JACQUES WHITFORD PROJECT # NFS11094
MINASKUAT PROJECT MIN110

RESPONSE OF MOULTING BLACK DUCKS TO JET AIRCRAFT ACTIVITY PRELIMINARY INVESTIGATION

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RESPONSE OF MOULTING BLACK DUCKS TO JET AIRCRAFT ACTIVITY - A PRELIMINARY INVESTIGATION

PREPARED FOR

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EXECUTIVE SUMMARY

In June and July, 2002, Jacques Whitford conducted a pilot study to investigate heart rate response in moulting Black Ducks (*Anas rubripes*) to jet aircraft activity within the military Low-level Training Area (LLTA) at Lac Fourmont, Labrador. From 15 male Black Ducks captured and released in the field, the study team was able to monitor 10 individuals fitted with heart rate monitors during a series of military aircraft events. Twenty-four aircraft noise events were recorded while monitoring six telemetered black ducks. Maximum estimated and modeled noise exposures to each telemetered duck being monitored ranged from 55-120+ dB. Based on a review of all data, including those instances when inadequate sample of heart rate vlues either before or following a noise event occurred, there were occasions when reactions were suggestive of a 'startle effect'. An additional five noise events occurred when non-telemetered black duck were visible but no overt reaction or change in activity was detected. Black ducks were rarely observed after the water level at Lac Fourmont increased dramatically during 9-10 July.

In a previous draft report outlining the results (August 2003), heart rate data was assessed as untransformed pulse periods using autocorrelation, spectral, and runs analyses. The outcome of the analyses was that the results were inconclusive given the available data. Following the receipt of two peer reviews of the draft report, Minaskuat Limited Partnership (operating as a Partner of Jacques Whitford and Innu Environmental in Labrador) was engaged to re-analyze the data and consider additional techniques in light of the reviewers' comments before considering whether to proceed with further field investigations. In the re-analysis, heart rates up to ninety seconds before and after a direct overhead flyover were compared. Average heart rates during this time were correlated with decibel (dBA) levels from each event. In general, ducks either exhibited significant bradycardia (slowed heart rate), tachycardia (increased heart rate), or appeared to have no response at all to aircraft activity. Heart rate appeared to increase with dBA, with heart rates being highest 10 seconds post-event, and returning to pre-event levels generally before 90 seconds post-event. The results of this pilot study suggest that the technology was feasible and that valuable data on the response of Black Ducks to aircraft and other stimuli can be collected. Suggestions for future field studies have been incorporated into this document.

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1.0 INTRODUCTION

North American waterfowl undergo synchronous moults that involve a simultaneous loss of all primary feathers. Such a period of flightlessness occurs after breeding and at a time when waterfowl are more vulnerable to predation and other disturbances. Waterfowl generally compensate for the added risks of flightlessness by migrating to isolated areas to forage and escape predators. During moulting, birds allocate much of their energy to growing new feathers. In fact, metabolic rates can increase by 45% in order to accommodate feather growth (Gill 1990). This is likely followed with a concomitant increase in energy consumption. Thus, any event causing excessive expenditure of energy for activities other than growing feathers (e.g. movement, increased basal metabolic rate) may be potentially detrimental to moulting birds.

Aircraft disturbance has been linked to changes in waterfowl behaviour and habitat use that may in turn affect individual fitness and survivorship (Gladwin et al. 1987, NPC Report to Congress 1994). Waterfowl responses, however, differ among species and appear related to factors such as aircraft type, altitude, time of year (Gollop et al. 1974a and 1974b; Ward et al. 1987; Ward et al. 2002; Conomy et al. 1998a and 1998b). Factors that disrupt daily activity patterns may cause negative energy budgets (Drobney and Frederickson 1979), and therefore may affect moult (Taylor 1993), reduce over-winter survival and subsequently impede reproductive potential (Morton et al. 1989). Owens (1977) reported that Brant Geese (*Branta bernicla*) responded to aircraft disturbance by taking flight and then settling in the same area several minutes later. Belanger and Bedard (1989) documented that Greater Snow Geese (*Anser caerulescens*) disturbed by aircraft experienced an increase in energy expenditure and a concomitant decrease in energy intake. Resting Snow Geese were disturbed by a Cessna 185 at altitudes varying from 300 to 10,000 ft. AGL and incidents of severe disturbance were followed by a reduction in flock sizes. Gunn and Livingston (1974) reported that non-breeding birds appeared more sensitive to aircraft disturbance than nesting birds. Moulting waterfowl were driven from land by helicopter disturbance at altitudes of 100 to 750 feet.

Others have reported that birds are capable of tolerating some levels of aircraft disturbance (Rylander et al. 1974; Burger 1981; Ellis and Ellis 1991). Conomy (1993) reported that changes in behavioural responses (and heart rate) to disturbance from military aircraft were infrequent among Black Ducks and other waterfowl. As a result, it was concluded that aircraft disturbance was not adversely affecting the energetic budgets of wintering waterfowl, particularly Black Duck, because the proportion of birds affected by aircraft disturbance was low. Wooley and Owen (1977) reported that although observable behaviour did not change in response to aircraft over flights (or other birds), Black Ducks did exhibit increased heart rates. However, heart rate quickly returned to pre-disturbance levels, and it was concluded that the observed increase was probably of limited energetic significance. In support of this, Conomy et al. (1998b) concluded that the time-activity budgets of wintering Black Ducks were not adversely affected by aircraft disturbance (i.e. > 80 dBA). A related study found that initial exposure to aircraft noise elicited behavioural responses in captive Black Ducks (Conomy et al. 1998a) but reactions declined in subsequent exposure suggesting habituation to aircraft noise. Experiments monitoring heart rates of captive Black Ducks exposed to simulated aircraft noise support this contention (Harms et al. 1997). Spontaneous heart rate 'spikes' (brief increase in heart rate) were most common on the first day but despite subsequent daily exposures, were similar to baseline conditions thereafter. As Wooley and Owen (1977) demonstrated a significant relationship between heart rate and metabolism for black ducks (as well as other waterfowl), techniques examining this parameter for physiological response have been developed.

Studies conducted in support of the Environmental Impact Statement on Military Flying Activities in Labrador and Quebec (DND 1994) did not show any consistent trends suggesting that survey areas exposed to a high frequency of overflights had lower breeding densities than areas with fewer overflights or areas that were not overflown. However, observations by CWS indicated that use of an important moulting area (Snegamook Lake) by moulting waterfowl ceased after intensive low-level flying activity was initiated in 1980, but that waterfowl returned to the area when it was briefly excluded from low-level flying (DND 1994). This is a contentious observation as researchers in the field noted a greater physical response to the presence of the canoe than to the LLF jets (B. Barrow, pers. comm.).

In its evaluation of impact hypotheses, the Environmental Impact Statement on Military Flying Activities in Labrador and Québec (DND 1994) suggested that military training flights may negatively affect habitat use by moulting Black Duck. A worst case scenario of repeated exposure of waterfowl to low-level military aircraft activity during vulnerable periods and in the absence of mitigation was predicted to result in a moderate and therefore significant impact (DND 1994). A moderate impact is defined as a measurable but less serious decline of a population (a small proportion is affected), spanning several generations or persisting for the life span of the project. The decline occurs through changes in rates of productivity or survival, but the population recovers within two generations or within the life span of the project. The stressor will likely result in localized changes in the distribution, movements and/or behaviour of the animals involved (DND 1994).

The Black Duck was considered particularly at risk within the Low-level Training Area (LLTA), as it has declined in numbers along the Atlantic flyway in recent decades, although the reason for this decline is unclear (Erskine 1987). Thus, impact hypotheses dealing with habitat use patterns and/or energy balance remained valid and were considered the most relevant for the Black Duck. Even following the application of avoidance criteria only known moulting sites could be protected. It was therefore concluded that a residual minor impact resulted because other moulting locations were not known and techniques for identifying it were not considered effective except as incidental sightings. A minor impact does not result in changes to total species abundance that can be distinguished from those resulting from natural influences in the environment. Changes are localized and occur either through extremely local reduction in survival and/or productivity or through changes in the distribution, behaviour and/or movements of animals that do not affect population parameters (DND 1994).

DND has gathered information on the location and use of such Black Duck (and other waterfowl) moulting areas through its annual wildlife studies conducted in association with the Canadian Wildlife Service and the Raptor/Harlequin Duck Avoidance Monitoring Program (Jacques Whitford 1992, 1994, 1995, 1996, 1997, 1998, and 1999; unpublished). Currently, moulting areas for black ducks have been identified in several other locations along coastal Labrador and in smaller concentrations in the interior of the region. The largest known Black Duck moulting area is at Lac Fourmont on the Petit Mecatina

River. During the 1990's, Jacques Whitford was able to survey Lac Fourmont eight times as part of the annual monitoring and mitigation program managed by the Goose Bay Office of DND. On each occasion, several black ducks (maximum 140) were observed during mid-June to late July. In addition to large numbers and timing, use of the local habitat was also consistent and well defined. Another feature of this location is its proximity to the Practice Target Area (35-km northwest) used as a focal point for operations, and that the lake is adjacent to frequently used flight corridors for training.

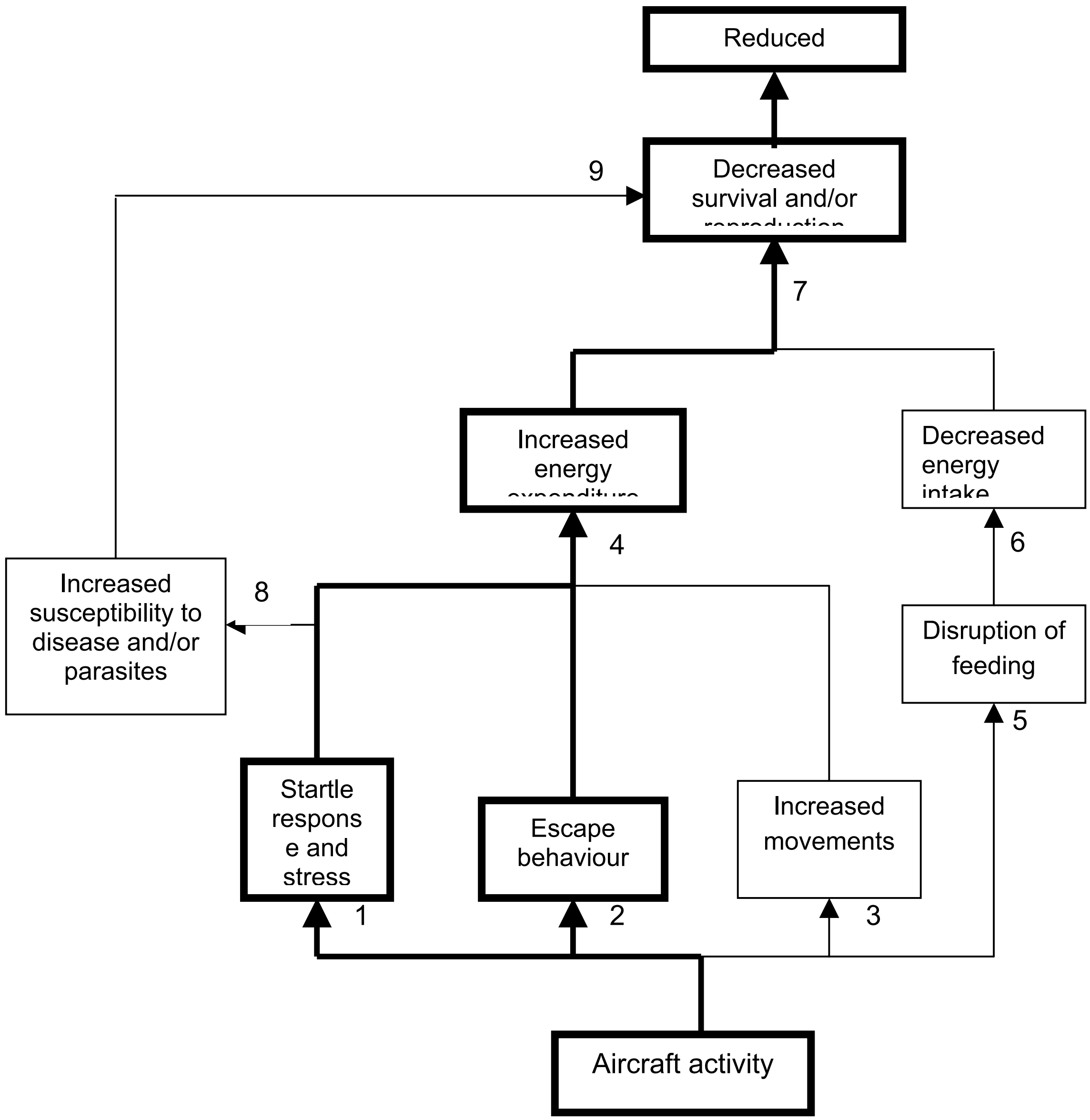
To further understand the moulting activity and whether it was possible to investigate the potential effects of aircraft noise on free-ranging Black Ducks [versus the previous studies employing captive Black Ducks (Harms et al. 1997; Conomy et al. 1998a and 1998b)], tree blinds and a reconnaissance were completed of the area in 1999 courtesy of funding from Industry Canada (Industrial Research Assistance Program). With this background, Jacques Whitford submitted a proposal to the Institute for Environmental Monitoring and Research (IEMR) to fund a pilot study to investigate heart rate changes in moulting Black Ducks during aircraft activity from June-July 2002. Following the receipt of two peer reviews (August 2003) of a draft document summarizing the findings of the pilot study, Minaskuat was engaged to re-analyze the data in light of the reviewers' comments before considering whether to proceed with further field investigations.

2.0 OBJECTIVE OF PILOT STUDY

The proposed pilot study was designed to investigate potential linkages between moulting free ranging Black Ducks and noise events from jet training. The following hypothesis (DND 1994) was amenable to testing (Figure 1): Disturbance caused by noise and visual stimuli associated with military training flights will result in changes in the energy balance or stress levels of animals, eventually leading to reduced abundance of wildlife.. Note that only some of the links will be addressed in this study.

Waterfowl have consistently used the Lac Fourmont area prior to and following the initiation of avoidance mitigation by DND in 1991. However there is still uncertainty regarding the effect of jet noise disturbance on the behaviour and energetics of waterfowl using the moulting areas in the LLTA. Specifically, the objective of this investigation was to compare the physiological response (in this case heart rate) of moulting Black Ducks, before and after military jet aircraft activity (as indicated by noise level measured in dB).

Figure 1 **Mechanisms Investigated Whereby Aircraft Activity Could Result in Reduced Abundance of Black Ducks Through Changes in Energy Balance or Stress Level**



Hypothesis and Linkages

Link 1: Aircraft activity elicits a startle response increasing the stress levels of Black Ducks.

Link 2: Aircraft activity elicits escape behaviour.

Link 4: Startle response and increased stress levels (Link 1) as well as increased movements during escape behaviour (Link2) or daily activity (Link 3) results in increased energy expenditures.

Link 7: Changes in the energy budget causes negative effects on survival and/or reproduction of Black Ducks.

3.0 METHODOLOGY

Measuring energy expenditure in animals is generally quantified via direct and indirect calorimetry (e.g., direct: measuring heat production, indirect: measuring oxygen consumption) (Eckert et al. 1988). For free-ranging animals, metabolism is often determined by injecting doubly labelled water (e.g., containing hydrogen and oxygen isotopes) into the animal and measuring isotope levels again after a given time. Energy expenditure is then calculated based on the depletion rate of the isotopes in the body (Godfrey et al. 2003). These techniques are not suitable for a study such as this because they provide an average estimate of metabolic expenditure over the entire measurement period, while heart rate is an instantaneous measure of energy expenditure. Recently, Ward et al. (2002) measured heart rate in geese during periods of flying and walking and related it to energy expenditure; Weimerskirch et al. (2002), attached heart rate monitors to albatross to determine energy expenditure during incubation; and Froget et al. (2004) surgically implanted heart rate monitors in penguins to assess energy expenditure while birds were ashore and diving at sea.

As the black ducks were unable to fly, the study team employed a capture technique used previously by the Canadian Wildlife Service (CWS) during waterfowl studies elsewhere in Labrador during 1982-1983 (B. Barrow, unpublished data). A German Wire-haired Pointer was used to search suitable wetland habitat over a 15-km^2 area. Non-flying and moulting black ducks were captured by hand and carefully transported by canoe to the field camp for surgery.

Surgeries were completed within a walled-tent using hot and cold packs to control temperature. An experienced wildlife veterinarian conducted the implantation of 25 g heart rate transmitters (Model HR-150, Telonics, Mesa, AZ). Ducks were anesthetized through a facemask over the bill using a combination of a gas anesthetic (Isoflourane) and 100% oxygen. Following the initial induction period of approximately 3 to 5 minutes an endotracheal tube was placed in the trachea and the surgery sites were prepared by plucking a small amount of feathers and sterilizing the skin with surgical scrub. Vital signs (e.g., heart rate, oxygen saturation and body temperature) were continuously monitored throughout the surgery with a pulse oximeter attached to a toe and an electronic thermometer inserted in the esophagus. A clear plastic adhesive sterile drape was placed over the entire chest and ventral abdomen of the bird and through this an initial mid-abdomenal incision was made to expose the coelomic cavity. A plastic catheter was then advanced under the skin in a forward direction toward the left collarbone where a second smaller incision was made. The positive wire electrode, or lead, was inserted into the flared back end of this catheter and the entire apparatus pulled forward through this 'skin tunnel' where the lead was anchored to an underlying bone and the skin incision closed. The transmitter was then placed into the coelomic cavity through the right abdominal air sac and sutured to the body wall. The negative wire electrode or lead was then anchored in place at the back portion of the keel or sternum and the abdominal incision was closed with absorbable suture material. As the weather varied dramatically (10-33°C) over the course of the 40-50 minute surgeries, subjects were either heated with hot packs or cooled with alcohol applied to the feet webs according to body temperature during the surgery. Each black duck was given an antibiotic during the surgery and an injection of a non-steroidal anti-inflammatory drug for post-operative pain relief. Following a 1-2 hour post surgery monitoring period for possible complications, birds were released completely alert

Birds were marked with metal leg bands and nasal discs for the identification of individuals in the field. We attempted to monitor the location and activity of each bird daily. As the range of the transmitters was described by the manufacturer as 800-1,600 m (D. Crowe, Telonics, pers. comm.), stealth and mobility of the observers was essential using a canoe or an elevated blind (constructed in 1999) whenever possible to improve reception. Search tracking effort was also expended on foot where no water access was available. The signal received on the TR-5 receiver (Telonics) was the pulse period, a value representing the amount of time between each heartbeat. Essentially, the lower the pulse period value, the higher the heart rate. Pulse period values (displayed on the TR-5 receiver), were displayed continuously but recorded every 5 seconds over a 15-minute observation period. Instantaneous heart rate, in beats per minute (bpm), was determined by dividing 60,000 by the pulse period. In addition to recording these values manually, a second person would monitor weather, other stimuli such as predators and aircraft activity if present.

In advance of the field experiments, Jacques Whitford and the IEMR met with the Military Coordination Centre (MCC) at 5 Wing Goose Bay to discuss protocol and requirements for military aircraft activity during 1-15 July 2002. Flights were encouraged during the second week (to allow telemetered birds an opportunity to adjust) with the participating pilots attempting to over fly the Petit-Mecatina River in the study area. The study team would communicate daily by satellite telephone with the MCC to discuss approximate timing and configuration of aircraft activity. This information greatly assisted field measurements although the remoteness of the area and other logistical challenges resulted in several noise events being recorded without warning. Each aircraft event was plotted on a 1:50,000 topographic map sheet according to direction, location, height, speed and estimated L1 or maximum sound energy in decibels (dB). In combination with environmental parameters such as temperature, wind, precipitation, distance and location, the noise exposure to the telemetered black duck was estimated using previously collected information from May 2002 (N. Standen, unpublished data) and a noise propagation model developed for the LLTA (Standen et al. 1998). At that time, the CWS and IEMR completed a waterfowl staging and jet aircraft activity investigation at the same Lac Fourmont study area. Through detailed noise measurements and development of a noise propagation model, Dr.

Neil Standen of Urban Aerodynamics, was able to describe each noise event as perceived by the telemetered Black Duck later in July.

In the previous draft report (August 2003), heart rate data was assessed as untransformed pulse periods using autocorrelation, spectral, and runs analysis. The overall conclusion of the analysis was that the results were inconclusive given the available data. This was not surprising considering the need for large sample sizes when using such statistical techniques. Autoregressive moving average models (ARIMA) are sometimes used for heart rate data analysis, but are difficult to conduct and difficult to interpret. Accordingly, the study team decided to approach the data re-analysis in an exploratory nature, using parametric statistics to determine if the data changed before and after a noise event [e.g., bradycardia (slowed heart rate) or tachycardia (increased heart rate)], and visual graphic analysis to determine the effects of noise after the event at given time periods (e.g., heart rate regularity, recovery time to pre-noise events).

4.0 RESULTS

Considering the challenges of implementing this complex program in a remote field setting, the experimental design was implemented successfully. The greatest challenge during the two weeks was the weather. After three days of daily maximum temperatures in excess of 30^0 C, rain continued virtually unabated for the next 10 days with temperatures often below 10^0 C. Due to the excessive precipitation, the water level rose over 1.1 m on 9 July (and continued to rise throughout the remainder of the experiment) such that the habitat structure and resultant behaviour of the black ducks changed. Flooded wetlands enhanced accessibility for the study team but obscured sightability by providing cover over water. Observations of black ducks including those previously captured, were rare after this date. Poor weather also affected low-level flight sorties although fighter pilots over flew the study area whenever periodic improvement in the weather permitted.

Fifteen male black ducks were captured during 2-8 July (Table 1). All of these birds were undergoing moult at the time and incapable of flight. Primary feathers were absent or just beginning to emerge.

Table 1 Moult Status and Tracking Fate of Captured AHY (after hatch year) Male Black Ducks

Band and Frequency	Capture Date	Length of Primary Feathers (mm)										Fate
		1	2	3	4	5	6	7	8	9	10	
1537-48051 148.600	02.07	8	7	9	9	9	8	9	9	10	10	Not relocated until 13.07
1537-48052 148.560	02.07	0	0	0	0	0	0	0	0	0	0	Never relocated
1537-48053 148.460	02.07	19	22	21	22	23	21	20	20	20	21	Relocated on 03.07 only
1537-48054 148.680	03.07	23	24	21	25	21	22	24	23	22	22	Trans. malfunction, never relocated
1537-48055 148.580	03.07	0	0	0	0	0	0	0	0	0	0	Relocated on 04.07, killed by mink on 05.07
1537-48056 148.740	03.07	0	0	0	0	0	0	0	0	0	0	Relocated on 04.07, 09-11.07, and 13.07
1537-48057 148.720	03.07	3	4	5	7	5	5	5	4	4	5	Relocated on 04-05.07, 09.07, 12-13.07
1537-48058 N/A	04.07	46	49	41	45	46	41	41	43	37	39	Banded only
1537-48059 148.660	04.07	0	0	0	0	0	0	0	0	0	0	Relocated on 05.07, 10-13.07
1537-48060 148.760	04.07	71	73	79	81	81	79	79	76	68	64	Relocated on 05.07, 10-11.07, 13.07
1537-48061 148.640	07.07	15	17	18	20	20	16	18	15	14	12	Relocated on 12-13.07
1537-48062 148.540	07.07	25	24	25	28	28	29	25	25	20	18	Relocated on 13.07
1537-48063 148.420	07.07	0	0	0	0	0	0	0	0	0	2	Relocated on 10-11.07, 13.07
1537-48064 N/A	07.07	0	0	0	0	0	0	0	0	0	0	Banded only
1537-48065 N/A	07.07	17	17	16	18	17	19	17	17	15	16	Banded only

Twelve black ducks underwent surgery for implantation with HR-150 transmitters. Unfortunately one of the transmitters malfunctioned as did two others that were not implanted. Despite ambient air temperatures of 8-29^0 C during the various surgeries, body temperature tended to decline during the operation. The pulse oximeter indicated that heart rate tended to peak at the point of the first incision (Table 2).

Table 2 Body Temperature and Heart Rate of Black Ducks During Surgery

Frequency	Intubation			Start of Surgery			Suturing		
	Time	^{0}C	Rate (bpm)	Time	^{0}C	Rate (bpm)	Time	^{0}C	Rate (bpm)
148.600	0955	41.5	180	1010	40.5	197	1033	40.0	234
148.560	1743	42.0	167	1756	40.5	163	1817	40.5	151
148.460	1907	41.0	217	1918	40.0	215	1842	40.0	174
148.680	0950	39.5	190	1003	39.0	234	1021	38.5	>255
148.580	1122	40.0	218	1132	39.5	251	1154	39.0	218
148.740	1216	40.5	150	1228	40.0	220	1254	40.5	193
148.720	1400	40.0	171	1413	40.0	174	1441	40.0	186
148.660	1436	40.0	240	1447	40.0	209	1516	38.5	157
148.760	1549	43.0	220	1604	42.5	>255	1635	41.5	210
148.640	1316	39.0	209	1331	38.5	>255	1355	37.0	148
148.540	1451	39.0	164	1501	38.0	207	1526	37.0	175
148.420	1604	39.0	201	1612	39.0	207	1633	38.5	153
Mean		40.4	193.9		39.8	215.6		39.2	187.8

In terms of equivalent values for heart rate during surgery, values ranged from 150-240 bpm during intubation, 163 to >255 bpm at the start of the surgery, and 148 to >255 bpm during suturing. Note that on occasion heart rate exceeded the limitations of the surgical monitoring equipment (i.e. >255 bpm). Of the 11 birds available for monitoring, 10 were relocated at least once in the study area (exception was 148.560) and all were believed to have moved (>1 km) from their release point. One of the released birds (148.580) was killed by a mink (*Mustela vison*) two days following surgery. The 49 monitoring sessions of the 10 telemetered ducks were distributed unevenly according to the ability to relocate individuals (Table 3).

Table 3 Summary of Tracking Effort on Telemetered Black Ducks

Frequency	Total Sessions without Noise Events (mins)	Average bpm	Total Sessions with Noise Events (mins)	Average Bpm
148.420	11 (165:00)	182.8	4 (47:35)	204.5
148.460	1 (15:00)	161.2	0	N/A
148.540	1 (15:00)	162.6	2 (30:00)	157.5
148.580	1 (1:15)	198.6	0	N/A
148.600	2 (30:00)	234.7	0	N/A
148.640	1 (10:00)	134.9	3 (40:05)	179.5
148.660	5 (55:35)	136.3	1 (15:00)	163.3
148.720	4 (60:00)	209.2	1 (15:00)	213.9
148.740	6 (68:55)	163.2	0	N/A
148.760	4 (51:55)	252.8	2 (30.55)	213.9
Total	36 (472:40)		13 (178:35)	

Throughout the field program, the study team was able to record twenty-four aircraft noise events while monitoring six telemetered black ducks (Appendix A). Maximum (L1) estimated and modeled noise exposures to each telemetered duck being monitored ranged from 55-120+ dB. An examination of all data, including those instances when inadequate sample of heart rate values either before or following a noise event indicated reactions suggestive of a 'startle effect'. These heart rate spikes (Harms et al. 1997), defined by an obvious shift in heart rate during the one minute following an event occurred on 8 of 16 incidents (50%) when L1 was > 70 dBA and on all occasions (100%) when L1 was > 90 dBA (Table 4) (Appendix A). During those incidents when 'spikes' were detected the increased heart rate persisted for less than 80 seconds and usually lasted for < 30 seconds. It must be noted that for several of these monitoring periods, there were inadequate data to describe pre-disturbance heart rate and therefore these were not used in the analysis. An additional five noise events occurred when non-telemetered black duck were visible (Table 5). On each occasion, no overt reaction or change in activity as a result of the aircraft was detected. Black ducks were rarely observed after the water level at Lac Fourmont increased during 9-10 July.

Table 4 Monitored Reactions of Telemetered Black Ducks During Aircraft Noise Events

Noise Event (time)	Aircraft	L1 (dBA)	Frequency	Reaction
04-01a (0947.45)	F-16 (RNLAF)	75	148.720	bpm remained consistent
04-02a (0948.40)	F-16 (RNLAF)	70	148.720	Spike, bpm from 216 to 335, recovered in 20 sec.
10-01 (1100.25)	Tornado (IAF)	70	148.420	bpm remained consistent
10-02 (1110.15)	Tornado (IAF)	75	148.420	Spike, bpm from 273 to 370, recovered in 20 sec.
10-03 (1120.25)	Tornado (IAF)	100	148.420	Spike, bpm from 226 to 652, recovered in 65 sec.
10-04 (1131.00)	Tornado (IAF)	105	148.420	Spike, bpm from 172 to 283, recovered in 20 sec.
10-05 (1425.00)	Tornado (IAF)	90	148.660	Spike, bpm from from 200's to 600's for 15-20 sec
10-06 (1526.15)	Unknown	70	148.660	bpm remained consistent
10-07 (1608.00)	Transal (GAF)	55	148.760	Transmitter possibly malfunctioning
10-08 (1610.35)	F-16 (RNLAF)	65	148.760	Transmitter possibly malfunctioning
10-09 (1619.35)	F-16 (RNLAF)	65	148.760	Transmitter possibly malfunctioning
11-01 (1629.00)	Unknown	60	148.420	bpm remained consistent
12-01 (1003.15)	Unknown	75	148.640	bpm remained consistent
12-02 (1004.45)	Unknown	65	148.640	bpm remained consistent
12-03 (1023.20)	Tornado (IAF)	80	148.640	bpm remained consistent
12-04 (1023.25)	Tornado (IAF)	80	148.640	bpm remained consistent
12-05 (1035.20)	Unknown	65	148.640	bpm remained consistent
12-06 (1123.00)	Tornado (IAF)	75	148.640	bpm remained consistent
12-07 (1123.05)	Tornado (IAF)	75	148.640	Spike, bpm from 171 to 308, recovered in 30 sec.
13-01 (1228.00)	Unknown	70	148.540	bpm remained consistent
13-02 (1249.45)	Unknown	65	148.540	bpm remained consistent
13-03 (1250.05)	Unknown	65	148.540	bpm remained consistent
13-04 (1321.05)	F-16 (RNLAF)	>120	148.760	Spike, bpm increased from 204 to 984, noise event 13-05 occurred 20 sec. later, possible malfunction
13-05 (1321.25)	F-16 (RNLAF)	95	148.760	Spike, values remained high for 80 sec. since noise event 13-04, possible malfunction

Note: RNLAF – Royal Netherlands Air Force, IAF – Italian Air Force, GAF – German Airforce, RAF – Royal Air Force

Table 5 Observed Reactions of Black Ducks During Incidental Noise Events

Noise Event (time)	Aircraft	L1 (dBA)	Reaction
04-01b (0947.45)	F-16 (RNLAF)	70	9 ducks flushed from shore by black bear, continued swimming across cove during and following event away from observers
04-02b (0948.40)	F-16 (RNLAF)	65	9 ducks flushed from shore by black bear, continued swimming across cove during and following event away from observers
04-03 (1400.00)	Harrier (RAF)	80	7 ducks continued swimming in channel during and following event, from observers
04-04 (1400.05)	Harrier (RAF)	80	After 2nd aircraft noise event, 7 ducks continued swimming in channel during and following event, from observers
10-10 (1707.00)	Tornado (IAF)	100	Female (believed to be with brood) had been calling beneath cover, moved into open water and continued calling following noise event

The study team was able to monitor the influence of their presence (and other non-aircraft stimuli) on the heart rate of telemetered black ducks on several occasions (Table 6). The heart rate values during obvious movement (related or believed unrelated to the presence of the observers or other non-experimental stimuli) were approximately 600 BPM, returning to 150 to 200 BPM when the apparent movement had stabilized.

Table 6 Observed Reactions of Black Ducks to Non-experimental Stimuli

Monitoring Session	Frequency	Reaction
02.07.02 (1234 hrs)	148.600	Post surgery bpm values ranged from 134-192, upon and following release bpm values remained approximately 600 for > 10 min.
10.07.02 (1010 hrs)	148.420	Common loon swimming/feeding in pond, no apparent influence on bpm values for approx. 1 hr before loon left.
10.07.02 (1400 hrs)	148.760	Duck detected observers and began swimming away, bpm values increased from 200 to 600 until signal strength weakened. Continued to follow duck over 500 m during approx. 9 min.
10.07.02 (1436 hrs)	148.760	Red-tailed Hawk circling pond, could not observe duck. No apparent change in bpm.
10.07.02 (1648 hrs)	148.740	Duck moved out of signal range, bpm values went from 150 to periodic 600's or higher, in < 10 min.
11.07.02 (0909 hrs)	148.420	From blind, duck seemed motionless based on consistent (150-200's) bpm values, signal direction changed and bpm values increased to 300's and later 600's before resuming to consistent low values. No observer influence.
11.07.02 (1602 hrs)	148.420	Variable bpm values indicating that the duck was active, signal strength became weak, observers relocated closer to regain adequate strength.
12.07.02 (0955 hrs)	148.640	From concealed location, duck swam towards and past observers without being detected. Although not visible, bpm values increased from 150-200 to 300-600.
12.07.02 (1349 hrs)	148.720	Observers came upon duck (not visible) based on strong signal, bpm values increased to 300 and then 600, direction changed and eventually could not relocate.
12.07.02 (1352 hrs)	148.660	Variable bpm values indicating that the duck was active, signal strength became weak, observers unable to relocate.
13.07.02 (0933 hrs)	148.420	Changing signal direction and high bpm values indicated duck moved approx. 400 m during session
13.07.02 (1400 hrs)	148.600	Changing signal direction and high bpm values indicated duck was close and moving away, bpm values later decreased to 150-200 as location stabilized
13.07.02 (1427 hrs)	148.740	Variable bpm values indicating that the duck was active, signal strength became weak, observers relocated twice before losing altogether.
13.07.02 (1513 hrs)	148.640	Variable but relatively lower bpm values indicating that the duck was active, signal strength became weak, observers unable to relocate.

Of the numerous data files available for heart rate analysis in response to aircraft events, only, those meeting the following criteria were selected for re-analysis: 1) a minimum of 90-seconds (approximately) of heart rate measurements were available pre- and post- noise event, 2) both over-flight and non-over-flight data was available for an individual, and 3) no substantial data gaps (> 1 minute) or short recording periods (< 6 minutes) were present in the recording. Files from 6 ducks met these requirements (Table 7), but duck number 760 was excluded due to the irregularity of the heart rate data. For example, heart rate could go from being in the 100s beats/minute to the 900s beats/minute over a 10 second period, and this variability could be maintained for the 15 minute recording period. This pattern of heart rate is not likely "real", and indicates either 1) that a faulty monitor was implanted, or 2) the pulse periods were influenced by electrical activity from nearby muscle (Weimerskirch et al. 2002).

Table 7 Summary of available data files available for analysis.

Duck	No. of data files during non-noise events	No. of data files during noise events
420	11	2
540	1	1
640	1	2
660	4	1
720	4	1

4.1 Heart Rate Pre- and Post- Noise Event

There did not appear to be a consistent animal response to over flight events. Some ducks experienced significant tachycardia, some significant bradycardia, and some did not seem to respond to over flights at all. Duck 148.420 experienced 2 over flight events and in both cases, heart rate increased after the event. For event 10-01, heart rate after the noise event was significantly greater (paired t-test, p=0.04) than before, and stayed elevated for as long as 90 seconds after the fly over (Figure B-1). For event 10-02, heart rate increased rapidly but was not significantly different (paired t-test, p=0.45) than pre-noise as early as 10 seconds after the event (Figure B-2). In both cases, heart rates started to increase approximately 10 seconds before the over flight event. For duck 148.540, heart rate was significantly greater after the noise event 13-02 (paired t-test, p=0.004), and appeared to stay elevated (Figure B-3). Unlike duck 148.420, no "anticipatory" increase in heart rate was noticed. For duck 148.640, heart rate appeared unaffected by the over flight 12-01 (paired t-test, p=0.30) (Figure B-4), but was significantly reduced after flight 12-03 (paired t-test, p=0.0001) (Figure B-5). However, heart rate was already declining prior to the over flight so it is difficult to interpret the significance of this bradycardia. For over flight 12-05, heart rate appear unaffected by noise (paired t-test, p=0.41) (Figure B-6). For duck 148.660, heart rate was significantly lower after over flight event 10-06 (paired t-test, p=0.026) but appeared to stabilize almost 60 seconds later (Figure B-7). For duck 148.720, there was no change in heart rate after over flight 04-01 (paired t-test, p=0.35) (Figure B-8).

4.2 Heart Rate and dBA Levels

Figure B-9 graphically depicts data from 10, 30, 60, and 90 seconds pre- and post-overhead flights based on the corresponding dBA levels. Data are given with standard error bars (average of heart rates during time period). Only cases where more than 1 bird was recorded for each dBA level are shown (65 dBA, pre: n=2, post: n=3; 70 dBA, pre: n=3, post: n=2; 75 dBA, pre and post, n=3). The value given for ambient heart rates is an average of all six birds taken during no flyover periods where ambient noise levels ranged from 35-45 dBA. These values were obtained from various times during the day, and in some cases over multiple days, so they should be considered indicative of normal, basal heart rates.

At noise levels of 65 dBA, no change in heart rate was observed at any of the pre- or post-noise event periods. At 70dBA, heart rate appeared to slowly increase from 90 seconds pre-event to 10 seconds pre-event. Heart rate remained elevated 10 seconds post-event, after which time it was somewhat sporadic. For 75 dBA, heart rate increased more quickly from 90 seconds pre-event to 10 seconds pre-event, was much higher for the 10 second period after the event, and then slowly decreased to pre-event levels by 90 seconds. There also appeared to be an increasing trend in overall heart rate with dBA level, with heart rates being lower at 65 dBA and greater at 75dBA.

5.0 DISCUSSION

The timing for the field investigations in 2002, 1-14 July was appropriate in that all birds handled were undergoing moult and unable to fly. Based on the research of others, it was estimated that some of these birds would have been able to fly by the third week of July. While an inventory was not possible, frequent sightings suggested that several hundred black ducks were present in the study area.

The opportunity to evaluate changes in activity as a result of an aircraft noise event was limited. Despite the availability of observation platforms, waterfowl tended to remain under cover of the dense vegetation (particularly following flooding) consistent with other investigations in Labrador (Canadian Wildlife Service, unpublished). For the five occasions when black ducks were visible, their activity remained unchanged during and immediately following an aircraft noise event. Reactions of staging black duck and other waterfowl to military jet activity were of similar consequence at Lac Fourmont during April-May 2002 (T. Newbury, pers. comm.) and elsewhere (Conomy 1993).

To overcome the visual limitations of cause and effect experiments in a field setting with free-living black ducks, the study team relied upon recent advances in technology regarding the investigation of heart rate response. For example signal detection ranges for Harms et al. (1997) were limited to 100 m with the aid of a pre-amplifier compared to as much as 1 km observed in this study. The mobility of the study team and configuration of riparian habitat in the study area further aided detection and reception. Black ducks that were believed to be resting reflected a more consistent (narrower range) heart rate than when at least moving or engaged in other activities. As previously mentioned duck 148.760 was an exception due possibly to some malfunction or anomaly with the implantation. However, even this bird would exhibit prolonged or more frequent display of elevated heart rate when moving, or exposed to louder noise event, and was therefore included in the experiments.

In general, there was no consistent response of heart rate in individual wild moulting black ducks in relation to over flights of military aircraft. Ducks either exhibited significant bradycardia (Ducks 640, 660), tachycardia (Ducks 420, 540, 660), or did not appear to respond at all (Duck 640, 720). When ducks experienced tachycardia after the event, the heart rate 'spike' generally lasted no more than 90 seconds. These heart rate 'spikes' were also observed by a previous researcher (Harms et al. 1997) in captive black ducks exposed to simulated aircraft noise.

When the data were pooled, heart rates at 70 and 75 dBA appeared to increase with time leading up to the direct flyover event, but tended to recover to the 90 second pre-flyby time within 90 seconds of the over-flight. Heart rates 10 seconds post-event tended to be highest (Figure B-9). Additionally, there also appeared to be an increasing trend in overall heart rate with dBA level, with heart rates at 65 dBA being the lowest and heart rates at 75 dBA the greatest. These trends of increasing heart rate with dBA are intriguing, but a larger sample size is needed to further investigate this finding. Presently, the data are suggestive of a relationship. A minimum of five birds would be required per dBA measurement in order to establish any sort of statistical relationship between heart rate and dBA. Since researchers cannot control dBA level, and are at the mercy of weather conditions, flight patterns, and duck location, this may not be possible. However, an increase in sample size should be considered in the design of any future study. One measurement was taken at 105 dBA, but only post-event data was available.

In a similar study using captive black ducks, daily mean heart rates did not increase in response to simulated noise events of a military jet with L1 values up to 110 dB, 48 times per day (Harms et al. 1997). These same authors noted heart rate spikes during other non-experimental and occasionally visual stimuli. A possible threshold of 'spike' reaction during the more random and non-simulated stimulus of aircraft noise events at Lac Fourmont, appeared when L1 at the telemetered duck was >70 dBA. This was consistently observed when L1 > 90 dBA. In all cases, these reactions were brief and recorded for < 80 seconds. Otherwise heart rates remained consistent throughout the day regardless of the aircraft noise events.

Recognizable acute heart rate increases corresponding with a noise event occurred with increased frequency during the first day of noise presentation but on subsequent days the responses did not differ significantly from baseline (Harms et al. 1997). Acute heart rate responses to aircraft noise diminished rapidly, indicating the ability of black ducks to habituate to the auditory component of low altitude aircraft overflights. Opportunities to observe this adjustment over the course of the study were limited by the two aspects beyond the control of the study team. First, aircraft events were random with subsequent variable L1 stimuli occurring at different times of the day. Secondly, the ducks were free ranging and not always within range to detect whether heart rate indicated habituation to repeated noise events. Regardless, telemetered ducks continued to exhibit tachycardia, bradycardia or heart rate 'spikes' throughout the experiments.

Wooley and Owen (1977) observed certain visual stimuli caused brief increases in black duck heart rates, including flying herons and hawks, and low-flying planes. They stated that the heart rate-metabolism relationship for black ducks is sufficient to allow monitoring the energy expenditure of free-living ducks. They suggested that psychological stimuli might result in a different relationship than exists for ducks by temperature variation. But the resting metabolism of ducks equipped with small radio transmitters was 19% higher than that of birds without radios. This aspect was difficult to investigate during the pilot study, as black ducks were usually secluded and rarely visible to observers.

6.0 CONCLUSION

The 2002 study was a pilot investigation to determine if heart rate monitoring technology could be practically applied in a remote field setting. The results of the study indicate that the technology was feasible and that valuable data on the response of Black Ducks to aircraft and other stimuli may be collected. Ideally a future study should aim to have a larger spread in dBA values in order to determine a better noise-heart rate response and to facilitate a more rigorous statistical analysis. Visual observations may also add strength to any new study design. For example it would be possible to determine, with little more investment than observation hours, if birds become behaviourally and physiologically habituated to over-flights, and if their moulting period is different than birds in low noise areas. As mentioned previously, it is possible to link heart rate to energy expenditure, but only during sustained periods of activity (or inactivity) (Ward et al. 2002; Weimerskirch et al. 2002; Froget et al. 2004). Note that heart rate does not reliably relate to energy expenditure during periods of excitement (Wooley and Owen 1977)(e.g., during a startle). Thus, it is unlikely that the heart rate 'spikes' observed in this pilot study can be related to an alteration in daily energy expenditure. Perhaps continuous disturbances by aircraft, repeated daily for numerous weeks would, but the data collected in this pilot study are insufficient to test this hypothesis. If the study is to be expanded or extended over a longer period, energy expenditure could be measured directly with the doubly-labelled water technique and related back to heart rate. This technique would require the recapture of the telemetered waterfowl, but may yield useful insight regarding the long term effects of aircraft disturbance.

Where possible, it would be advisable to collect greater and a more similar number of monitoring sessions for each telemetered duck. This would allow the use of statistical methods such as ANOVA to analyze within-duck variation as well as sources of variation between ducks. Pending funding availability, the study team would suggest conducting a further year of study in order to increase the sample size and attempt to address additional links in the previously noted hypothesis. Johnson (2002) recently emphasized the importance of metareplication (the replication of an entire study) when conducting wildlife ecology studies. Similar conclusions obtained from similar studies conducted under differing conditions will provide greater confidence in the generality of those findings than would any single study, however well designed and executed.

Based on the telemetry monitoring of 10 individuals during this pilot study, black ducks during moulting appear to react to aircraft noise events by increasing their heart rate (shortening pulse period) when maximum noise levels (L1) are at least 70 dB. The heightened heart rate is temporary, usually lasting a few seconds if at all up to approximately one minute. These reactions were also consistent or below those levels recorded during other non-resting behaviour such as swimming and/or avoiding perceived threat such as the presence of the study team.

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APPENDIX A

Results of Heart Rate Monitoring from Telemetered Black Ducks at Lac Fourmont

APPENDIX A-1

Monitoring with Aircraft Noise Events

APPENDIX A-2

Monitoring without Aircraft Noise Events

APPENDIX B

Statistical And Graphical Analyses of Collected Data from Telemetered Black Ducks at Lac Fourmont

Figure B-1 Duck 420, Over-flight event 10-01. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

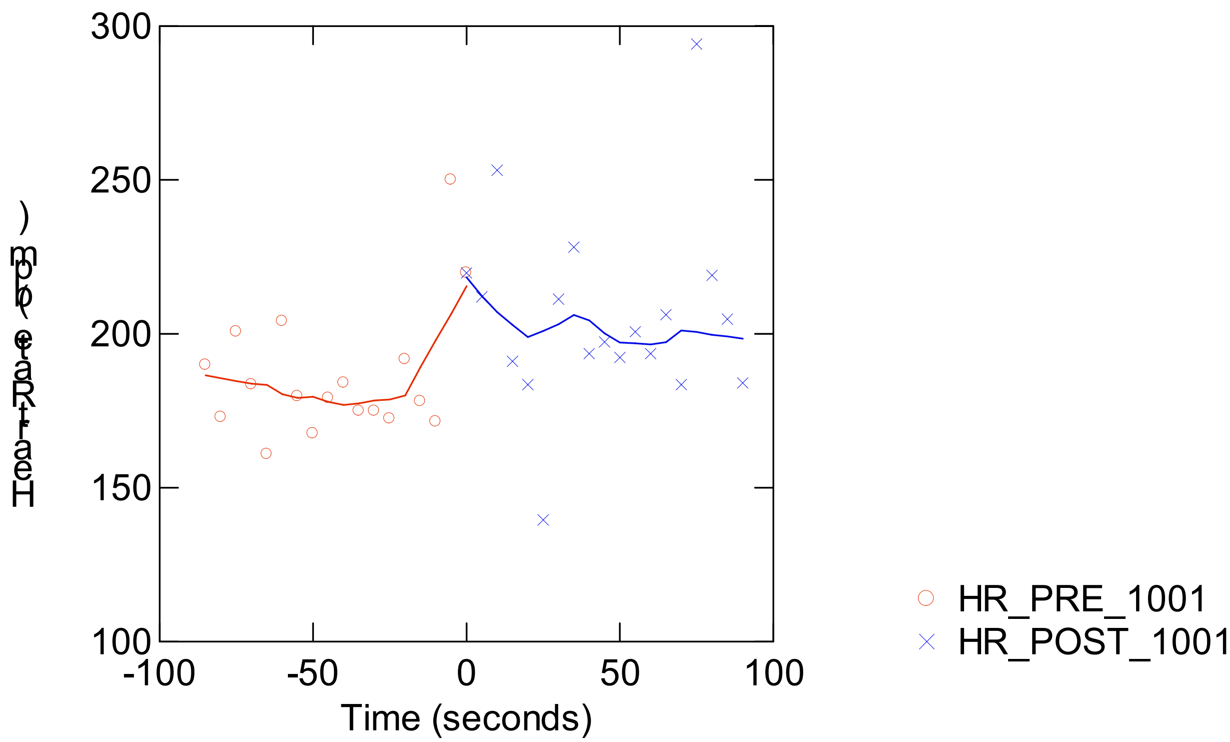

Figure B-2 Duck 420, Over-flight event 10-02. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

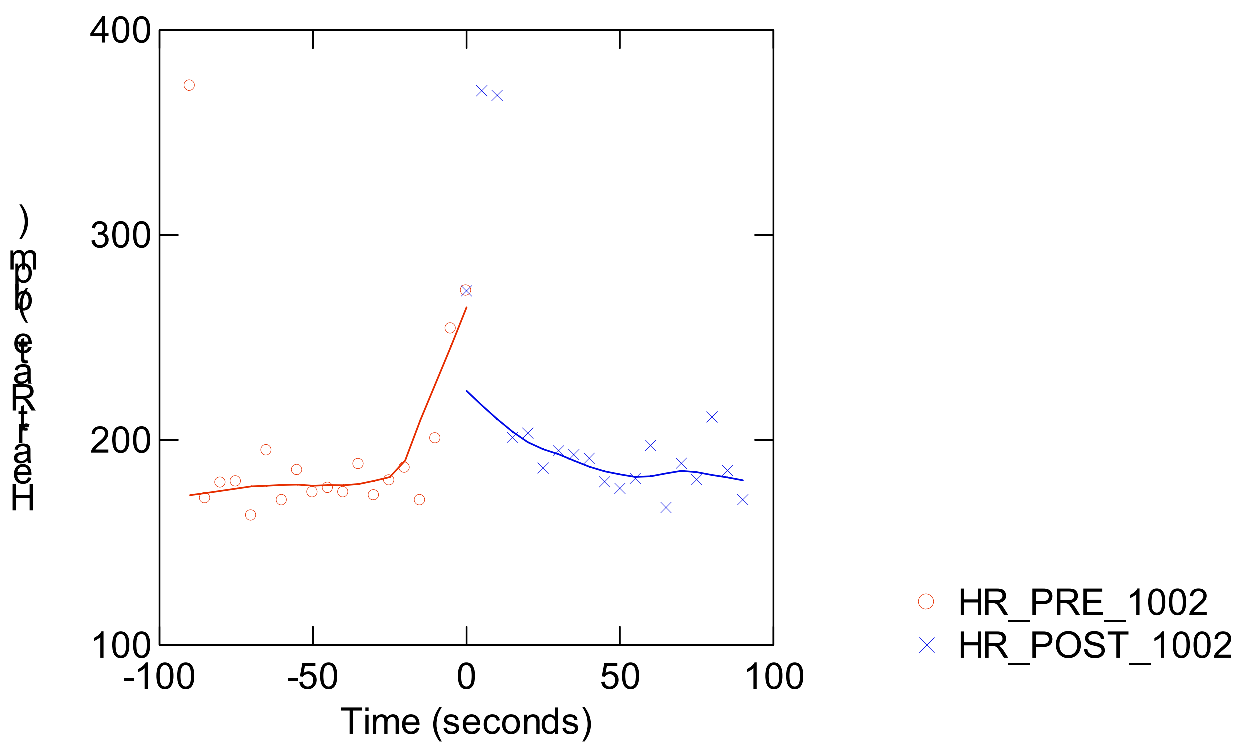

Figure B-3 Duck 540, Over-flight 13-02. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

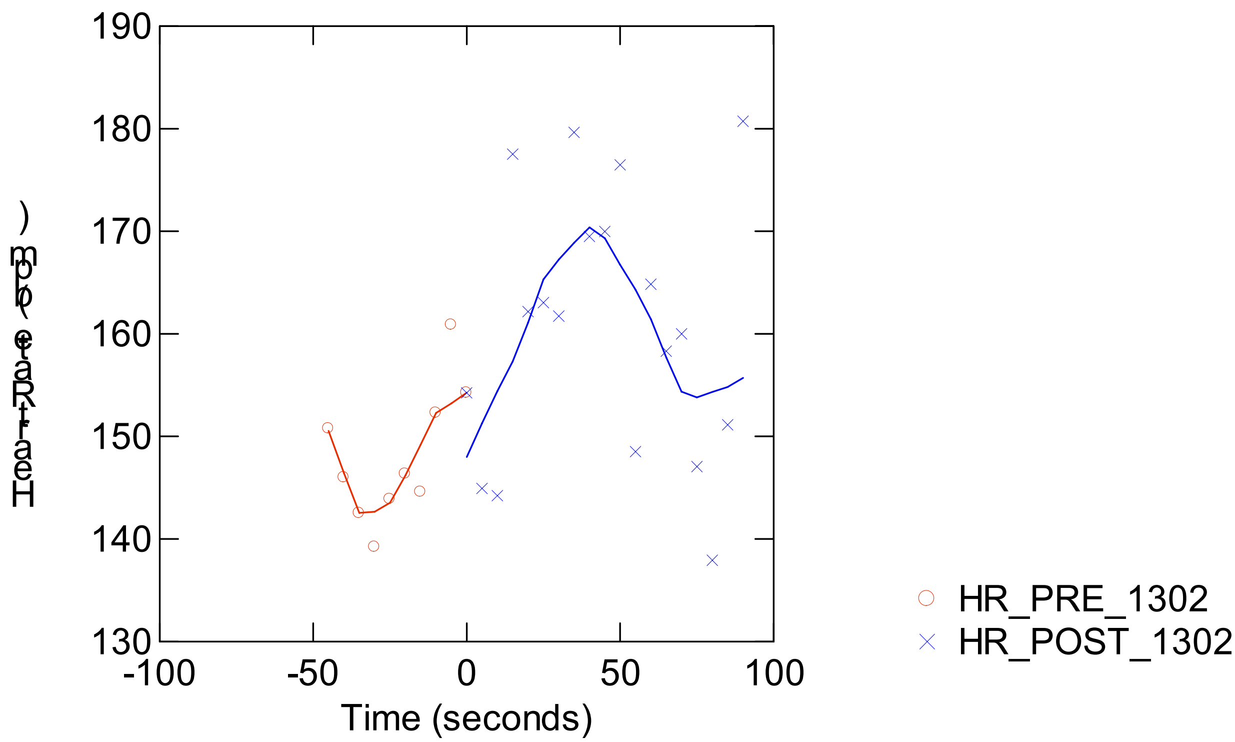

Figure B-4 Duck 640, Over-flight 12-01. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

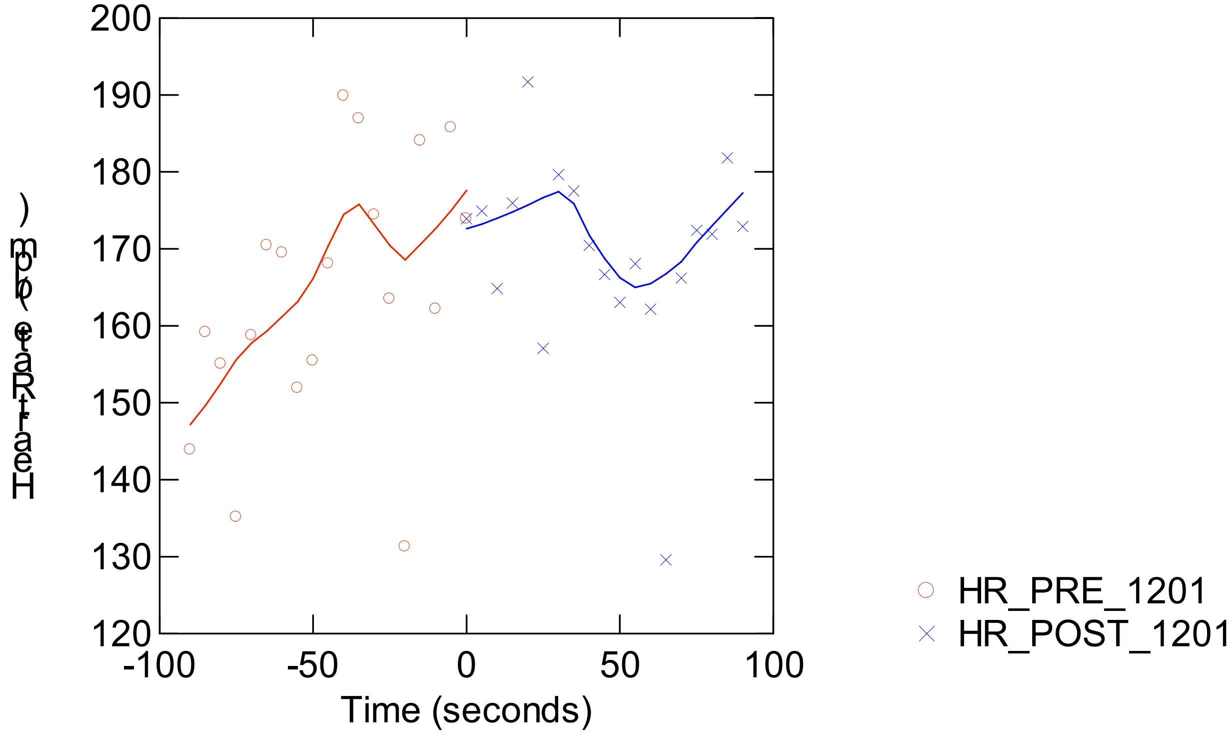

Figure B-5 Duck 640, Over-flight 12-03. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

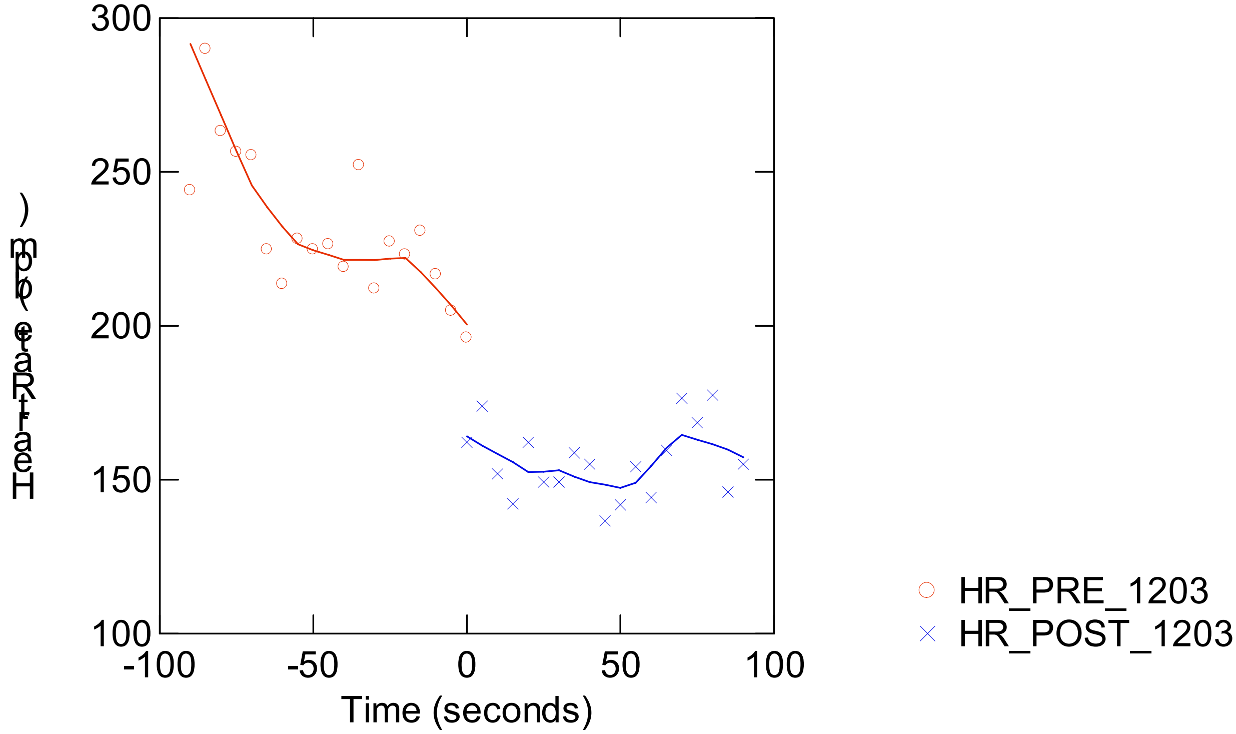

Figure B-6 Duck 640, Over-flight 12-05. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

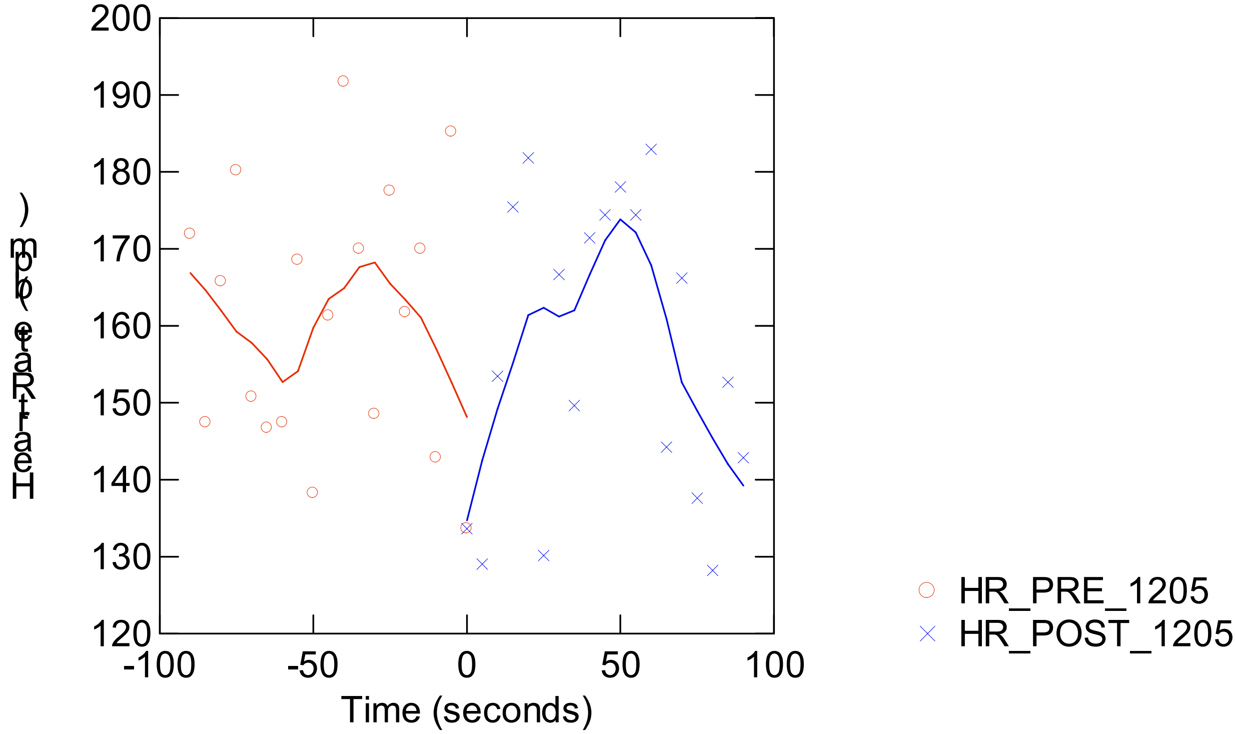

Figure B-7 Duck 660, Over-flight 10-06. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

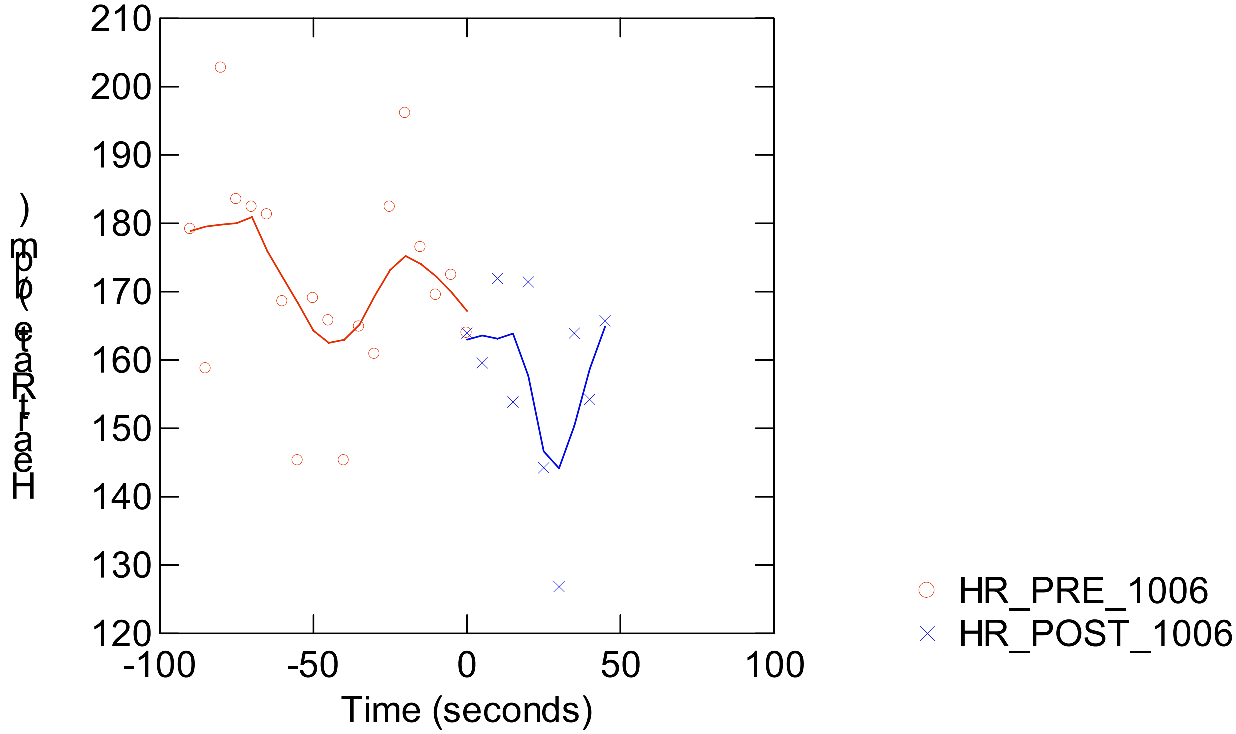

Figure B-8 Duck 720, Over-flight 04-01. Times post noise event are marked as positive times and designated with blue labels, while pre-noise events are marked as negative times and designated with red labels.

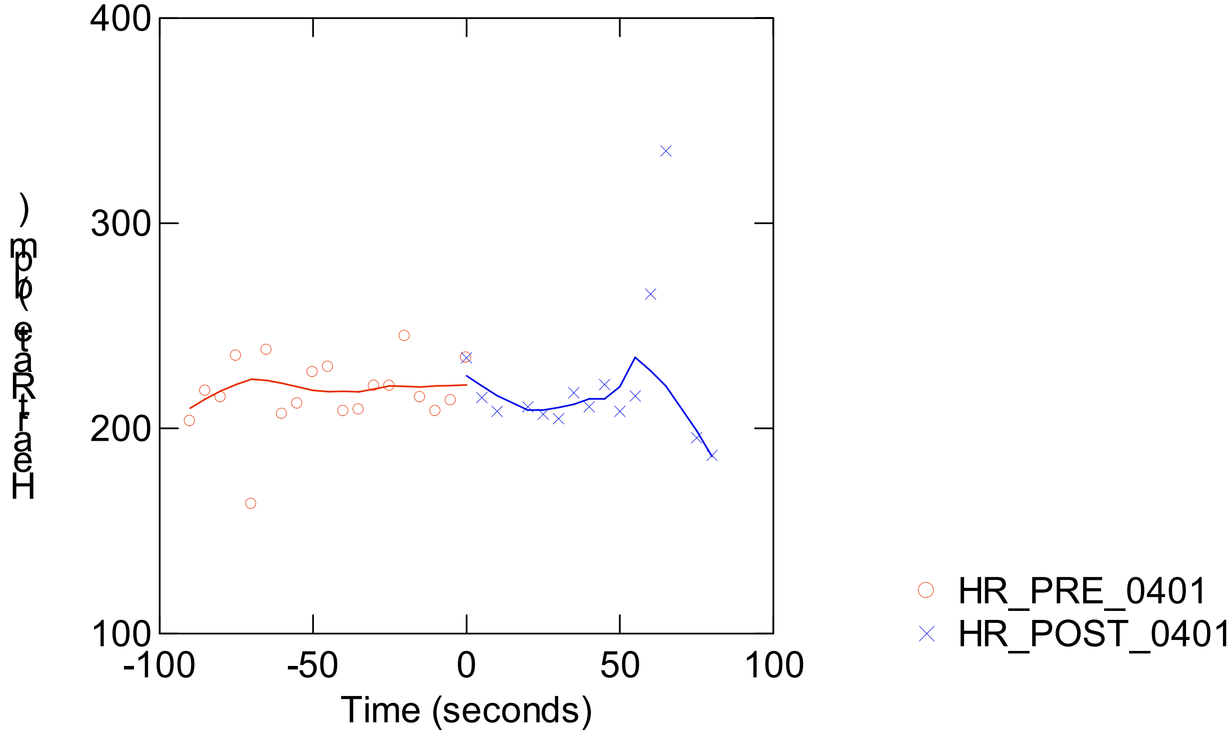

Figure B-9 Heart rate and dBA level during ambient conditions and over-flights. Heart rate for ambient conditions (dBA 35-45) is an average of the measured heart rates of the five ducks during non-flyover periods (i.e., from 21 recording periods).