THE HUDSON BAY PROJECT

ECOSYSTEM STUDIES IN COASTAL ARCTIC TUNDRA

2015 PROGRESS REPORT

The results presented in this report are preliminary and the interpretation is subject to change as more data become available. The information is being made available for the purpose of keeping our supporting agencies and sponsors, collaborating investigators, and other researchers informed of progress as of December 2015. Much of the material will be incorporated into publications as soon as analyses are complete.

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OVERVIEW

When we arrived in Churchill on 25 May 2015 for our 47th year of research at La Pérouse Bay and on the Cape Churchill Peninsula, we found no snow and some open ponds and lakes. We thought we were in for a repeat of 2013 – an early year, at least for the vegetation. However, when we flew east and crossed Knight's Hill we returned to a world of snow and ice and realized that we were in for yet a 47th version of a different kind of season. The first snow geese were seen by locals on 9 May with peak migrations occurring during the middle of May. Because the bulk of migration was over and snow geese were already nesting, we suspended our annual coastal surveys until early June when we determined phenology and nesting density at standard plots. For the Cape Churchill Peninsula, 2015 was a slightly early year for nesting snow geese and average for common eiders. Plants, especially graminoids, were about a week behind the long term average. Although we encountered our first polar bears early (16 June), sea ice conditions kept many polar bears off shore until mid to late July. The early polar bear and encounters with grizzly bears (1 at the camp on 12 June and 19 June) put us on early bear alert.

Consistent with projections from new estimates of snow goose survival, the colony has increased numerically and has expanded geographically with pairs nesting at least 3 km further inland along much of the coast between the White Whale and Broad Rivers. Some of this shift also may be related to extreme coastal flooding due to persistent land fast ice. Reproductive success was low with a juvenile:adult ratio of 0.18 (15% goslings immediately prior to fledging). This reduction was primarily the result a mismatch between peak hatch and the greening up of graminoids. Predation by wolves, foxes, polar and grizzly bears, herring gulls, ravens, and sandhill cranes further reduced success. There was some nest predation by polar bears but since the bulk of them arrived onshore after hatch, their impact on snow geese this year was minimal. While the polar bear that arrived 16 June consumed the eggs of several common eider nests, arctic and red foxes as well as sandhill cranes caused nearly complete nest failure of the colony.

Our vegetation recovery exclosure work continues to show that plant recovery is certainly possible when geese are eliminated from the picture, with recovery being greatest when the duration of destructive foraging is minimized. Succession has advanced sufficiently in the Big Ass Lake region and new species of both graminoids and eudicots (including *Salix* spp.) are appearing in the exclosures.

Although our first observations of polar bears were earlier than anticipated, the number of polar bears around the La Pérouse Bay Research Station and along the Cape Churchill Peninsula coast was down during July and August. This likely reflects the pattern of sea ice break-up and the last large ice pan located near the Manitoba and Ontario coast. Many of the bears, especially large adults, may have come ashore there. The numbers of females with 1 and 2 cubs and yearlings were lower than usual and only 1 especially skinny bear was seen along with five that were exceptionally obese. Two distinct grizzly bears were observed and photographed.

At Akimiski Island, Nunavut, we continued our Southern James Bay Population (SJBP) Canada goose nesting ecology studies, goose banding and collection of data on forage plants and bird communities in our 22nd consecutive year.

At Burntpoint Creek on the southern Hudson Bay coast, our 11th year of study of Mississippi Valley Population (MVP) Canada goose reproduction study was accompanied by our 4th year of intensive shorebird research as part of the Arctic Shorebird Demographics Network (ASDN). This expanded monitoring work includes permafrost transects, terrestrial insect biodiversity and phenology of vegetation development. Vegetation community change is being analyzed with emphasis on shrub and woody species expansion into tundra areas with aerial photography work at two study areas, including Burntpoint Creek. A new sleeping cabin was constructed in June 2015 to replace the old cabin which will eventually be converted to lab and storage space.

In the Hudson Bay Lowlands of Ontario and southern Nunavut, spring phenology was much earlier than in 2013 and 2014. Snow pack on both ranges was near average. Nesting success for Canada geese in the Ontario and Nunavut portions of the Hudson Bay Lowlands was higher than average. Undesirable weather conditions (rain, mist and fog) limited banding effort along the coast though productivity was average or better when examining age ratios. The Cape Henrietta Maria snow goose colony was surveyed using aircraft mounted cameras for the first time. We are currently processing that imagery and hope to have population estimate available before the end of 2015.

SEASONAL PHENOLOGY

La Pérouse Bay and Cape Churchill Region, Manitoba

Ice and Weather

Hudson Bay has a substantial effect on the weather of coastal and near-coastal habitat on the Cape Churchill Peninsula. The pattern of spring break-up directly affects drainage of snow melt and the onshore arrival of polar bears. This year's pattern was unique (Figure 1). Early open water north of Churchill led to some polar bears arriving in mid-June. The bulk of the Western Hudson Bay polar bear population remained on the ice that remained east of York Factory and Cape Tatnum until late July and as a consequence, they were not a major source of predation on the region's snow geese during the incubation period.

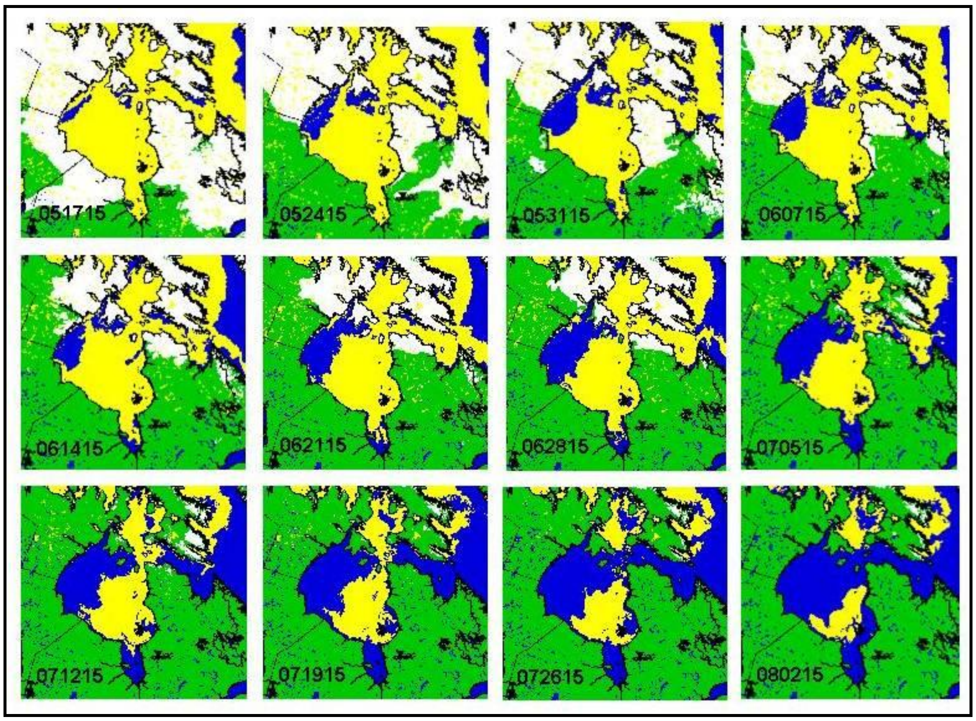
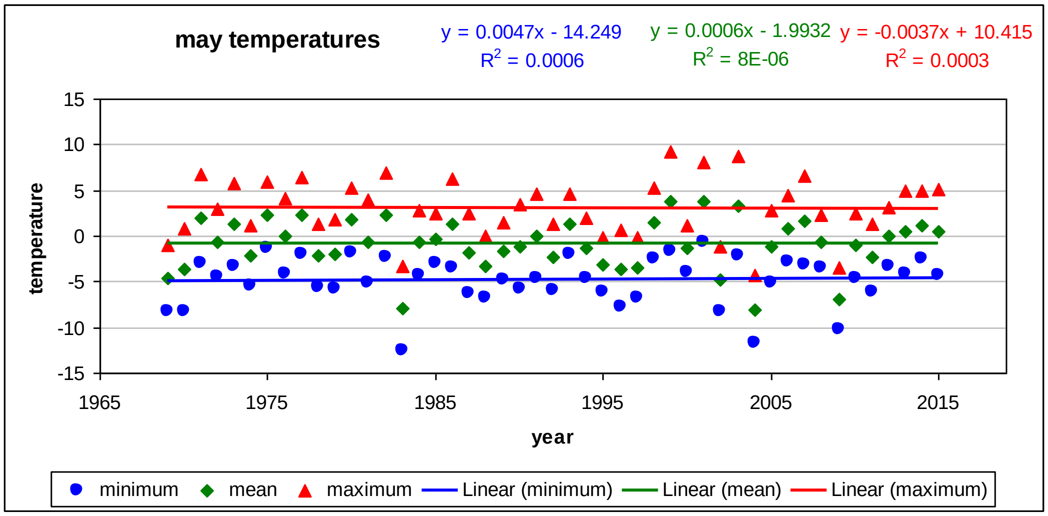
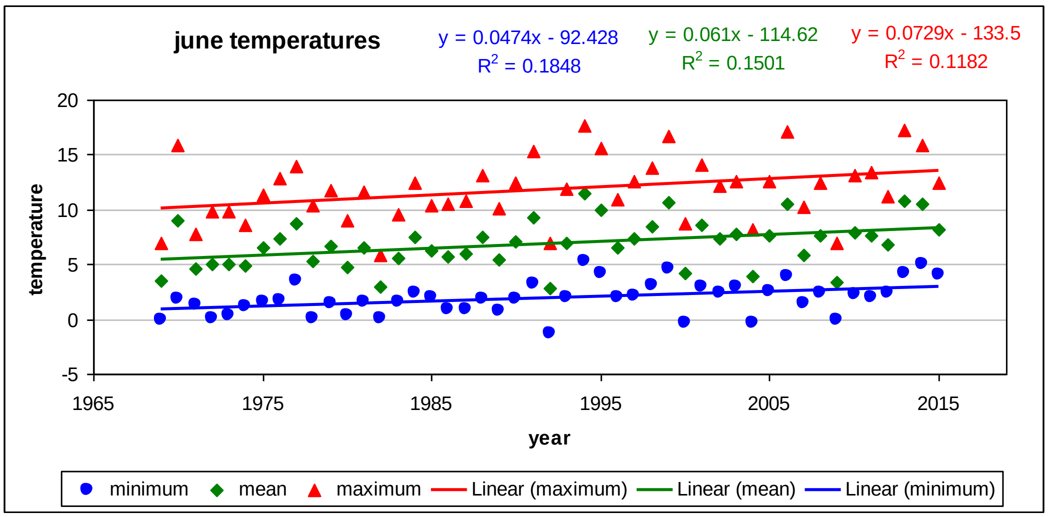


Figure 1. The pattern of weekly ice dissolution in Hudson Bay from 17 June to 2 August 2015. Images are from the US National and Naval Ice Centers.

Although not obvious from the satellite based images, retention of land-fast ice north of Thompson Point resulted in flooded habitat conditions for the snow geese nesting between the White Whale River and Thompson Creek. As a result, those snow geese had a peak hatch 3 to 4 days later than other snow geese in the region (see Nesting Phenology) but, as a result, were more successful as their hatching period closely matched the new growth of graminoids in the region.

The delay in graminoids was not likely due to an abnormally cold spring as the 2015 average minimum, mean and maximum temperatures were not far off of the long term projections (Figure 2).





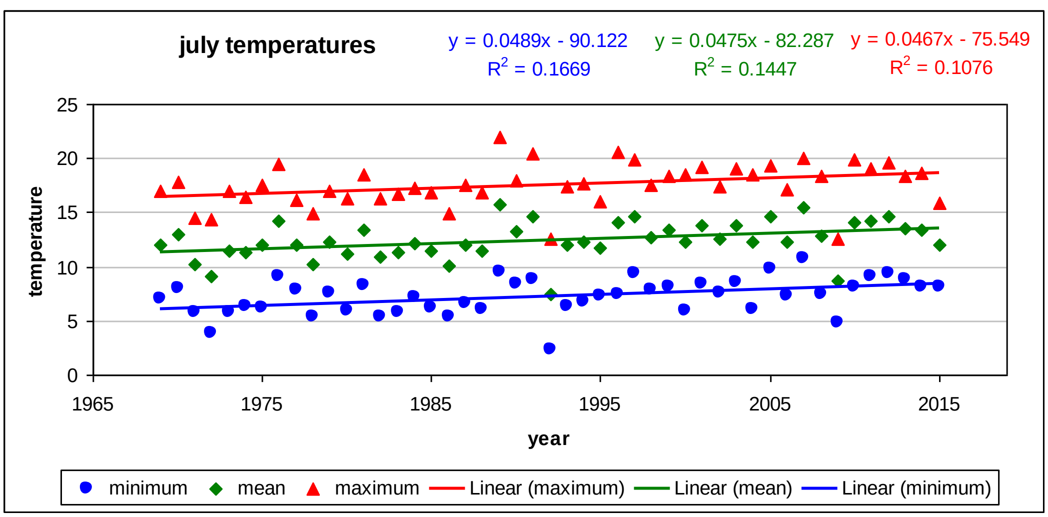


Figure 2. Minimum, mean and maximum monthly temperatures have increased for June and July but not May. Maximum average temperatures for June and July were below the long-term projection in 2015.

It is worth noting, however that the average maximum temperature for June (the critical month for the match/mismatch of hatch and green-up) is below the long-term projection, as it is for July. It is also worth noting that while the average temperature continue to increase for both June and July, there appears to be no systematic change for May.

Cumulative degree days (CDD) is often a good surrogate for plant phenology (see Effects of Climate Change on Trophic Interactions in a sub-Arctic Ecosystem). We examined CDD through the end of the hatching period to see if 2015 was below average, possibly explaining the mismatch between hatch and green-up. It is clear from Figure 3 that this is not the case.

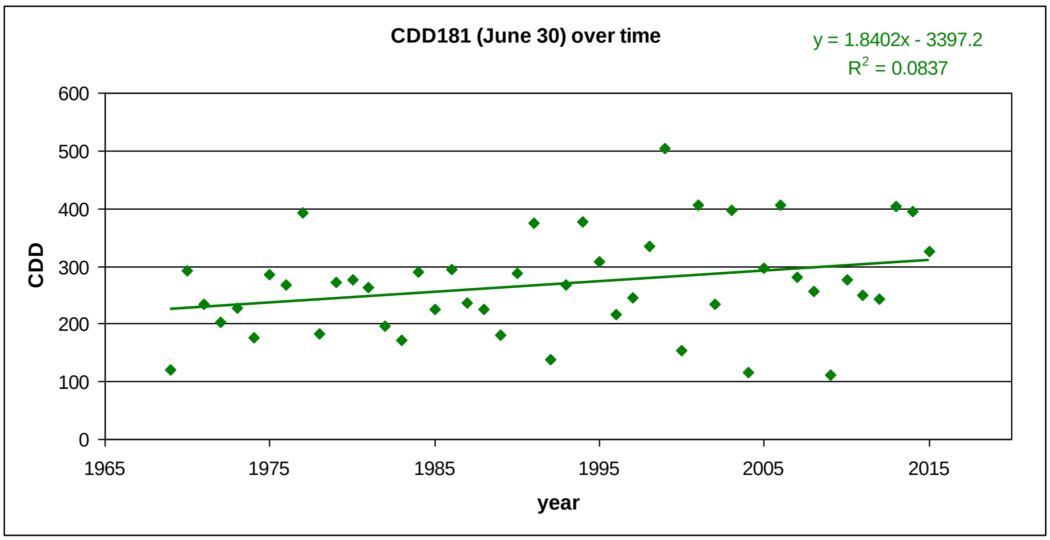


Figure 3. The cumulative degree days until 30 June has increased over time. The level for 2015 is very close to the value projected from linear regression.

It is possible that graminoids, unlike eudicots, are not primarily affected by cumulative degree days or at least not so over the scale assessed by mean or cumulative measures. For example, it is possible that the pattern of temperature (number of consecutive days below some critical value) may be important. It is also possible that graminoids, with basal meristematic tissue, may be more sensitive to soil or subsurface temperatures rather that air temperatures that we have access to. We plan to examine these possibilities in the future including using additional metrics such as growing degree days.

Akimiski Island, Nunavut, and the Ontario coasts of James Bay and Hudson Bay

Phenology

Spring phenology within the SJBP range was much earlier than in 2013 and 2014 but was close to the 10 year average (Brook and Badzinski 2015a) and on MVP range it was similar to the short-term average (5-year). Snow pack on both ranges was near average in winter 2014-15 and March and April experienced rapid snow melt on the SJBP range while the MVP area snow pack persisted longer than normal, but not so much that it set back phenology noticeably (Brook and Badzinski 2015a, b). Snow pack measured at Burntpoint Creek indicated there was a snow storm that occurred in April but that the majority of snow melted by mid-May (Figure 4). Snow melt and river break-ups were earlier than in 2014 on the MVP range and were similar to the longer-term (Brook and Badzinski 2015b). The spring harvest by Cree hunters was average or slightly above average; relatively good for those that hunted inland of the James Bay coast and were ready for early migrants whereas those that hunted closer to the coast where phenology was a bit later and melt occurred more rapidly had a relatively poor harvest (P. Kapeshesit, pers. communication). The hunt was generally poor in the MVP region (L. Walton, per. communication).

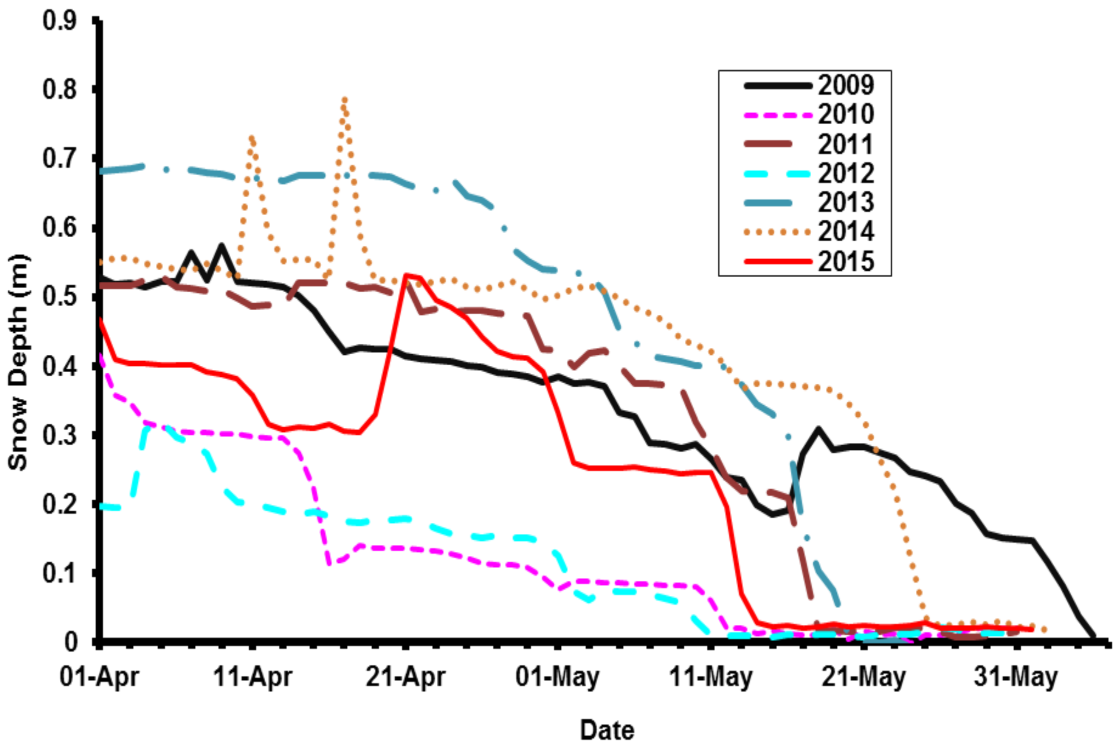


Figure 4. Daily reduction of snow depth at Burntpoint Creek study area, 2009-2015. Data courtesy of K. Middel, Ontario Ministry of Natural Resources and Forestry.

Snow Melt and Timing of Canada Goose Hatch

Snow melt (0cm) recorded by the permanent weather station at Burntpoint Creek is highly correlated with the timing of peak in hatch of MVP Canada goose nests (Figure 5). Future research will look at satellite imagery to attempt to quantify what a 0 cm reading at the weather station means for total snow cover on the Burntpoint study area. The annual variation also speaks to the plasticity in breeding strategies of sub-arctic nesting Canada geese and the potential to adapt to the effects of climate change on spring phenology.

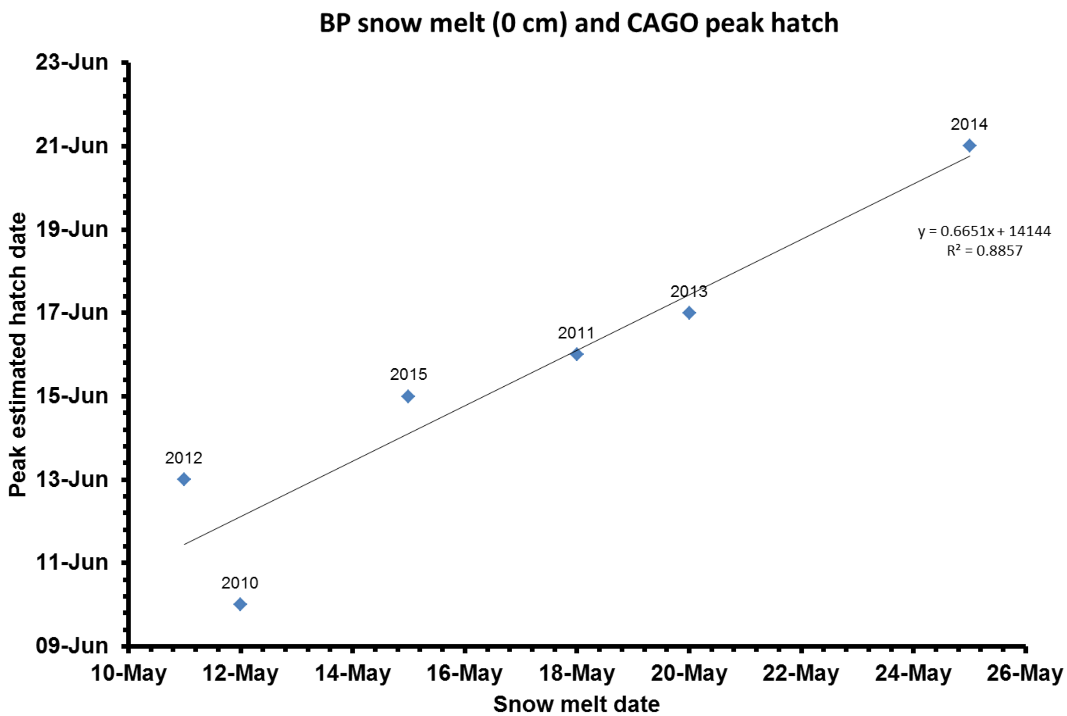


Figure 5. Correlation between the annual date of peak Canada goose hatch date at the Burntpoint Creek study site and the date of 0 cm snow at the onsite weather station.

VEGETATION AND HABITAT RESEARCH

La Pérouse Bay and Cape Churchill Region, Manitoba

Recovery Exclosures

Processes initiated by destructive foraging of the Mid-continent Population of lesser snow geese (*Chen caerulescens caerulescens*) have led to severe degradation of portions of both coastal and inland landscapes in Wapusk National Park. A primary goal of the Canada/US management plan addressing this degradation is to reduce the population of lesser snow geese until "…*there is no further damage to the habitat and there are indications of recovery*". It is not known what population size will result in a cessation of damage or the onset of recovery. It is possible, however, to begin assessing the potential for recovery in the region. Recovery of vegetation is predicated on the quality of the soil and the potential presence of a remnant seed bed or deposition of air, water or animal borne seeds of various plants and seeds or viable tissues from graminoids. Little is known about the recovery dynamics of the severely damaged freshwater habitat now being used by lesser snow geese.

We began our recovery exclosure work in 2005 and have reported on it annually. We established replicate, paired exclosed and associated control (unexclosed) plots at sites in 4 regions of the Cape Churchill Peninsula: Big Ass Lake Region, with 6 paired plots at two sites in 2005; Weatherhead Region, with 6 paired plots in 2005; Thompson Point South Region, with 6 paired plots in 2007; and Thompson Point North Region, with 3 paired plots in 2008. Habitat details and precise locations can be found in previous reports on file with Wapusk National Park.

In the following we summarize recovery progress in all 4 regions. Because we are interested in the recovery of the forage plants once used by lesser snow geese (and Canada geese), we have summarized the data as the annual percentage of barren habitat. Following Rockwell et al. (2003), barren habitat is defined as that which does not include plants potentially used by lesser snow geese and Canada geese for forage or possible shelter.

Our habitat recovery work is overseen by Kit Uvino (Figure 6) who just completed her Ph.D. on control strategies for reducing the impact of the Colorado potato beetle.

Figure 6. Kit Uvino ready to score an exclosure at Big Ass Lake.

Big Ass Lake Region

There is almost complete recovery in all 6 exclosures in this region with several of them now containing extensive stands of *Puccinellia phryganodes* and other graminoids in just 9 years. Additional and new successional plants include *Scirpus* spp., *Festuca rubra*, *Alopecurus* spp., *Poa* spp., *Triglochin maritima*, *Salix candida*, *Salix planifolia* and *Spergularia marina*. The willows are particularly interesting as their appearance suggests that at least local soil salinity has decreased and that the area could return to the supra-tidal marsh it once was. The paired control sites are actually displaying an increase in the proportion of barren habitat. This likely reflects resurgence in use of this area for brood rearing by lesser snow geese and possibly caribou. Trends are summarized in Figure 7.

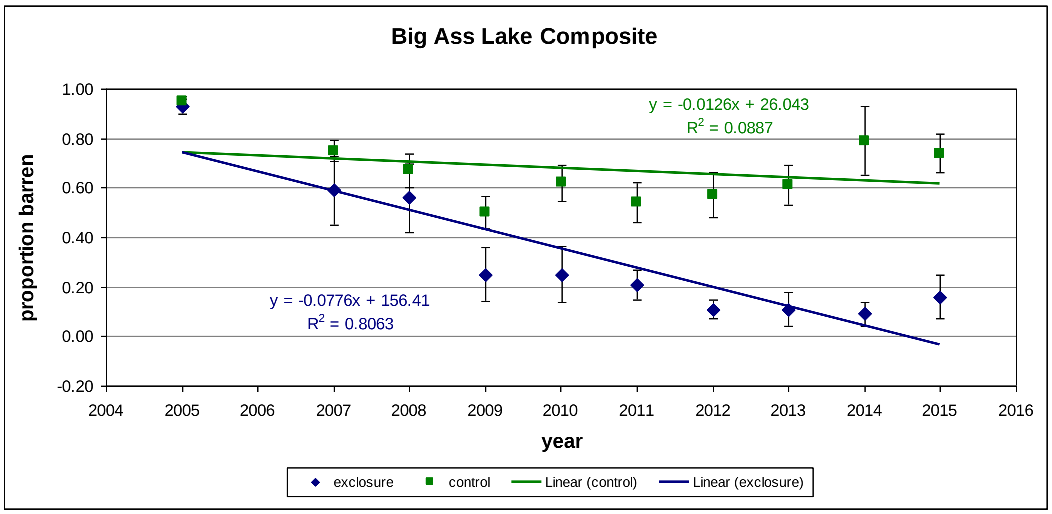
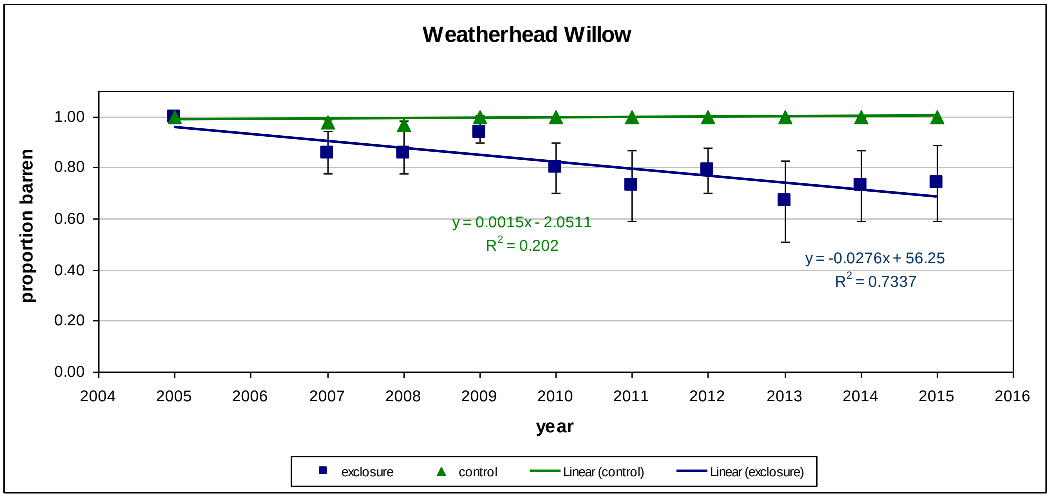


Figure 7. Since recovery and trends at the two study sites in this region are the same, results have been combined. The average percentage of barren habitat has clearly declined in the Big Ass Lake region with recovery from barren being almost complete in all exclosures. The rate of decline is substantially higher in exclosed plots than in the unexclosed controls where a trend of increasing barren habitat beginning in 2011 has grown. This is consistent with a large number of brood rearing families photographed in this region during this year’s aerial survey flight.

Weatherhead Region

Recovery in this supratidal marsh region is much less and slower than in the Big Ass Lake region. There is evidence of recovery in three of the six exclosures and two of those include dead willow stumps that may be serving a “nursing” effect. Unlike the Big Ass Lake region, this area is seldom used by lesser snow geese anymore but was destructively foraged by both staging and resident lesser snow geese for more than 30 years, a situation contrasting it with the Big Ass Lake region. We are investigating whether the length and intensity of destructive foraging could impact recovery. Trends are summarized in Figure 8.



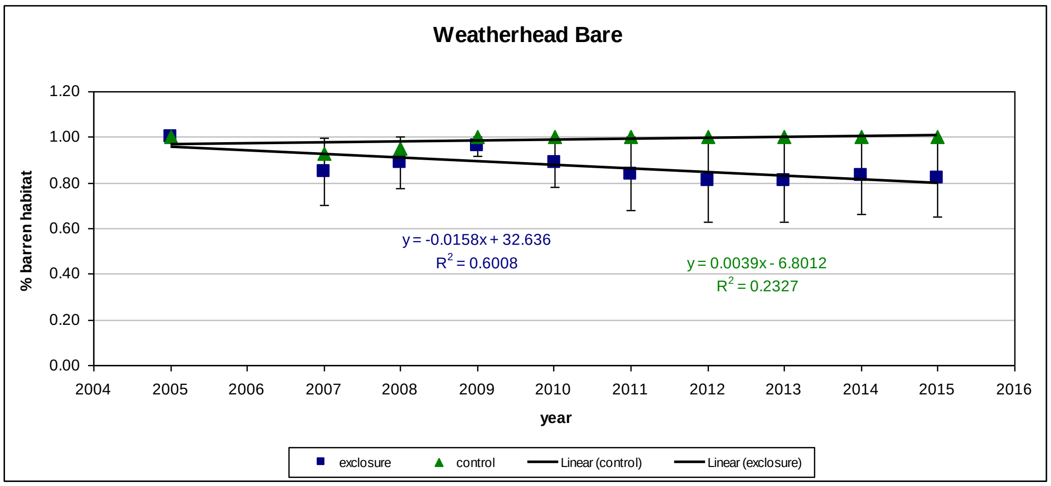
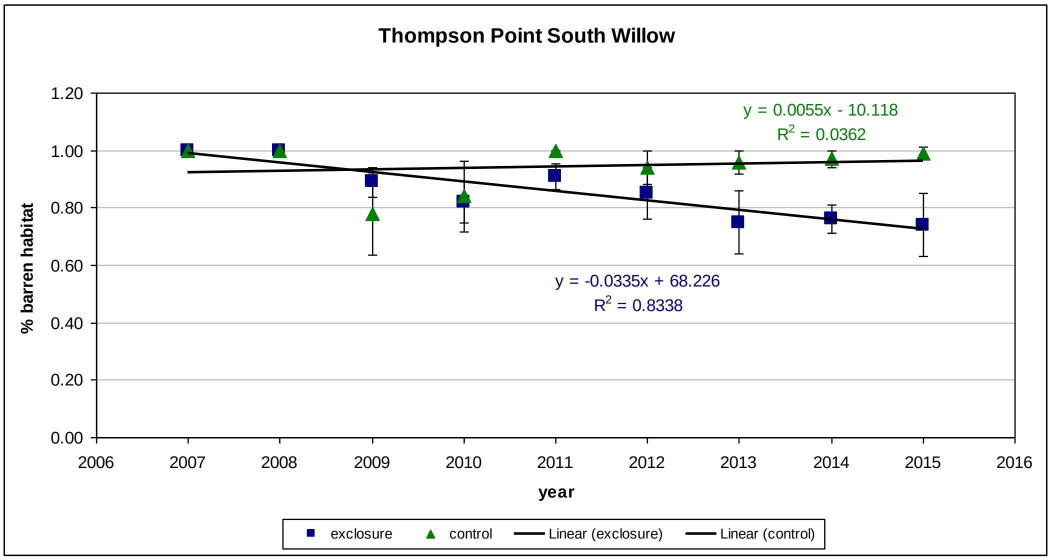


Figure 8. The average percentage of barren habitat has declined in the exclosed plots in the Weatherhead region. Recovery is greater in the plots containing dead willow which may serve a "nursing" function.

Thompson Point South Region

All of the exclosed plots in this region are beginning to show signs of recovery. One willow stump control plot is also finally showing some recovery. This area had not been used by resident geese for nearly as long as the Weatherhead region and the faster recovery here is consistent with the notion that the duration of consistent degradation may play a role in recovery potential. Trends are summarized in Figure 9.



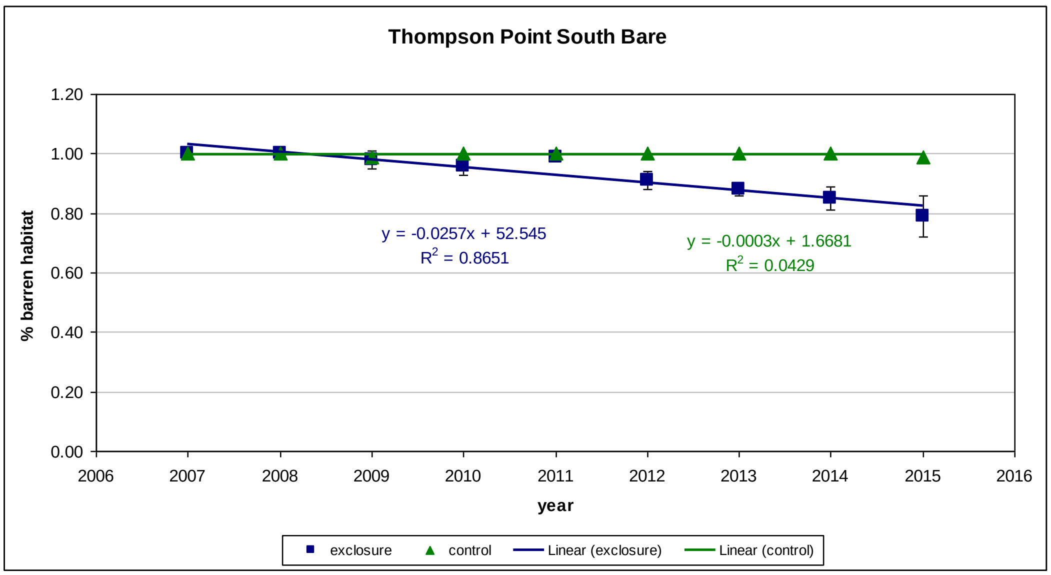


Figure 9. The average percentage of barren habitat has declined in the both types of exclosed plots in the Thompson Point South region.

Thompson Point North Region

Unfortunately, 3 exclosures were ripped out and crushed in 2010 (by what appeared to be the grizzly bear seen twice in the general area) and had to be redeployed. They survived well in 2011 and 2012 but 2 of the three were destroyed in 2013 – One was “balled-up” and moved 37 meters. The recovery clock is again reset but there does appear to be some recovery starting (Figure 10).

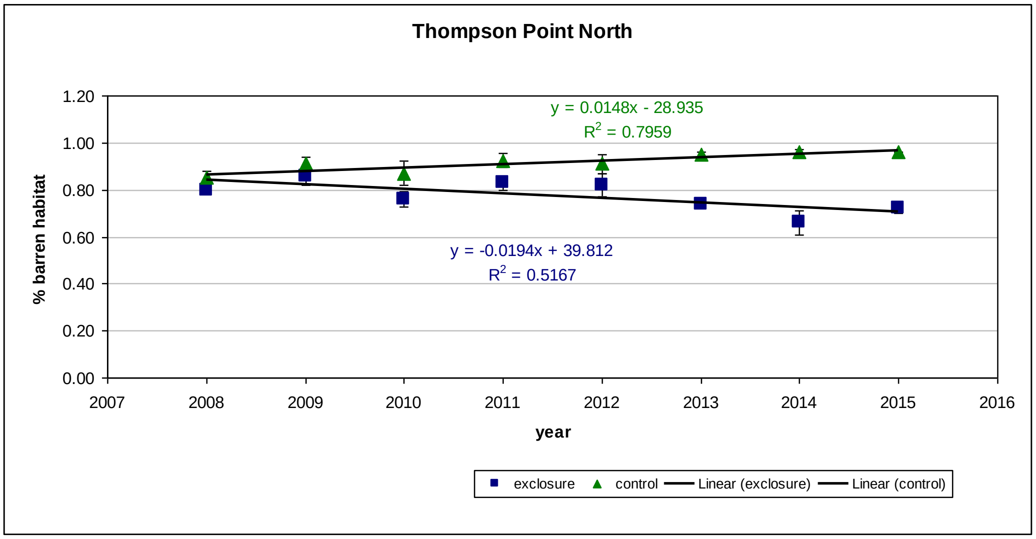


Figure 10. Barren habitat is beginning to decline in the Thompson Point North region exclosures. The increase in barren habitat in the control plots is consistent with our observations of brood rearing snow goose families in the area.

Akimiski Island, Nunavut and Burntpoint Creek, Ontario

Standing Crop and Goose Grazing Impact Studies

Above-ground standing crop of pure *Puccinellia phryganodes* and *Festuca rubra* grazed stands was sampled at 5 different locations along the north shore of Akimiski Island at presumed peak biomass. Three 100 cm^2 samples of each species were taken at each site. Sampling of standing crop has been done annually at these sites on Akimiski since 1997.

Plant Phenology and Climate Change

Plant phenology observations were recorded at Akimiski Island and Burntpoint Creek during nesting ecology and banding projects. At Akimiski Island we monitored 10 plant plots (*Potentilla egedii*, *Geocaulon lividum*, *Ribes oxyacanthoides*, *Fragaria virginiana*, *Botrychium lunaria*, *Elymus arenarius*, *Achillea nigrescens*, *Saxifraga tricuspidata*, *Honckenya peploides*, and *Senecio congestus*) on a regular basis. At Burntpoint Creek, 11 plant species were monitored (*E. arenarius*, *Betula grandulosa, Rhododendron lapponicum, Empetrum nigurm, Dryas integrifolia,Vaccinium uliginosum, Hedysarum mackenzii, Arctostaphylos alpine-rubra, Vaccinium vitis-idaea, Salix reticulate,* and *Petasites frigidus*). First blooming dates were also recorded for common plant species found at each study area.

Southampton Island, Nunavut

For the second consecutive year, we collaborated with habitat evaluations at a larger scale on Southampton Island. These studies are being conducted by the Canadian Wildlife Service, Prairie and Northern Region and are led by Todd Kemper and Joel Ingram. Ken Abraham was contracted to develop a rapid assessment protocol for evaluation of arctic goose habitats. In 2014, the protocol was tested at Southampton Island and elsewhere and refined as a result. Ken joined the CWS crew between 21 July and 2 August 2015 to implement the revised protocol at a number of locations on the island. The number of sites assessed in 2015 was 49 across the southern half of the island, including colonies at East Bay, Native Bay, Coral Harbour, Bear Cove, Sutton River, Boas River and Ell Bay. The protocol was also used by shorebird research crews at East Bay, Coats Island and other locations in a side project of the Arctic Shorebirds Demographic Network led by Paul Smith (Environment Canada Science & Technology).

GOOSE RESEARCH

La Pérouse Bay and Cape Churchill Region

Nesting Phenology, Nest Density and Nesting Success of Snow Geese

Nesting phenology, nest density and nesting success are three of the key attributes contributing to the reproductive success of lesser snow geese that we have monitored since research began at La Pérouse Bay in 1968. As part of that monitoring program, we established three permanent sites in the "traditional" La Pérouse Bay area in 1993 (Figure 11). Prior to that, we had attempted to monitor nesting across the entire colony with total enumeration. As the colony continued to grow numerically and expand geographically, it became clear that such complete enumeration was not feasible. We picked sites that reflected the breadth of habitat types used by nesting lesser snow geese. The Blue Poles site is located in a traditional supra-tidal marsh region of willows. The Lakes District site is an inland area south of the Research Station. The Peter's Rock site is located inland from the east coast of La Pérouse Bay. All sites have been used for nesting since the late 1970s. At each site, we established 5 sampling plots, with the center of each marked by a metal fence pole. Nests within a 50m radius circle of the pole are enumerated annually about 10-12 days into the 24 day incubation period. Prior to making these density estimates (and shortly after aerial surveys indicate incubation has begun), we determine the float status of 2 eggs from at least 25 nests at each site and, following Westerkov (1950), use this to estimate the dates of nest initiation and projected hatch. That system takes advantage of the fact that while the gosling are being incubated, waste gases accumulate in the egg and make them increasingly buoyant.

Due to the increase and expansion of nesting lesser snow geese, we have added additional sites to our annual monitoring. Stony Knoll is an area west of the Knight's Hill Esker and is typical of the habitat in that region. Although it is outside Wapusk National Park, it is in the Churchill Wildlife Management Area and is reachable via 4-wheeler, allowing us to get an estimate of phenology prior to the arrival of a helicopter if need be. We have also added a sampling site in each of the higher-density nesting clusters in the Thompson Point region (Figure 12). Both sites are ~1 mile inland in sedge meadows, pock-marked with both lone and clumps of willow (*Salix* spp.). As with our other sites, we established 5 sampling plots at each of these sites. Coordinates for these and our other sampling sites are in reports on file with Wapusk National Park.

Figure 11. Locations of the original permanent sites located near the La Pérouse Bay camp.

Figure 12. Locations of the Thompson Point North (TPN0) and South (TPS0) clusters with detailed positions of the 5 sampling plots shown in the insets.

Snow goose nesting phenology is summarized for 2015 in Table 1. Flooding conditions due to land fast ice south of Cape Churchill again led to flooding in the Thompson Point sites, although many geese nested synchronously with the rest of the Cape Churchill Peninsula population by taking advantage of higher spots. The Thompson Point sites were delayed by about 1 day relative to the other sites. The average span of hatching at Peter's Rock and Thompson Point south was higher than other areas, being consistent with our observations during early survey flights of scattered early nesting during flood conditions. We formed a weighted mean hatch date, based on relative nesting densities (see below), and projected that peak hatch for the snow geese would be on 23 June 2015.

Table 1. Projected hatching dates for lesser snow geese in Wapusk National Park in 2015.

Site	Earliest Date	Mean Date	Latest Date
Blue Poles	14 June 2015	17 June 2015	20 June 2015
Peter's Rock	13 June 2015	17 June 2015	19 June 2015
Lakes District	13 June 2015	16 June 2015	20 June 2015
Thompson Point North	16 June 2015	20 June 2015	23 June 2015
Thompson Point South	11 June 2015	18 June 2015	23 June 2015

The mean hatch date of 17June is 6 days earlier than the previous 46 year average and 3 days later than the deterministic linear advance projected from the previous 46 years (Figure 13). Hatch date continues to advance for the Cape Churchill Peninsula colony currently at a rate of 0.12 days/year.

Nesting density was estimated for all 5 standard areas on 5-6 June 2015. In the traditional areas, we found that density decreased slightly at Blue Poles and increased slightly at Peter's Rock (Figure 14). Nesting density increased substantially at Thompson Point North and decreased slightly at Thompson Point South (Figure 15).

Average mid-incubation nesting failure for all sites combined was 0.19, nearly twice the long-term average levels of <0.08 (Figure 16). However, predation was heterogeneous and was especially high at all sites except Peter's Rock and Thompson Point north. Failure at the Lakes District was also high.

Although we did not evaluate absolute numbers of nesting pairs in the region this year, we did document that the colony has further expanded geographically. Combining data on geographic expansion, nesting density at our standard plots and new estimates of adult survival that use both recapture and recovery data, we estimate the Cape Churchill Peninsula population is again growing at pre-management rates of λ=1.05 to 1.06 and that there are approximately 76,000 pairs nesting in the area. We are planning to perform our 3rd decadal estimate of total abundance within the next few years.

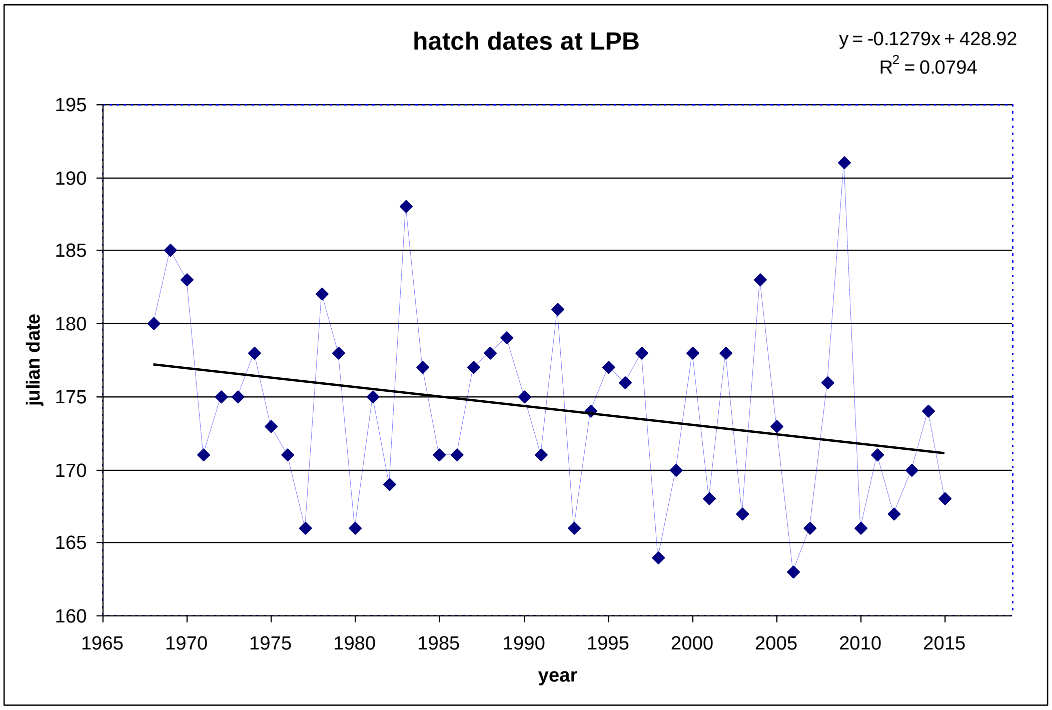


Figure 13. The 2015 projected mean hatch date of 17 June is 6 days ahead of the long-term average. Overall, the mean date of hatch continues to advance, currently at a rate of ~0.12 days per year.

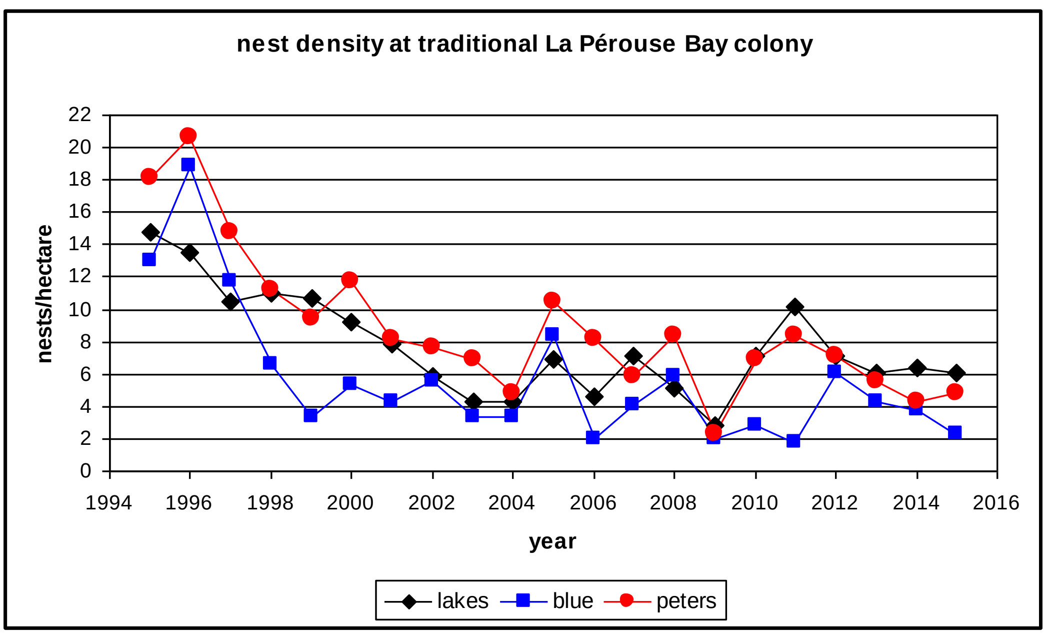


Figure 14. Nesting density decreased slightly at Peter's Rock and the Blue Poles.

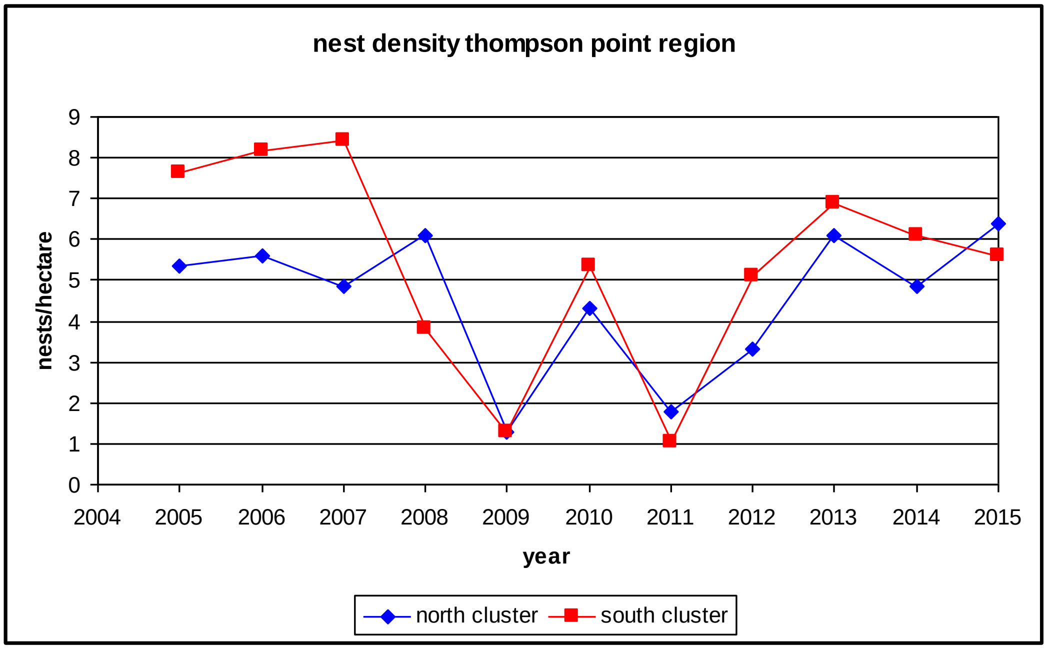


Figure 15. Nesting density in the Thompson Point declined slightly.

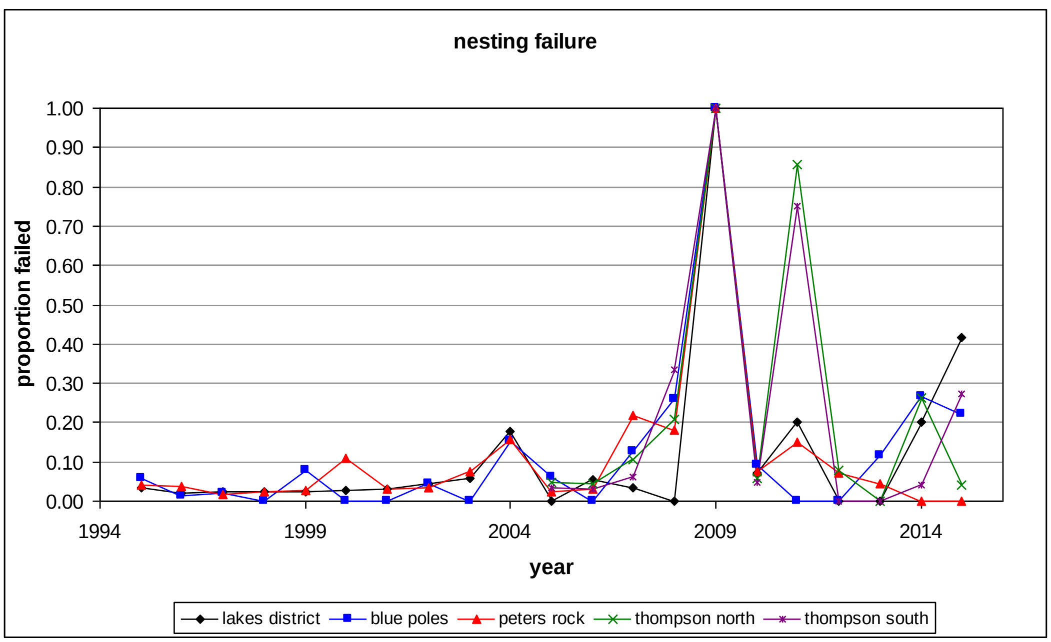


Figure 16. Nesting failure was at near-normal levels of <0.08 across the entire Cape Churchill Peninsula, except for the blue poles area.

Aerial Brood Surveys

We annually fly a fixed route and photograph brood flocks (Figure 17) immediately before banding to estimate both the ratio of juvenile to adult snow geese and the ratio of blue to white phase adults and juveniles. These ratios, rather than data from banding drives, are used to estimate these important variables since some individuals, especially juveniles, are not always captured during banding operations. This year, the survey was flown on 20 July. Kit Uvino recorded waypoints of the photographed flocks and Susan Felege and Mike Corcoran assisted RF Rockwell in taking the pictures and recording ancillary data. The survey was flown at 60-90m (200-300 feet) in a Bell Long Ranger 206L (C-FYGB) by Justin Seniuk.

The coastal segment of the survey extended form Watson Point to La Pérouse Bay to Cape Churchill and south to the Broad River. We returned on a more inland track to Big Ass Lake and then to the La Pérouse Bay Research Station. We attempted to photograph 3-5 broods in a given area. The distribution of the189 flocks photographed this year is depicted in Figure 18. Data are currently being analyzed and results will be forwarded to funding agencies upon completion of the analyses.

Figure 17. A typical brood flock encountered during the aerial survey. Note the low proportion of juveniles among the white and blue phase adult lesser snow geese.

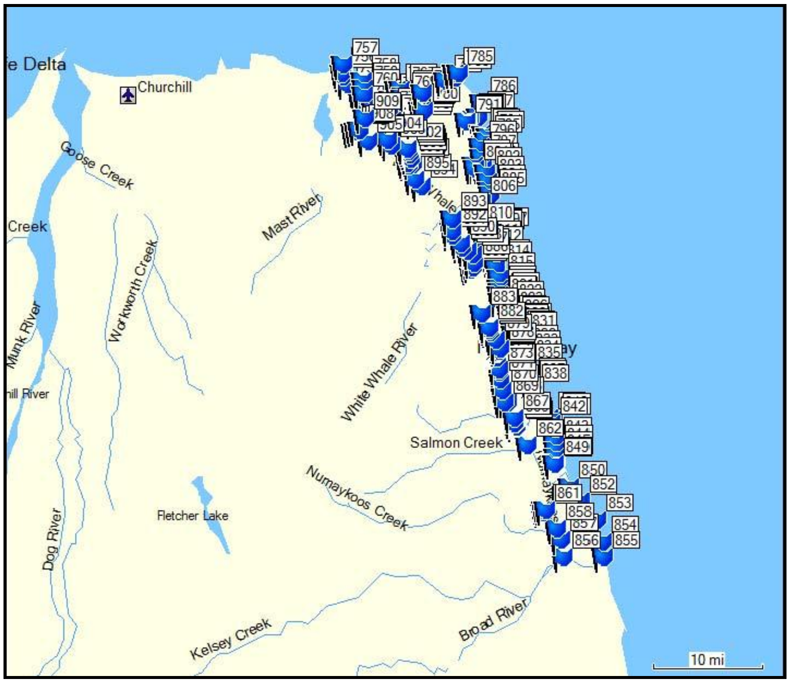


Figure 18. Locations for the broods photographed during the annual aerial survey.

Banding Operations

Banding operations on the Cape Churchill Peninsula involved 11 drives from 21 July through 24 July. We used a crew of 10 individuals plus our pilot and operated with a 206 Bell Long Ranger C-FYBG. Exceptionally wet conditions prevented us from banding at several inland sites but we were able to band in an historic portion of La Pérouse Bay proper and our 11 sites provided a representative geographic coverage of inland and coastal habitat between La Pérouse Bay and Thompson Point.

In total, we processed 6,064 geese that included 935 juveniles and 5,129 adults, 866 of which were recaptures. The juvenile to adult ratio was 0.18 (15% juveniles) which reflects the extremely high juvenile mortality and nest failure due to predation (arctic foxes and sandhill cranes) and starvation. A breakdown by drive and habitat type will be forwarded when analyses are completed.

Unmanned Aircraft Systems (UAS) as a tool for surveying a sub-Arctic ecosystem

University of North Dakota – Department of Biology

The Hudson Bay Project (HBP) was joined by new team members from the University of North Dakota (UND) for the 2015 field season. Members from UND included: Dr. Susan Ellis-Felege, Chris Felege, Michael Corcoran, Dr. Robert Newman, and students Samuel Hervey and Andrew Barnas. The goals of the UND crew were to utilize an unmanned aircraft system (UAS) for surveying lesser snow geese and other aspects of the local arctic ecosystem.

The team used a Trimble-UX5, fixed wing aircraft capable of preprogrammed flight (Figure 19). Images are collected by a Sony 16 megapixel camera mounted in the body of the aircraft and operated by an automatic infrared trigger. These images are then stitched together to create a larger landscape mosaic.

Figure 19. The Trimble-UX5 mounted on its catapult launcher ready to launch from Nestor 2.

All flight operations were conducted under a Special Flight Operations Certificate (Permit Number: 5812-11-302, ATS: 14-15-00067822, RDIMS: 106100691) issued by Transport Canada on 28 April 2015. All operating protocols were approved by Parks Canada and the Wapusk National Park Board prior to the commencement of operations in Wapusk National Park. Further, the team had an approved institutional animal care and use permit (A3917-01, Protocol 1505-2) and a UAS Research Compliance Committee Permit (approved 10 April 2015) issued through the University of North Dakota.

Specific aims of the unmanned aircraft project in 2015 were to:

1. Determine optimal flight scenarios to minimize impacts on birds but allow the resolution of imagery necessary to count birds and assess habitat characteristics.
2. Evaluate the effectiveness of a UAS for counting nesting birds (snow geese and common eiders) compared to historical ground counts.
3. Determine what information could be obtained from UAS imagery to evaluate plant phenology and vegetation damage caused by snow geese.

Flight Projects

Technique Validation

As UAS become more popular for use in wildlife research, there will be an increasing need to validate and verify the accuracy of any collected data (Jones 2006). It will also be important to determine the relationship between historical data collection and modern sampling methods to insure changes are true reflections of biological processes and not sampling bias. To do so it will be necessary to ground truth any imagery collected by a UAS (Vermeulen et al. 2013). The HBP team has conducted circular plot estimates of goose nesting density for the past 20 years that can facilitate such comparisons for snow goose nest estimates.

The imagery collected will allow for a two-way validation of techniques. As the number of nests in a circular plot should be accurately recorded by researchers on the ground, comparisons with imagery collected by aircraft should provide estimates of UAS accuracy. In order to validate the effectiveness of the UAS as a tool, we conducted a double-sampling effort by counting nests on the ground and flying the UAS over 12 circular plots in the Peters Rock area. Given the UAS can sample a larger area than just the 50m radius plot, there is an opportunity to validate the circular plot method density estimates across a much larger landscape than is feasible on the ground by comparing density estimates derived from within the 50m plots with the entire area sampled using the UAS.

Preliminary imagery is proving to be adequate to identify nests due to the high contrast of nest down with the landscape. Identification of white phase geese is relatively easy, but blue phase geese are more difficult to identify (Figure 20). As the UND team continues to collate data from the summer, the validation process at both scales will be determined. Further, methods are simultaneously being developed by collaborating computer scientists to automate the counting process. Thus, comparisons between ground sampling, human counts of imagery, and computer automated methods can be achieved.

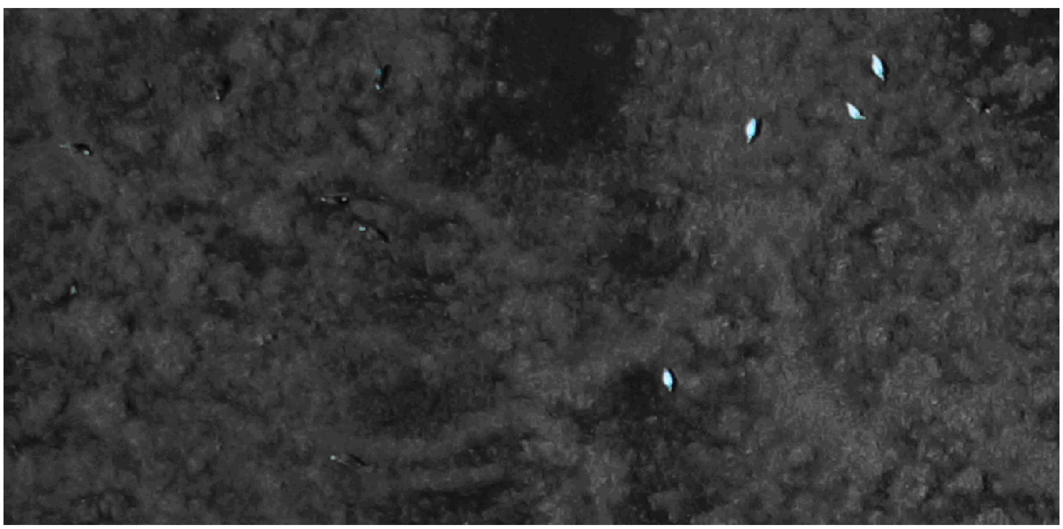


Figure 20. Imagery of blue and white phase geese collected from Peter's Rock at 75m. The left side of the photo contains 7 blue phase geese. The right side contains 4 white and 1 blue phase goose.

Behavioral Evaluation – Ground Evaluation

The growing use of UAS in wildlife research has created a need for an evaluation of potential impacts on focal species. One of the projects that coincided with the estimation of nesting density was an evaluation of behavioral impacts on nesting snow geese and common eiders as a result of a UAS surveys. Behavioral impact flights were conducted in such a way that imagery could be collected for nest counts and vegetation assessments simultaneously.

The goal of this study was to determine if flying a UAS overtop an active nest would result in changed behavior from either parent bird or affect nest success in any way. It has been postulated that UAS may be a source of noise disturbance that may negatively affect wildlife; therefore, noise disturbance factors were also explored (Chabot and Craik 2015).

To answer these questions, nests were located via ground-based searches. At a subset of the nests, miniature surveillance cameras were installed and recorded continuously (Figure 21), 24 hours a day. Twelve lesser snow goose and 10 common eider nests were monitored with nest cameras in 2015, producing 4,560 hours of footage. The cameras were miniature security cameras with 24 light emitting diodes (LEDs), camouflaged to blend into the surrounding vegetation, and mounted on a wooden dowel rod approximate 20-40cm (8-16 inches) above the ground. The cameras were connected by a 25m cable to a waterproof box that housed a DVR that recorded to SD cards and the system was powered by a 12 volt, 33 amp battery. Video is being reviewed for periods at similar times during the day; on days prior to UAS flight operations, during operations, and after operations in order to determine behavioral responses to aircraft operations.

In addition to nest cameras capturing visual behaviors of the birds, eight nests of each species were also equipped with sound recorders to determine if the UAS could be heard at the nest as it passed overhead, and if vocal responses to the UAS were elicited during flight operations. Eight Wildlife Acoustics Sound Recorders (SM2 and SM3 models) were placed randomly amongst nests and were set to record audio continuously day and night (Figure 22). In 2015, we collected 2,832 hours of audio from 16 nests (Figure 23). In similar sampling fashion, audio files will be extracted and spectrograms will be produced to evaluate the potential impacts UAS have on vocal behavior of nesting waterfowl and what level of sound the birds may have heard during flight operations.

Figure 21. A cryptically positioned 24-hour surveillance camera monitoring a common eider nest. The systems are designed to be low profile and not influence hen or predator behavior.

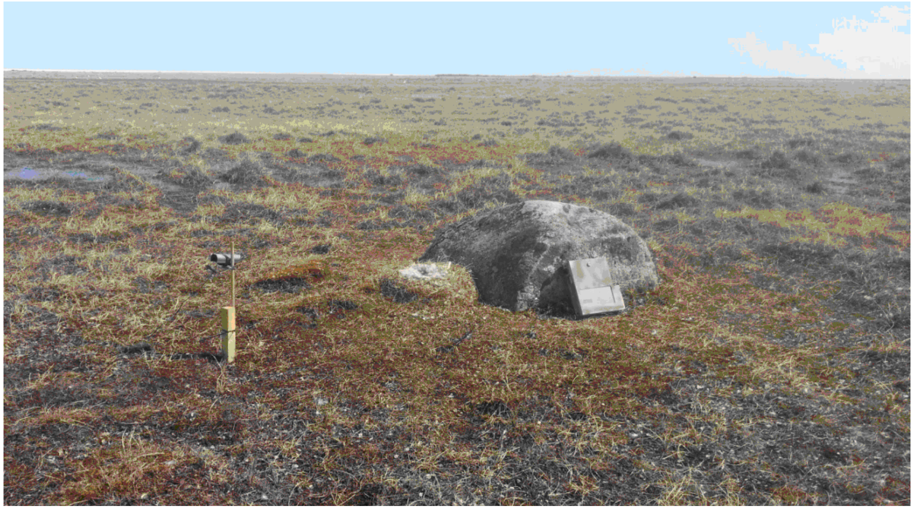


Figure 22. A lesser snow goose nest equipped with a 24-hour surveillance camera and a Song Meter 3 acoustic recorder from Wildlife Acoustics. The large acoustic recorders are cryptically colored so they won't attract aerial predators.

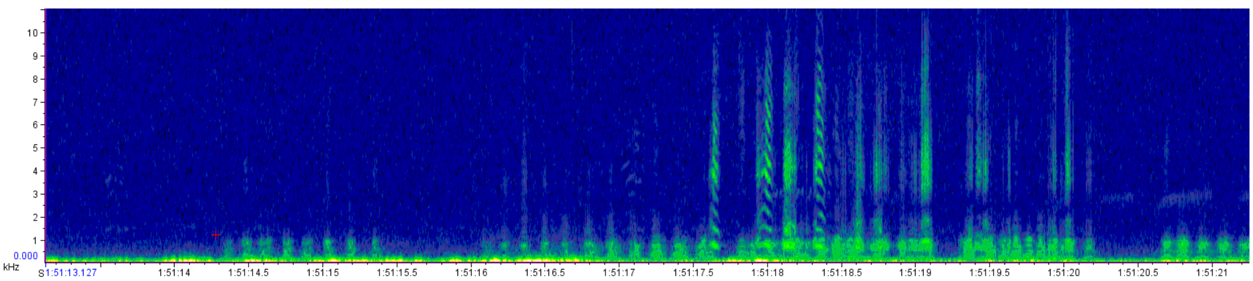


Figure 23. A spectrogram showing differences in snow goose vocalizations collected at a monitored nest in 2015. The short peaks at 1:51:15 represent typical "grunting", whereas the taller high frequency peaks at 1:51:18 are characteristic of honking.

<u>Behavioral Evaluation - Flight Operations</u>

Behavioral study flights were designed in such a way to ensure the aircraft flew transects covering specific nests at a predefined altitude. Flights were conducted at 75, 100, and 120 meters above ground level and randomized over nests (3 nests were flown at each altitude for geese). Three randomly selected nests were monitored for behaviors but were not flown over, serving as a control group. For each flight, we recorded the location of the launch and landing site so we can calculate distance between launch and landing to each nest.

Preliminary results suggest that snow geese appear to notice researcher presence during the initial set up and maintenance of camera systems, or repeated visits to the nest for data collection. However, we observed several individuals that continued to incubate within 50 meters of the launch and landing site, or returned to the nest shortly after we arrived and remained on the nest during the flight operations from launch to landing. Video is currently under review for specific responses at nest during flight operations. It will be more difficult to quantify the impact on common eider behaviors, as a number of the cameras failed due to unfavorable weather conditions (i.e., heavy rain and wind events) or were depredated before flights occurred.

Future behavioral studies should evaluate different types of aircraft to facilitate optimal flight scenarios relative to aircraft shape, aircraft and sensor quality, and sound to determine the best platform and sensor combinations to assess both wildlife and vegetation that minimally impact wildlife.

Vegetation and General Mapping

To assess vegetation, flights were conducted in the Weatherhead area (located east of Nestor 2) over historical transect lines used to characterize vegetation communities. This area has experienced substantial damage caused by the destructive feeding habits of snow geese, resulting in dramatic changes in vegetation communities (Peterson et al. 2013). A series of 75 ground-truth points for major vegetation cover classes of shrub, water, barren, and graminoids were collected to validate UAS imagery. This dataset will be compared with UAS flights conducted using both a red, green, blue (RGB) camera and a near-infrared (NIR) camera to determine if the UAS could facilitate larger scale vegetation mapping of the damage and potential recovery areas. This method has the added benefit of minimizing time researchers have to be on the ground, reducing potential wildlife conflicts, specifically with the presence of polar bears in the area. In addition, it provides an opportunity to characterize a larger spatial scale of vegetation than can be done on foot.

Similar UAS flights were conducted in the Thompson Point area over 3 historical transects evaluated for vegetation changes relative to snow goose use. Both the RGB and NIR cameras flew the UAS transects to provide a baseline of vegetation sampling in that area.

In addition, we conducted several flight operations in the surrounding area of Peter's Rock and near Nestor 2 to collect high resolution imagery that can be used to assess habitat characteristics and nest densities once methods have been validated using the ground-sampling methods previously described. This dataset can provide information that can be archived and later compared to future UAS imagery collected in the future to monitor changes in bird populations and vegetation.

Summary

The inaugural season of unmanned aircraft flights with the HBP was an overwhelming success in terms of deliverables and personnel achievement. In total 87 flights were conducted, amounting to almost 55 hours of flying time, and over 80,000 images. These flights were conducted over a 17 day period (11 and 6 flight days in June and July, respectively) between 10 June and 16 July 2015.

Use of the UAS this summer was limited by technical failures in equipment, unfavorable weather conditions for flying, and regulations permitting only within line of sight operations. On average, the aircraft battery life was lower than expected (rated for 50 minutes but averaged about 35 minutes); reducing the amount of ground the aircraft could cover in a single flight. In high winds this problem was exacerbated and overly windy or rainy conditions prevented field operations on several occasions.

Future Directions

With plans to return to the field in 2016, the flight crew from the University of North Dakota has several projects planned;

1. The continuation of behavioral impact assessments on lesser snow geese and common eiders, with an expanded array of cameras, sound recorders, and potentially an additional survey-grade aircraft.
2. Vegetation work will be expanded to allow for additional ground sampling method comparisons in the Weatherhead area to assess vegetation damaged from lesser snow geese.
3. The use of imagery to collect estimates of adult-juvenile ratios, and how those ratios may change over the course of approximately 4-6 weeks (hatch to banding in late July).

Hudson Bay Project Contributions to the State of the Park Report for Wapusk National Park

As part of our Contribution Agreement with Wapusk National Park we collect data on and estimate snow goose nesting density and phenology and reproductive success, which are then used in their assessment of the State of Ecological Integrity within the Park. The following is our annual update for 2015.

Nesting Density provides a good surrogate for abundance in a given area, because it is easily monitored and highly repeatable. The HBP has data from 1995 for the core La Pérouse Bay nesting colony using 3 locations (habitat types) and 5 sampling plots for each area. Changes in nesting density over time reflect weather impacts on the nesting geese as well as habitat conditions. As habitat becomes degraded, the geese disperse to other parts of the Park. Thus, annual estimates within the established thresholds would indicate that fewer geese are nesting but more importantly that habitat has become degraded. The statistical thresholds for the baseline data were defined over the period 1995 to 2005 and the mean was computed across the three sites for the 11 year period. The standard deviation was defined as the square-root of the variance of the 11 annual means. Yellow and red bounds were computed as 1.6 (yellow) and 2.0 (red) times that standard deviation (Figure 24).

Results: Nesting density in 2009 was below the green zone, likely an effect of it being the latest year on record. There is a highly significant downward trend over the entire time series but in recent years that trend seems to have somewhat stabilized.

Nesting Phenology provides a second good measure for the activities of the snow geese. This is monitored at the 3 Nesting Density sites and 3 other sites (Stony Knoll, Thompson Point North, Thompson Point South), expanding the geographic coverage to as far south as the Broad River. The nesting success of snow geese is higher in early years than late years. More importantly, since their fall migration is related more to day length (and thus fairly fixed in time), early years result in the geese spending more time in Wapusk National Park and therefore a greater negative impact on forage plants. The mean hatch date was used as an annual measure of phenology for the colony. The statistical thresholds for the baseline were defined over the period 1969 to 2005 and the mean was computed at 6 sites over 37 years. The standard deviation was defined as the square-root of the variance among the 37 annual means. Yellow and red bounds were computed as 1.6 (yellow) and 2.0 (red) times that standard deviation (Figure 25).

Results: There is a decline in the long term trend indicating a slight advance in the hatching date.

Reproductive Success provides a third measure of snow goose activity and impact. Although there are some annual effects of timing and weather, the proportion of goslings in the Park declines as the habitat becomes degraded. Late years and harsh weather have similar but less extensive effects. Years with higher reproductive success result in higher consumption of vegetation in the Park. We assessed the proportion of goslings among the geese captured during our annual banding operations. The statistical thresholds for the baseline were defined over the period 1971 to 2005 and the mean was computed over 33 years (there are no estimates for 1996-1997). The standard deviation was defined as the square-root of the variance among the 33 annual means. Yellow and red bounds were computed as 1.6 (yellow) and 2.0 (red) times that standard deviation (Figure 26).

Results: Productivity was low in three years, 2000, 2004 and 2009, being substantially below the green zone. All three years showed a late snow and ice melt during the incubation and hatching period. There is a significant long-term decline in reproductive success that is coincident with increased habitat degradation, as we have reported in several papers. The recent upturn may reflect increased exploitation of non-degraded habitat, an effect we are examining. The extremely low 2015 value reflects a mismatch between snow goose hatching and graminoid “green-up”. Goslings retain sufficient yolk material for energy needs for approximately 3 days. Unfortunately, new graminoid growth was not available until nearly 7 days after the peak of hatch and most of the goslings died. Goslings that more closely matched green-up were subjected to prey swamping by the many predators staged to forage on snow goose goslings.

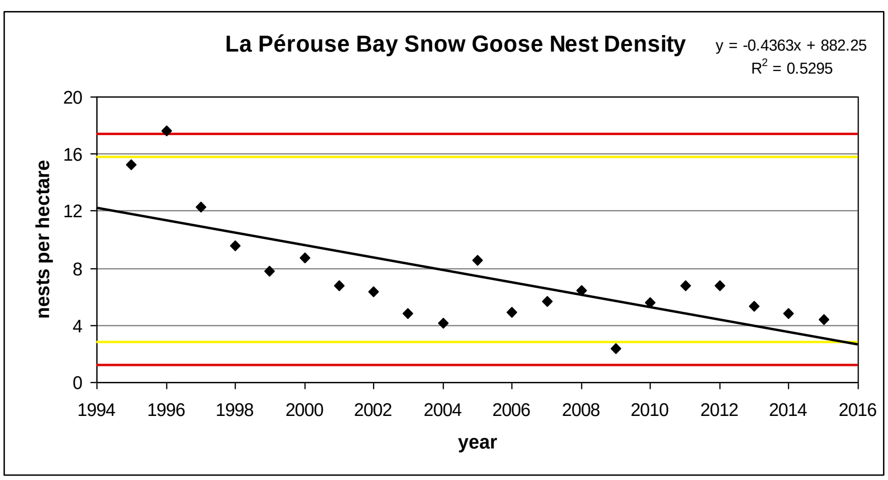


Figure 24. Mean snow goose nest density of the main nesting colony at La Pérouse Bay from 1995-2015. The baseline and boundaries are based on 1995-2005 data.

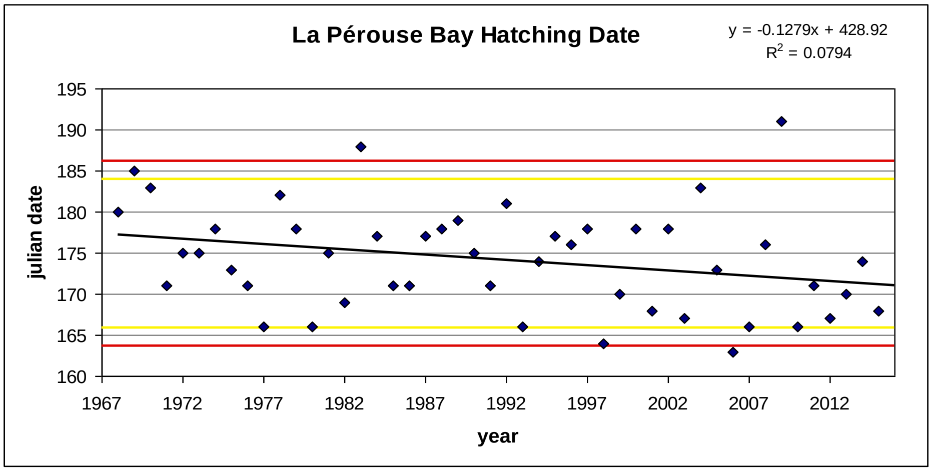


Figure 25. Mean hatch date of snow geese nesting in the main nesting colony at La Pérouse Bay from 1995-2015. The baseline and boundaries are based on 1969-2005 data.

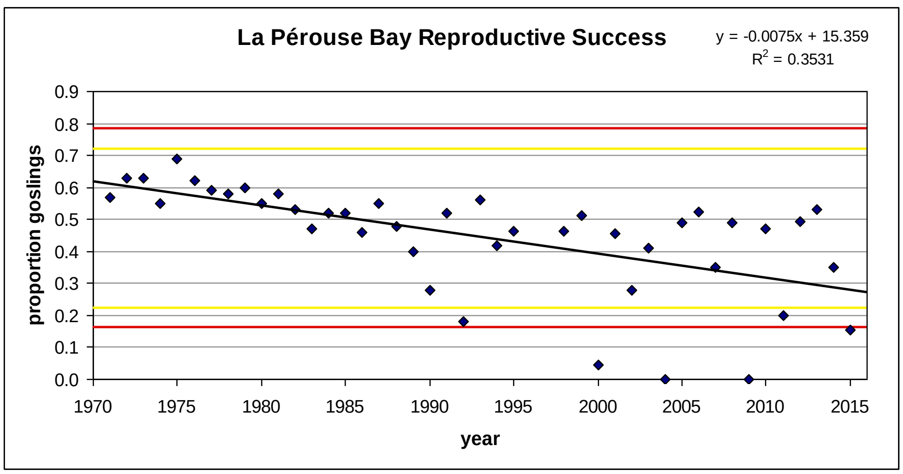


Figure 26. Proportion of goslings in the main nesting snow goose colony at La Pérouse Bay from 1995-2015. The baseline and boundaries are based on 1971-2005 data.

Akimiski Island, Cape Henrietta Maria and Ontario coasts of James Bay and Hudson Bay

Snow Goose Nesting on Akimiski Island, Nunavut

Snow goose nests were not monitored on Akimiski Island in 2015 because weather prevented a visit to the colony; however, productivity indicators at banding (below) suggest a successful effort.

Snow Goose Banding at Akimiski Island, Nunavut

Snow goose banding at Akimiski Island, Nunavut, contributes data for mid-continent snow goose population monitoring during the continental-scale population reduction effort currently underway (AGJV 1998). These data are used to determine survival rates and to determine the pattern of mixing among eastern Arctic nesting colonies during nesting, migration and on wintering areas. For this population, banding also occurs in Manitoba (at La Pérouse Bay/Cape Churchill) and in Nunavut (at Baffin Island, Southampton Island, and Queen Maud Gulf). These data also allow comparison of survival and harvest rates between colonies to help assess the effectiveness of conservation efforts for this population.

We captured flightless snow geese on 23 and 25 July 2015 along the north shore of Akimiski Island in an area from 53°12'N, 81°25'W to 53°10'N, 81°0'W. We banded 1064 lesser snow geese of which 567 were adults and 497 were goslings. We recaptured 153 previously banded adults (21.0% of adults handled). The sex ratios (male:female) of newly banded adults and goslings were 1.59:1 and 1.00:1, respectively. The high proportion of males in newly banded adults reflects a sex bias in philopatry (females being more site faithful and males returning with them to the female's natal or previous breeding colony). When previously banded adults were included, the adult sex ratio was 1.09:1, reflecting the capture of complete social units. The overall age ratio, including all adults (newly banded, previously banded and escapes) and goslings (newly banded and those released unbanded), was 1.3 goslings per adult (56.6% young). This represents a good estimate of brood size among successful pairs at the mid-point of the rearing period. This is slightly above the long term average which is 1.12 (SE = 0.06) and indicates average reproductive success in 2015 (Figure 27). Some caution must be taken with using age ratios as a measure of annual productivity as there were some uncounted adults that escaped, and as a result, the age ratio could be biased high.

Seventy percent of adults and 67.8% of goslings were blue morph geese which are below the long-term composition of 76% for Akimiski Island (Figure 28). One adult (0.1% of adults handled) and 4 goslings were euthanized during banding operations (0.6% of goslings handled).

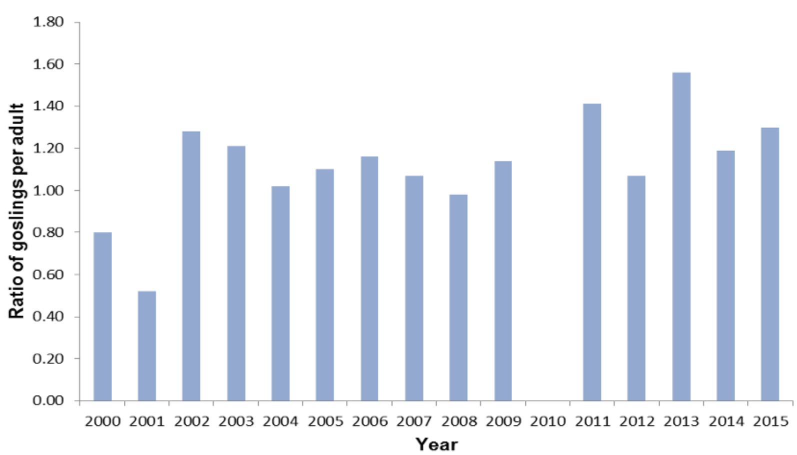


Figure 27.   Age ratios of snow geese at banding on Akimiski Island, Nunavut, 2000-2015. There was no banding in 2010.

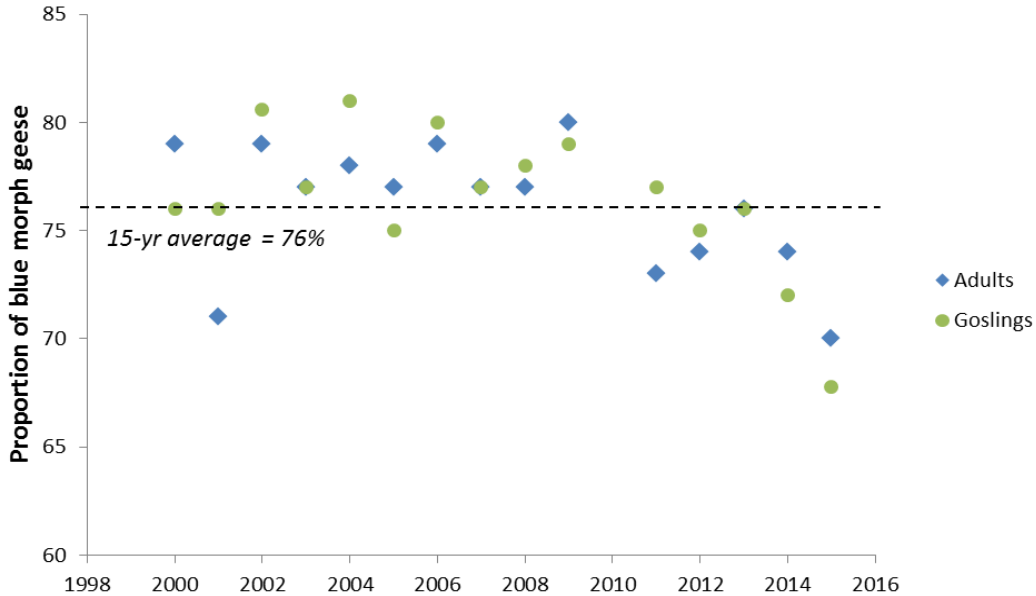


Figure 28. Proportion of blue adult and gosling snow geese banded on Akimiksi Island, Nunavut from 2000-2015.

Snow Goose Nesting on the Hudson Bay Coast

A photo survey of the Cape Henrietta Maria snow goose nesting colony was flown on 5 June 2015. We used a Twin Otter aircraft outfitted with two cameras to fly the historical helicopter transects (Figure 29). We are currently processing the imagery and counting nests from the imagery to make a population estimate comparable to previous helicopter observation based estimates (Table 2). We hope to have this completed by the end of 2015. An advantage over the helicopter method of survey is that we now have a permanent record of each nest location and of the habitat condition.

No surveys were conducted at the other two Ontario Hudson Bay colonies (Shell Brook colony and the West Pen Island colony.

On 28 July, we undertook photographic surveys of representative molting flocks to determine colour and age ratios at the Cape Henrietta Maria colony. A total of 5,479 geese were counted in 34 photographs of brood flocks. The colour ratio was 35% white adults, similar to the 34-38% white geese found in the previous three years. The proportion of goslings was 35%, resulting in a gosling to adult ratio of 0.55, which is lower than 2014 and 2013, but similar to 2012 (Figure 30), indicating below average reproductive success in 2015 and much poorer success than Akimiski Island in 2015 (1.3 goslings per adult). We were not able to search for snow goose brood flocks at the West Pen Island colony because of poor weather conditions, so its 2015 productivity status is unknown.

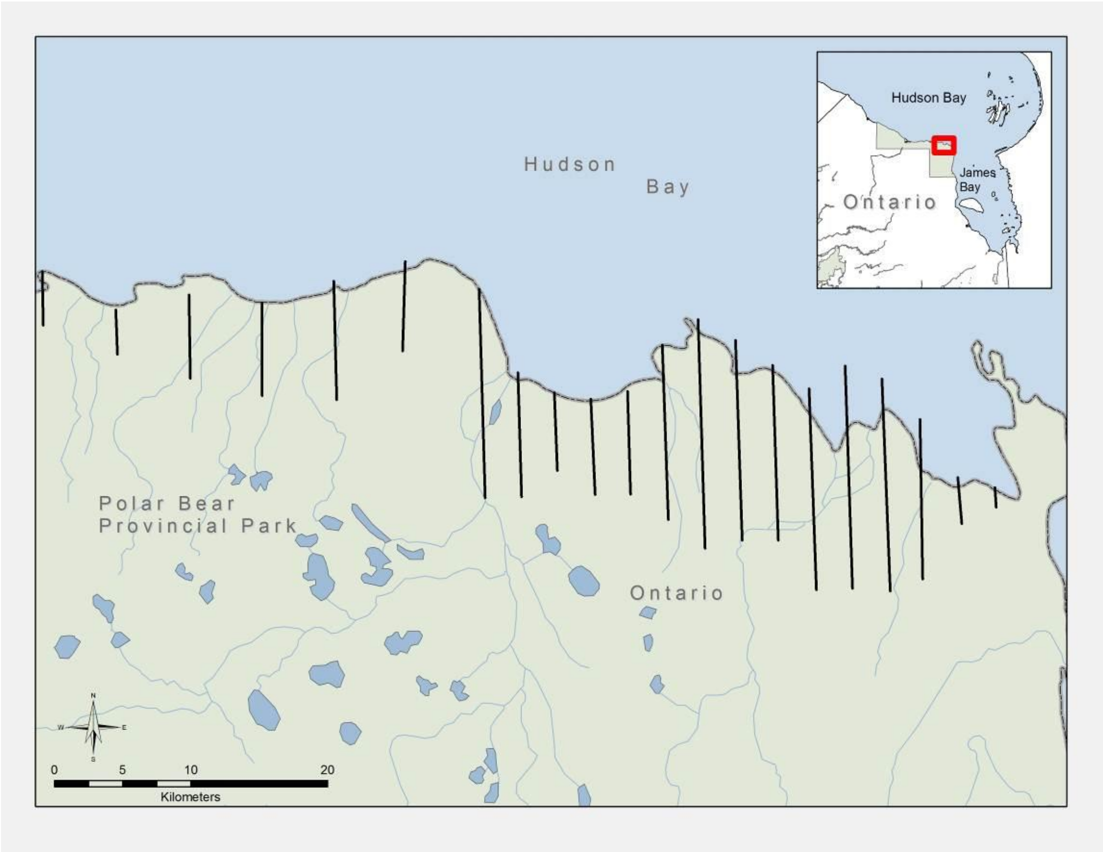


Figure 29. Location of the lesser snow goose aerial photo survey. Twenty transects were flown at Cape Henrietta Maria, Ontario, using a Twin Otter aircraft on 5 June 2015.

Table 2. Estimates of the number of breeding pairs of lesser snow geese at the Cape Henrietta Maria, Ontario colony, from 1996-2015.

Year of Survey	Breeding Pairs-kriging	Breeding Pairs-statistical
1997	183,657	160,013 + 24,084 (SE)
1999	154,386	115,347 + 22,775 (SE)
2001	147,570	128,735 + 18.478 (SE)
2003	164,490	139,884
2005	180,996	103,298
2007	115,278	n/a
2009	8,972	n/a
2012	101,070	n/a
2015	TBD	TBD

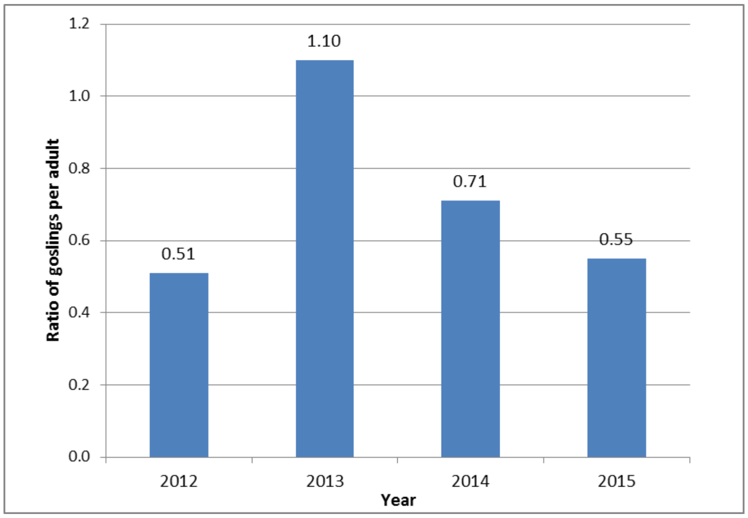


Figure 30. Age ratios of snow geese at Cape Henrietta Maria, 2012-2015. Results are from photographic surveys taken during banding.

Canada Goose Nesting in the Hudson Bay Lowlands of Ontario and Nunavut

Estimates of the number of Canada geese breeding in 2015 were made for two main populations in the Hudson Bay Lowlands of Ontario and southern Nunavut: 1) the MVP which nests on the mainland of the Hudson Bay Lowlands north of the Attawapiskat River and west into Manitoba, and 2) the SJBP which nests on the mainland south of the Attawapiskat River and on Akimiski island. These breeding ground surveys are undertaken annually as part of the operational management of these populations by the states and provinces of the Mississippi and Atlantic Flyway Councils and their federal partners. Reproductive success was monitored for both of these populations at ground camps on Akimiski Island, Nunavut, and at Burntpoint Creek, in Polar Bear Provincial Park, Ontario.

Both study sites had a relatively early spring compared to 2014. In 2015, nesting effort was higher than average on Akimiski Island, and greatly improved from the previous year. Larger clutch sizes and a greater number of fledglings also reflect a more successful year than 2014.

Hunters reported that SJBP spring migration north was slightly slower than normal on the mainland, but once started geese passed through quickly and arrived relatively early on the breeding grounds. There was a slightly lower than average snow pack that quickly melted, providing geese with early available nesting sites. Even though there was a rapid melt, nesting habitat dried out fairly quickly so flooding on Akimiski Island was likely not an issue, unlike the previous year.

Nesting effort at Burntpoint Creek was also improved from last year and nest success was above average. This is likely due to an earlier spring as mentioned previously, making nesting habitat available earlier in 2015 during the nest initiation period. Snow persisted slightly longer than normal, but most disappeared by mid-May. June temperatures were average or slightly below average on MVP range with near or above average wetland conditions at the start of June, though wetlands quickly dried during the month as the area near Burntpoint Creek received little to no precipitation during the month (Brook and Badzinski 2015b). On 1 June we observed little snow in the nesting areas and excellent wetland conditions.

An increased nesting success on the MVP range could have also been aided by decreased predation pressure. We found below average nest predation, which could reflect either a lower density of predators in the area or some predators taking advantage of alternative prey. This year was the first time in 3 years that small mammals were observed in the field at Burntpoint Creek, although there was some evidence of activity (e.g., winter nests, runways).. However, predation rates by gull species wouldn't have been impacted as it is unlikely they consume many small mammals. In addition, predation could have been lower due to the fact that we did not begin nest searching until the day before peak hatch; there is always at least some observer influenced predation. This late monitoring start may have resulted in higher nest attendance by females, giving predators less opportunity to steal eggs from the nest.

Southern James Bay Population Canada Goose Population Survey

The survey was flown using an Ontario Ministry of Natural Resources and Forestry (OMNRF) Twin Otter from 17 to 22 May under fair weather conditions with Akimiski Island being surveyed on 22 May. The survey was delayed on Akimiski Island to 22 May because of snow on 20 and 21 May.

Peak hatch at Akimiski Island occurred from about 6 to 9 June indicating that the population survey was conducted during the second week of incubation and thus timing was good for both Akimiski Island and the mainland.

With the completion of the SJBP management plan (Abraham et al. 2008), it was decided to use the number of breeding birds (Indicated Pairs X 2) as one of the metrics (among other indicators such as trend and annual change) to measure population status. The estimated number of indicated breeding birds for both Akimiski Island and the mainland were down from recent years. Similarly, the combined estimate of indicated breeding birds for Akimiski Island and the mainland (54,347, SE = 7,052) was lower than in 2014 but was still above the threshold level of 50,000 birds. The total population estimate (60,684, 95% CL = 45,887 – 75,481) was also below that for 2014 and estimates of non-breeding or flocked birds were about double those in 2014 and 2013 but were still well below average.

To estimate change in the breeding population from previous years, we averaged the number of indicated breeding pairs for each transect for the previous 5 years (2010 to 2014). We used a repeated measures regression analysis at the transect level to compare transects for Akimiski Island (χ^2DF < 1.59) and the mainland (χ^2DF < 1.04) separately. Model fit was adequate for both locations using a negative binomial distribution and an auto-regressive covariance structure. There was a significant change (decrease) detected when comparing indicated breeding pair numbers (by transect) between 2015 and the previous 5-year average (alpha = 0.05) on Akimiski

Island (effect size = -0.47, SE = 0.131, 95% CI = -0.725 to -0.210, P < 0.001). Also, a significant change was detected (decrease) for the mainland (effect size = -0.36, SE = 0.130, 95%CI = -0.614 to -0.104, P = 0.006).

Southern James Bay Population Canada Goose Nesting

On Akimiski Island, 780 nests were located of which 96 nests (12.3%) were already predated when found. The remaining 684 nests were active and were monitored between 28 May and 11 June. Nest density (45.7 nests/km^2) was comparable to the 2005 to 2014 average (mean = 40.3 nests/km^2, SE = 3.9) though much higher than in 2014 (12.6 nests/km^2).

First hatch was recorded on 31 May and continued to 10 June. End of hatch was estimated to be 17 June using float data from the remaining active nests and peak hatch was estimated to be on 7 June, about 12 days earlier than 2014. Mean clutch size of active nests at mid-incubation when first found (4.66, SE = 0.05, n = 686), mean clutch size at hatch (4.66, SE = 0.05, n = 536) and the mean number of goslings leaving nests (4.46, SE = 0.06, n = 476) were above average (2008-2014). Web-tagging was not part of the 2015 nesting ecology work on Akimiski Island.

Fates were determined for 629 of the 780 nests. Total nest success (78.5%), was much higher than in 2014 (41.0%) and the 10-year average (2005-2014; 57.8%, SE = 6.7. However, the relatively high proportion of nests (22.1 %, 151 out of 684) still active when monitoring was terminated on 11 June is a caution that the high apparent nest success rate is not strictly comparable to previous years. This is evidentby the extremely high nesting success of active nests (92.7%) compared with the long-term average (mean = 75.9%, SE = 3.01, n = 22.

The dominant nest predators were avian (crows, gulls and ravens) based on frequent observations by the nest monitoring crews. There was no evidence of predation by polar bears in 2015 but there were a few sightings of red fox in the study area during incubation. These mammalian predators were not observed eating eggs in 2015 as they were in previous years but were likely responsible for some nest predation.

Southern James Bay Population Canada Goose Banding

We banded on SJBP range along the northern coast of Akimiski Island and the southwestern coast of James Bay from the Quebec border as far north as Attawapiskat from 8 to 29 July 2015. We banded 2,513 *Branta canadensis interior* Canada geese of which 1,073 were adults and 1,440 were goslings. In addition, we banded 560 temperate-breeding Canada geese (*B. c. maxima*) and recaptured 478 previously banded adults of which 449 were previously banded SJBP adults. Of all *B.c. interior* adults captured, 28.0% were previously banded SJBP birds. Of all *B.c. maxima* geese captured, 1.6 % were previously banded. The mainland SJBP range capture subtotal was 530 adults and 471 goslings, 487 *B. c. maxima* molt migrants, and 63 previously banded SJBP adults. The Akimiski Island capture subtotal was 543 adults and 969 goslings, 73 *B. c. maxima* molt migrants and 386 previously banded SJBP adults.

The sex ratio (male:female) of newly banded *B. c. interior* adults was 0.94:1(from drives deemed complete); the overall sex ratio when previously banded *B. c. interior* adults were included was 0.94:1. The overall age ratio was 1.30 goslings per adult (55% young), including all *B. c. interior* adults (new, recaptures and escapees) and goslings (banded and unbanded) from all drives deemed complete. Sixty-eight percent of *B. c. interior* females had brood patches (presence of a brood patch indicates a nesting attempt) and the ratio of goslings to breeding females was 3.50:1 (not including escapees). Thirty-three percent of *B. c. maxima* females captured on the SJBP range had brood patches.

Fourteen *B .c. interior* adults were measured for growth and condition assessment (10 males and 4 females). We measured the ninth primary on 81 *B. c. interior* adults (37 males, 44 females) and 42 *B. c. maxima* geese as part of a growth and molt timing study. This study's objectives were to assess 1) the relative timing of molt for breeding *B. c. interior* in comparison with molt migrant *B. c. maxima*, and 2) the synchrony of molt between members of breeding pairs (*B. c. interior*), between breeding pairs and young and between breeding pairs and molt migrants *(B. c. maxima)*. We also measured 13 temperate-breeding females as part of a project to assess condition of molting birds at different molting locations. Two goslings were euthanized during banding operations on SJBP range which represents 0.1% of all goslings handled.

Mississippi Valley Population Canada Goose Population Survey

We flew the survey using an OMNRF Twin Otter aircraft meaning the results are directly comparable with those of previous years. We flew the survey from 2 to 3 June under fair conditions. Weather conditions were overcast and windy but were deemed suitable for surveying and we do not feel that conditions affected visibility greatly.

We visited the Burntpoint Creek camp east of Peawanuck on 1 June and observed little snow in the nesting areas and excellent wetland conditions. Peak hatch was between 14 to 18 June confirming our earlier estimate. Therefore, the survey was conducted near the start of the third week of incubation which is about 5 days later than ideal but not out of the range of timing for previous surveys.

The estimated 2015 breeding population of 226,544 (number of indicated breeding pairs x 2) was below that in 2014 (322,506 – a corrected value following the 2014 report of 323,099) and was about 35% below the 1989-2014 average of 350,982 breeding birds. Numbers of flocked birds observed on transects were below average and were the second lowest counted (2010 was the lowest) since surveys began in 1989. Note that total population estimates reported here are slightly different from those in annual reports produced before 2008 because we did not include observations from supplementary coastal transects (1991-2000) or add a constant value for coastal flocked birds (2002-2007).

A primary purpose of this survey continues to focus on detecting temporal changes in transect level counts rather than comparison of annual population estimates. To estimate change from previous years, we first averaged the number of indicated breeding pairs on each transect for the previous 5 years (2010-2014). The transect level counts indicated the number of breeding pairs was significantly lower in 2015 compared to the previous 5-year mean (effect size = -0.608, SE = 0.086, 95% CL = -

0.777 to -0.439, $P < 0.0001$) for all strata combined and was also lower by stratum (all strata $P < 0.03$).

Mississippi Valley Population Canada Goose Nesting

We located 218 nests during mid-incubation at the Burntpoint Creek study area with 65 nests (29.8%) already predated when found. We monitored 125 active nests until 28 June. Fifteen of 125 nests (12.0%) were predated during the period of monitoring. Nest density (10.1 nests/km^2) was greater than 2014 (8.4 nests/km^2) but comparable to the 5-year average (2010-2014 mean = 11.4 nests/km^2, SE = 1.2). Similar to previous years, only a small number of nests (1.6%, n = 2) were abandoned during the monitoring period. Mean initial clutch size of active nests at mid-incubation (4.09, SE = 0.13, n = 127) and mean clutch size at hatch (3.97, SE = 0.16, n = 76) were higher than average (2008-2014 mean = 3.89 and 3.83, respectively) but mean number of goslings leaving the nests (3.13, SE = 0.12, n = 134) was comparable to 2014 and low compared to other years. Goslings were not web-tagged in 2015.

Total nest success was 62.4% which is higher than 2014 (41.0%), and then the long-term average (mean = 55.1%, SE = 5.9%, n = 10). Success of nests that were active when found was 86.4%; considerably higher than in 2014 (61.3%) and higher than the long-term average (mean = 70.7%, SE = 5.03%, n = 10). First hatch was observed on 11 June and peak hatch occurred on about 13 June. Twenty-eight nests were hatched when initially found. Two nests had fates that were not determined by 28 June but later determined when the site was revisited on 29 July.

Avian predators were observed on a regular basis at Burntpoint Creek, about as frequently as in 2014. Gulls were observed predating incubating nests on several occasions. One polar bear and at least one arctic fox were observed within the study area, along with an active fox den. There was no evidence of polar bear predation, but there were signs that fox were feeding on goose eggs (e.g., fox feces present at nest sites). We found below average predation of total nests; 36.7% compared to a long-term average (mean = 43.8%, SE = 5.6, n = 11).

Unlike previous years, there were several observations of small mammals during field work. We counted winter vole nests during nest searching to estimate vole nest density. This year's estimate (0.16 nests/km^2) was considerably higher than in 2013 (0.04 nests/km^2) and 2014 (0.05 nests/km^2). As well, a small mammal live trapping project that occurred during nest monitoring period within the study area produced our first capture, a southern red-backed vole, over a 1-day trapping session; likely more would have been captured due to our high sighting frequency but trapping ended early due to polar bear activity at the trapping site.

Mississippi Valley Population Canada Goose Banding

We banded geese on MVP range from the Attawapiskat River (Ontario coast of James Bay north of Attawapiskat) along the coast of Hudson Bay to 55°56'N, 87°12'W, about 17 miles SE of Fort Severn, Ontario from 23 July to 1 August 2015. We banded 3,216 *B. c. interior* Canada geese of which 988 were adults and 2,228 were goslings. We also banded 170 molt migrant temperate-breeding Canada geese (*B. c. maxima*), as determined by morphometric criteria. We recaptured 221 previously marked adults of which 217 were previously banded MVP birds. Of all *B. c. interior* adults captured, 16.8% were previously banded MVP birds. Of all *B. c. maxima* geese captured, 3.6% were previously banded. The sex ratio (male:female) of newly banded *B. c. interior* adults was 0.99:1; the overall sex ratio when previously banded *B. c. interior* adults were included was 0.97:1. The overall age ratio was 3.13 goslings per adult (75% young), including all *B. c. interior* adults (newly banded, recaptures and escapees) and goslings (banded and unbanded) from drives deemed complete. Ninety-four percent of females had brood patches and the ratio of goslings to breeding females was 6.66:1 (includes complete drives, not including escapees). Thirty-eight percent of *B. c. maxima* females captured on the MVP range had brood patches.

We measured 33 temperate-breeding females as part of a project to assess condition of molting birds at different molting locations. On MVP range, 2 goslings were euthanized during banding representing <0.1% of goslings handled.

Southampton Island, Nunavut

One of the major concerns about the increase of snow and Ross's geese is its effect on other vertebrate species, including other waterfowl such as Atlantic brant. HBP work in 2010 revealed a 90% decline of Atlantic brant and a corresponding 1000% increase in cackling goose nesting pairs at East Bay (unpublished data). In 2014 and 2015, we collaborated with the University of Delaware (UD) and Trent University on the second year of goose research being conducted at East Bay, Southampton Island, for the Arctic Goose Joint Venture (AGJV) supported project: "Assessing the impact of lesser snow geese and cackling geese on breeding Atlantic brant". This work forms the research program of M.Sc. student Clark Nissley under the direction of Chris Williams (UD) and Ken Abraham (Trent/OMNRF). In its first year, the study corroborated the shift in abundance of the three species and also documented an increase in Ross's geese (Nissley et al., in review, Canadian Field-Naturalist). Data on nest locations of the three major species showed an apparent usurpation of historic (1979-1980) brant nesting islands by cackling geese and absence of brant from any high density clusters. It also demonstrated nearly complete predation of brant nests, primarily by arctic fox. In 2015, the study focused on both competition among the three major nesting goose species at East Bay (snow geese, cackling geese and Atlantic brant) and predation. Nesting was delayed and effort much reduced in comparison with 2014 due to extended snow and ice cover and a very late thaw. One upside was that the delay allowed the crew to capture 10 arctic foxes and uniquely mark them so that they could be monitored by a series of automatic cameras throughout the study area. Total nest counts included 48 lesser snow goose nests (80% reduction), 355 cackling goose nests (38% reduction), 78 Atlantic brant nests (44% increase), and 18 Ross's goose nests (59% reduction). The search area for lesser snow geese was expanded slightly in 2015 so the overall reduction in snow goose nests is an underestimate. The apparent nest success was low as expected in a late season, but conditions in summer 2015 favored later nesting species: lesser snow geese 6.3%, Ross's geese 11.1%, cackling geese 26.1%, and Atlantic brant 16.7%. Arctic foxes were responsible for 50% of the predation on brant nests in 2015, but in addition to fox depredation, 4 brant nests were depredated by a single polar bear late in the nesting period. Higher prevalence of polar bears was observed in summer 2015 as compared to summer 2014.

On the habitat side, using rapid-assessment protocol, four 25 meter vegetation transects were surveyed at a random sample of 30 snow goose nests, 30 cackling goose nests, 78 brant nests, and 30 randomly selected locations. The predominant vegetation within a 10 cm diameter at each meter mark was noted. These transects will aide in establishing the nesting vegetation composition for the different goose species in the East Bay study area. Island size and the distance to the mainland for all brant nests on islands was measured. The distance to the mainland was determined by finding the shallowest path and measuring the distance to land and the water depth along that route. This protocol was implemented to determine how accessible each brant nest was to arctic foxes during the brant incubation period. Fox depredation was prevalent throughout the season, and water depth and distance appeared to be the limiting factors

The field work portion of the study is complete and analysis of data is underway. Data from 1979 and 1980 studies at East Bay (Abraham, unpublished) and from 2010 (Hudson Bay Project) will be integrated into the analysis to maximize our ability to understand the changes that have taken place over 35 years.

OTHER SPECIES RESEARCH

La Pérouse Bay and Cape Churchill Region

Common Eider Research

Long-term monitoring

In 2015 we continued to monitor the success of Hudson Bay common eider (*Somateria mollissima sedentaria*) nests associated with the Mast River, building on a 27-year dataset at La Pérouse Bay. We began nest searches of the Mast River adjacent to the La Pérouse Bay Research Station on May 31 2015. After exhaustive searches of the Mast River, we located a total of 164 eider nests, suggesting that breeding effort was low relative to previous years; we normally locate over 300 nests in the Mast River. This nest density is even lower than in 2014, where only 169 nests were located despite exhaustive searches of the colony. Reduced density of nests for two consecutive years may suggest that several recent years of low nest success have reduced overall population abundance. The earliest initiation date was 25 May and the mean initiation date (first egg laid in clutch) was 7 June, 2 days earlier than average (Figure 31).

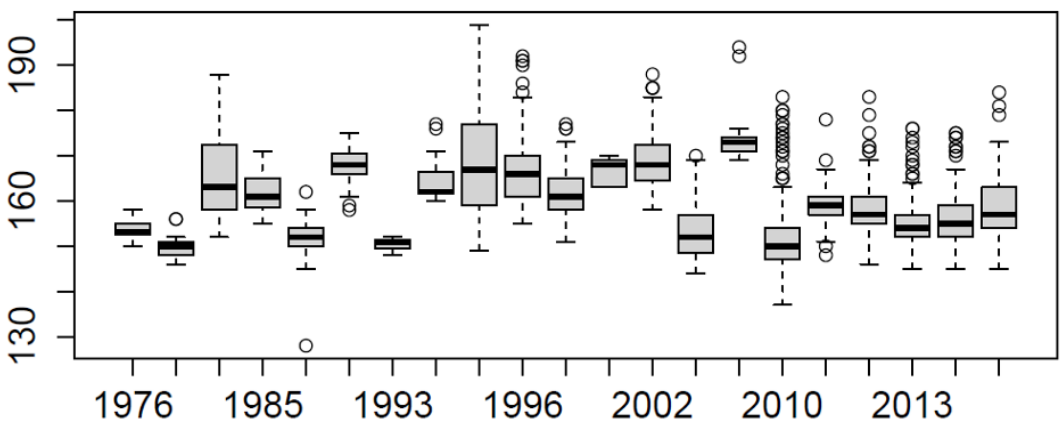


Figure 31. Distribution of nest initiation dates in the common eider colony in each year of study. Mean nest initiation in 2015 was 2 days later than 2014 and 2 days earlier than the long-term average. There is no trend in mean nest initiation date across years of study.

The eider colony experienced widespread reproductive failure in 2015 (only 9.7% of monitored nests were successful; Figure 32) due to predation by multiple predator species, including arctic foxes, sandhill cranes, grizzly bears, and polar bears (see Wildlife Cameras). This estimate of apparent nest success (the raw proportion of monitored nests that successfully hatched at least one duckling) is slightly higher than 2014, but still represents much lower nest success than was traditionally observed in the colony. The cause of this decline in nest success through time is unclear, but possibly reflects shifts in the predator community caused by both changes in the dynamics of the snow goose colony (increased effects of arctic foxes and avian predators via apparent competition) or by climate change (increased presence of polar bear and grizzly bear caused by shifts in phenology and range limits).

This contrasts sharply with the lesser snow goose colony which experienced generally high nest success (>90% in most areas). These highly contrasting rates of nest failure can likely be attributed to differences in both nesting phenology and nest defense behavior between eiders and snow geese. For snow geese, both parents aggressively defend nests from small predators throughout incubation (e.g., arctic foxes, gulls, ravens, etc.), reducing the risk of total clutch failure due to predation by small predators. Common eider nests are only attended by females, which only have limited ability to defend against meso-predators such as arctic foxes once nests are discovered. Neither snow geese nor eiders are able to defend nests against large predators (e.g., polar bears, grizzly bears, and wolves).

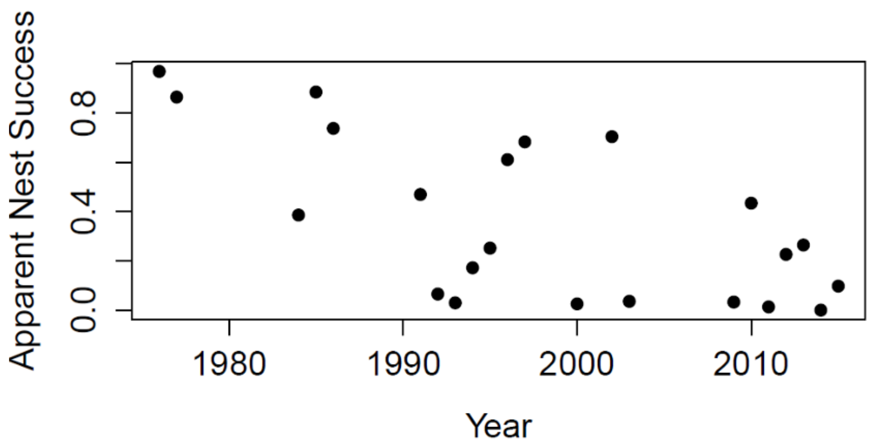


Figure 32. Apparent nest success of Mast River eider colony across the duration of the study.

Wildlife Cameras

As part of an ongoing effort (initiated in 2012) to document predation pressure and predator identity within the eider colony, we positioned 45 wildlife game cameras (Reconyx, Scoutguard, and video cameras) within the colony throughout incubation. Nests and cameras were rechecked regularly, and upon nest failure cameras were repositioned on active nests.

A main objective of this research is to examine spatial and temporal patterns in nest failure caused by different species of predator. For example, we are interested in testing whether polar bears respond to spatial variation in nest density (and thus prey availability) in fundamentally different ways than more traditional predators such as arctic foxes or sandhill cranes. Due to the large number of images collected, thorough analysis of nesting imagery is forthcoming. However, we have selected several highly compelling images from 2015 for presentation (Figure 33, Figure 34 and Figure 35).

Figure 33. A grizzly bear was observed in the colony on multiple occasions throughout incubation. Several nests failed as a result of predation by this individual.

Figure 34. Arctic foxes appeared to cause the majority of nest failure in 2015. We documented at least 2 individual foxes present in the colony, based on differences in fur pattern and personal observations of vocalizations.

Figure 35. Similar to our observations from 2014, sandhill cranes were responsible for a significant number of nest failures in 2015. Pictured here, a sandhill crane pulls a developing duckling from an egg before swallowing it whole.

Waterfowl Nesting Behaviors and Citizen Science.

University of North Dakota – Biology and Computer Science

UND graduate student Andrew Barnas and undergraduate, Sam Hervey, contributed to an expanding citizen science project on video monitoring of ground-nesting birds in the Felege lab at UND. Currently, many such avian monitoring studies focus on identifying predators, but nest cameras also allow evaluation of nesting behaviors such as incubation constancy (Burnam et al. 2012), responses to predators (Ellis-Felege et al. 2013), and responses to partial clutch loss (Ellis-Felege et al. 2012). As such, the use of nest cameras has become common and extremely popular in the field of avian ecology as they provide opportunities to monitor animals in remote locations and with reduced researcher disturbances (Cox et al. 2012, Ellis-Felege and Carroll 2012). By use of 24 hour surveillance cameras, changes in nesting behaviors such as increased frequency or duration in recess events can provide the first indications of stressors on birds that may result in reduced reproductive output.

While time-lapse photography (as has recently been conducted in both the eider and goose colonies) is able to provide information on predation patterns and incubation constancy, continuous video provides an opportunity to conduct a more comprehensive evaluation of nesting behaviors, responses to predators, and responses to behaviors of neighboring hens on nests. Further, 24 hour surveillance cameras are able to capture small scale nest events that standard trigger or time lapse cameras may miss. Such information can provide important insights into the ability of arctic-nesting waterfowl to cope with shifting predation regimes amidst changing climates.

Given the value of cameras, we conducted a small-scale monitoring project to allow us to evaluate the effectiveness of current camera methodology used by the Felege Lab. We installed miniature surveillance cameras at 12 snow geese and 8 common eider nests. This information was then paired with the complementary UAV study to understand behavioral responses to this new survey method. We are currently reviewing the many hours of video footage from start to finish classifying nesting behaviors of these species. Preliminary video reviews have found arctic foxes, among other predators, depredating eider nests (Figure 36) while many of the snow goose nests hatched (Figure 37).

Video collected from the cameras has been uploaded to our UND Citizen Science server and is currently being converted for streaming on the Wildlife@Home citizen science project (http://csgrid.org/csg/wildlife/). In collaboration with computer scientists (led by Dr. Travis Desell), our team hosts this web-based citizen science project (Figure 38) which incorporates undergraduate and graduate project scientists, citizen scientists who watch video and classify nesting events (crowd-sourcing), computer scientists who conduct computer vision research and manage the website's database, and volunteer computers to harness additional computational power to test computer vision algorithms. This project allows us to not only process nesting video to answer our research questions in biology and computer science, but also provides an opportunity for conservation outreach that can be used in schools and within government agency outreach programs.

Figure 36. An arctic fox raiding a common eider nest moments after flushing the hen off her nest.

Figure 37. A female lesser snow goose leaves her nest with two recently hatched goslings.

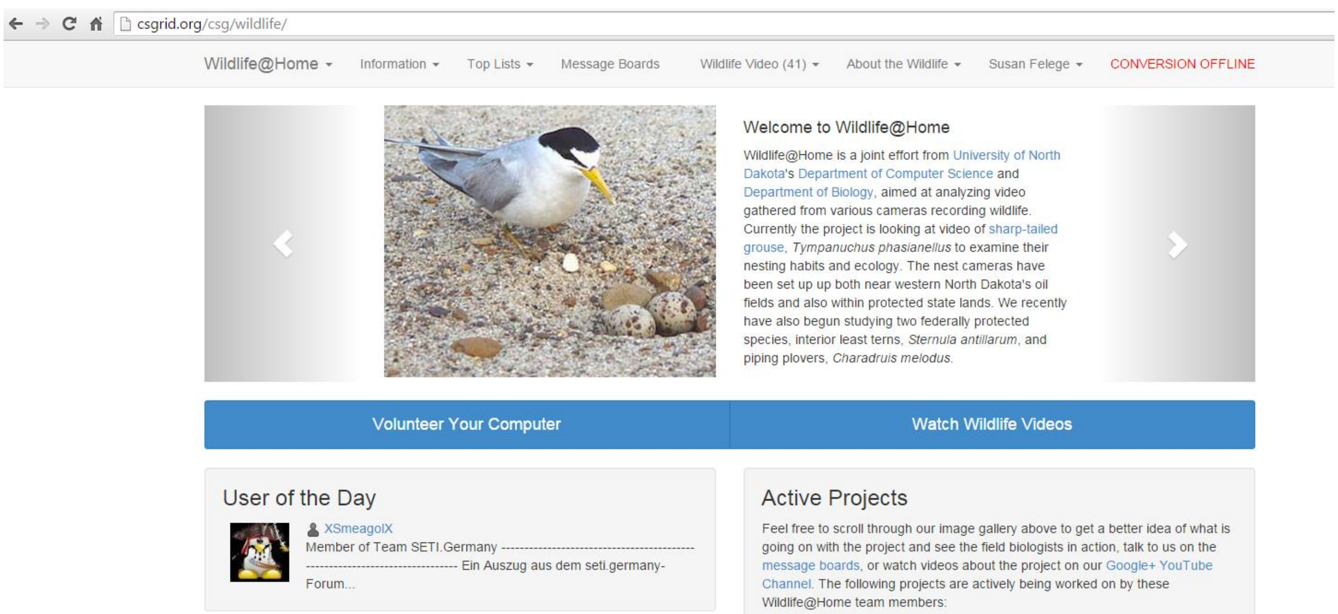


Figure 38. Homepage of Wildlife@Home web-based citizen science project (http://csgrid.org/csg/wildlife/) that is run by University of North Dakota students and faculty from Biology and Computer Science.

Tree Swallow Monitoring

Kit Uvino continued her project initiated in May 2014 on nesting tree swallows in and around Churchill. Tree swallows are aerial insectivores, a group that have been reported as declining in the north and east. There is a paucity of data for northern Manitoba on this species which makes data from this project quite valuable. Efforts focused heavily on building and installation of nest boxes (Figure 39) and recruitment of citizen science volunteers. The group of volunteers spans a wide age range, and nest box installation was across a broad geographical area covering several different habitats.

Installation of nest boxes began 25 May which was after tree swallows had arrived in the area. Volunteers monitored their nest box(es) several times per week. One hundred and seventeen new boxes were built and installed bringing the total in the Churchill area and at the La Pérouse Bay Research Station to 195. Occupation rate was 55%. A total of 154 eggs were laid and 39 hatchling tree swallows fledged.

Some nest boxes had intense competition with house sparrows in some areas and even resulted in the death of an attendant tree swallow – it appeared to have been pecked to death by the house sparrow that built its nest on top of the tree swallow nest. Several other nests were completely predated by unknown predators. A red squirrel chewed its way into one of the boxes and took up residence. Also, more than 75% of all nest boxes had multiple adults (>2) near the boxes, in the boxes and/or on the overhead wires.

Future plans include adding cameras, increased banding and manipulating density of nest boxes.

Figure 39. Occupied tree swallow nest boxes.

Bear Research

For the fifth time, we observed all three North American ursids on the Cape Churchill Peninsula. Our expanded program is summarized on a new webpage (http://research.amnh.org/users/rfr/hbp/bears). One interest is in the top-down control these predators bring to the burgeoning snow goose population but also their impact on other species of nesting waterfowl. This work was overseen this year by Ph.D. student

Dave Iles whose use of remote camera arrays to investigate the timing, extent and pattern of bear (and other) predation of snow geese and common eiders is covered in a separate section of this report.

The most recent paper on polar bear foraging series was published in PLOS ONE as:

Gormezano, LJ and RF Rockwell. 2015. *The Energetic Value of Land-Based Foods in Western Hudson Bay and Their Potential to Alleviate Energy Deficits of Starving Adult Male Polar Bears*. PLOS ONE DOI:10.1371/journal.pone.0128520.

The paper re-examines claims made by Molnár et al. (2010) that a 60 day increase in the ice-free period would lead to a substantial increase in polar bear mortality. Molnár et al. (2010) used an energy density model that made daily deductions for metabolic maintenance costs but assumed no energy input from land-based food. Mortality was assumed when the overall energy density reached a minimum threshold. In the first part of the Gormezano and Rockwell (2015) paper, Linda calculated the total energy required to keep the modeled sample of polar bears above that minimum threshold. She then computed the total energy available to the bears from snow geese and their eggs and from caribou, the most common three items found in polar bear scat. The energy available from these land-based resources alone is more than enough to offset the increased mortality. Current research is focusing on the extent to which the bears are availing themselves of land-based resources and the energetic expenditures associated with using them.

The paper was highlighted in a press release by the American Museum of Natural History:

http://www.amnh.org/explore/news-blogs/research-posts/polar-bears-may-survive-the-ice-melt-with-or-without-seals

and that generated a flurry of interviews for her and commentary on various outlets.

Annual Surveys

Our annual surveys are designed to define the date and pattern of onshore arrival of polar bears and to determine the overlap of polar bears (and grizzly and black bears) with the incubation period of snow geese and common eiders. Some of these are flown in conjunction with snow goose survey flights and others are specifically performed to detect bears. Flights cover the coastal zone and the primary nesting habitat of snow geese, generally from Watson's Point, east to Cape Churchill and then south to the Broad River and sometimes further to the Owl River or Rupert Creek. We also record all other occurrences of bears during air or ground work. Aerial surveys are flown at 250-300 feet in a Bell Jet or Bell Long Ranger. The overall results for 2015 are summarized in Table 3. Locations of polar bears during the 8 August 2015 survey are depicted in Figure 40.

In general, this was a low polar bear abundance year during the timeframe we operated, especially relative to 2011. This is most likely related to the presence of extensive pack ice east of Cape Churchill through early July and east of Port Nelson and north of Cape Tatnam and the Pen Islands through late July.

In total, we had encountered a total of 134 polar bears from the air this year. This included 120 sightings of single animals and only 6 family groups – a rather low number. The bulk of the bears we could score were medium to fat (3 to 4). We encountered only one exceptionally skinny bear (that also appeared scarred and old) and at least five that were obese (5).

Table 3.   Summary of 6 bear surveys performed during 2015 field season.

Date	Comments
22 June 2015	coastal survey from Fox Island to Broad River – 14 polar bears
9 July 2015	coastal survey from Prince of Wales Fort to Broad River – 15 polar bears and 1 grizzly bear seen
25 July 2015	coastal survey done in conjunction with vegetation work – 36 polar bears seen
8 August 2015	coastal survey from Churchill to Rupert Creek – 69 polar bears seen

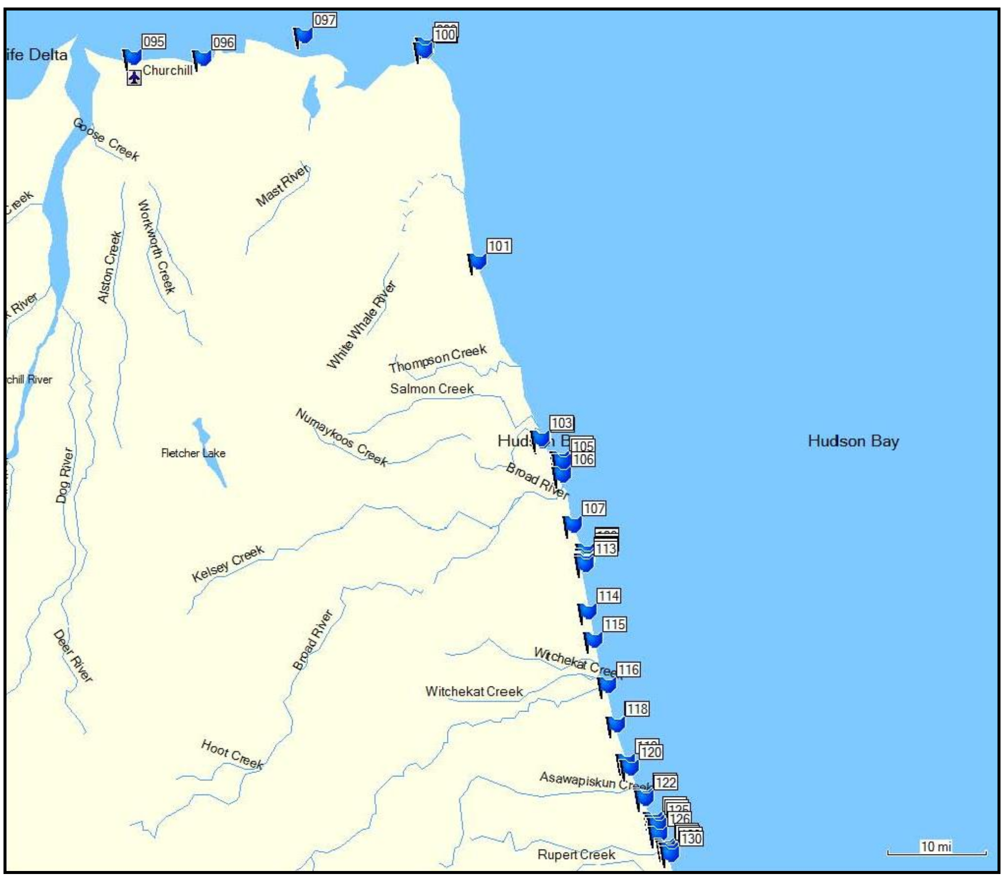


Figure 40. Locations of polar bears during the 8 August 2015 survey flight.

Hair Collection

As part of our continuing monitoring program, passively shed hair was collected from day beds between Churchill and Rupert Creek from 8 to 10 August. RF Rockwell oversaw this project and was assisted by Andrew Barnas and Sam Hervey. This is a helicopter-based project and Jamie Boles of Hudson Bay Helicopters performed admirably as both pilot and "hair picker". In total, we collected 262 samples in the Rupert Creek, Kiosk Island and Cape Churchill areas.

Grizzly Bear Encounters

On 19 June a single, large male grizzly bear without any distinctive markings appeared at the camp perimeter before we were able to deploy our electric fence. He ran off in response to yelling by RF Rockwell. Possibly the same grizzly bear was seen on 12 June northwest of Peter's Rock and again on 27 June north of the Research Station. The distinctively marked, large male grizzly pictured below (Figure 41) was seen on 9 July near the White Whale River and again on 25 July near Kiosk Island, where he had a rather elaborate day bed dug into the coastal plain.

Figure 41. Large male grizzly bear observed 9 July 2015 near the White Whale River and again on 25 July 2015 near Kiosk Island.

Effects of Climate Change on Trophic Interactions in a Sub-arctic Ecosystem

Doctoral Work of David T. Iles

Overview

Widespread, climate-driven changes in the distribution and phenology of species are well-documented (Parmesan & Yohe 2003; Root et al. 2003). However, phenological response to climate warming has not occurred uniformly across taxonomic groups or trophic levels (Parmesan 2007; Gauthier et al. 2013). As a result, important species interactions (including trophic dynamics) may become increasingly disrupted with accompanying effects on species demography (Miller-Rushing et al. 2010). One of the most pressing challenges in modern ecology is identifying the factors that influence species response to changing climate. Such an understanding is critical for prioritizing management efforts in a rapidly changing environment.

In 2013, Ph.D. student David Iles began a multi-year field study examining how climate change is influencing trophic interactions within the Hudson Bay Lowlands. Specifically, his work is focused on the relative strength of bottom-up and top-down controls on waterfowl demography and population dynamics in relation to climate change.

Part 1 – The Effects of Plant Phenology and Diversity on Gosling Survival and Body Condition

Background

The effects of climate-driven trophic mismatch are predicted to be strongest on specialized consumers inhabiting seasonal environments for which the duration of resource availability is low. Alternatively, generalist consumers are expected to be buffered against the negative effects of phenological mismatch, since greater trophic diversity increases the chances of overlapping with at least one resource (Miller-Rushing et al. 2010).

Spring climate at La Pérouse Bay appears to be increasing at a slower rate than late-spring temperatures, and both are becoming more variable through time. Since snow geese initiate nesting early in the season and incubate eggs for a fixed 24 day time period, the reliability of early-season cues used to predict the timing of high-quality forage later in the season may be declining as a result of climate change. Furthermore, snow geese are generalist herbivores that now utilize a diverse array of vegetation communities for brood rearing. Thus, the degradation of historically used salt marsh habitat by the Cape Churchill Peninsula population of lesser snow geese and subsequent expansion into new vegetation communities provides an ideal natural experiment with which to test the prediction that trophic diversity buffers consumers against the effects of phenological mismatch.

Gosling Collections

Beginning one week after mean hatch, we collected goslings continuously for four weeks, up until the end of banding operations. Goslings were collected from a wide variety of habitat types within approximately 6 km of La Pérouse Bay (Figure 42). We made an explicit effort to collect goslings from traditional coastal saltwater marsh areas, non-traditional freshwater sedge meadow areas (up to 6 km inland), as well as from transitional areas between them. In total, we collected 67 goslings in 2014 and 44 goslings in 2015. We only sampled one gosling per family group and collected a maximum of two goslings per flock.

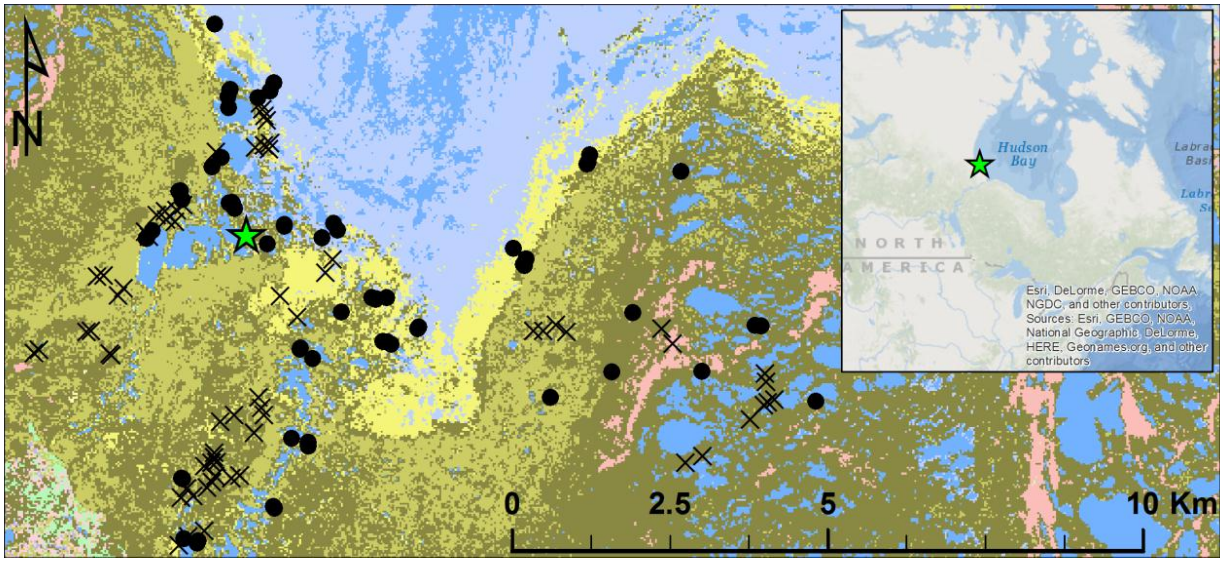


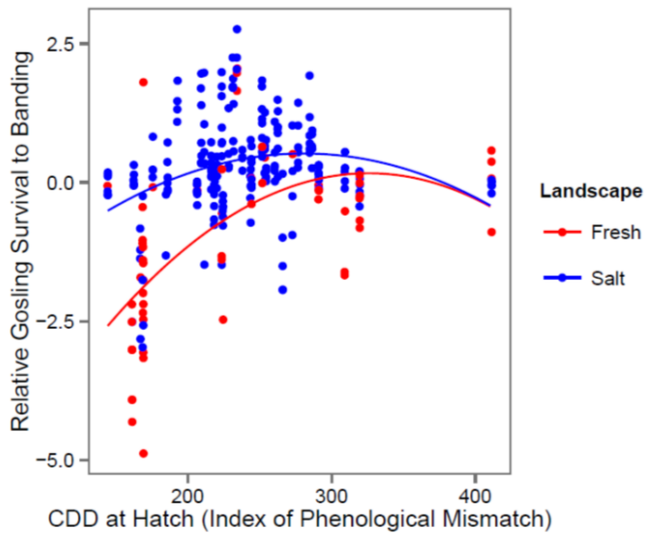
Figure 42. Overview of gosling collections and vegetation sampling. Solid circles represent location of gosling collection in 2014; crosses represent location of 15 m vegetation sampling transect. Sampling locations were similar in 2015.

Upon collection, goslings were humanely euthanized. Goslings were returned to our research camp, measured, and necropsied on the same day of collection. We measured body mass, total head length, culmen 1, culmen 2, total tarsus length, and length of 9th primary. To investigate potential variation in gut morphology due to differences in rearing habitat, we measured length and mass of the duodenum, jejunum, ileum, cecae, and colon. We also measured length, width, and mass (both full and empty) of the gizzard, as well as bursa depth (a potentially important surrogate for exact gosling age). We removed all contents from the foregut (upper esophagus and proventriculus), and either preserved contents in 95% ethanol for later identification, or rinsed contents in water and identified them immediately. Once contents were identified and sorted, samples were dried to a constant mass and weighed.

Preliminary Results

Cluster analysis indicated that banding locations were broadly divided into two categories based on landscape composition: coastal saltwater marsh and inland freshwater marsh. Vegetation diversity was strongly correlated with landscape type; saltwater landscapes were significantly more diverse than freshwater landscapes ($p < 0.0001$).

Gosling survival to banding (measured as percentage of goslings in each flock on a logit scale) was best explained by an interaction between CDD at hatch (a surrogate for vegetation phenology) and vegetation community ($R^2 = 0.38$; Figure 43). Survival was maximized at intermediate values of vegetation phenology. Consistent with the hypothesis that diversity buffers geese against trophic mismatch, gosling survival responded less strongly to climate variation in areas of diverse saltwater marsh.



Gosling early life survival is influenced by vegetation phenology and vegetation community.

Figure 43. Gosling early survival influences

Although analysis of gosling foregut contents is ongoing, we have already detected a surprising array of plant species in gosling diets, including *Puccinellia phryganoides*, a variety of *Carex* spp., *Eriophorum* spp., *Eleocharis* spp., *Equisetum variegatum*, *Triglochin maritima*, seeds from a number of graminoid species, leaves and catkins from several *Salix* spp., and flowers, leaves, and stems of multiple perennial species (including *Ranunculus cymbalaria*, *Argentina egedii*, *Andromeda polifolia*, *Tofieldia pusilla*). Upon completion of this analysis, we will evaluate relationships between gosling diet diversity and landscape vegetation diversity to provide a mechanistic explanation for the demographic trends observed above. We will explore relationships between diet composition and gut morphology of collected goslings, providing insight into the developmental plasticity of individuals reared in different habitats.

Ongoing Research Goals

While the data we have collected will be instrumental in understanding how vegetation diversity influences plant utilization by geese, it will ultimately be used to test the mechanisms responsible for observed patterns in gosling performance based on long-term datasets collected at La Pérouse Bay. In addition to long-term data for gosling body condition and juvenile:adult ratios (a coarse measure of reproductive success) collected annually at each banding drive, we will determine juvenile:adult ratios at a larger spatial scale from aerial imagery collected annually as part of a pre-banding survey.

We will then use a combination of vegetation phenology models and previously developed remote-sensed land-cover maps (Brook and Kenkel 2002) for Wapusk National Park to test the prediction that areas of higher forage diversity buffer snow geese against phenological mismatch. Finally, we will evaluate the potential future effects of climate change on snow goose reproductive output by coupling vegetation phenology models with climate projections, and we will examine how these predictions may differ across the landscape as a function of local forage diversity.

Part 2 – Predator Effects on Waterfowl Breeding Success

Background

In Western Hudson Bay, the date of sea ice breakup and subsequent polar bear arrival onshore is changing at a faster rate than the phenology of snow geese (Rockwell & Gormezano 2009) and other waterfowl (Iles unpublished data). Simulations suggest that increased duration of overlap with the nesting period of waterfowl could offset significant caloric deficits in polar bears caused by sea ice decline (Rockwell, Gormezano & Koons 2011). However, the factors that influence the strength of interaction between polar bears and waterfowl (given sufficient phenological overlap) are unclear. Similarly, the strength of polar bear predation pressure on nesting waterfowl relative to other predator species has not been evaluated.

Camera Placement

Continuing our study design from 2013 and 2014, we positioned 57 Reconyx Professional trail cameras in three key snow goose nesting areas (Peter's Rock, Thompson Point North, and Thompson Point South) along the Cape Churchill Peninsula. All cameras were placed on steel T-posts far enough away from each other such that their frames of view did not overlap. Each was outfitted with 12 AA Lithium Ion batteries, a 32 GB memory card, set to take a picture every 2 minutes during the 24 hour day, and equipped to rapidly take 30 images if the infrared motion sensor was tripped. We positioned 35 cameras at Peter's Rock between 1 June and 7 June, and 11 cameras at each Thompson Point North and Thompson Point South on 5 June. Thus, camera placement occurred 2-3 weeks before the mean hatching date of snow goose nests.

Common eiders initiate nesting less synchronously and later in the season than lesser snow geese and have not shifted their breeding phenology in response to warming spring climate. As such, predation of common eider nests that occurs later in the season may provide important early insights into the potential for shifts in predator phenology to affect the much larger snow goose colony in the future. We positioned 45 cameras in the eider colony throughout the season (cameras that were repositioned following the failure of monitored nests are included in this total). These cameras included Reconyx cameras (as above), as well as motion-sensor Scout Guards and video cameras.

Preliminary Findings

Over 120 lesser snow goose nests were monitored over a 15-20 day interval until their eventual hatch or failure. Additionally, the cameras at Thompson Point North and South were left at nest locations for several weeks after the completion of snow goose hatching, allowing us to examine goose and predator activity during the brood rearing phase of the snow goose life cycle. Ultimately, we collected over 2 million images in the snow goose colony over a 5-6 week period. Given the vast number of images, it will take some time to thoroughly scan through all of them and formally measure rates of predator-prey encounters, attacks, and handling times. However, a rapid preliminary assessment of images has yielded interesting results.

Initial estimates of nest success in the Peter's Rock, Thompson Point North, and Thompson Point South study areas were 94%, 92%, and 84% respectively, based on the presence of egg membranes in monitored nests. These estimates of nest success are likely biased low, as egg membranes and shells in successful nests are sometimes removed by other animals shortly after hatch. Thus, snow geese experienced high nest success in 2015. A preliminary search of camera images suggests that while avian predators and arctic foxes caused the failure of several snow goose nests (Figure 44, A & B), larger predators such as polar bears and grizzly bears (Figure 44, C-E) only entered the study area after the majority of snow goose nests had hatched.

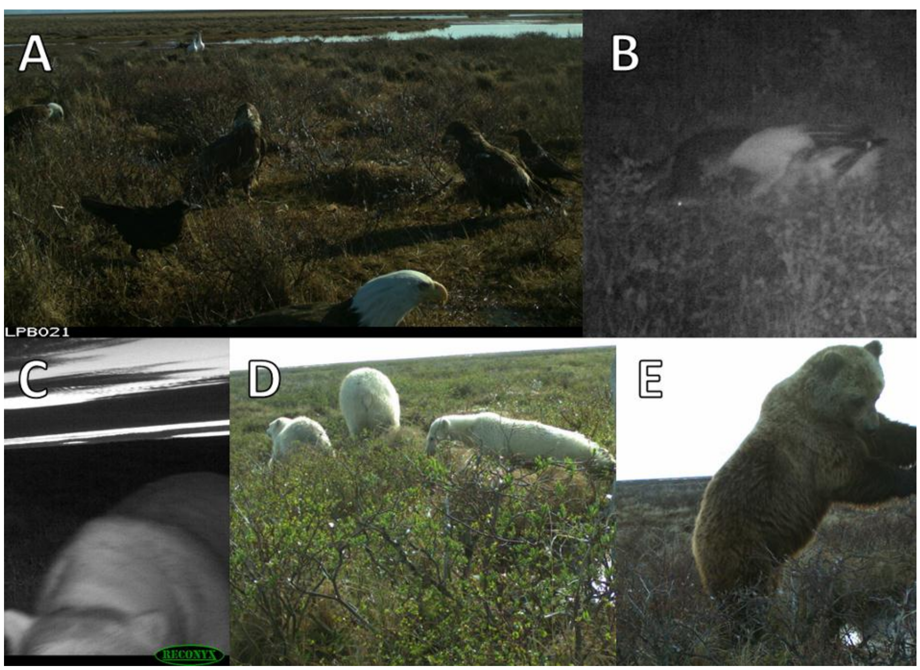


Figure 44. Examples of predators detected on Reconyx cameras within the snow goose colony in 2015. (A) Four bald eagles and several ravens consume several remaining eggs in a recently hatched snow goose nest. (B) An arctic fox attacks and kills an adult snow goose during incubation; the carcass was found during subsequent nest surveys. (C) A polar bear approaches a nest camera after the completion of incubation. (D) A female with two cubs examined a hatched snow goose nest before leaving the study area. (E) A grizzly bear stands over a hatched snow goose nest.

Common eider nest success was extremely low in 2015, owing to heavy predation pressure by multiple predator species. Examples of predator imagery collected in the eider colony in 2015 are included in the *Common Eider Research* section of this report. The discrepancy between snow goose and common eider nest success could be due to differences in predator phenology (i.e., a more diverse predator assemblage later in the season resulted in higher rates of predation on late nesting eiders), behavioral differences between snow geese and eiders (i.e., aggressive nest defense by snow geese reduced the likelihood of nest predation), and/or differences in space use by predators (predators are less abundant in the snow goose colony). Forthcoming analysis of imagery collected in 2013-2015 will attempt to evaluate these non-mutually-exclusive hypotheses.

Akimiski Island and Burntpoint Creek

Daily Bird Sightings

Daily bird species sightings were recorded on Akimiski Island from 28 May to 10 June and 17 to 30 July 2015. A total of 85 species was recorded, including a white-winged dove that was new for the list. The cumulative checklist for Akimiski Island since we started regular daily counts in 1995 now contains 193 species. Daily bird species sightings were recorded at Burntpoint Creek from 1 to 27 June 2015. A total of 79 species was recorded, including two new species (scarlet tanager and Philadelphia vireo). The cumulative total since 2001 is 151 species. We found a total of 56 non-Canada goose nests within the study area: 26 shorebird nests (see Shorebird Research for details), 1 northern pintail, 9 willow ptarmigan, 1 red-throated loon, 3 herring gull, 1 Arctic tern, 2 parasitic jaeger, 2 horned lark, 1 tree swallow, 1 barn swallow, 1 American robin and 8 savannah sparrow.

Shorebird Research

Populations of many arctic-nesting shorebird species have undergone long-term declines, some in excess of 50%. The ASDN was established in 2010 and we joined the network in 2012. The ASDN comprises 12 arctic field stations where the nesting ecology and dynamics, habitat, foods and general environment of shorebirds are being studied using standard protocols. These standard data from all stations are maintained in a central database which will facilitate cross-continent analysis of the condition of selected species and their habitats. The goal of the ASDN is to conduct demographic analyses for several target species that will help determine the factors limiting their populations. For further information, please visit: http://www.manomet.org/arctic-shorebird-demographics-network.

We undertook ASDN related studies at the Burntpoint Creek Research station. We monitored four intensive 16 ha plots and a 22 km^2 extensive monitoring study area, terrestrial insect food monitoring using aerial-intercept and pitfall traps, daily bird and mammal observations, and continuous weather monitoring. We located and monitored 26 nests of 7 species of shorebirds (5 semipalmated plover, 3 killdeer, 5 whimbrel, 2 Hudsonian godwit, 6 least sandpiper, 4 dunlin and 1 red-necked phalarope) and banded 12 nesting shorebirds of 3 different species (2 killdeer, 5 least sandpiper, and 5 semipalmated plover). We re-sighted three shorebirds (1 whimbrel, 1 semipalmated plover and 1 Hudsonian godwit) that were previously banded at Burntpoint in 2013. The semipalmated plover was nesting with a foreign banded bird that was banded 30 June 2013 at the Monomoy National Refuge in Massachusetts. The collection of arthropods is being analysed for species composition, frequency and biomass at Trent University in the MNRF laboratory. Our site is the southernmost site in the network and can contribute information on boreal nesting shorebirds and arctic-nesting species at the south end of their ranges.

New to our site in 2015 was the addition of a Motus Wildlife Tracking System tower which is used to monitor shorebirds equipped with nano-tags. Each nano-tag emits a unique signal that can be received within a 20 km radius of a tower and will provide valuable information on the movement and behaviour of shorebirds. Receiving stations span much of southeast Canada and the northeast United States with additional receivers along the James Bay coast (Figure 45). As of 26 July, the Burntpoint tower had detected a total of 6-tagged shorebirds: 1 adult dunlin banded in Churchill, 1 semipalmated sandpiper banded on Coats Island, 2 red knots and 2 semipalmated sandpipers all banded in Delaware Bay.

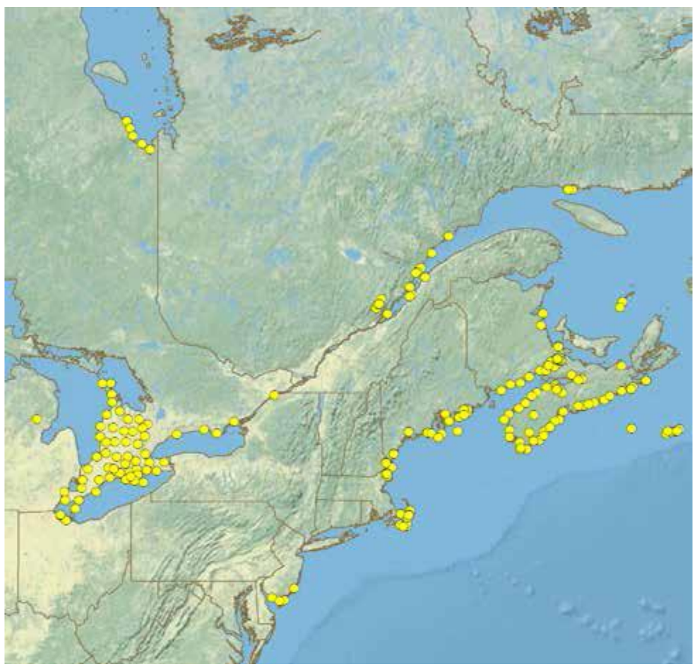


Figure 45. Motus Wildlife Tracking System receiving stations in southeast Canada, James Bay and northeastern United States as of 2014. Source: Bird Studies Canada.

Wildlife Acoustics

Between 9 June and 29 July 2015, we deployed 3 SM2 song meters and 2 SM2 bat recorders, which record bird and bat vocalizations, respectfully, at Burntpoint Creek. These recordings will be analyzed to identify species present in the area.

Invertebrate Herbivory Study

The goal of the Herbivory Network's insect herbivory study is to assess the occurrence and intensity of invertebrate herbivory at different tundra sites. Focus was on the impacts of invertebrate herbivores that cause leaf damage. Each site was asked to estimate foliar biomass at the community level and to collect leaf samples of the most abundant species within their plots.

Five (we only had time to finish 4 sites in 2015) 25m x 25m sites that were at least 100m apart in similar habitat were chosen. Each site consisted of 16 points that were spaced equally (5m apart). To estimate foliar biomass, a 50cm x 50cm point frame with 10 fixed intercepts was used, where all plants that hit the points were recorded. As well, all live green biomass from 3 frames from each site was collected and dried. Leaf samples from the three most abundant plant species (*Carex aquatilis*, *Trichophorum* spp., *Andromeda polifolia*) within the study sites. At least 300 leaves from each species per site were collected and dried. These samples will be examined to determine invertebrate damage levels.

Vegetation samples and data were submitted to Isabel Barrio from the University of Iceland. For further information, you may visit: http://herbivory.biology.ualberta.ca/protocol/invertebrate-herbivory-protocol/ .

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