic ecosystems because these animals usually roam over large areas, which increases the logistic challenges to study them.

Among these top predators, the Snowy Owl (Ookpik; *Bubo scandiaca*) is a mythic species and a powerful symbol of the Arctic. This species occupies a prominent place in the legends and culture of many Indigenous people, including the Inuit. At local scale, Inuit have long known the relationship between Snowy Owls and lemmings. However, and despite its symbolic value, Ookpik remains one of the least known species of birds in the Arctic, especially in Nunavut. A key reason for this is that the Snowy Owl is a highly nomadic species that can range over distances of several hundred kilometers to find its main prey, lemmings, in sufficiently large numbers. The extent of its migratory behaviour between its breeding and wintering areas is poorly known, as well as movements between breeding attempts in successive years (Fuller et al. 2003). For instance, at our long term study site of Bylot Island, Sirmilik National Park, owls breed in abundance in years of peak lemming abundance (every 3 or 4 years) but in between those years they have never been observed to breed there and are almost completely absent during the summer (Gauthier et al. 2004). These erratic movements, which are among the most spectacular of all terrestrial birds, explain in part why we know so little on the biology of this species.

The paucity of basic knowledge on Snowy Owls in Nunavut, and especially on their movements, is most unfortunate as it hinders the development of management plans for the species. For instance, we do not know the population structure of the species or its basic demographic parameters such as fecundity, survival or dispersal. This makes it impossible to determine the conservation status of the species in Nunavut or to evaluate how the species may be impacted by current change taking place in the arctic ecosystem.

In the context of the International Polar Year (PY; 20007-2009), a circumpolar project called Arctic Wildlife Observatories Linking Vulnerable EcoSystems (ArcticWOLVES) was developed and funded by the Canadian IPY program. The aim of the project is to improve the understanding of the functioning of the Arctic terrestrial food webs and to assess the effect of climate change on the tundra ecosystem and its wildlife species over a large geographical range. Avian predators, including Snowy Owls, are high priority species in this project. Therefore, this provided an opportunity to launch a study on this little known species.

An important knowledge gap identified for Snowy Owls was the lack of specific information on its large-scale movements, distribution, and habitat use. Satellite tracking has proven to be a useful technique to document migratory routes of large bird species (Fuller et al. 1998, 2003, Trierweiler et al. 2007), including raptors. This technology is particularly appropriate to track large scale movements of birds over long distances in remote areas such as the Arctic (Britten et al. 1999). In many cases, satellite tracking can provide new information of major importance for the conservation of bird species, information that cannot be collected using alternative techniques. This is why this project focused primarily on the use of satellite telemetry to study Snowy Owls breeding in Nunavut.

1.1 Objectives

This project had two major objectives.

1. Study the long-distance migration of Snowy Owls breeding in Nunavut by tracking animals using satellite telemetry over a full year. This will allow us to answer some basic questions, such as: how far south do Nunavut owls go in winter? How far can Snowy Owls move between breeding attempts in consecutive years? Can they breed successfully in two years in different areas? What is the scale of owl’s population in Nunavut?

2. Organize a workshop in the community of Pond Inlet during winter to allow a two-way exchange of knowledge between scientists and northern residents on the biology and movements of Snowy Owls.

In addition, the project also had two secondary aims:

3. Measure the impact of owl predation on lemming populations.

4. Provide training in wildlife management and conservation to northerners by hiring a field assistant from the community of Pond Inlet to assist in the capture snowy owls.

2. MATERIAL AND METHODS

2.1 Study area

The study took place in the south-west plain of Bylot Island, Sirmilik National Park, in summer 2007. The closest community to the study site is Pond Inlet (figure 1). This area is characterized by a low elevation plateau (ranging from 100 to 300 m above sea level) cut by numerous rivers flowing from the mountains and glaciers in the central portion of the island to the sea. These rivers create a diverse landscape ranging from small, narrow valleys to deep and wide glacial valleys. Most of the landscape is covered by lush tundra vegetation and is dominated by mesic tundra on the plateaus and slopes or wet polygon fens in the valley bottom (Gauthier et al. 1996). This area is a very important breeding ground for many bird species in Nunavut, including Snowy Owls, and is a Migratory Bird Sanctuary as well as a Canadian National Park. A large snow goose (*Chen caerulescens atlantica*) colony is also located in this area. Activities were conducted from two field camps located in this area (camp-1: 73° 08' N; 80° 00' W; camp-2: 72° 53' N, 79° 55' W).

2.2 Nest monitoring and lemming abundance

In June and early July 2007, a team surveyed on foot areas suitable for nesting owls over approximately 200 km^2 of the south plain of Bylot Island to locate their nests (Figure 2). The area searched for owl nests represent only about 15% of the south plain of Bylot Island, which extends over aproximately 1,600 km^2 (Figure 1). All nests found were positioned with a GPS receiver and their content noted (number of eggs or chicks). Most nests were revisited at about 2-week intervals until successful departure of the last chick or until failure (i.e. all eggs or chicks disappear). A nest was considered successful when at least one chick fledged. At each visit, we also collected regurgitation pellets near the nest to study their diet. Pellets were brought back to the laboratory for analysis. Bones and hairs present in pellets were sorted and identified to the species level. Clutch size was defined as the maximum number of eggs (or eggs and chicks) recorded in a nest. The laying date (defined as the date that the first egg was laid) was inferred from the nest content assuming that one egg was laid every other day.

We sampled the abundance of lemmings at two sites near Camp-1 (one in wet meadow habitat and one in mesic habitat) and one site at the Camp-2 (mixed habitat) in July 2007. At each site, we used 204 traps set at 15-m intervals along two to four parallel transect lines 100 m apart (51 to 102 traps/transect depending on the site) and left open for 4 days. We used Museum Special snap-traps baited with peanut butter and rolled oats. Similar data were available for the sites since 1993 (data from Gruyer et al. 2008).

2.3 Marking and tracking or radio-marked owls

We captured 12 adult breeding females on their nest using a bow-net trap (Figure 3a, b) and marked them with 30g satellite transmitters (Microwave Telemetry Inc., MD, USA; PTT-100) fixed on the birds with a Teflon ribbon harness (Bally Ribbons Mills, PA, USA) (Figure 3c, d). The size of the transmitter and the method of attachment were chosen following Steenhof et al. (2006) and after extensive consultation with experts that had previous experience in marking snowy owls or similar species with radio-transmitters (Mark Browning, Pittsburgh Zoo; Mark Fuller and Kirk Bates, Raptor Research Centre, Boise State University; Guy Fitzgerald, veterinary school, Université de Montréal). In addition, Jean-François Therrien, the PhD student responsible of the field component of the project, conducted extensive tests on captive owls at the birds of prey rehabilitation center of Ste-Hyacinthe, Quebec (UQROP), with the assistance of a veterinarian. During winter 2007, he marked snowy owls with dummy transmitters in a large outdoor aviary to ensure that the transmitter and harness did not cause any harm to the birds. All marking took place in late June and early July. The capture, manipulation and the transmitter itself can be a source of stress for an animal and we therefore reduced as much as possible all stress imposed to the birds. Captures were done quickly by experienced personnel. Jean-François Therrien received the assistance of Marten Stoffel, a technician from the University of Saskatchewan who has captured and banded several owl species during many years. Thanks to the experience acquired with the captive owls, Jean-François was able to attach the harnesses quickly (<10 minutes) and without the use of drugs. All birds were weighed to the nearest 10g using a 5kg PESOLA spring scale in order to assess general body condition. Following release of the bird, activity was observed at the nest with a spotting scope from a hidden, distant vantage point (>300 m) for a few hours.

Transmitters were programmed to transmit continuously for about 6 hours and then turned off for a number of hours on a varying schedule. Rate of transmission ranged from one transmission bout every 5 days to one every 2 days depending of the season. Transmitters were programmed to last for at least 16 months, and potentially up to 24 months. Real time locations of marked owls have been received via internet since the installation. Each location estimate is associated with a measure of its accuracy determined by the Argos system. The estimated accuracy of location classes 0, 1, 2 and 3 are > 1 km, ≤ 1 km, ≤ 350m and ≤ 150 m of the actual location, respectively. Location classes A, B, C and Z are considered to be of poor accuracy by the system and we therefore only used localisations with accuracy of ≥ 0 for all analyses. Given the good satellite coverage of polar regions, numerous localisations were received for each bird during each 6-h transmission bout. In order to avoid overestimation of the total distance moved, all localisations were averaged for a given bout.

The analysis of owl movements for this report covers a full year, from marking in early July 2007 until the end of June 2008. The data was divided into 2 periods: 1) the fall-winter period extends from July 2007 to 29 February 2008 and includes the fall migration and most of the wintering period; 2) the spring-early summer period extends from 1 March 2008 to the end of June 2008 and includes the spring migration and the period of settlement on a summer range. Total distance moved was evaluated by summing the length of all segments between successive transmission bouts during each migration. Net linear movement in the fall-winter period was measured as the distance between the nesting site (on Bylot Island) and the localisation at the end of February, and in spring as the distance between the localisation at the end of February and the localisation at the end of June. Migration speed was measured as the total distance moved divided by the number of days taken into account. General orientation of migration was roughly evaluated between the breeding and wintering areas according to the path followed during migration. Initiation of the fall and spring migration was defined as the date midway between the date of the first localisation beyond 5 km of the nest site (or the wintering site) and the previous date of localisation (Ganusevich et al. 2004). The end of the fall and spring migration was defined as the date midway between the first date when movements ranged for less than 5 km from the last localisation and the previous date of localisation. Wintering sites were defined as the area where movements between successive localisations were less than 5 km. All movement parameters were analysed using ArcGIS 9.2 software (ESRI Inc., Redlands, CA, USA), and this software was also used to plot movement paths of the birds.

During summer 2008, attempts were made to revisit the sites where radio-marked owls had settled. Although these sites were outside our study area on Bylot Island, most of them were accessed with the help of a helicopter provided by the Polar Continental Shelf Project. At each of these sites, the helicopter circled briefly to observe for any signs of owls before landing. On the ground, 1 to 3 persons searched the site for a few hours and scanned the surrounding area with a spotting scope in order to find the marked bird and to determine if it was nesting. When a nest was found, its content was checked. For the 3 birds whose signal had stopped moving during the fall or winter (see results), we also attempted to visit the site from which the stationary signal was coming from in summer 2008. We conducted a thorough search on the ground for the transmitter and/or for any evidence of an owl carcass around the position provided by the satellite.

2.4 Workshop and local community participation

On 5 March 2008, a 1-day workshop was organized at the Nattinak Visitor Center of Pond Inlet, followed by a public presentation in the evening. The workshop and public presentation were centered on 2 themes, one of which was the Snowy Owl project. Jean-François Therrien, attended the workshop, as well as several members from the Parks Canada's staff in Iqaluit and Pond Inlet. People invited to the workshop included members from the Sirmilik National Park Joint Management Committee, the Hamlet of Pond Inlet, the Mittimatalik Hunters and Trappers Organization (HTO), the Government of Nunavut, Elders of Pond Inlet and the Inuit Knowledge Working Group of Pond Inlet. Official letters of invitation had been sent to all of these people approximately 2 months before the workshop, and were translated in Inuktitut. Jean-François Therrien made presentations and lead the discussion. A translator was hired to provide simultaneous translation during the workshop. All presentations were supported by visual material (Power Point presentations are available upon request). An English/Inuktitut leaflet presenting this project and preliminary results was presented to the community during this workshop (this leaflet is included in appendix B of this report). Finally, Jean-François Therrien also made 2 presentations on the project at the Pond Inlet High School on 6 March 2008.

For the field work on Bylot Island, a field assistant was hired from Pond Inlet to assist the research team in summer 2007. The position was advertised locally (at the Parks Canada office and the COOP store) as well as on the community radio to recruit that person.

3. RESULTS

3.1. Satellite telemetry and long-distance movements

3.1.1 Reproductive success of radio-marked owls in 2007

A total of 17 owl nests were found on Bylot Island in 2007 over an area of approximately 200 km^2 (Figure 2). Nests were widely scattered throughout this area but mostly associated with rivers, often located on bluffs overlooking a stream. From 27 June to 11 July, 12 nesting females among these nests were captured and marked. Hatching had started at the time of capture and thus all nests had a mixture of eggs and chicks. Marked females were observed returning to their nest a few minutes to a few hours after marking, and all of them resumed normal activities, i.e. they incubated the eggs and brooded their chicks. Thus, no females deserted their nest following marking.

Average clutch size of all owl nests found in 2007 was 5.6 ± 1.8 and did not differ significantly between marked (6.1 ± 1.8) and unmarked ones (4.3 ± 0.8; t-test = -1.84, df = 13, p = 0.09). Overall, reproductive success was moderate (60%) as 9 nests out of 15 with known fate produced at least one fledgling (Table 1). Reproductive success did not differ between females that were caught and marked at the nest (64%) and those that were not caught (67%) (Fisher's exact test: F = 0.77, n = 14, p = 0.79; note that the comparison of reproductive success between marked and unmarked females exclude one nest that failed very early in the season and was therefore not available for marking). Among marked birds, the body mass of females who failed to fledge at least one young (2.17 ± 0.10 kg) was not different from females who fledged at least one young (2.17 ± 0.18kg) (t-test: t = 0.03, n = 11, p = 0.97).

3.1.2 Survival of radio-marked owls

No owls were hurt during the capture and marking process. Among the 12 transmitters attached to owls, 3 became stationary at some point during the fall (13 August, 23 October and 26 November) and did not move afterward. Those 3 transmitters had nonetheless moved over distances ranging from 104 to 1072 km (Table 1) before becoming stationary and were transmitting properly both before and after stopping their movements. All transmitters are equipped with a temperature sensor and those 3 have been indicating a much lower temperature after they became stationary than the remaining 9 transmitters. The mean body mass of the birds wearing the transmitters that stopped moving (2.10 ± 0.02 kg) did not differ from that of the remaining birds (2.20 ± 0.17 kg) at the time of marking in July (t-test, $t = -1.56$; $df = 10$, $p = 0.16$). Movements of the remaining 9 transmitters have been normal until the end of June 2008.

In summer 2008, we were able to visit the site where one transmitter had been stationary since fall 2007. This site was located on Borden peninsula, Baffin Island, near Navy Board Inlet (Fig. 5). Within 31 m of the position provided by the satellite, we found the carcass of the owl with the transmitter attached to it. The harness was intact and well positioned on the bird, all body parts were still attached to the carcass and there was no sign of external injuries, although the carcass was partly decomposed. We recovered both the transmitter and the harness. There was no evidence that the transmitter or the harness had been damaged by the bird with its beak or claws. Visits to the two other sites with stationary transmitters were not possible because they were too far (>350 km) from the camp. Therefore, it is not possible to determine the reason for the stationary transmissions.

3.1.3 Movements during the fall-winter period

The radio-marked birds showed an enormous amount of individual variability in almost every aspect of their migratory pattern. Birds generally initiated their fall migration in early September although some birds (especially those whose nest failed) started in July or August (Table 2). South-east was the most common (n = 6) orientation taken by fall migratory owls although some took a south-west orientation and 2 birds even moved north (Figure 5; Table 2). Some birds followed a relatively linear path during the migration (e.g. #48837 and # 48839) whereas others followed a very tortuous path (e.g. #39097 and # 39103 Figure 5). Total distance moved during the fall migration, net linear movement and migration speed also varied enormously among marked birds; total distance moved ranged from 2173 to 5253 km (excluding transmitters that became stationary during the fall), net linear movement ranged from 410 to 3245 km and migration speed ranged from 9 to 30km/day (Table 2). The consequence of this large inter-individual variability in fall migration is that the wintering sites used by marked owls differed considerably in latitude and longitude (Figure 5). Some birds wintered as far south as the east coast of Newfoundland (48°N, 53°W) or North Dakota (44.5°N, 98°W), two sites separated from each other by 3562 km. The majority (n = 6) of owls spent the winter around southern Baffin Island and northern Quebec but, surprisingly, 2 others went north to Ellesmere Island (78.5°N, 84.5°W and 76.5°N, 81°W). The fall migration was relatively long because birds settled on a wintering area only in late January or early February. However, not all birds settled into a definite wintering area as some kept moving most of the winter, hence the absence of a date of end of fall migration for a few birds in Table 2.

The most surprising and unexpected result from the winter tracking of owls is that many individuals spent a considerable amount of time over the sea ice during the period extending from December to March (Figure 5). Among the 7 birds that wintered at high latitudes (>55^{o} N), 6 of them used the sea ice (the only one that did not use it is the owl that wintered on Ellesmere Island), including 5 for extended periods of time (between 1 and 2.5 months; Table 2). Birds that used the sea ice were mostly in the eastern portion of Hudson Strait and north of the Labrador Sea although one was in west Hudson Bay near Belcher Islands (Figure 5). Considering the speed of movements of owls during migration (Table 2) and the length of time spent by these birds offshore, these birds were undoubtedly using the sea ice as a wintering habitat and were not merely passing over it while moving between islands or from islands to the continent.

3.1.4 Movements during the spring-early summer period

For birds that had settled at some point during the winter, the spring migration started over a narrow time window during the last week of March, and extended until early May for most birds (Figure 6, Table 3). Total distance moved during the spring migration again differed enormously among birds, ranging from 534 to 5162 km (Table 3). Similarly, linear movement varied greatly, from 204 to 3646 km, as well as migration speed, which ranged from 15 to 80 km per day. Migration speed was fastest for the two birds that wintered the furthest south, at temperate latitudes. Despite the large inter-individual variability, migration speed of owls was faster in spring than in fall (33.7 km/d vs 20.2 km/day; paired t-test = 2.62, df = 8, p = 0.03).

Owls settled over a restricted area for the summer on average on 12 May. All the owls had settled by the third week of May except the one that settled only on 15 June (Table 3). It is noteworthy that this owl (#48839) had the longest migration in both fall and spring, and is the one that settled the farthest from Bylot Island in 2008 (Figures 5 & 6). None of the birds showed any fidelity to its previous year breeding site on Bylot Island. Although the bird that wintered on Ellesmere Island overflew its previous year breeding site on Bylot Island in spring, it did not settled there (Figure 6). The distance between the site where the birds settled in 2008 and their nesting site in 2007 averaged 733 km, a very long distance, and ranged from 235 to 1228 km (Table 3). In 2008, most birds settled throughout Baffin Island (2 in North Baffin, 3 in Central Baffin and 3 in southern Baffin) but one bird settled on Prince Patrick Island in the Northwest Territories, the westernmost island in the Canadian High Arctic archipelago (Figure 6).

3.1.5 Breeding activity of radio-marked owl in 2008

All the owls (8) that settled throughout Baffin Island in late June-early July 2008 (Table 4) were visited. In all cases, the radio-marked females were resighted at close range (50 to 200 m) with a spotting scope, either on the ground or on flight. All the birds looked healthy and the transmitter was well positioned on the back of the bird. All of them were paired with a male, which was also observed. For 7 of these 8 birds, we found a nest well within the cloud of positions provided by the satellite since the bird had settled in May. Based on the nest content, we estimated that the average laying date of these birds was 18 May ± 7 days in 2008, which is earlier than the laying date of these same individuals in 2007 on Bylot Island (28 May ± 7 days; paired t-test = 2.65, df = 6, $p = 0.04$). The minimum clutch size of these birds also tended to be higher in 2008 (7.1 ± 2.0) than in (6.1 ± 1.7) although the difference was not significant (paired t-test = 1.87, df = 6, $p = 0.11$). Although we failed to find a nest for the 8th bird, we believe that it is likely that this bird also attempted to breed considering that 1) it settled in early May, 2) it was paired with a male and 3) it had a very restricted range afterward, like all the other owls for which we found a nest. It is possible that the nest of this bird was missed or that its nest failed before the site was visited. Finally, the bird that settled on Prince Patrick Island could not be visited but this bird settled there very late (12 June) in the season. Considering that the latest laying date recorded for any owl was 12 June on Bylot Island in 2007 and that the radio-marked birds started laying about 10 days after settling in 2008, we believe that it is unlikely that this bird bred in 2008 due to its very late settling date.

3.2 Community workshop

Despite a flight cancellation by First Air on 4 March due to bad weather, which prevented the participation of some people from Iqaluit and Arctic Bay, the workshop on 5 March was very successful, with 17 participants. The list of participants is presented in appendix A of this report.

In the first part of the workshop, we presented the preliminary data obtained thus far on the tracking of radio-marked snowy Owls during the fall migration. A map of movements was presented and generated many comments and discussions. Participants had the chance to manipulate dummy transmitters identical to those used on owls as well as regurgitation pellets that were collected in the field to determine the diet of owls based on prey remains (hairs and bones). This hands-on material generated lots of comments and discussion.

In the second part of the workshop, Local participants were asked to share their knowledge about Snowy Owl movement and reproduction. Several people reported their observations and thoughts about owl's behaviours, feeding habits and general ecology as well as legends and myths related to that powerful symbol. A summary of those observations is presented here.

- Snowy Owls have been observed nesting around the community of Pond Inlet and elsewhere on the land and it is known that this does not occur on a regular basis, i.e. not every year. Some years there are many birds nesting, some years there are very few and birds do not show fidelity to a nest site from year to year.

- Snowy Owls are known to eat lemmings, but also birds, in a lower proportion.

- Snowy Owls move to follow animals and it has always been known that high densities of lemmings can occur very far from where it has occurred the year before.

- Local residents do not observe Snowy Owls spending time over the sea ice during the winter period (or at any other time). In fact, they do not observe Snowy Owls during the winter. They said that local people from Iqaluit or other more southern communities could have observed that and could confirm the observations we have from satellite telemetry. They might also have cues about what they eat and what are the behaviours observed during that period.

- A suggestion was made that Inuit Traditional Knowledge should be incorporated in the Snowy Owl research. It would be helpful because they want to know more about them and some people might have information that could be shared among Inuit and western scientists. Snowy owls are mysterious to them, they said.

- A legend was told. The story is about a Snowy Owl who had married a goose; they were together and they went over the water. As the owl did not want (or like) to settle on free water, he stood on the back of his goose partner but made her sink and she died. According to the legend, this is why Snowy Owls tolerate goose nests around their own without attacking them and that the two species nest in association during the love period.

In addition, several questions were asked to the researchers and a few concerns were expressed. These are summarized below, along with the response provided by the researchers.

- There was an awareness that Snowy Owls only breed in a given area on an irregular basis but they were questioning if the global population was stable.

  Response: we have no information on Snowy Owl populations in Nunavut

- Has any Snowy Owl telemetry research been done elsewhere before?

  Response: Two other studies have marked Snowy Owls with radio-transmitters before in North America, one in Alaska and one in Massachusetts on wintering birds.

- Do the harnesses have an automatic release device? What is life expectancy of the batteries in the transmitters?

  Response: The harness has no automatic release system. However, it will eventually wear out and fall off the bird. Batteries should last between 16 and 24 months.

- Comments were expressed that they are happy that studies are done on animals. However, there were also concerns expressed regarding the manipulation (capture of birds on the nest, putting transmitters on them) of Snowy Owls. They were afraid that the birds will spook and that they will not come back to Bylot Island. They were most concerned about the fact that if Snowy Owls do not come back, would the geese also not return?

Response: The question of the potential effect of marking on the owls is addressed in the discussion below. However, even if Snow Geese do associate with Snowy Owls to nest when they are present, owls nest on Bylot Island only in peak lemming years, i.e. once every 3 or 4 years. Geese are nonetheless present on the island every year and therefore their numbers are independent of the presence or absence of owls. In years with owls, only the distribution of nesting geese changes (i.e. some move their nest site near owl nests).

3.3 Impact of owl predation on lemming populations

This objective is part of a long term investigation of the trophic dynamic on Bylot Island. The reciprocal interactions between predators such as raptors and foxes and their prey are being examined, primarily lemmings and migratory birds such as geese and shorebirds. During our lemming survey using snap traps, we accumulated 1567 trap-nights at our 2 trapping sites of the Base-camp Valley from 31 July to 3 August 2007, and 792 trap-nights at the Camp-2 from 11 to 14 July 2007. In the Base-camp sites, 9 Collared Lemmings (*Dicrostonyx groenlandicus*) were caught in the mesic site and none in the wet meadow site, and 1 Brown lemming (*Lemmus sibiricus*) was caught in the mesic site and 2 in the wet meadow site. This yielded a combined index of abundance of 0.80 lemmings/100 trap-nights in 2007, an intermediate value (Fig. 4). The abundance was similar in the Camp-2 area, as 3 Collared Lemmings and 4 Brown Lemmings were caught, for an index of 0.90 lemmings/100 trap-nights. Although our index suggests that lemming abundance had increased on Bylot Island compared to the previous year, it was only moderate (Fig. 5).

A total of 781 regurgitation pellets were collected during visits to 17 owl nests. Preliminary analysis of 255 pellets revealed that 95% of the food items are lemmings. Other prey identified in the pellets included Snow Geese (adult and young), Lapland Longspurs (*Calcarius lapponicus*), Snow buntings (*Plectrophenax nivalis*), sandpipers (*Calidris* sp.) and Stoat (*Mustela erminea*). Once analysis of all these pellets is completed, a comparison will be made with the pellets of owls that were collected in 2004, another year where owls were nesting on

Bylot Island. An assessment will then be made of the impact of owls on the local lemming predation by combining information on their diet, daily energetic requirements and density of breeding owls measured in those 2 years. These analyses are still underway.

3.4 Training of northerners

Initially M. Bernie Kilukishak was hired to assist the research team in finding owl nests and especially in capturing adult females on their nests to mark them. However, M. Kilukishak had to leave the field camp and return to Pond Inlet for personal reasons after a few days. M. Terry Killiktee was then hired as a replacement to finish the work. These 2 persons helped the team during the capture and marking of most Snowy Owls for this project. They thus receive valuable training in the study, capture and marking of an important avian species. These 2 persons also participated in the workshop that in Pond Inlet in March 2008 and thus could share the experience acquired while working with the research team with other participants to the workshop.

4. DISCUSSION AND MANAGEMENT IMPLICATIONS

4.1 Effects of the manipulation and radio-transmitters on Snowy Owls

Any studies involving the capture, handling and marking of animals should be concerned about potential negative effect on the studied animal, especially when using an invasive technique such as satellite transmitters (Steenhof et al. 2006). If these negative effects are severe, they cannot only be an undue source of stress for the animal but they can also lead to biased results. Potential negative effect fall into two categories: short term effects (in the days or weeks following marking) and long term effects (in the months or years following marking).

All the evidence suggests that short term effects of marking were negligible in our study. Distant observations of the owls immediately following marking did not reveal any abnormal behaviour as females preened lightly and perched quietly on the ground following release. All females quickly returned to their nest to brood their chick (within minutes to a few hours) and none abandoned their nest after marking. Overall, the reproductive success (defined as the probability to fledge at least one chick) of owls on Bylot Island in 2007 (60%) was moderately low compared to previous years (80 to 90%; Cadieux et al. 2008). However, the reproductive success did not differ between females that were captured and marked and females that were not manipulated, and thus marking is unlikely to be the cause of the low overall success. This may be due to the relatively low abundance of lemmings, their primary prey, because our index of lemming abundance was fairly low compared to some previous peak of abundance (e.g. 1996 or 2000; Fig. 4). Lemming abundance is a strong determinant of the reproductive success of Snowy Owls (Parmelee 1992, Gauthier et al. 2004). We believe that the experience of the team in capturing and handling owls and the fact that they trained on captive owls in winter 2007 with the method used to fix the transmitter on the bird are key reasons for the absence of short term effects of marking owls.

The evaluation of long term effects of marking owls is more difficult because we cannot compare our sample of marked birds to a control sample of unmarked ones. Over the 12 months period that we have monitored the radio-marked birds, we had one confirmed death (approximately 6 weeks after marking). This yields a maximum annual survival rate of 92% for these 12 birds, which is close to what we would expect for such a species. Indeed, although there are no previous estimate of survival rate for Snowy Owls, annual survival of other Strigidae is usually in the range 80-90% (Great-horned Owl (*Bubo bubo*): 90.5% in Yukon, Rohner 1996; from 81 to 88% in Saskatchewan, Houston and Francis 1995). However, 2 other transmitters became stationary over the winter but we were not able to confirm if the birds died or if they lost their transmitter. Harnesses used to attach transmitters are made of resistant material (Teflon ribbon) but they still need to be smooth and flexible to prevent any harm to the bird. It has been previously observed in raptors that some individuals can cut such harness with their powerful beak and drop the transmitter (Dr Guy Fitzgerald, veterinarian school, Université de Montréal, personal communication). Moreover, these 2 birds had moved over a much longer distance (over 1000 km each) than the one confirmed dead (100 km) and for periods of 3 to 4 months. Nonetheless, the 3 birds with transmitters that became stationary tended to be slightly lighter than the others when weighed at the nest, which suggests that they may have been in poorer body condition. If we assume, under the worse case scenario, that all of these birds died, this would bring the annual survival of our marked owls to 75%, a value slightly lower than what would be expected for a bird like the Snowy Owl. However, we must stress that we have no evidence to substantiate this hypothesis. In the only case of confirmed mortality, the transmitter did not appear to be a direct cause: the harness was still well positioned on the bird and there was no evidence that the bird tried to get rid of the transmitter (e.g. there was no mark on either the transmitter or the harness). We therefore tentatively conclude that transmitters did not impair the survival of owls.

Even though we failed to detect an effect on the survival of the bird, it is still possible that the transmitters had more subtle effects, either by affecting the migration or subsequent reproduction of the owls. Despite the large individual variability in migratory behaviour that we observed, the 9 birds tracked over a full year moved over distances ranging from 3,000 to >10,000 km, which is considerable. When animals are disturbed or weakened (e.g. due to carrying a transmitters), one of the first activities that curtailed is breeding. Negative impacts could include a reduced clutch size, a delayed laying or in the worse case they could completely forego breeding. However, at least 7, and possibly 8, of our 9 radio-marked birds bred in the following year. Moreover, our radio-marked birds started laying about 10 days earlier in 2008 than the year before, and their clutch size tended to be higher. These results therefore strongly suggest that the radio-transmitters had no long term effects on the birds.

In 2008, lemming abundance was still high on Bylot Island and owls bred there again (20 owl nests were found, Therrien and Gauthier, unpubl. data). Considering that breeding conditions were apparently adequate for owls again in 2008, could the fact that none of the radio-marked birds returned to Bylot Island to breed be a consequence of disturbance experienced during marking in 2007? In many bird species, dispersal distance between consecutive breeding attempts is dependent on previous reproductive success: individuals successful in raising chicks tend to return at (or near) the same site the following year (because they associate their previous success to the site) whereas those that failed in raising chicks move farther away for the opposite reason (Newton and Marquiss 1982, Gavin and Bollinger 1988, Part and Gustafsson 1989, Gauthier 1990, Serrano et al. 2001). Among radio-marked owls, distance between the breeding site used in 2007 and in 2008 was similar for birds that were successful compared to those that failed in 2007 (769 km vs 723 km, respectively; t-test = 0.14, df = 6, $p = 0.89$). This suggests that movements of the owls between consecutive years are independent of conditions experienced in the previous year. Moreover, if disturbance caused by handling was the primary reason for owls to change nesting site in 2008, then why move over several hundred kilometres? Much shorter movements would have been sufficient to avoid the potential disturbance they experienced in the previous year. We thus believe that it is unlikely that handling can explain the low site fidelity shown by radio-marked owls between 2007 and 2008 and we suggest that other factors are involved (see section 4.4).

Although the size of the Snowy Owl population is unknown for any part of the Arctic, the 12 adult females marked in 2007 certainly represents a small fraction of that population, even at the local scale. Even though we found only 17 owl nests over a 200 km^2 area on Bylot Island, less than 25% of the potential breeding habitat for the species on the south plain of the island was searched for owls. Thus, the total breeding population that year was undoubtedly higher, possibly 3 to 4 times higher if we extrapolate the density of nests found in our study area to the rest of the south plain of the island. Moreover, in 2008 we found 20 owl nests on Bylot Island over a smaller area, which suggests that the population of Snowy Owls at the regional scale is at least in the hundreds.

4.2 Quality of the radio signal

We experienced no technical failures with the transmitters and after 1 year all of them were still functioning properly. We consistently received locations at all times according to the duty cycle programmed on the transmitter, even in the middle of the Arctic winter. The quality of the locations provided by the ARGOS system was impressive. The filters used to convert the transmissions received only selected the high quality localisations (precision ≤ 1km). In some instance, we were able to confirm the quality of the localisations on the ground. All birds resighted during the summer 2008 at their breeding sites were within a few hundred meters from the average localisation provided by the satellite over the preceding weeks. In April 2008, Martin Stoffel was also able to find on the ground the radio-marked bird that was passing through Saskatchewan at that time (see picture on the cover of this report); the bird was about 1 km from the localisation that we provided to him 3 days earlier. Finally, using the localisations of highest precision (class 3), we found the carcass of the dead owl at 31 m from the average localisation provided by the satellite. Therefore, we are confident that the data obtained by our radio-tracking are of high quality.

4.3 Fall migration and wintering strategy

Our study shows an enormous variability among individuals in many aspects of the migration strategy, including its timing, travel path, duration, distance travelled and final destination. This confirms the erratic nature of movements previously described for the species. The prevalent view in the literature was that many (and perhaps most) Snowy Owls were migrating to temperate areas of southern Canada in winter (Parmelee 1992). Our results do not support this hypothesis. Although most individuals generally moved south during the winter, only 2 went to southern Canada/northern United States during the winter, the other birds remaining at fairly high latitudes (i.e. above the tree line). Moreover, 2 actually moved further north to Ellesmere Island, thus confirming that Snowy Owls can winter at very high latitudes. This suggests that the primary strategy of adult females is to winter at high latitudes. Based on our results and other analyses relating the abundance of wintering Snowy Owls in eastern North America to lemming abundance in the Arctic (Bêty and Gauthier, unpubl. data), we further suggest that owls wintering at southern latitudes may be mainly young of the year and immature birds. The only other study that followed the migratory movement of breeding Snowy Owls is the one of Fuller et al. (2003) who tracked 4 adult birds marked in northern Alaska. In their study, all 4 birds also remained at high latitude during the winter, either moving east (to north-western Canada) or west (to eastern Siberia and Bering Sea), thus supporting the hypothesis that adult birds may primarily winter at high latitudes.

Adult birds may be better able to withstand the harsh arctic winter conditions (cold, darkness and low prey availability) than young birds due to their experience. Moreover, it may be beneficial for these birds to stay at high latitudes in winter because this shortens the spring migration and may allow them to time their migration more accurately and hence move to the breeding site at the optimal time. By remaining at high latitudes, they may also be able to assess the abundance of prey (especially lemmings) in late winter and early spring more effectively, which would assist them in selecting a high quality breeding site. Several individuals did not settle on a fixed, small wintering area, as commonly observed in other species of migratory birds, but they kept moving. Constant movements of owls during the winter have been reported before (Kerlinger and Lein 1988, Fuller et al. 2003).

One of the most exciting results has been the observation that most owls wintering at high latitudes spent a significant amount of time over the sea ice, as far as 160 km from the nearest coast. We hypothesize that these birds may be concentrating at polynias, which are common around south Baffin Island and west Hudson Bay in winter. Many sea ducks and especially eiders concentrate at polynias in the eastern Arctic during winter (Gilchrist and Robertson 2000) and Snowy Owls have been previously observed preying on these birds (Parmelee 1992, Gilchrist and Robertson 2000). Therefore, use of the marine environment may be a major strategy used by wintering adult Snowy Owls in Nunavut. However, with only one year of data, it is too early to tell if this is a regular strategy used in all years or if it is only used when feeding conditions on the mainland are poor (e.g. in low lemming year). It is noteworthy that the only arctic wintering individual that did not use the sea ice is the one that spent most of the winter on Ellesmere Island. This island is known for its abundance of Arctic Hare (*Lepus arcticus*) and it is possible that this large animal is a high quality prey for owls and may have allowed them to survive during the complete darkness.

4.4 Spring migration and selection of breeding site

The northward spring migration of owls started relatively late during the winter and was generally rapid. Indeed, migratory speed of owls was faster in spring than in fall, possibly because owls were in a hurry to get to the breeding site on time. Settlement of most owls occurred quickly and over a relatively short time period in late April and early May. Owls are known to be nomadic and to exhibit low breeding site fidelity (Parmelee 1992). This fact was further confirmed by observations reported by local participants to the Pond Inlet workshop. However, our study is the first one to show that owls can breed successfully in two consecutive years and to precisely document the distance moved between successive breeding sites. If we exclude the owl that moved to Prince Patrick Island because it may not have bred in 2008, the average distance between nesting sites in consecutive years was 671 km for 8 individuals, a truly impressive distance for experienced breeders. To our knowledge, this is the greatest average breeding dispersal distance reported for any bird species in the world. Indeed, the vast majority of birds generally show high breeding site fidelity and, although long distance dispersal are occasionally reported for some individuals, the average distance is usually less than a kilometre (Koenig et al. 1996).

Site fidelity is considered to be an advantageous strategy in migrating birds because individuals returning to the same site to breed in subsequent years can benefit from being familiar with the site. On the contrary, individuals moving to a new, distant site incur the cost of acquiring new knowledge about the site (e.g. suitable nesting site, good feeding sites, etc).

Because of the cyclic nature of the primary food of owls in summer, lemmings, the benefit of moving to a new site where lemming are abundant presumably outweigh the costs of finding such sites every year. Participants to the workshop in Pond Inlet also believe that year-to-year movements of owls were primarily associated with the local abundance of lemmings. How owls decide where to settle in spring remains unknown. Given the difficulty of predicting the abundance of lemmings at a given site based on the situation experienced in the previous year (lemming populations rarely remain high at a given site for two consecutive years, Gauthier et al. 2004), owls should rely more on information on local food abundance acquired during their northward spring migration. Therefore, one possibility for owls would be to settle in the first area encountered in spring where breeding conditions (i.e. lemming abundance, availability of nesting site, vacant breeding territory) are adequate regardless of where they bred the year before. In 2008, we have evidence that lemmings were abundant throughout most of Baffin Island (Therrien and Gauthier, unpubl. data). Therefore, as owls were moving north in spring, they may have rapidly encountered suitable conditions for breeding, thereby triggering their decision to settle there. This hypothesis may explain why no marked owls returned to Bylot Island in 2008, even though lemming abundance was still high that year, and why they all bred further south.

4.5 Conclusions and future work

Our study has so far yielded exciting new knowledge on the biology of owls and provided information relevant for their conservation. They include:

- We showed that satellite transmitters, when properly applied, can yield high quality data on movements and reproduction of Snowy Owls with little, if any, negative effects on the animals.

- Snowy owls have erratic movements in Nunavut although their primary migratory movement is oriented north south.

- The movement of owls documented in this study suggests that there are no distinct owl populations in different parts of Nunavut and that all the owls of the territory belong to the same population.

- Adult female Snowy Owls apparently winter primarily at high latitude, in South Baffin and northern Quebec. However, those that winter in southern Canada can use very distant sites, from the Atlantic coast to the Great Plains.

- The sea ice may be an important wintering habitat of Snowy Owls in southern Nunavut. Therefore, owls may be another species vulnerable to the rapid melting of the sea ice due to climate warming.

- Variation in lemming abundance, the primary prey of Snowy Owls in summer, is likely the most important factor explaining the low breeding site fidelity of owls. Owls appear well adapted to the cyclic fluctuations in lemming abundance as we showed that individuals can breed successfully in consecutive years by moving over considerable distance (700 km on average)

Even though our project was highly successful, some questions remained unanswered while others have emerged from our work. For instance, it is still unclear what are the exact mechanisms used by owls to select a suitable breeding site in spring considering their total absence of site fidelity. The use of the sea ice by wintering owls needs to be further explored to determine if this is a regular strategy used in all years and what resources are used by the owl there. Considering that our conclusions are based on a study that lasted a single year, it is difficult to know if the patterns observed are normal or due to unusual conditions that may have prevailed during the study. We believe that further marking and radio-tracking of owls in the future would be useful and would address these questions. We therefore recommend pursuing these studies.

Information gathered during the workshop with the community was also highly valuable. Several of the qualitative observations made by participants confirmed some of the scientific results. However it appears that people of Pond Inlet also have very little information on the wintering ecology of owls, one of the least known period of their life cycle in the North and the most difficult period to study them. Considering that our study has identified South Baffin as a significant wintering area for owls, the suggestion made at the workshop to conduct a Traditional Knowledge Study on the wintering ecology of owls in communities of this region should be pursued in the future. This could yield highly relevant information on Snowy Owls.

5. REPORTING TO COMMUNITIES/RESOURCE USERS

The workshop held in Pond Inlet in March 2008 was the most important event in reporting results of this project to the community. The evening public talk and the talks presented at the Pond Inlet high school were other useful activities. The leaflet produced on initial results of the project and distributed to the community at the workshop was another means to report information to local residents. On 27 June, Gilles Gauthier also attended a meeting with the Mittimatalik Hunter and Trapper Organization in Pond Inlet. He presented an update of the results on radio-tracking of the owls and discussed the concerns expressed by some HTO members on the marking of owls with radio-transmitters.

Copies of this report will be sent to the community. Furthermore, now that we have completed the study, we intend to produce a new, updated leaflet based on the results presented in this report. As with the previous one, the leaflet will be translated in Inuktitut.

Tracking of the radio-marked Snowy Owls continues as the transmitter batteries could last up to 2 years (thus until summer 2009). Results obtained from the tracking of these birds until the end of the battery life will be analysed by Jean-François Therrien in his PhD thesis. A copy of all scientific publications eventually arising from this work will be sent to the NWMB, as well as the community.

6. ACKNOWLEDGEMENTS

We thank the many people and agencies that helped us conducting this study. They include the Bylot Island field crews of 2007 and 2008 and especially Marten Stoffel, Julie Tremblay, Terry Killiktee, Bernie Kilukishak, Monty Yank, Sarah Chisholm and our outstanding helicopter pilots (Fred and John Innes). We thank Marie-Christine Cadieux for her assistance in managing the long-term data from the Bylot Island project, in organizing the workshop in Pond Inlet and for preparing the leaflet. We are also grateful to the community of Pond Inlet, the Hunters and Trappers Organisation of Pond Inlet, the Joint Park Management Committee of Sirmilik National Park, the Parks Canada's staff in Pond Inlet, Iqaluit and Pangnirtung, the Union Québécoise de Réhabilitation des Oiseaux de Proie and the Baffinland Iron Mines Corporation for their assistance. Financial partners include the Nunavut Wildlife Management Board, the International Polar Year program from the Department of Indian and Northern Affairs Canada, the Natural

Sciences and Engineering Research Council of Canada, the Fond Québécois de Recherche sur la Nature et les Technologies (FQRNT), the Centre d'Études Nordiques, Université Laval, Université du Québec à Rimouski, University of Saskatchewan and the network of Center of Excellence ArcticNet. Finally, this study could not have been conducted without the financial assistance and outstanding support of the Polar Continental Shelf Project.

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Table 1. Transmitter number, body mass upon capture in July, and reproductive success of the 17 Snowy Owl nests found on Bylot Island in summer 2007. Gray lines represent transmitters that became stationary during the fall period (see results). The dash (-) indicates unmarked owls.

Nest #	Transmitter #	Body mass (kg)	Clutch size	Laying date*	Reproductive success
SNOW01	39075	2.08	7	20 May	Failed
SNOW02	-	na	2	na	Failed
SNOW03	39103	na	7	24 May	Unknown
SNOW04	38610	1.88	7	25 May	Successful
SNOW05	38602	2.18	6	2 June	Failed
SNOW06	-	na	5	18 May	Failed
SNOW07	39100	2.03	8	26 May	Successful
SNOW08	38596	2.45	5	25 May	Successful
SNOW09	-	na	4	25 May	Unknown
SNOW10	39097	2.33	9	4 June	Failed
SNOW11	39061	2.10	5	30 May	Successful
SNOW12	39078	2.33	3	23 May	Successful
SNOW13	48837	2.18	7	12 June	Successful
SNOW14	39093	2.11	4	29 May	Failed
SNOW15	-	na	5	5 June	Successful
SNOW16	-	na	2	na	Successful
SNOW17	48839	2.23	6	7 June	Successful
Mean		2.17	5.6	29 May	
SD		0.15	1.8	7.1	

* Date on which the first egg was laid

Table 2. Movement parameters during fall 2007 and winter 2008 of the 12 Snowy Owls marked on Bylot Island in summer 2007. Gray lines represent transmitters that became stationary during the fall period (see results). These individuals are excluded from the calculation of the mean and standard deviation (na = not applicable).

Transmitter #	Color on map	Total distance moved (km)	Net linear movement (km)	Migration speed (km/day)	Initiation of fall migration	End of fall migration	General orientation	Time spent over sea during the whole winter (days)
38596	Light blue	2200	1170	13.4	7 Sept 2007	18 Feb 2008	SE	6
38602	Dark green	3116	1665	18.7	15 Sept 2007	na	S	57
38610	Light green	2325	1297	18.6	15 Sept 2007	18 Jan 2008	SE	33
39061	Dark gray	104	30	13.0	5 Aug 2007	13 Aug 2007*	W	na
39075	Light gray	1001	652	9.1	5 July 2007	23 Aug 2007*	NW	na
39078	Yellow	2173	410	10.8	11 Aug 2007	na	N	0
39093	Dark blue	1072	367	13.7	9 Sept 2007	26 Nov 2007*	SE	na
39097	Orange	4300	1577	19.7	26 July 2007	na	S	27
39100	Black	2749	1503	16.9	12 Sept 2007	22 Feb 2008	SE	65
39103	White	3923	1569	22.8	10 Sept 2007	na	SE	71
48837	Pink	3932	3107	30.2	7 Sept 2007	15 Jan 2008	SE	0
48839	Red	5253	3245	30.4	9 Sept 2007	Na	SW	0
Mean		3330	1727	20.2	2 Sept 2007	2 Feb 2008		28.8
SD		1020	852	6.3	16.8	17.3		27.7

* For these individuals, the date corresponds to the date that the transmitter stopped moving

Table 3. Movement parameters during spring and early summer 2008 of 9 snowy owls marked on Bylot Island in summer 2007. Transmitters that became stationary during the fall are excluded (na = not applicable).

Transmitter #	Color on map	Total distance moved (km)	Net linear movement (km)	Migration speed (km/day)	Initiation of migration	Date of settlement	General orientation	Settlement distance from last year (km)
38596	Light blue	778	222	24.3	23 Mar 2008	24 Apr 2008	NW	861
38602	Dark green	2519	1254	30.0	na	24 May 2008	N	471
38610	Light green	1743	1099	37.9	29 Mar 2008	14 May 2008	NW	262
39078	Yellow	1091	204	17.3	na	3 May 2008	S	235
39097	Orange	1270	439	19.2	na	6 May 2008	NW	975
39100	Black	534	363	15.3	25 Mar 2008	29 Apr 2008	NW	985
39103	White	2050	1234	28.5	na	12 May 2008	NW	539
48837	Pink	3667	2161	79.7	30 Mar 2008	15 May 2008	NW	1041
48839	Red	5162	3646	51.1	na	12 June 2008	N	1228
Mean		2090	1180	33.7	26 Mar 2008	12 May 2008		733
SD		1416	1062	19.4	2.9	13.9		342

Table 4. Fate of the 12 snowy owls radio-marked on Bylot Island in 2007 determines during ground checks of the position provided by the satellite during the summer 2008. Gray lines represent transmitters that became stationary during the fall period (see results).

Transmitter #	Date of the visit	Sighting of the radio-marked bird	Presence of a male	Nest found	Nest content	Approximate laying date*	Comments
38596	4 July	Yes	Yes	Yes	5 chicks	8 May 2008	
38602	7 July	Yes	Yes	Yes	6 eggs, 4 chicks	29 May 2008	
38610	4 July	Yes	Yes	Yes	7 chicks	19 May 2008	
39061	14 July	(Yes)					Carcass found with transmitter attached
39075	None						
39078	5 July	Yes	Yes	Yes	4 chicks	23 May 2008	
39093	None						
39097	25 June	Yes	Yes	No			
39100	25 June	Yes	Yes	Yes	2 eggs, 7 chicks	11 May 2008	
39103	6 July	Yes	Yes	Yes	7 chicks	21 May 2008	
48837	25 June	Yes	Yes	Yes	5 eggs, 3 chicks	19 May 2008	
48839	None						
Mean					7.1	19 May 2008	
SD					2.0	7	

* Date on which the first egg was laid

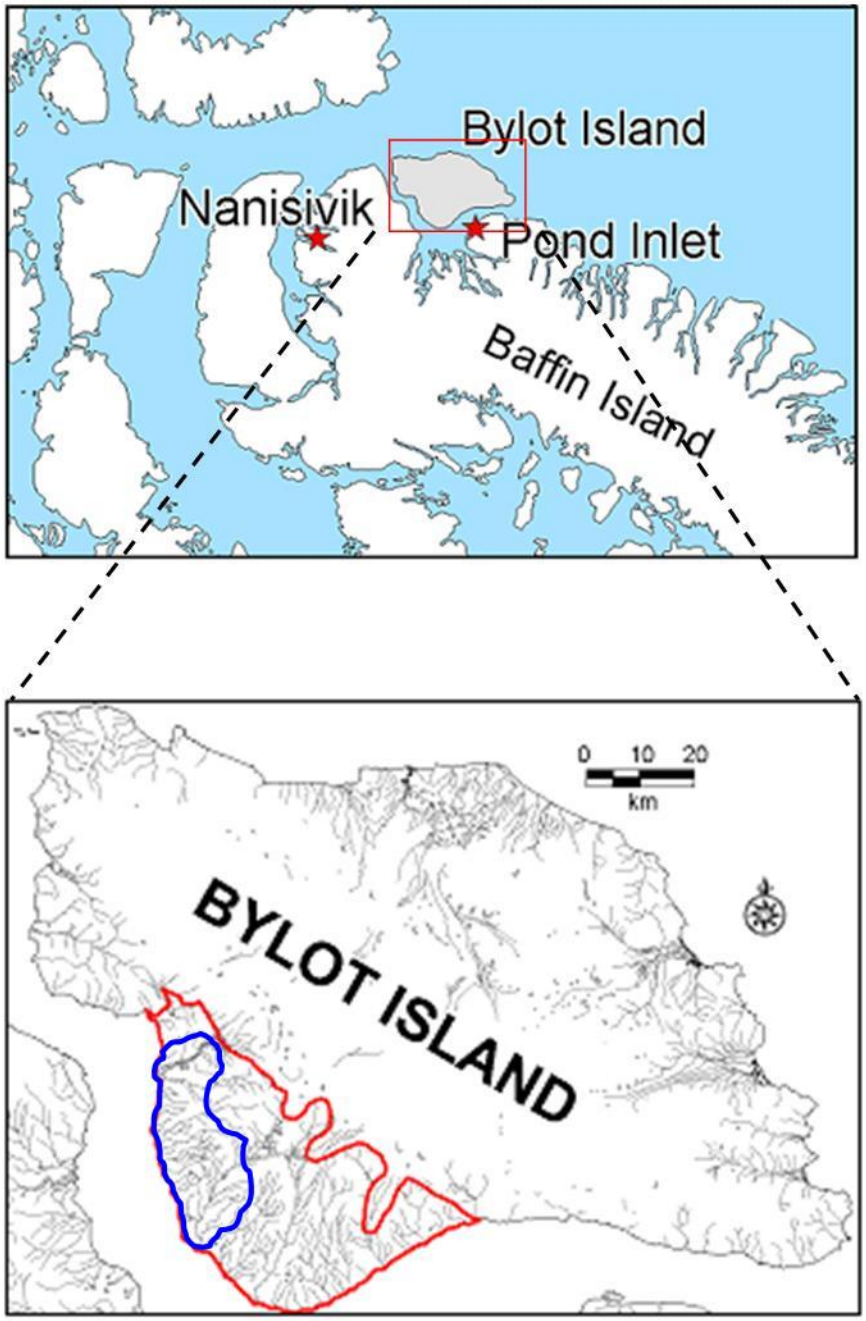


Figure 1. Map showing the location of Bylot Island in the North Baffin area. The area enclosed in red is the south plain of Bylot Island and the blue line enclosed the areas that were searched for owl's nests.

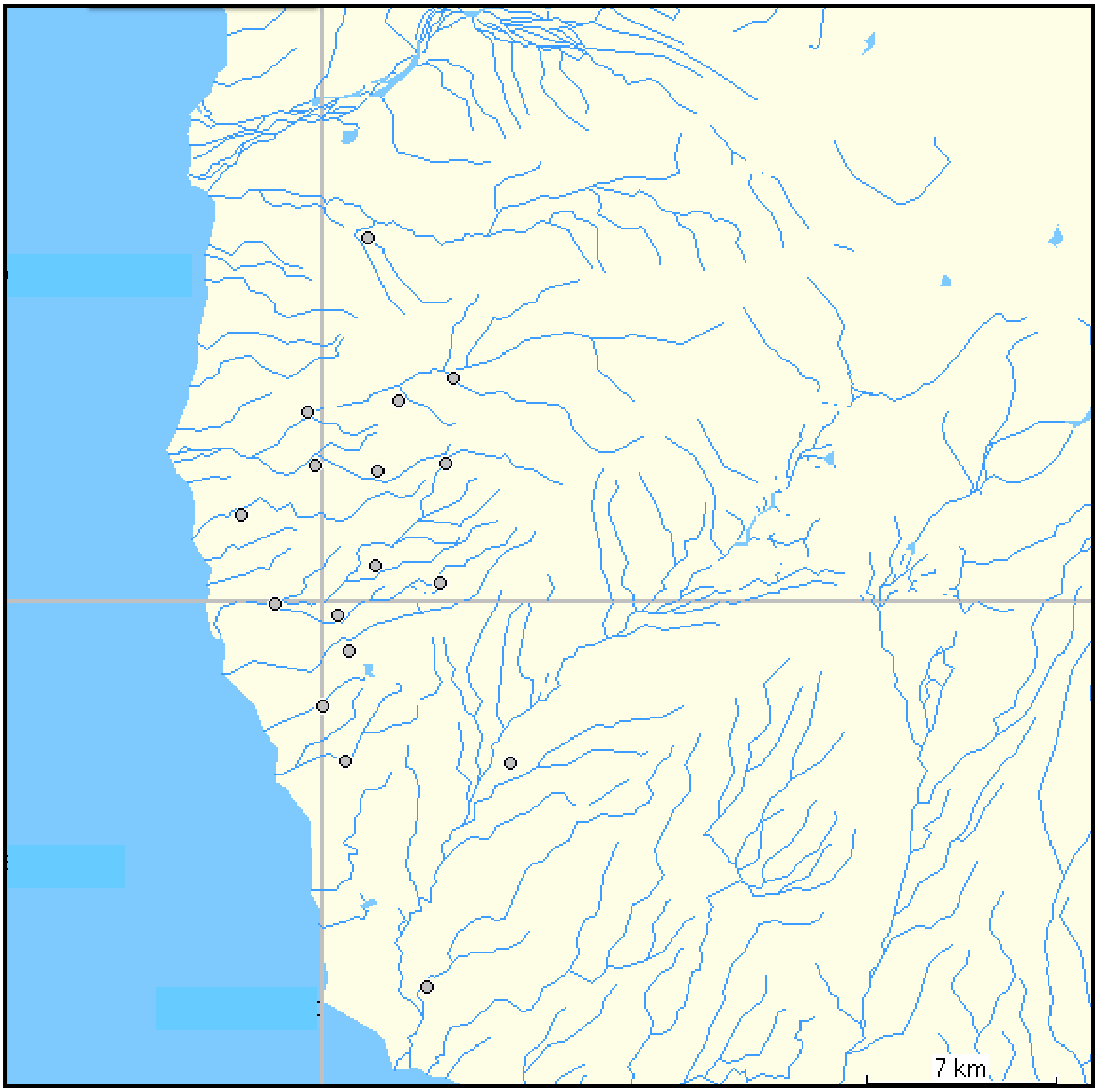


Figure 2. Localisation of the 17 Snowy Owl nests found on the south-west plain of Bylot Island in summer 2007.

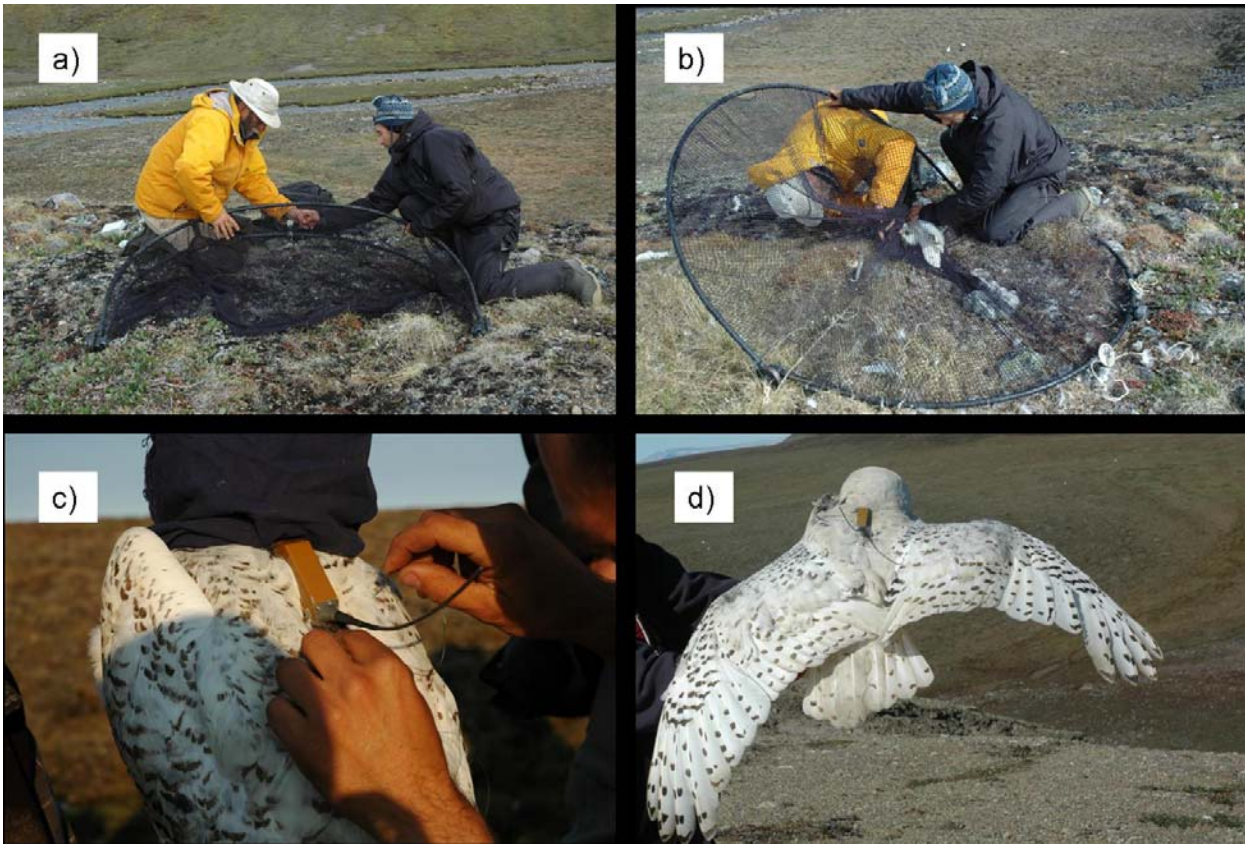


Figure 3. A Snowy Owl capture; a) bow-net trap installation, b) retrieving the owl from the net, c) transmitter fitting and d) release.

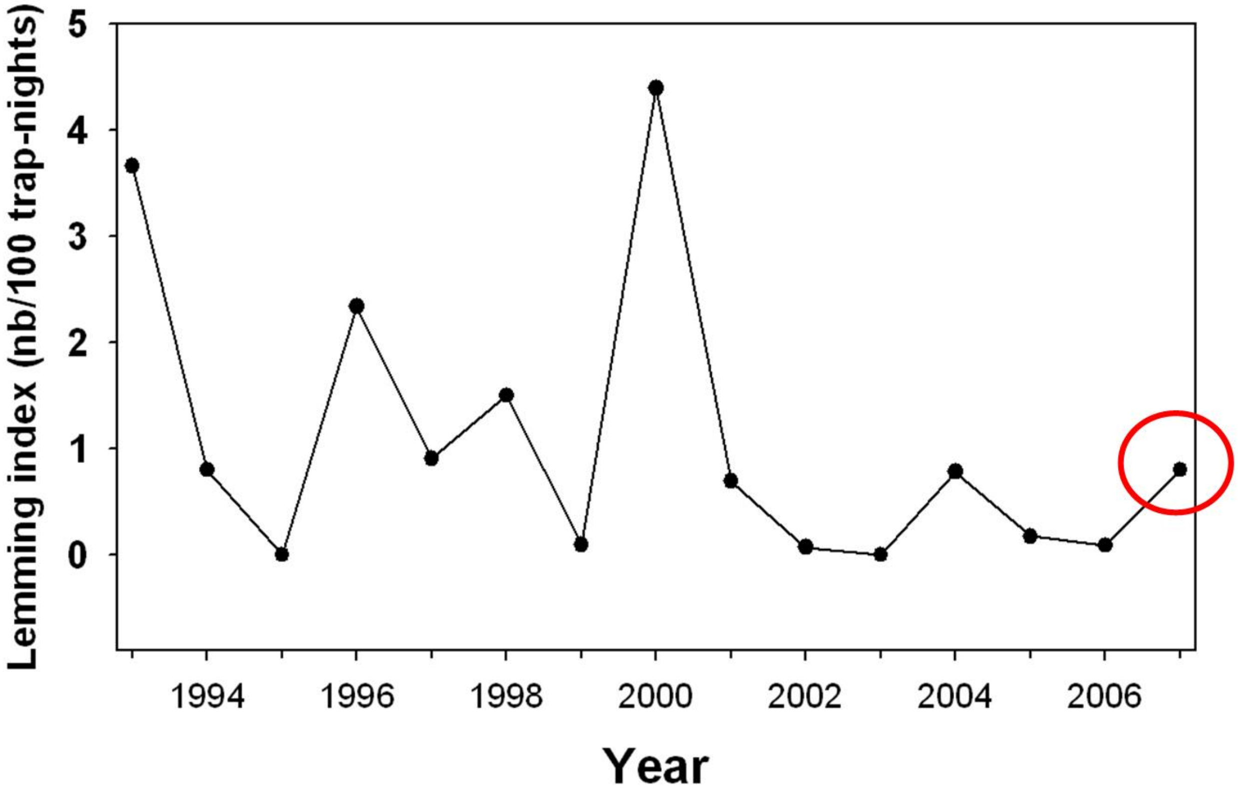


Figure 4. Lemming index measured in the base camp valley (Camp 1) on Bylot Island with snap-traps. The red circle emphasizes the year that Snowy Owls were marked.

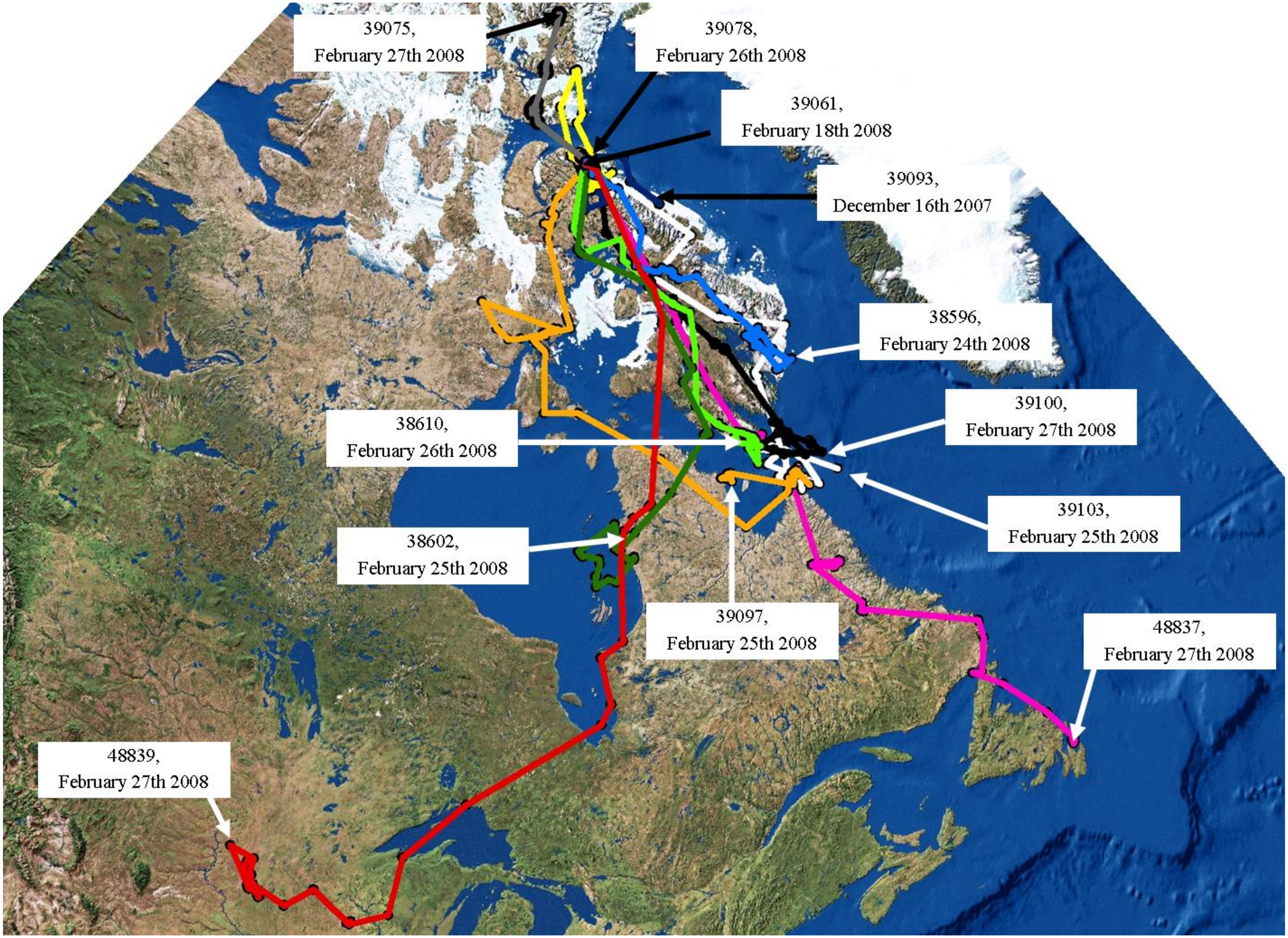


Figure 5. Fall and winter movements of the 12 snowy owls marked on Bylot Island in summer 2007.

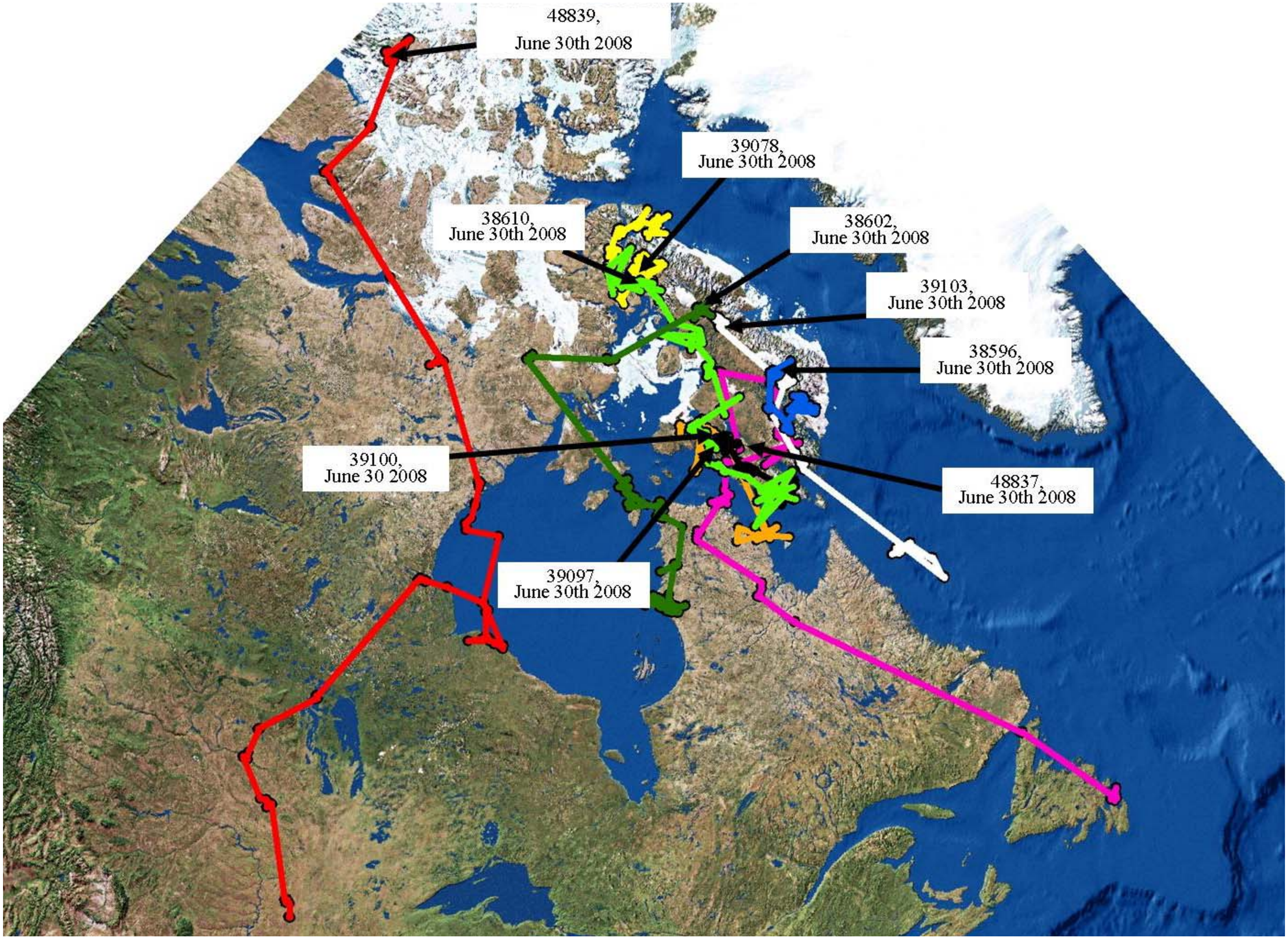


Figure 6. Spring movements of 9 snowy owls marked on Bylot Island in summer 2007.

APPENDIX A

List of participants to the Workshop and public presentation held on 5 March 2008 at the conference room of the Nattinak Visitor Center, Pond Inlet.

Name	Affiliation	Workshop	Public meeting
Debbie Jenkins	Dept Environment, Gov. Nunavut, Pond Inlet	X	
Gregor Hope	Dept Environment, Gov. Nunavut, Pond Inlet	X	
David Qamaniq	Joint Park Management Committee, Pond Inlet	X	X
Gesoni Killiktee	Joint Park Management Committee, Pond Inlet	X	
Qavavauq Issuqangituq	Joint Park Management Committee, Pond Inlet	X	
Mike Richards	Pond Inlet Senior Administration Officer	X	
Andrew Maher	Parks Canada, Pond Inlet	X	X
Brian Koonoo	Parks Canada, Pond Inlet	X	
Carey Elverum	Parks Canada, Pond Inlet	X	X
Israel Mablick	Parks Canada, Pond Inlet	X	
Bernie Kilukishak	Local field assistant on Bylot Island, 2007	X	
Terry Killiktee	Local field assistant on Bylot Island, 2007	X	
Daniel Ootova	Local field assistant on Bylot Island, 2007	X	
Isidore Quasa	Inuit knowledge group research assistant 2005	X	
Andrew Sangoya	Mittimatalik Hunters and Trappers Organization	X	
Sheatie Tagak	Mittimatalik Hunters and Trappers Organization	X	X
Elijah Panipakoochoo	Mittimatalik Hunters and Trappers Organization		X
James Atagootak	Mittimatalik Hunters and Trappers Organization		X
Darlene Willie			X
Tommy Tattatuapik	Joint Park Management Committee, Pond Inlet		X
Katy Hanson	Parks Canada, Iqaluit		X
Gary Mouland	Parks Canada, Iqaluit		X
Paul Ashley	Parks Canada, Iqaluit		X
Richard Carbonnier	Architect, Pond Inlet		X
Philip Panneak	Inuit Qikiktani Association, translator	X	X
Esther Lévesque	Professor, Université du Québec à Trois-Rivières	X	X
Catherine A. Gagnon	MSc student, University Quebec Rimouski	X	X
José Gérin-Lajoie	Research assistant, Université du Québec à Trois-Rivières	X	X
Jean-François Therrien	PhD student, Université Laval	X	X

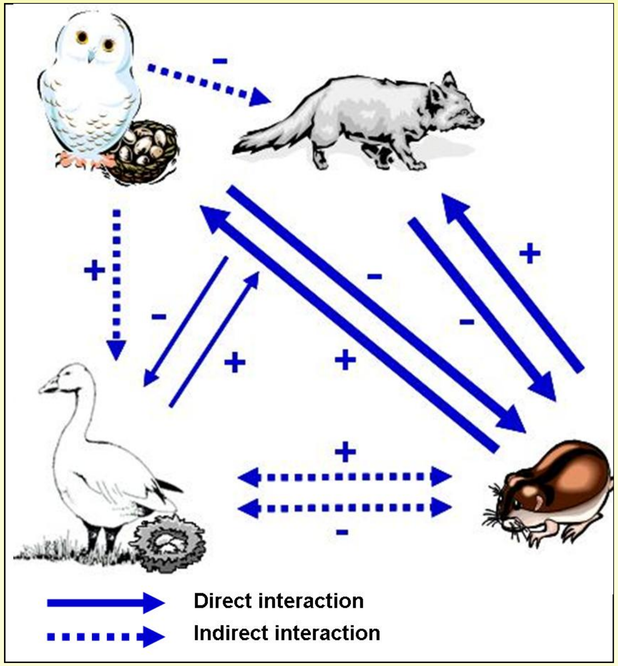
APPENDIX B

Leaflet on the snowy owl study on Bylot Island, Sirmilik National Park, distributed to the participants of the Pond Inlet workshop on 5 March 2008

ᓱᒻᒪᑦ ᖃᐅᔨᓴᖅᑕᐅᕙᑦ ᐅᐸᐱᒃᔪᐊᑦ?
Why study Snowy Owls?

ᐅᐸᐱᒃᔪᐊᑦ ᐱᒻᒪᕆᐅᖁᖕᒍᖃᑕᐅᔪᖅ ᖁᕙᓯᑦᑐᓂ ᓂᕿᑐᖃᑦᑕᖅᑐᖅ ᐅᑭᐅᑕᖅᑐᒥᑦ ᐊᕙᑎᖓᓂᑦ ᐊᒻᒪ ᐃᓚᒌᓪᓗᐊᑕᓇᓪᓗᓂᐅᒃ ᑲᑎᙵᑎᐊᕐᓂᖓᓂᑦ. ᑭᓯᐊᓂᓕ ᖃᐅᔨᒪᑦᑎᐊᖏᓐᓇᑦᑕ ᓇᒧᙵᑦᑕᕐᓂᖏᓐᓂᑦ, ᐅᓄᕐᓂᖏᓐᓂ ᐊᒻᒪ ᖃᐅᔨᓴᖅᑕᐅᓂᖏᑦ ᐊᒥᓃᓂᖏᑦ. ᐊᑦᑕᓇᖅᑐᒦᖑᓇᕐᒥᔪᑦ ᓯᒪᐅᑉ ᐊᓯᔾᔨᕐᓂᖓᓄᑦ ᐅᐱᓐᓇᕐᓂ ᐊᔾᔨᐅᓐᓇᓂ ᓂᕿᑐᖃᑦᑕᖅᑐᖅ ᓄᓇᒥᐅᑕᐅᓪᓗᓂ.

Snowy Owls are one of the most important top predator of the arctic ecosystem and a key component of its integrity. However we know little about its movements, abundance and demography. They are also vulnerable to climate change because it is a specialist predator well adapted to the tundra.



ᐊᐱᖅᑯᑎᒃᓴᖃᕈᕕᑦ? ᐅᕙᑦᑎᓐᓂ ᑐᑭᓯᒋᐊᓇᒃᓯ!
Questions? Contact us!

Gilles Gauthier
Université Laval
gilles.gauthier@bio.ulaval.ca
(418) 656-2131 #5507

Jean-François Therrien
Université Laval
jean-francois.therrien.3@ulaval.ca
(418) 656-2131 #6327

Joël Bêty
Université du Québec à Rimouski
joel_bety@uqar.qc.ca
(418) 723-1986 #1701

ᖁᔭᓐᓇᒦᒃ! Thank you!

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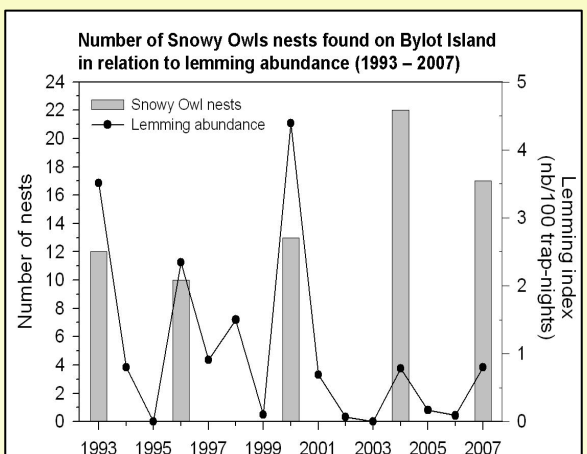
ᐅᐸᐱᒃᔪᐊᓂᑦ ᖃᐅᔨᓴᕐᓂᖅ ᒥᑦᑎᒪᑕᓕᐅᑉ ᐊᑭᐊᓂ
Snowy Owl studies on Bylot Island

ᐱᕈᐅᖃᖃᑦᑕᕐᓂᖏᑦ ᖃᐅᔨᓴᖅᑕᐅᓂᖏᑦ
Breeding biology

ᑖᓐᓇ ᐊᖏᔪᖅ ᐅᑭᐅᑕᖅᑐᒥᑦ ᐅᐸᒃᔪᐊᖅ ᐱᕈᐅᖃᖃᑦᑕᖅᑐᑦ ᓄᓇᐃᓐᓇᕐᒥᑦ ᓯᓚᕐᔪᐊᒥ ᐅᑭᐅᑕᖅᑐᒥᑦ. ᐊᒥᓱᓚᐃᑦ ᐅᐸᒃᔪᐊᑦ ᐱᕈᐅᖃᖅᐸᑦᑐᑦ ᒥᑦᑎᒪᑕᓕᐅᑉ ᐊᑭᖓᓂ ᑭᓯᐊᓂ ᐊᕐᕌᒍᖏᓐᓂ ᐊᕕᓐᖓᐃᑦ ᐊᒥᓃᑎᓪᓗᒋᑦ. ᐊᕕᓐᖓᖃᑦᑎᐊᖏᑦᑐᖅ ᕿᑭᖅᑕᒥᑦ ᐊᓯᖏᓐᓂ ᐊᕐᕌᒍᖏᓐᓂ.

This large northern owl breeds in the open tundra of the circumpolar Arctic. Numerous Snowy Owls breed on Bylot Island but only in years when there is a high abundance of lemmings. There are almost absent from the island in other years.



ᒫᓐᓇᐅᔪᒥᑦ ᖃᐅᔨᓴᕐᓂᐅᔪᖅ ᓯᕐᒥᓕᒃ ᒥᕐᖑᐃᓯᕐᕕᒻᒥᑦ
Current research in Sirmilik National Park

ᐅᐸᒃᔪᐊᑦ ᖃᐅᔨᒪᔭᐅᔪᑦ ᓇᒧᐃᓐᓈᕈᓐᓇᕐᓂᖏᓐᓂ. ᑖᓐᓇ ᖃᓄᐃᓘᕐᓂᖓ ᐃᓱᒪᒋᔭᐅᔪᖅ ᐊᓯᔾᔨᖃᑦᑕᕐᓂᖏᓐᓄᑦ ᐊᕕᙵᐃᑦ ᐊᒥᓲᓂᖏᑦ. ᑖᓐᓇ ᑎᒻᒥᐊᖑᔪᖅ ᑕᑯᔭᐅᖃᑦᑕᖅᑐᑦ ᖃᓪᓗᓈᑦ ᓄᓇᖓᓐᓂ ᑲᓇᑕᒥ ᐅᑭᐅᒃᑯᑦ, ᐅᑎᖅᑕᖃᑦᑕᕐᕕᒋᕙᑦᑕᖏᑦ ᐊᕐᕌᒍᑕᒫᑦ ᖃᐅᔨᒪᔭᐅᑦᑎᐊᖏᑦᑐᑦ. ᐊᑐᖅᑐᒍᑦ ᖃᖓᑦᑕᖅᑎᑕᐅᓯᒪᔪᒃᑯᑦ ᖃᐅᔨᓴᕈᑎᒥᑦ ᐅᖓᓯᑦᑐᓄᑦ ᓇᒧᖓᖃᑦᑕᕐᓂᖏᑦ ᐅᐸᒃᔪᐊᑦ ᐊᒻᒪ ᐊᑦᑐᐊᓂᖃᖅᑎᓪᓗᒋᑦ ᐊᕕᙵᐃᑦ ᐊᒥᓲᓂᖏᑦ.

Snowy Owls are known for their erratic movements. This behaviour is believed to be related to fluctuations in the abundance of its main prey, the lemming. Although this bird is seen in southern Canada during winter, its seasonal and annual movements are largely unknown. We are using satellite telemetry to track long-distance movements of owls and to relate them to lemming abundance.

ᐅᖓᓯᑦᑐᒨᖃᑦᑕᕐᓂᖏᑦ
Long-distance movements

ᖃᐅᔨᓴᖅᑕᐅᓃᑦ ᑎᓴᒪᑦ ᐅᐸᒃᔪᐊᑦ ᐱᕈᐅᖃᖅᑐᑦ ᓇᓗᓇᐃᒃᑯᓯᖅᓯᒪᔪᑦ ᒥᑦᑎᒪᑕᓕᐅᑉ ᐊᑭᖓᓂ ᐱᒋᐊᖅᑐᒍ ᔪᓚᐃ 2007 ᑎᑭᑦᑐᒍ ᕕᕗᐊᕆ 2008. ᑖᒃᑯᐊ ᑎᓴᒪᑦ ᑎᒻᒥᐊᑦ ᐊᔾᔨᒌᖕᒋᑦᑐᒻᒪᕆᓐᓂ ᓇᔪᖅᑐᑦ ᐊᒻᒪ ᑕᑯᒃᓴᐅᑎᑦᑎᔪᑦ ᓇᒧᐃᓐᓈᕈᓐᓇᕐᓂᖏᓐᓂ ᑎᒻᒥᐊᑦ.

Tracking of 4 Snowy Owl breeding females marked on Bylot Island from July 2007 to February 2008. These 4 birds followed very different paths and illustrate the erratic movements of the species.