MINASKUAT LIMITED PARTNERSHIP

FIELD TESTING OF NEST MONITORS™
CANADA GOOSE (*Branta canadensis*) COMPONENT

PROJECT MIN0439
2007

PROJECT NO. MIN0439

REPORT

TO

INSTITUTE FOR ENVIRONMENTAL MONITORING AND RESEARCH

FOR

FIELD TESTING OF NEST MONITORS™
CANADA GOOSE (*Branta canadensis*) COMPONENT

2007

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1.0 INTRODUCTION

Since 1995 (Trimper et al 1998), Environmental Effects Monitoring (EEM) related to the low-level military aircraft training at 5 Wing Goose Bay has addressed a variety of issues affecting several species of avifauna. With support from the Department of National Defence (DND) and the Institute for Environmental Monitoring and Research (IEMR), Minaskuat has selected and investigated parameters of interest that could be measured objectively and have biological significance. Three species of nesting avifauna [Osprey (*Pandion haliaetus*) (Trimper et al. 1998a, 1998b, Minaskuat 2003a, 2004a, 2005a), Canada Goose (*Branta canadensis*) (Minaskuat 2004b, 2005b), and Gray Jay (*Perisoreus canadensis*) (Minaskuat 2003b, 2004c, 2004d)] and one species of moulting avifauna [American Black Duck (*Anas rubripes*) (Minaskuat 2005c)], have been the subject of detailed EEM studies assessing noise and visual disturbances associated with low sub-sonic flying aircraft (e.g., military jet, helicopter, twin otter).

Behavioral EEM studies of nesting Canada Geese were conducted in 2004 and 2005 (Minaskuat 2004b, 2005b). These were designed to investigate whether aircraft events influenced A) the exposure of eggs or nestling to ambient temperatures, or B) the time spent by adults defending the nest. Observers used Sound Level Meters (SLMs) located at the blind to quantify the estimated noise energy dosage at the nest from passing aircraft. Behavioural reactions were noted, but this approach did not permit for ambient temperatures or noise exposure at the nest to be measured directly. Note that observations of directed aircraft overflights of Canada Geese in 2004 and 2005, generally did not cause exposures to eggs undergoing incubation.

In late 2005, the Waterfowl Technical Committee of the IEMR recommended that the Canada Goose monitoring program continue in 2006, with the objective of field-testing an egg-shaped NestMonitor™ developed by TenXsys (see http://www.tenxsys.com/nestmonitor.htm), in addition to further investigating behavioural reactions to low-flying aircraft. The monitor, suitable for placement in birds' nests, was developed by TenXsys in consultation with the IEMR for use in nest monitoring studies in Labrador. It was configured to record noise level and ambient temperature. Changes in ambient temperature are an indicator of how long an adult remains off a nest following a disturbance. Supplementing the NestMonitor™ with field observations provides an opportunity to verify the data it collects and to relate them to the nature of each disturbance.

In 2006, the IEMR engaged Minaskuat Limited Partnership (Minaskuat) to field test the Nest Monitor™, during incubation for Canada Goose, Bald Eagle (*Haliaeetus leucocephalus*) and Osprey (*Pandion haliaetus*). Minaskuat (2007) found that the NestMonitor™ (readily accepted by the attending adults) was able to record noise levels at the surface of the unit but could not discern proximate and distal sounds. Temperatures recorded within the nest by the NestMonitor™ were consistent with those reported in other incubation studies including the relatively slow declines exhibited (by natural eggs) during recesses by the attending females. As such, the technique of using this device to monitor possible sudden departures (and declining temperature within the nest) by some disturbance was suggested to be limited.

Following the 2006 investigation, a series of recommendations were proposed including: reconfiguring the audio sensor to either: establish the noise threshold according to the expected noise energy and frequency of an aircraft and/or place the device (or perhaps the sensor) near the nest but away from other natural background sources of noise; and further exploring the accuracy of temperature sensors in a more controlled environment (reported in Minaskuat 2007) and/or through possible redesign. Minaskuat was awarded a contract in 2007 to consider these recommendations and develop greater insight regarding this research question. The following document outlines the 2007 field program involving Canada Geese and this technology.

2.0 BACKGROUND

2.1 Technical Monitoring Equipment

Following the 2006 Canada Goose monitoring program, TenXsys redesigned the NestMonitors™ to further improve data collection and processing. The 2006 NestMonitors™ did not distinguish between proximate nest sounds (i.e. goose readjusting on the nest) and the distal aircraft noises of interest, resulting in excessive and unnecessary recordings that occupied storage space and required additional time for data downloading, processing and analysis. Separate AudioMonitors™ were therefore developed for the 2007 study to be used in conjunction with the NestMonitors™. The AudioMonitors™ are intended to be placed within 50m of the nest, effectively recording air traffic noise disturbances as heard at the nest, while eliminating recordings of sounds within the nest. Specifics of both devices are described below.

2.2 NestMonitors™

As delivery of the 2007 NestMonitors™ was delayed until after the incubation period for Canada Goose in the Study Area (Minaskuat 2007), the 2006 NestMonitors™ were redeployed for this study in 2007. The 2006 NestMonitors™ measure dB levels and temperature. The Subject Temperature is recorded at the core of the NestMonitor™ by a highly accurate biomedical sensor designed to operate over animal temperatures only, such that it will report 0˚C if it is exposed to temperatures that are outside of this range. (F. Riskey, pers. comm.). The Ambient Temperature is recorded at the surface of the NestMonitor™, providing a reading for outside air. The NestMonitors™ are battery powered, with an operational life of four weeks, and have a real-time clock for accurate data collection. Data are stored on an SD card, and software provided by TenXsys allows for viewing, storage, and analysis of data.

The size of the NestMonitor™ was based on mean length (89.14 mm), width (60.53 mm) and mass (166.85 g) of 140 Canada Goose eggs measured in Newfoundland in 1995 and 1996 by the Eastern Habitat Joint Venture and the Canadian Wildlife Service (P. Ryan, pers. comm.). The risk of NestMonitors™ being rejected was considered small, as the eggs were readily accepted in the 2006 study (Minaskuat 2007), and there is high natural variability in egg size within a given population, with the smallest eggs measuring only 60% of the largest (Manning 1978).

2.3 AudioMonitors^{TM}

The AudioMonitors^{TM} consist of a black box (approximately 20 x 20 cm) featuring the following:

- Ambient sound level and waveform recording;
- Data storage SD card;
- Noise event capture capability;
- Battery powered: Extended operational life > 4 weeks;
- Real time clock for accurate duty cycling and data collection; and
- Software to allow viewing of data and data storage for data analysis.

3.0 STUDY OBJECTIVES

The primary aims of this program were to continue testing the TenXsys NestMonitor^{TM}, conduct an initial test of the AudioMonitor^{TM}, and collect additional data on Canada Goose nesting behavior at sites near the Goose Bay Airport. Specifically the program addressed the following objectives:

- Directly measure noise dosage and temperatures at the nest during incubation;
- Document the behaviour of nesting Canada Geese in response to the NestMonitor^{TM};
- Compare information collected within and adjacent to the nest (to assess the influence of the adult on the sensitivity of the NestMonitorTM);
- Determine whether a response (e.g., flushing) to a disturbance can be detected by the NestMonitorTM (i.e. whether noise and temperature data can be used to determine periods when eggs are exposed) using field observations to measure accuracy;
- Assess the reliability and value of these devices for future Environmental Effects Monitoring (EEM) studies in Labrador;
- Continue evaluating the effects of low-flying aircraft on the behaviour of nesting Canada Geese.

4.0 METHODS

Prior to the start of the field program, research permits were obtained from the Newfoundland and Labrador Department of Wildlife and Conservation, Wildlife Division, and the Canadian Wildlife Service (CWS), Environment Canada.

4.1 Study Team

Mr. Perry Trimper was the Project Manager for this study and was responsible for project design and quality control. Behavioural observations were carried out by a combination of aboriginal and non-aboriginal staff including Mr. Apenam Pone (Innu), Ms. Jennifer Mitchell (Nunatsiavut beneficiary), Ms. Lisa Stepnuk, Mr. Lem Mayo, Mr. Marcel Gahbauer, and Ms. Caroline Hong. NestMonitors™ and AudioMonitors™ were deployed/collected by Mr. Trimper with assistance from Mr. Pone, Ms. Mitchell, Ms. Stepnuk and Mr. Gahbauer. Data analyses and report preparation were the primary responsibility of Ms. Stepnuk and Mr. Gahbauer. In addition, Minaskuat received support from Mr. Frank Riskey at TenXsys throughout the planning stages of this program. Pilots for deployment/collection of eggs and transportation of observers were Mr. Ken Cashin, Mr. Lorne Pike and Mr. Geoff Goodyear of Universal Helicopters Newfoundland and Labrador.

4.2 Health and Safety

Consistent with Minaskuat corporate procedures, a health and safety checklist was completed prior to the start of the field program, and daily last minute risk assessments were reviewed to ensure the Study Team was aware of potential hazards and appropriate Safe Work Procedures.

4.3 Nest Location and NestMonitor™ Deployment

On 1 June 2007, the Study Team performed an aerial search for active Canada Goose nests in the vicinity of the Goose Bay Airport (Minaskuat 2007), focusing on wetland complexes with small islands and dominated by lichen and heathland ground cover, with some stunted black spruce (*Picea mariana*) and tamarack (*Larix laricina*). The majority of nests were identified from the air by the presence of an incubating female, though an adult (presumably the male) in a wetland often alerted the Study Team to the presence of an active nest in the area.

Once an active nest was located, the Study Team landed (at least 200 m from the nest or further depending on the site) and identified a suitable location for observers at a distance of 50-100 m from the nest. As per the issued permits, Mr. Trimper then walked/waded to the active nest and carefully placed one NestMonitor™ amongst the natural clutch. Simultaneously, a blind was assembled at the observer location using black spruce or other trees located in the area, and an AudioMonitor™ was placed on high ground within 50 m of the nest.

All nest locations were recorded on 1:50,000 topographic map sheets using coordinates obtained from a Global Positioning System (GPS). Note that to minimize disturbance, adult geese were not banded or otherwise handled.

4.4 Nest Monitoring

Behavioural observations at the nests began on 3 June 2007, two days following deployment of the NestMonitors™ and AudioMonitors™. All transportation to and from nest sites was by helicopter. Except for two days at nest 4, the female was always on each nest as the field crew arrived. A single observer was positioned at the blind near each nest and equipped with a tripod mounted video camera, binoculars or spotting scope, stopwatch, required safety equipment, and customized data sheets. A digital thermometer was also placed at the observation site, to provide an indication of actual ambient temperature.

Observations typically commenced between 0930–1100 h and ended between 1600-1700 h. depending on weather (note that the Study Team did not travel to the blinds if there was precipitation). Observers focused on activity at the nest, recording any interruptions to incubation, and any other vocal or behavioral responses by the female to overhead aircraft or other potential disturbances. When in sight, the location and behavior of the male were also noted, including any visits to the nest. Consistent with studies in 2005 and 2006, nests were considered protected when one or both adults were in the field of view of the observer and appeared vigilant.

In addition, "noise events", referring to unsolicited aircraft activities in the vicinity of a nest during the observation period, were recorded with the noise level measured or estimated. Aircraft type and direction of travel were also documented, when known. The Study Team returned to the nests to retrieve the Nest and AudioMonitors™ between 12 and 15 June.

4.5 Data Analysis

Data from NestMonitors™ were downloaded to a computer and converted to a form compatible with MSExcel that was used for graphic analysis. Data from AudioMonitors™ were downloaded and converted to a form compatible with Windows Media Player. Audio files were listened to for 900s before and after any obvious temperature drops displayed on the ambient temperature graphs to determine if interruptions in incubation could be associated with an identifiable noise disturbance.

Observed behavioural data were evaluated in relation to aircraft (i.e., noise) events, and were compared with temperature data from the NestMonitors™ to assess the accuracy of the NestMonitors™ to identify changes in attendance behavior by the incubating adult.

5.0 RESULTS

Five active Canada Goose nests were located, within 5 km of the Goose Bay Airport (Table 1). Nests were widely spaced (>500m apart), although suitable nesting sites (i.e., small islands) were abundant within the Study Area. All five nests were located on small islands (Figure 1) within large wetland complexes dominated by heathland ground cover, stunted black spruce and tamarack. Each nest contained between 3 and 6 eggs. The females were generally reluctant to leave the nest, flushing only after Mr. Trimper was as close within 6 m away from the nest. Only at one nest did the female flush due to helicopter activity.

Table 1 Summary of Active Canada Goose Nests, 2007

Nest Code	Latitude	Longitude	Description of Site	# Eggs	Initial Reaction[1]	Distance at Flush[2] (m)	Comments
CAGO1	N53 19.766	W60 19.900	On island, beside clump of black spruce < 50 cm in height	5	Female held	6	Male calling from the west
CAGO2	N53 20.586	W60 14.038	On island beside small larch < 40 cm in height	3	Female held	2-3	Male seen first, later calling from nearby
CAGO3	N53 21.931	W60 26.569	On island	5	Female held	2-3	Male seen first
CAGO4	N53 19.639	W60 31.617	On island, clump of black spruce < 40 cm in height	6[3]	Female held	2	Male not observed
CAGO5	N53 20.276	W60 30.688	On island	4	Female flushed as A/C passed overhead	n/a	Male not observed

[1] Initial Reaction describes the reaction of the female to the helicopter during initial nest surveys.
[2] Distance at Flush is the distance that the Study Team was from the nest when the female flushed, during placement of the NestMonitor[TM] in the nest.
[3] One of these eggs was approximately 40 % smaller than the others

5.1 Behavioural Observations

5.1.1 Nest Attentiveness

Observations at the five nest sites were made over 21 person-days. Of these, there were 14 days when the female remained on the nest the entire period and two days when the female was off the entire observation period. Only on three days were observations made of the attending goose taking breaks from incubation, with six arrivals and four departures from the nest recorded.

Of a total 6,580 minutes of observation, the female was observed on the nest 74.4% of the time, and probably on (visibility from blind at nest 5 was occasionally compromised by position of the female) another 3.5% of the time. Eggs were known to be exposed for at least 17.4% of the time, and likely exposed for another 4.7%. Changes of position by the female while on the nest were considered to be time spent on the eggs, since most had events were less than one minute, and none exceeded three minutes. Also, in most cases the female remained low and continued covering the eggs while she repositioned, such that eggs had minimal exposure to sun or wind.

5.1.1.1 Aircraft Events

All Canada Goose nests monitored in 2007 were within 5 km of the Goose Bay Airport and were therefore exposed to a variety of unsolicited aircraft movements including passenger jets, twin otter and other propeller driven aircraft, float planes, and helicopters. Aircraft were generally in view of the observer, but rarely passed directly (or within 200m) over the nest. The volume of traffic observed at each nest ranged from zero to 33 movements per day, with means throughout the study of 2.2 helicopter and 10.6 fixed wing events per daily.

Despite careful and distant (> 200 m) approaches, geese flushed from the nest on several occasions as the helicopter arrived to deposit the observer and on three days they did not return for the duration of observations (334 to 384 minutes). These absences totaled 1,284 minutes, accounting for 88% of the time spent off the nest. Another 17 minutes (1%) were spent off the eggs in response to a helicopter passing by during the day. The remaining 157 minutes (11%) off the eggs were in response to no apparent stimulus; these absences ranged from 3 to 84 minutes. At no time were geese seen leaving the nest in reaction to the sight or sound of fixed wing or helicopter aircraft (unrelated to this study), or due to natural threats such as predators. Occasionally the incubating adult raised (n=24) or lowered (n=16) its head or looked around (n=9) in response to the passage of an aircraft. However, these reactions were uncommon and usually only in response to the closest and loudest stimuli, as the majority of aircraft movements (n=167) elicited no apparent response at all.

5.1.1.2 Other Threats

No potential predators were documented while observing the nests in 2007. Aside from the aircraft movements, off road motorcycles and vehicles were audible from some nest sites, and explosive blasts from construction work at the airport could also be heard. The geese exhibited no reaction to these stimuli, except for three occasions when the goose looked toward the road when a loud truck passed by. The blasts elicited a stronger response, with the head lowered in response to three of them, raised in two other cases, and only one instance where it appeared to be ignored.

5.1.1.3 Observer Effects

Time spent off the nest is summarized by day (Table 2). The strongest reaction to disturbance was on the first day, when three of the five nests were unoccupied for part of the day. Two of the geese that spent time off the nest on the first day did not leave the nest again on subsequent days. However, the females at nests 4 and 5 were absent for all of the second day, and at nest 4 also all of the third day. By the fourth day of observation, none of the geese were spending any time off the nest. Note that when NestMonitors™ were deployed on 1 June four of the incubating adults held tight to the nest and did not flush until a member of the Study Team approached within 6 m of the nest.

Table 2 Time Spent off the Nest by Incubating Canada Geese at Each Nest

	Time spent off nest (minutes / % of daily observations)				
	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5
Day 1	148 / 51%	0 / 0%	159 / 52%	76 / 24%	0 / 0%
Day 2	0 / 0%	0 / 0%	0 / 0%	384 / 100%	334 / 100%
Day 3	0 / 0%	0 / 0%	0 / 0%	357 / 100%	0 / 0%
Day 4	0 / 0%	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Day 5	0 / 0%	n/a	n/a	n/a	n/a

Note: for this table, "probably on" was considered on, and "probably off" was considered off.

5.1.2 Timing of Nesting/Nest Status

Prior to the end of the field program, eggs in at least two nests had hatched. Hatch dates and/or the status of the nests when NestMonitors™ were retrieved on 13 June were estimated (Table 3).

Table 3 Estimated Hatch Dates and/or Nest Status of Canada Geese Monitored During 2007

Nest Code	Estimated Hatch Date	Status on Last Visit
CAGO1	Unknown	Female flushed (at 3 m) from 5 unhatched and warm eggs in nest at 1700 hrs, 14 June.
CAGO2	Unknown	Female flushed (at 2-3 m) from 6 unhatched and warm eggs in nest at 1630 hrs., 14 June.
CAGO3	Unknown	Pair near nest upon arrival, 5 unhatched and warm eggs at 0810 hrs, 15 June.
CAGO4	10-11 June	Confirmed at least 4 eggs hatched (i.e., yolk sacs present), note NestMonitor™ was missing
CAGO5	Possibly 12 June	Female on nest at 1215 hrs on 12 June; pair near nest (with down 'blanket' in place) then flew away at 1700 hrs, 13 June; pair present, NestMonitor™ missing and no evidence of yolk sacs at 1710 hrs., 14 June

5.2 NestMonitors™

NestMonitors™ were recovered from Nests 1, 2 and 3 while the remainder could not be found at the end of the study and are suspected of having been predated. Table 4 summarizes the data collected from the three NestMonitors™ and five AudioMonitors™ retrieved.

For unknown reasons, there were no subject temperature data on the SD card for the NestMonitor™ at nest 3. The waveform files from all the AudioMonitors™ recorded only wind noise. Several hundred files were checked including those at known helicopter drop-off and pick-up times but no aircraft noise could be heard even at those times. From what was audible, wind appeared to trigger all recordings. Therefore the AudioMonitors™ could not be used to verify whether drops in NestMonitor™ temperatures potentially indicating an interruption to incubation corresponded with aircraft activity, leaving such associations possible only for times when observers were present.

Table 4 Data Available from NestMonitors™ and AudioMonitors™

Nest	NestMonitor™ Status	NestMonitor ™ Data	AudioMonitor™ Status	AudioMonitor™ Data
CAGO1	Retrieved 14 June	Continuous data from 1-14 June	Retrieved 14 June	Audio files recorded wind noise only, no aircraft data found
CAGO2	Retrieved 14 June	Continuous data from 1-14 June	Retrieved 14 June; Contained water when opened	No files on SD card after first four days; Audio files recorded wind noise only, no aircraft data found
CAGO3	Retrieved 15 June	Continuous data from 1-15 June, but only ambient temperature	Retrieved 15 June	Audio files recorded wind noise only, no aircraft data found
CAGO4	NestMonitor™ not located on 12 June	Unknown	Retrieved 12 June	Audio files recorded wind noise only, no aircraft data found
CAGO5	NestMonitor™ not located on 14 June	Unknown	Retrieved 14 June	Audio files recorded wind noise only, no aircraft data found

All incubating geese were displaced from the nest when adding the NestMonitor™ to their clutch. Temperature data suggest that incubation resumed within 20 minutes at nest 1 (Figure 1) and nest 2 (Figure 2), as that is when temperature began to increase toward a plateau. No such increase was observed during the first two hours at nest 3 (Figure 3), suggesting the female may have rejected the NestMonitor™ from the outset.

Figure 1 Temperatures Recorded at Nest 1 within Two Hours of NestMonitor™ Deployment

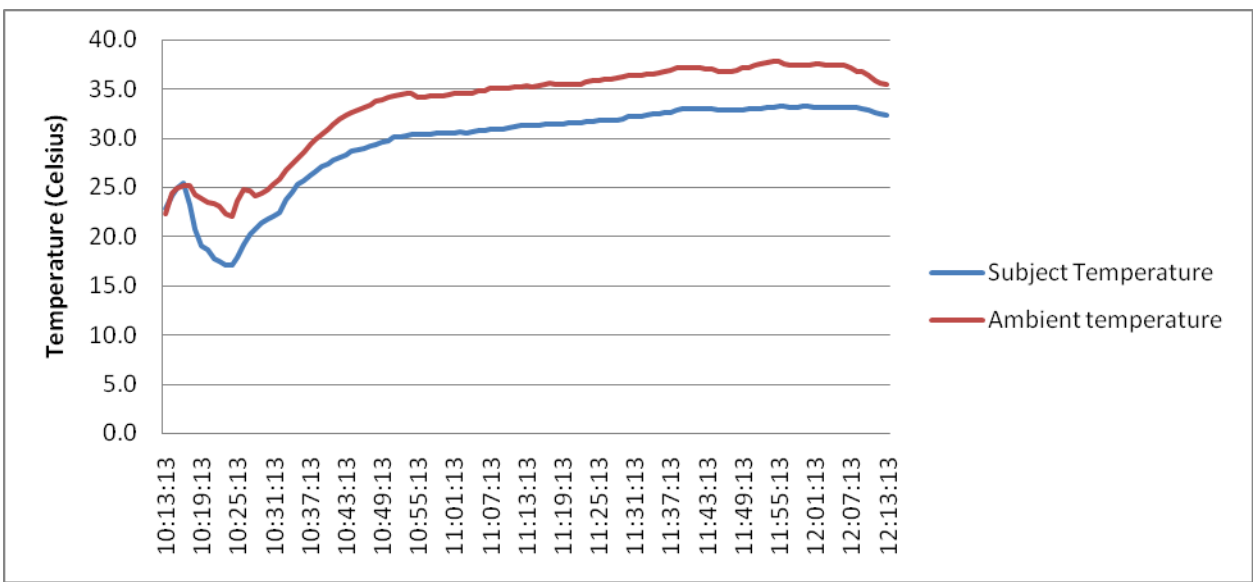


Figure 2 Temperatures Recorded at Nest 2 within Two Hours of NestMonitor™ Deployment

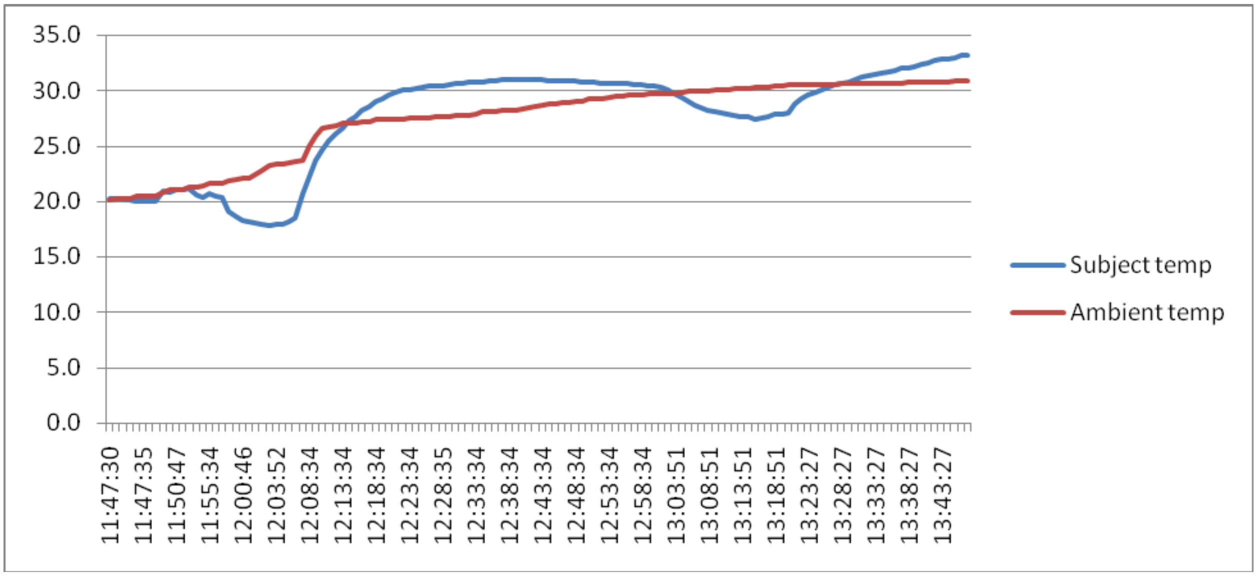
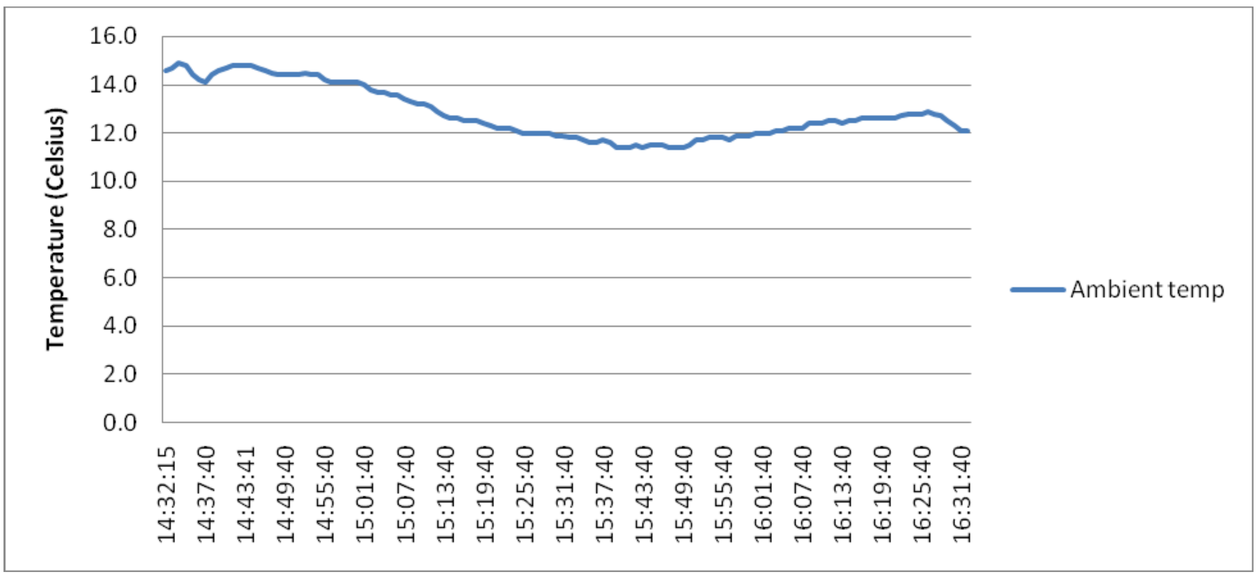


Figure 3 Temperatures Recorded at Nest 3 within Two hours of NestMonitor™ Deployment



5.2.1 Temperature Data

Subject Temperature data recorded in the nests varied on a daily basis (Table 5). At nest 1, the lowest mean temperature (31.3 ± 1.7˚C) was recorded on the first day of observations, corresponding to this being the only one of five observation days that the female spent time off the nest; the mean temperatures on the other four days were consistent, ranging only from 36.8 ± 1.5˚C to 37.5 ± 0.2˚C. At nest 2, the goose remained on the nest all four days, and the mean temperatures were also consistent, and similar to those at nest 1, ranging from 36.1 ± 0.8˚C to 37.1 ± 1.4˚C. The standard deviation and range of temperatures recorded are much greater for nest 3, as that NestMonitor™ appeared to have been abandoned and exposed to the elements, while the others were being incubated as part of the natural clutch.

Table 5 Summary of NestMonitor™ Temperature Data Collected at Canada Goose Nests, 1-15 June 2007, Temperatures ± SD (range)

Nest	Data	Overall Average	Observation Day 1	Observation Day 2	Observation Day 3	Observation Day 4	Observation Day 5
CAGO1	*Subject (˚C)*	35.1 ± 3.4 (12.9-41.4)	31.3 ± 1.7 (28.8-34.2)	37.3 ± 0.7 (35.9-38.4)	37.5 ± 0.2 (36.9-37.8)	36.8 ± 1.5 (28.3-37.7)	37.4 ± 1.1 (34.1-40.3)
	Ambient (˚C)	35.6 ± 3.1 (18.4-41.3)	31.9 ± 4.0 (26.9-37.4)	37.0 ± 1.5 (34.0-38.9)	37.1 ± 0.2 (36.6-37.4)	37.3 ± 1.5 (29.7-38.2)	38.6 ± 0.7 (36.8-39.8)
CAGO2	*Subject (˚C)*	35.9 ± 1.6 (17.8-39.0)	36.1 ± 0.8 (34.4-37.5)	37.1 ± 1.4 (34.6-38.4)	36.1 ± 0.8 (34.6-37.7)	36.8 ± 0.2 (35.9-37.0)	---
	Ambient (˚C)	36.8 ± 1.4 (20.1-39.9)	37.2 ± 0.6 (35.9-38.1)	37.0 ± 0.4 (35.9-37.6)	37.7 ± 0.5 (36.3-38.2)	37.8 ± 0.3 (37.2-38.2)	---
CAGO3	*Subject (˚C)*	---	---	---	---	---	---
	Ambient (˚C)	15.7 ± 12.0 (-4.6-47.7)	20.2 ± 3.7 (14.7-31.3)	34.6 ± 4.9 (21.9-41.5)	22.6 ± 2.1 (18.5-27.3)	22.6 ± 1.7 (18.3-25.3)	---
CAGO4	*Subject (˚C)*	---	---	---	---	---	---
	Ambient (˚C)	---	---	---	---	---	---
CAGO5	*Subject (˚C)*	---	---	---	---	---	---
	Ambient (˚C)	---	---	---	---	---	---

Note: "---" indicates data not available. Subject refers to core temperature and ambient surface temperature of the NestMonitor™

5.2.1.1 Temperature Patterns Throughout the Study Period

The ambient temperature fluctuated irregularly at nest 1 (Figure 4), reflective of natural variation in temperature as a result of periodic interruptions to incubation. The pattern recorded at nest 2 (Figure 5) indicated a constantly increasing ambient temperature throughout the two-week study period, which is highly unrealistic and suggests a problem with the sensor. At the other extreme, the NestMonitor™ at nest 3 recorded substantial fluctuations on a daily cycle, with temperatures at night dropping to between -4 and 11 Celsius, and daily highs ranging from 25 to 47 Celsius (Figure 6). Such a pattern suggests that the egg was ejected from the nest and exposed to natural variation in temperature, accurately reporting low temperatures at night, and registering inflated daily highs when exposed to the sun in the afternoon. However, this NestMonitor™ was found among the natural clutch of eggs upon retrieval on 15 June.

Figure 4 Ambient Temperature at Nest 1 Throughout Period of NestMonitor™ Deployment

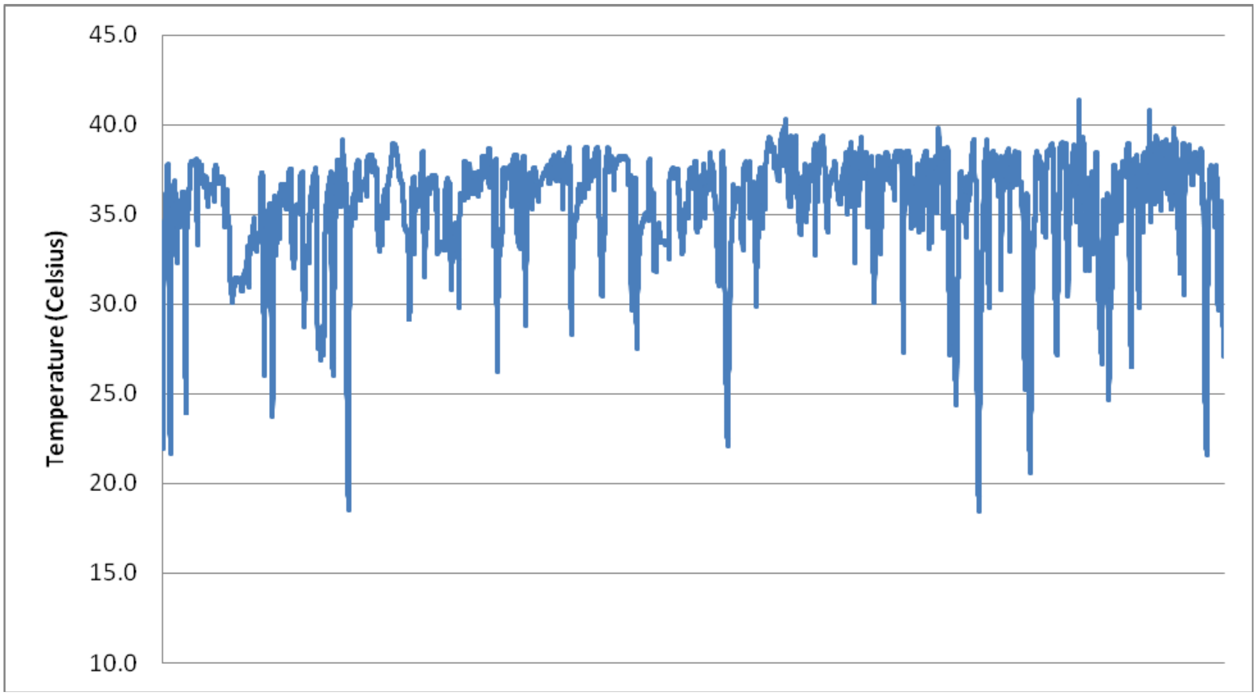


Figure 5 Ambient Temperature at Nest 2 Throughout Period of NestMonitor™ Deployment

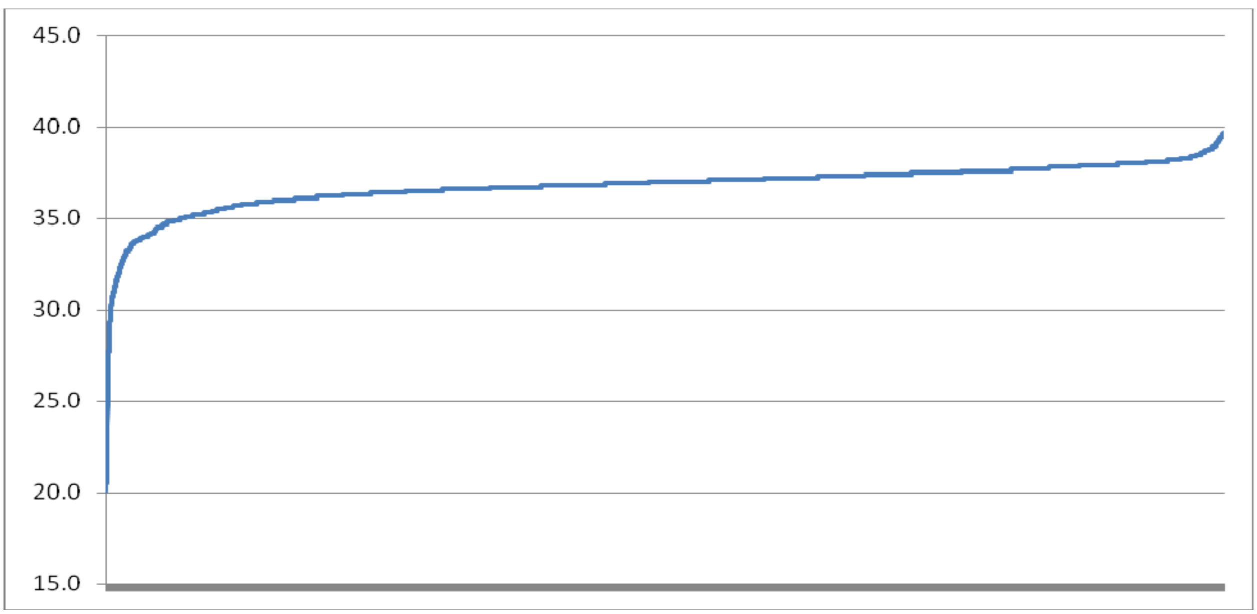
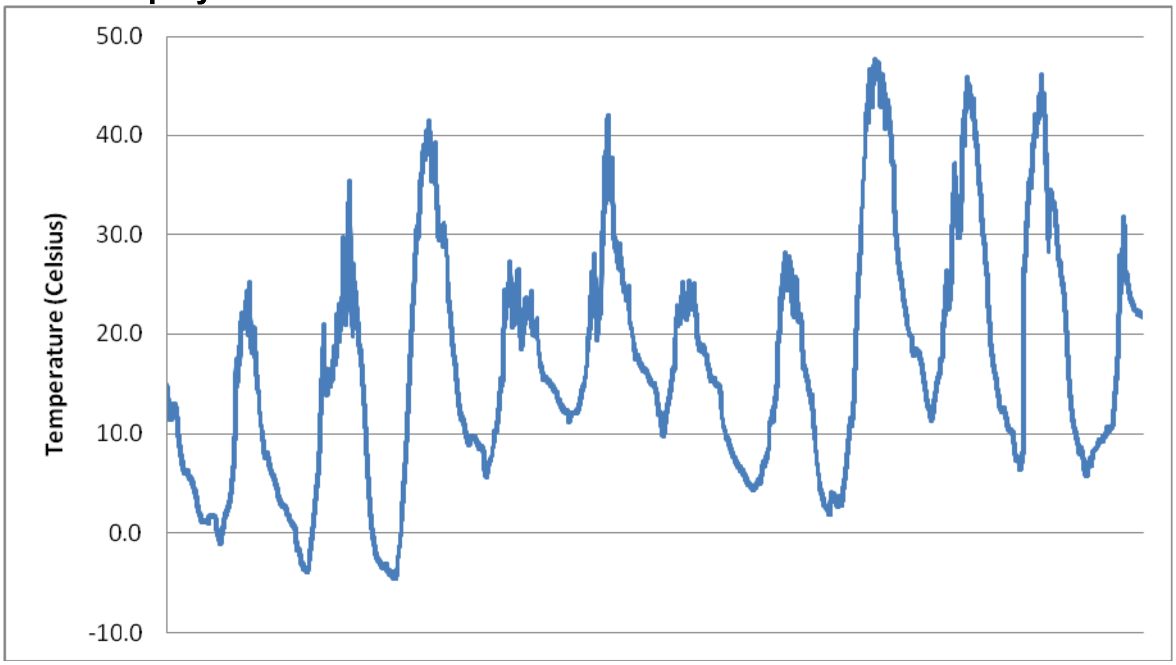


Figure 6 Ambient Temperature at Nest 3 Throughout Period of NestMonitor™ Deployment



Subject temperature at both nest 1 (Figure 7) and nest 2 (Figure 8) fluctuated irregularly throughout the study period, in a pattern largely similar to that shown for ambient temperature.

Figure 7 Subject Temperature at Nest 1 Throughout period of NestMonitor™ Deployment

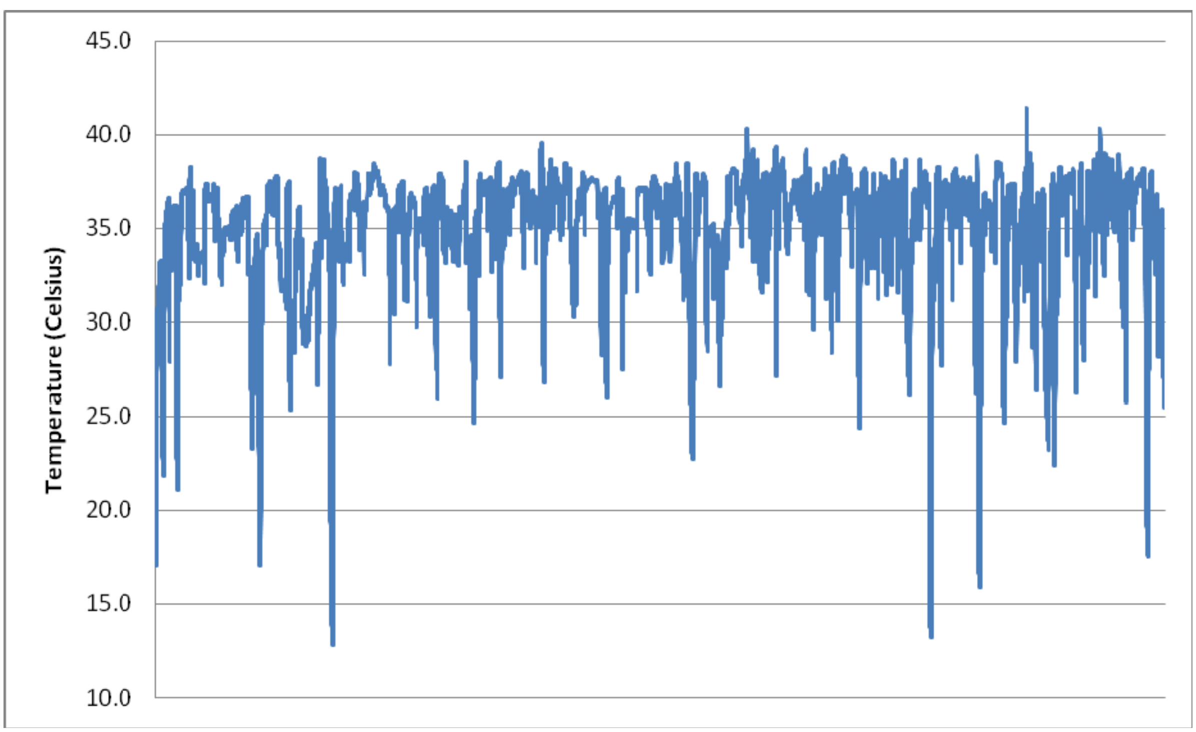
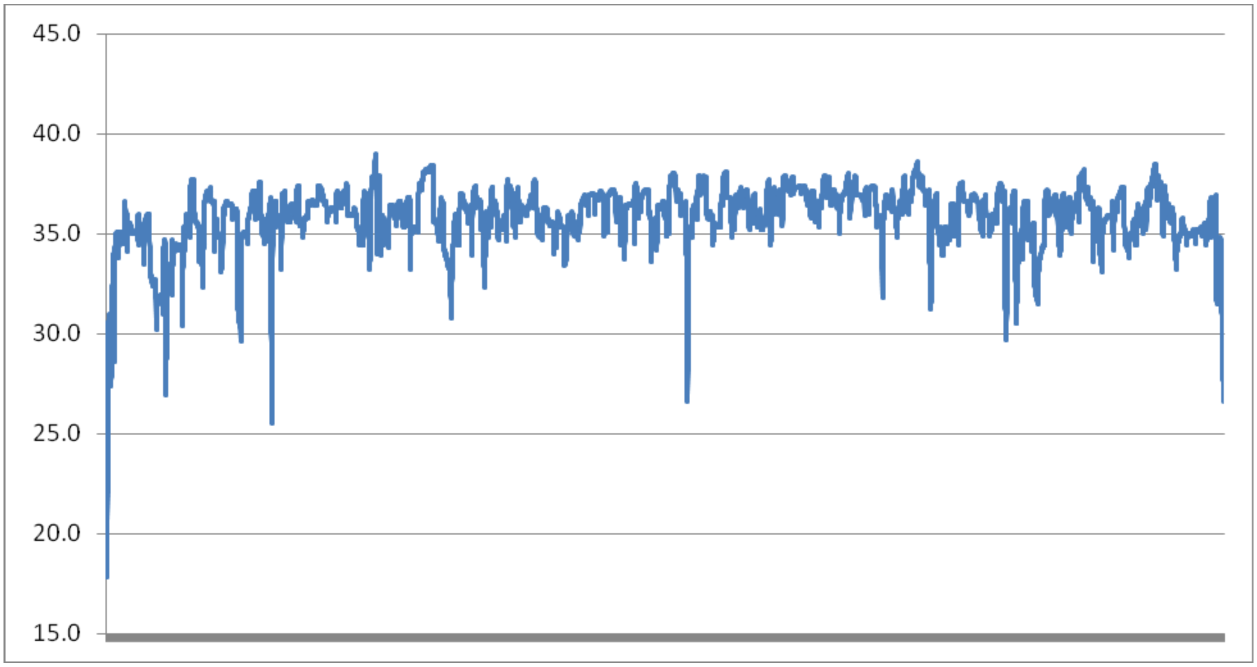


Figure 8 Subject Temperature at Nest 2 Throughout Period of NestMonitor™ Deployment



5.2.2 Noise Data

Noise data [decibel (dB) levels] were collected from the AudioMonitors™ every 60 seconds. In addition, sounds greater than or equal to 95dB triggered a 10s audio recording, with information transferred to a data storage card. As with the NestMonitors™ in 2006 (Minaskuat 2007), the sensitivity and clarity of the data was such that the Study Team found the devices could easily record conversations.

However, the AudioMonitors™ were extremely sensitive to proximate sounds and in particular the effects of the wind. Numerous audio files (10 second sound recordings) were recorded on a daily basis from a location within 50 m of the nest. Unfortunately, wind appeared to serve as the stimulus for all files during the observations. No aircraft sounds were detected until the devices were collected in the field (note that they were not activated until they were placed near the nest, an area that was avoided by the Study Team). Unlike the noise sensors in the NestMonitors™ in 2006, the AudioMonitors™ appeared to only capture proximate sounds such as wind moving through ground vegetation.

5.2.3 Nest Data vs. Observer Data

5.2.3.1 Temperature and Incubation Breaks

Temperature Changes During Observed Recess Periods

Recess periods, or time spent away from the nest by the female, are a typical element of the incubation process. A comparison between recorded temperatures and observed behavior was possible only for nests 1 and 2, as the NestMonitors™ at nests 4 and 5 were not retrieved, and the data from the NestMonitor™ at nest 3 indicated that it was ejected from the nest. As the female remained on the nest throughout the four days of observation at nest 2 (i.e. no observed recesses), there were no data with respect to temperature changes during recess periods. Conversely, the consistent temperature values during those four days were indicative of properly functioning equipment. Relevant data from nest 1 were restricted to the first day of observation, when the female remained off the nest for the first 44 minutes, and took an additional three recesses later in the day.

Three departures from nest 1 were observed (Table 6). Both subject and ambient temperature increased slightly during the first five minutes of the recess. In the first instance, ambient temperature registered a drop after ten minutes and subject temperature after twenty minutes; later in the day both started to drop again after ten minutes. However, neither subject nor ambient temperature deviated more than 0.5 Celsius from what they were at the time of departure, and such a change is well within the natural range of variation observed throughout the day while incubation was occurring.

Table 6 Temperatures Before and After the Onset of Recesses by Incubating Canada Geese

Nest	Date / Time	Temperature (subject / ambient)					
		5 min before	At departure	3 min after	5 min after	10 min after	20 min after
1	3 Jun 1154	29.6 / 28.1	29.8 / 28.2	29.8 / 28.3	29.9 / 28.6	30.2 / 28.4	29.9 / 27.8
1	3 Jun 1327	30.4 / 28.5	30.9 / 29.0	31.1 / 29.3	31.4 / 29.5	31.2 / 29.1	n/a
1	3 Jun 1345	n/a	31.5 / 33.5	31.8 / 34.0	n/a	n/a	n/a

n/a – the goose was back on the nest before this time had elapsed, or was on a previous recess

Three returns to the nest were also observed (Table 7). In two cases, both subject and ambient temperature increased gradually over a period of 10–20 minutes. In the other, the goose remained on the nest for only nine minutes, and both temperatures dropped during this period.

Table 7 Temperatures Before and After the End of Recesses by Incubating Canada Geese

Nest	Date / Time	Temperature (subject / ambient)					
		5 min before	At arrival	3 min after	5 min after	10 min after	20 min after
1	3 Jun 1144	29.1 / 27.7	29.3 / 27.9	29.5 / 28.0	29.6 / 28.1	29.8 / 28.2	n/a
1	3 Jun 1318	30.1 / 28.5	30.8 / 28.7	30.4 / 28.3	30.4 / 28.6	n/a	n/a
1	3 Jun 1348	31.3 / 32.6	31.8 / 34.0	32.0 / 34.5	32.0 / 34.7	32.0 / 35.0	32.1 / 35.4

Other Temperature Changes During Periods of Observation

For nest 1 and nest 2, where the NestMonitor™ complemented observations, the temperature plots were explored for significant changes, defined as an increase or decrease of at least 0.5 Celsius within a span of 15 minutes or less. A total of 10 increases and 22 decreases met these criteria (Table 8). Two increases and nine decreases were short-term in nature, lasting less than ten minutes, and with temperature changes of two degrees Celsius or less. Greater temperature changes were recorded for patterns that persisted at least 15 minutes, ranging from a decrease of 6.5 degrees to an increase of 7.4 degrees. While most changes were relatively gradual, there were two increases and seven decreases during which the rate of change was at least 0.5 degrees per minute over the first three minutes.

Table 8 Significant Temperature Changes recorded by the NestMonitors™ at Nests 1 and 2 during Periods of Observation

Nest	Date	Time	Change	Air Temp	Initial Temp	Temperature change after:				Observed Behaviour
						1 min	3 min	10 min	15 min	
1	3 Jun	1106	-	10	33.9	-0.7	-1.7	-3.4	-4.1	Already off nest
1	3 Jun	1208	-	10	30.3	-0.1	-0.3	-1.2	-1.4	Already off nest
1	3 Jun	1233	-	10	30.3	-0.1	-0.2	-1.2	-1.3	Already off nest
1	3 Jun	1305	+	10	29.1	-0.1	+0.3	+1.2	+1.4	Returned to nest
1	3 Jun	1336	-	11	31.3	-0.1	-0.9	n/a	n/a	Left nest
1	3 Jun	1339	+	11	30.4	+0.5	+0.8	+1.5	+1.6	Returned to nest
1	3 Jun	1543	-	14	34.1	-0.3	-1.1	-4.7	-6.5	Left (crew pickup)
1	4 Jun	1435	-	19	36.8	-0.1	-0.1	-0.3	-0.5	On eggs (no change)
1	7 Jun	1331	-	19	37.5	-0.6	-1.9	n/a	n/a	On eggs (no change)
1	7 Jun	1433	-	19	36.3	-1.1	-3.3	-5.6	n/a	Standing up
1	7 Jun	1446	+	18	28.3	+1.5	+3.7	+6.6	+7.4	Sitting back down
1	9 Jun	1159	-	23	38.1	-0.8	-1.8	n/a	n/a	Change of position
1	9 Jun	1257	-	29	36.8	-0.1	-1.5	n/a	n/a	Standing up
1	9 Jun	1300	+	29	35.3	+0.5	+1.2	n/a	n/a	Sitting back down
1	9 Jun	1306	-	29	37.2	-0.4	-1.5	n/a	n/a	On eggs (no change)
1	9 Jun	1334	-	29	35.6	-0.1	-0.5	-1.5	n/a	On eggs (no change)
1	9 Jun	1344	+	29	34.1	+0.3	+1.2	+2.8	+3.3	Change of position
1	9 Jun	1417	-	30	37.9	-0.1	-0.7	n/a	n/a	Change of position
1	9 Jun	1448	+	30	37.7	+0.1	+0.9	n/a	n/a	Standing up
1	9 Jun	1451	-	30	38.6	-0.9	-1.3	n/a	n/a	Sitting back down
1	9 Jun	1458	+	30	37.2	+0.4	+0.9	+2.5	+2.9	On eggs (no change)
2	4 Jun	1159	-	20	37.3	-0.5	-0.8	-1.2	-1.4	On eggs (no change)
2	4 Jun	1436	-	20	36.0	-0.1	-0.2	-0.6	-0.6	On eggs (no change)
2	4 Jun	1526	-	20	35.2	-0.4	-0.6	-0.8	-0.8	On eggs (no change)
2	5 Jun	1343	-	19	38.4	-0.4	-2.1	-2.6	-2.6	On eggs (head raised)
2	6 Jun	1121	-	n/a	35.9	-0.3	-0.7	-1.1	n/a	On eggs (no change)
2	6 Jun	1131	+	n/a	34.8	+0.6	+1.5	+2.5	+2.7	On eggs (no change)
2	7 Jun	1104	-	20	36.9	-0.1	-0.4	-0.5	-0.5	On eggs (head raised)
2	7 Jun	1153	-	19	36.5	-0.6	n/a	n/a	n/a	Standing up
2	7 Jun	1155	+	19	35.9	+0.2	+0.5	+0.9	+1.0	Sitting back down
2	7 Jun	1358	-	17	36.9	-0.5	n/a	n/a	n/a	On eggs (no change)
2	7 Jun	1400	+	17	36.0	+0.2	+0.4	+0.7	+0.8	On eggs (no change)

Recorded changes in temperature were cross-referenced with behavioural observations. In 12 instances, the goose remained incubating throughout the period of change with no change in behaviour observed; in another two cases the only movement visible was raising of the neck/head in response to a passing aircraft. Despite this, the temperature recorded by the NestMonitor™ changed by as much as 2.9 degrees Celsius over 15 minutes (e.g. at 1458 in Figure 9), and as rapidly as 2.1 degrees in 3 minutes (e.g. at 1343 in Figure 10).

In several cases, behavioural observations agreed closely with the NestMonitor™ data. On the two occasions that a goose returned to the nest after time off, a modest increase of 1.4 to 1.6 degrees was recorded after 15 minutes (e.g. at 1305 and 1339 in Figure 11). There were also four cases documented of the goose standing up and subsequently sitting down again, without leaving the nest. In three of these, the temperature recorded by the NestMonitor™ dropped when the goose stood up and rose again after it resettled on the eggs (e.g. at 1433 and 1446 in Figure 12), but in one case the reverse pattern was observed (at 1448 and 1451 in Figure 9).

Of the nine cases where temperatures changed rapidly, at a rate of at least 1.5 degrees over three minutes, there were four when the goose appeared to be incubating the whole time without changing position, and another when the goose was off the nest the whole time. The remaining four incidents corresponded to times when the goose was observed standing and then quickly sitting back down on the eggs. Rapid and significant decreases occurred even when air temperature was fairly warm. For example, the greatest drop recorded was 8.0 degrees in 13 minutes in mid-afternoon on June 7, when the air temperature was 18 Celsius (see 1433 to 1446 in Figure 12). On that occasion, the temperature dropped 3.3 degrees in the first three minutes, yet at 1336 on June 3, when the air temperature was only 11 Celsius, the subject temperature declined by only 0.9 degrees in the first three minutes after the goose left the nest.

Figure 9 Subject Temperatures recorded in Canada Goose Nest 1 (CAGO 1), 9 June 2007

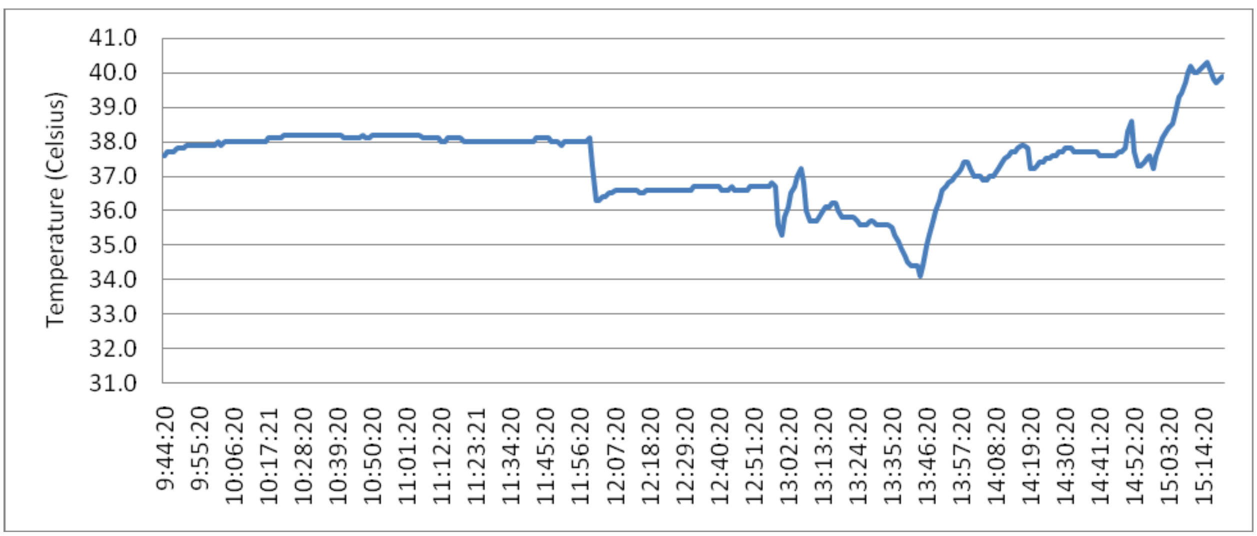


Figure 10 Subject Temperatures Recorded in Canada Goose Nest 2 (CAGO 2), 5 June 2007

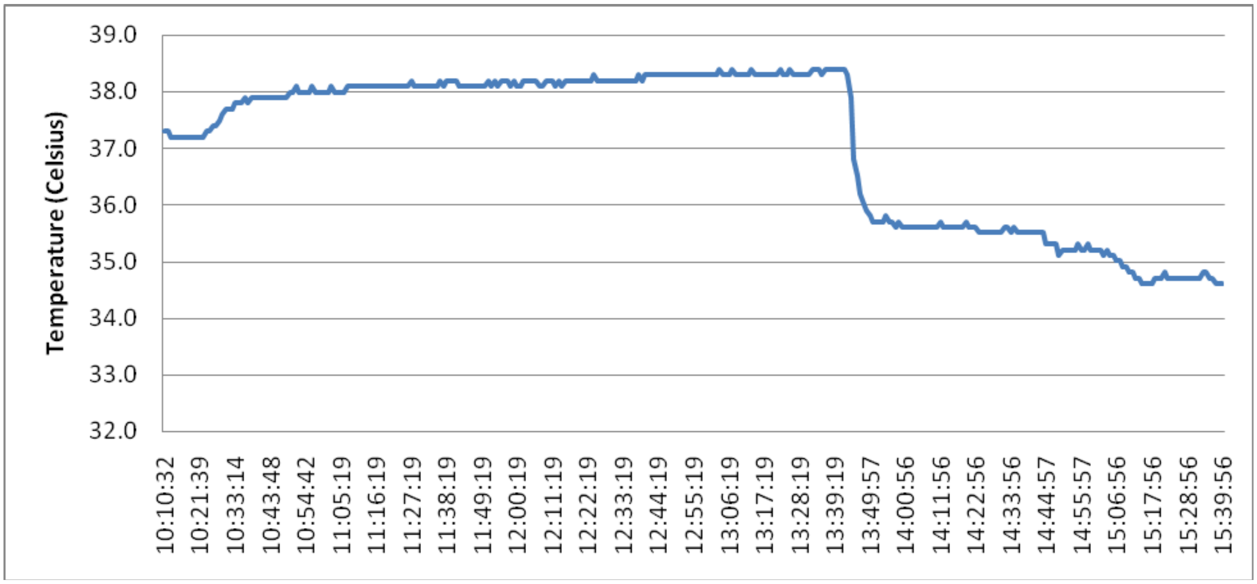


Figure 11 Subject Temperatures Recorded in Canada Goose nest 1 (CAGO1) 3 June 2007

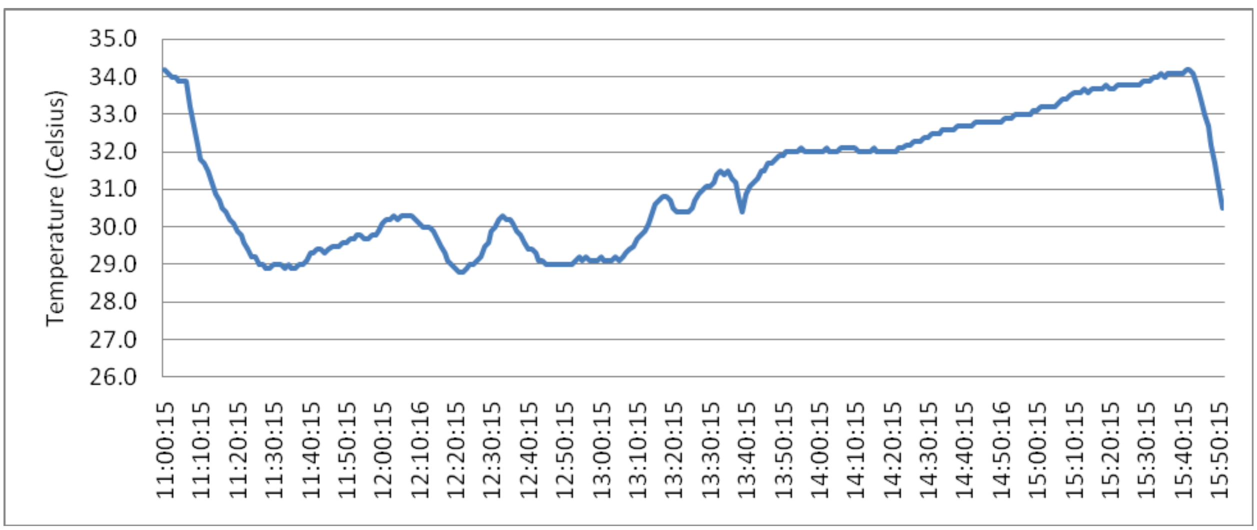
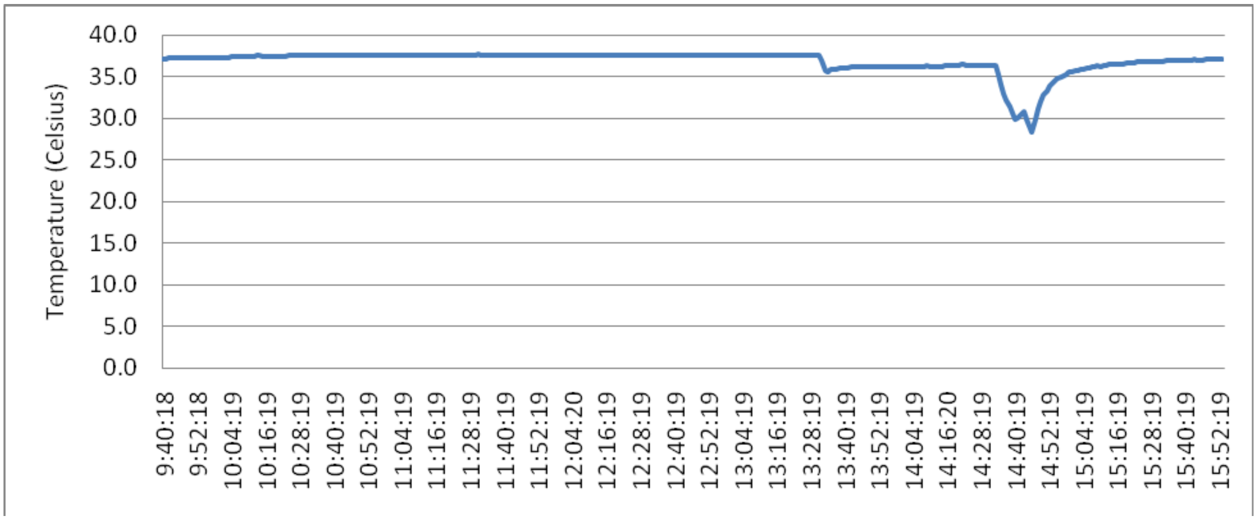


Figure 12 Subject Temperatures Recorded in Canada Goose nest 1 (CAGO1), 7 June 2006



The internal clocks on two of the three electronic boards recovered were out of sync with standard time by a consistent amount, one by 1.5 minutes, and the other by 10 minutes. This offset was corrected when matching NestMonitor^{TM} data with behavioural observations. However, this should be noted for future use.

5.2.3.2 Noise (dB) Level and Aircraft Events

Aircraft events recorded during observation sessions included helicopter (during drop-offs and other incidental events), twin otter, passenger jet and float plane. As indicated in Section 5.2.2, the AudioMonitors^{TM} did not reveal any peaks in dB levels corresponding to such events.

6.0 DISCUSSION

6.1 Measurement of Temperature at the Nest

Of the three NestMonitors^{TM} retrieved and analyzed, only one reported values for both ambient and subject temperature that appeared to be accurate. A second unit recorded both, but the ambient temperature data were clearly flawed as they steadily increased throughout the study, and on the third, ambient temperatures appeared realistic, but no subject temperatures were recorded. However, fewer such problems were reported during the 2006 field testing on Bald Eagle, Osprey, and Canada Goose (Minaskuat 2006).

Subject temperatures recorded by the NestMonitors^{TM} were generally consistent over the long term, and the means at nests 1 and 2 over the full period of study were close to the high end of the range (31.7 – 36.1 Celsius) reported by others (Huggins 1941, Webb 1987). However, during breaks in incubation (i.e. recesses) the subject temperature dropped to as low as 28.3 Celsius. There was no consistent pattern relating the rate of subject temperature change to air temperature, with some changes at cooler temperatures occurring far more slowly than others during mild conditions. Such discrepancies may reflect micro-site differences to wind and/or sunlight that could not be recorded by observers.

While the NestMonitors™ recorded many subtle temperature changes within the nest bowl, these did not necessarily correspond with changes in behavior. As expected, some of the larger changes in temperature coincided with departures from or returns to the nest, but several changes of similar intensity and pace occurred during periods when the goose appeared to be incubating without any change in position. At other times, temperature fluctuations of more than 1 degree over ten minutes occurred in the midst of periods when the goose was off the nest, reflecting the sensitivity of the nest microclimate to factors such as wind and direct sunlight. Therefore the present NestMonitor™ data cannot be used in isolation as a reliable predictor of incubation behavior, as they suggest more frequent breaks in incubation than actually occur.

In the 2006 study, rapid decreases in temperature were not recorded (Minaskuat 2006), an observation explained by the fact that embryonic heat production facilitates heating while retarding cooling (White and Kinney 1974, Poussart *et al.* 2000). However, there were several instances during the 2007 study when subject temperature declined suddenly and rapidly, even while incubation was occurring. Possible explanations include the NestMonitor™ being on the outside of the clutch of eggs on these occasions, and/or infertility of one or more adjacent eggs [although note that all natural unhatched eggs appeared viable (warm) when monitors were collected].

6.2 Measurement of Noise Near the Nest

Previous studies (Minaskuat 2006) using the NestMonitor™ to record aircraft noise yielded poor results, as aircraft events could not be detected in the data. It was speculated that distal noise such as that generated by aircraft was offset by proximate noise generated within the nest, such as abrasion on the surface of the device by slight movements of the incubating female, and/or that the sound of aircraft was muffled by the goose when incubating. To eliminate this confounding factor, a separate AudioMonitor™ was deployed away from the nest in 2007. However, once again the data files showed no peaks in decibel levels corresponding to aircraft events, even on occasions that observers noted flights to be particularly loud. While wind could account for the high level of background noise on some days, the decibel level was consistently high even on calm days. The Study Team has previously encountered this problem of overly sensitive noise monitoring equipment, during a study on the Naskaupi River in 1996 yielding many sound files triggered by the calls of nearby songbirds (Trimper *et al.* 1998b). However, such triggers were not noted during the 2007 goose study, and it is unclear why the noise levels recorded were so consistently loud. Unfortunately, it must be concluded that the AudioMonitors™ in their current configuration are not useful for identifying distinct noise events in the field.

6.3 Behaviour of Nesting Canada Geese

As expected (Lessells 1986, Mowbray *et al.* 2002, Minaskuat 2006), most of the Canada Geese in this study readily accepted the NestMonitor™ as part of their natural clutch. As the device was introduced, incubating females often held until an observer was within 10 m, consistent with Greater Snow Geese

(Poussart *et al.* 2000) later in their incubation period. Upon retrieval, the device was arranged with the natural eggs, except at the one nest where the female rejected the NestMonitor™ from the outset.

During observation periods, geese were incubating at least 74% of the time, and possibly as much as 83%, if they were on eggs during times when incubation status was uncertain. This is lower than the 94% of time spent on the nest during studies in 2004 and 2005 (Minaskuat 2005), but similar to the 77% recorded during the NestMonitor™ trials in 2006 (Minaskuat 2006). As in 2006, the majority of the time spent off the eggs was in response to the helicopter dropping off observers, especially on the first day of observations. Other aircraft movements accounted for only 1% of the time spent off eggs in 2006, but did not appear to cause any breaks from incubation in 2007.

Canada Geese monitored during this program seemed aware but largely tolerant of the presence of observer. However, on some occasions they were displaced from the nest when the helicopter dropped off the observer, and remained absent for periods of up to several hours. In such instances it was impossible to determine to what extent their return was delayed by the presence of the observer, but it is likely to have exacerbated the situation, given that all females held firm during egg deployment, yet several stayed away for extended periods on the first day the observer was present. This is reinforced by data showing that time spent off the nest by the geese was greatest on the first day of observation, as was the case in each of the previous three years of study (Minaskuat 2004b, 2005b, 2006). In all cases, once the goose was back on the nest, no activities by the observer were ever noticed to elicit any response from it. Strong reactions to the presence of a hovering helicopter during drop-off of observers were also observed in 2004-2005 (Minaskuat 2004b, 2005b).

In past years, the Study Team has documented a variety of natural stimuli that elicited a behavioural response from incubating geese (Minaskuat 2004b, 2005b, 2006). Reactions were strongest to mammalian predators such as fox, but were also observed in response to the presence of gulls, ravens, and other geese. However, no such behavior was documented in 2007.

7.0 SUMMARY AND CONCLUSIONS

1. Temperatures recorded within the nest by the NestMonitor™ were consistent with those reported in other incubation studies, but the data series needed to be screened initially as some sensors did not record properly.

2. The AudioMonitor™ failed to distinguish and record aircraft movements, and therefore yielded no information about possible links between such disturbances and nesting behaviour. The threshold of sensitivity may need to be raised further to isolate individual noise events or the unit designed to be less sensitive to proximate sounds.

3. The NestMonitor™ was readily accepted as part of the 'natural' clutch at four of the five Canada Goose nests, but appeared to be immediately rejected at one for the first time in two years and 10 nests of deploying these devices.

4. The NestMonitor™ immediately recorded noticeable temperature changes in response to some changes in goose position, but at other times indicated increases or decreases of similar intensity and rate despite the position of the goose remaining unchanged. Therefore the NestMonitor™ data alone cannot reliably predict periods during which the eggs are exposed.

5. With some further refinement to the sensors, the NestMonitor™ and AudioMonitor™ have the potential to be of great use to future Environmental Effects Monitoring studies in Labrador. The longevity of the battery, high storage capacity, ease of deployment and retrieval, and high rate of acceptance by the subject are all attractive features. The ability of the monitors to collect data around the clock for extended periods provides a distinct advantage compared to traditional methods dependent on human observers. The challenge will be to refine the AudioMonitor™ so that it filters out background noise and consistently records distal sounds such as aircraft, and to adjust the sensitivity of the NestMonitor™ to more accurately reflect the presence/absence of an incubating adult. Further field testing will be required to ensure that NestMonitor™ and AudioMonitor™ data have a sufficiently high rate of agreement with data recorded by human observers.

6. Behavioural observations suggested a high level of tolerance by nesting Canada Geese to low-flying aircraft, as only helicopters landing in the vicinity of the nest site stimulated them to leave the nest, and most others elicited no visible reaction at all.

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