Effects of Aircraft Disturbance on Harlequin Ducks Breeding in Central Labrador

Project Report 2002

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Executive Summary

In 2002, the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN) of the Department of Biology of Memorial University of Newfoundland (MUN) completed an optimal study design of the effects of low-level military jet over-flights on the behaviours of Harlequin Ducks breeding at Fig River in central Labrador. The close cooperation of the Military Control Centre (MCC) at 5 Wing Goose Bay resulted in the delivery of 94 military jet over-flights of the Fig River study area between 22 May and 18 June 2002, coinciding with the peak period of activity of breeding pairs of Harlequin Ducks.

Under funding from the Institute for Environmental Monitoring and Research (IEMR), Canadian Wildlife Service (CWS), ACWERN, and Northern Student training Program (NSTP), the Before After Control Impact (BACI) study design controlled for variation in time and space, and supported that paired Harlequin Ducks responded to military jet over-flights by increasing alert behaviours. Alert responses increased in magnitude with increasing noise levels generated from jets. The noise from military jets was sudden onset and generally loud, i.e., exceeding 80 dBA and reaching levels in excess of 125 dBA. Noise levels from military jets were substantially above the background sound levels of Fig Lake (40 – 50 dBA), and the rapids and riffles of Fig River (60 – 70 dBA) frequently used by Harlequin Ducks.

We examined standardized behavioural watches up to 2 hours following over-flights by military jets, and demonstrated apparent residual effects related to increased agonisitic (aggression) behaviours and decreased courtship behaviours. We concluded that direct behavioural responses, i.e., alert reactions, were unlikely to negatively affect time-activity budgets under this frequency of over-flights by military jets because these responses accounted for about 1% of the daily behaviours. Residual effects were potentially more problematic because increased aggression among individuals might affect stability of the long-term pair bonds, and decreased courtship might affect the fertility rate of eggs that are laid sequentially every 2 to 3 days during the spring period.

Female Harlequin Ducks averaged about 40% of the day in feeding, similar to previous years, and there was no evidence to support a constraint on the ability of birds to acquire sufficient food. Small rodent populations had recovered somewhat over 2001 but nevertheless rates of nest depredation by predators were high because only 4 broods of at lest 10 nesting pairs were subsequently observed in 2002.

Body condition of breeding pairs of Harlequin Ducks varied little across years and sites in central Labrador. Our samples of captured birds were small in 2002 due to very high water levels, and we were unable to make conclusive statistical inferences about effects of jet noise on body condition. The new bandings achieved in 2002 increased the marked samples of Harlequin Ducks to Fig River – 95 and Crooked River 43. Return rates continued to be high although they were marked lower at Crooked River presumably because of our late arrival to that site and the unusually high water levels experienced there. Using Program MARK we estimated high apparent annual survival rates as: Fig River - Adult female: 0.795 + 0.065 SE, Adult male: 0.874 + 0.089 SE, and Crooked River - Adult female: 0.857 + 0.089, Adult male: 0.500 + 0.112. In 2002, the first recruiting females from the 1999 juvenile cohort were known to attempt breeding. Our survival estimate of 0.876 + 0.212 SE related to the return of 6 of 8 of juvenile females from 1999, and is the first estimate of survival rate to recruitment age in Harlequin Ducks.

The 2002, the Harlequin Duck research project in central Labrador demonstrated that academic researchers, the IEMR and DND could coordinate respective interests and mandates in order to apply high quality scientific research of the effects of low-level military jet noise on the environment. We recommend further studies that apply the BACI design to these studies. For Harlequin Ducks, we recommend continuation of the mark-resighting program in 2003 in an effort to refine our estimates of survival of juveniles to recruitment age, and to formally test for an effect of military jet over-flights received in 2002 on survival of adults. Because residual effects of military jet over-flights on behaviours of Harlequin Ducks breeding at Fig Lake are cause for concern, we recommend further studies to substantiate these impacts.

<u>Introduction</u>

In 1999, the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN), with major funding from the Institute for Environmental Monitoring and Research (IEMR), initiated research on the effects of low-level military jet disturbance on the *endangered* Harlequin Duck (*Histrionicus histronicus*) breeding in the Military Training area (MTA) of central Labrador (Figure 1). In 2000, an expanded operational program continued the studies at Fig River, and investigated potential control sites in order to develop the *Before After Control Impact* (BACI) experimental design, an optimal statistical approach for detecting environmental impact because it incorporates spatial and temporal controls (Green 1979). This design, as applied to this project, has been endorsed by the Institute's scientific advisors and will likely serve as a model for future effects research conducted by the Institute and its partners (IEMR 2001). Subsequently, commencing in 2001, Crooked River at the outlet of Nipisish Lake (Figure 1) was selected as a control site outside of the 130,000 km^2 Military Training Area (MTA).

The objectives of the Year 2002 Harlequin Duck study were:

i. In conjunction with the IEMR, develop a protocol to encourage increased military over-flights of Fig Lake outlet through support from IEMR and DND.
ii. Measure aircraft noise and ambient sound at Fig Lake outlet.
iii. Quantify time-activity budgets of adult Harlequin Ducks breeding at Fig River.
iv. Assess behavioural responses of Harlequin Ducks to ambient sound.
v. Assess behavioural responses of Harlequin Ducks to aircraft over-flights.
vi. Assess behavioural response to aircraft over-flights in relation to generated noise dose.
vii. Assess breeding effort and productivity on study sites.
viii. Re-sight marked Harlequin Ducks banded in 1999, 2000 and 2001 in order to assess (i) site fidelity, (ii) longevity of pair bonds, (iii) return rates, (iv) apparent survival rates, and (v) recruitment rates of females born in 1999 and 2000.
ix. Mark unbanded adults and juveniles.

x. Collect standardized morphological data on adult and juvenile Harlequin Ducks, and develop indices of body condition.

xi. Collect complementary behavioural and morphological data at the control site at Crooked River (outside the MTA).

Methods

Chonology and Logistics

From 17 - 20 May 2002, the base camp at Fig Lake was re-established. At that time, ice and especially snow cover were very extensive. Individual tents were placed at sites established in previous years. The first Harlequin Ducks (~ 4 pairs) were observed in the open river at Fig Lake outlet on 18 May 2001, and spring was notably later than in previous years. Spring 2002 was noted for its protracted chronology and cool temperatures through May and into early June. The thaw of large amounts of accumulated snow resulted in high water levels and complicated logistics of moving to and from camp to study sites. In the previous fall, the two canoes had been moved up to Gabriel Lake by Innu, and we were unaware of this prior to returning to the study camp. In late May, we were grateful for the loan of an inflatable Zodiak from Canadian Wildlife Service. The camp at Crooked River at the outlet of Nipisish Lake was deployed on 5 June 2002. Overall, spring chronology and breeding phenology were about 7 days later at both sites than was experienced in previous years. Both sites experienced water levels that resulted in high discharge at the outlets, and considerable flooding of the shrub and woody backshores. At Crooked River, the 2002 water levels were much higher than experienced in previous years, e.g. there were no rapids at the outlet of Nipisish Lake. Harlequin Ducks made extensive use of the flooded backshores of Fig Lake, and to some extent Nipisish Lake, during these periods of high water levels.

Data on productivity of Harlequin Ducks at Fig River were collected from 22-31 August 2002, as well as some standardized observations on behaviours of females and broods. This was reduced in scope over previous years due to the limited field time. Water levels oscillated during this period but generally remained unusually high through late summer. Aquatic furbearers were common at Fig River in 2002, and mink (*Mustela vison*) were frequently observed. Small rodent and Snowshoe Hare (*Lepus americanus*) populations had increased noticeably, and this might be indicative of cyclic peak in numbers in the next year or two.

Capture, Banding, and Resighting

Under the Scientific Permit to Capture and Band Migratory Birds No.10702 and Scientific Capture Permit No. 2236 of Environment Canada, adult Harlequin Ducks and broods were captured in spring and summer using conventional mist nets. Individuals were marked with standard USFWS metal tarsal bands and a standard colour leg band bearing an unique alphanumeric code, i.e., yellow with a black numeric-alpha code. This unique code provided the basis for re-sighting of individuals within seasons, across seasons, and/or across years using spotting telescopes (20-60x zoom lens and high quality optics). Harlequin Ducks frequently haul-out on rocks to rest and preen which facilitates the reading of leg bands.

By resighting marked individuals, we linked behavioural budgets, productivity, noise levels and responses to disturbance to known individuals. Furthermore, this capture-mark-resighting (CMR) technique is the basis for estimation of apparent survival rates, and testing hypotheses about survival against other potentially interacting variables, such as location, age, and individual covariates including mass and condition, etc. (see Lebreton *et al.* 1992, Cooch and White 2001). Commencing in 2001, the technique supported the calculation of probabilities (maximum likelihood estimation) that the marked individuals were still alive but not observed and these are combined with return rates to generate estimates of apparent survival rates.

Blood samples were collected from most captured birds by puncturing the tarsal vein with 0.26 gauge hypodermic needle after initially sterilizing the site with an alcohol swap. Oozing blood was collected with a glass pipette and placed in vials containing Queen's lysis buffer. These samples were kept cool/refrigerated and delivered to Canadian Wildlife Service for further analyses as required under the scientific capture permit no. SC2236. These samples will be used in a study of genetic structure of populations of Eastern Harlequin Ducks (P. Thomas, CWS, Pers. Comm.).

Morphometrics and Body Condition

Morphometrics were collected on captured birds, including:

i. Mass to nearest 5g using a hand-held Avinet spring balance.
ii. Wing length, for wing chord and flattened wing from notch, to nearest mm using a ruler.
iii. Length of 9^{th} and 10^{th} primary from sheath to nearest mm using a ruler.
iv. Tarsus length, for inner and outer tarsus, using vernier calipers.
v. Tail length to nearest mm using a ruler.
vi. Culmen midline to nearest 0.1mm using vernier calipers.
vii. Exposed culmen to nearest 0.1mm using vernier calipers.
viii. Sternum length to nearest mm using pivoting calipers.
ix. Head length using vernier calipers.
x. Body Length by flattening the bird along a 70 cm ruler.

We used Principal Component Analysis (PCA) to reduce morphological measurements into the first principal component (PC1) to account for variation in structural size (Pimental 1979, Robb *et al.* 2001). Because we used the variance-covariance matrix, all variables were transformed to natural logarithms to ensure homogeneity of variance because variables varied in units of measure (e.g. mm, cm, g) and PCA is extremely sensitive to such heterogeneity (Green 1979, McGarigal *et al.* 2000). Body mass was regressed against associated PC1 scores; residuals then were used to assess condition, i.e., positive residuals indicated individuals with above average condition, and negative residuals indicated individuals below average condition.

Behavioural Observations

General Behaviour

Data on behaviour of Harlequin Ducks were collected from 18 May – 18 June 2002 at Fig River and 7 - 18 June 2002 at Crooked River, and also 24 – 31 August 2002 at Fig River. A focal sampling approach (Altmann 1974) was applied in this study, and where possible linked to known individuals. A more complete linking of known individuals to behavioural watches was possible in 2002 because a large proportion of our Harlequin Ducks marked in 1999, 2000, and 2001 returned in 2002.

Behaviour of Harlequin Ducks is characterized by bouts or states e.g. FEEDING and RESTING (see Martin and Bateson 1986), and each of these bouts generally lasts less than 30 minutes. Focal birds were monitored for 30 minutes (or until lost from sight) using binoculars and/or (20X-60X) spotting scopes. Instantaneous behavioural classifications of focal birds were recorded every 15 seconds, using digital watches with countdown-return beeper functions, from a suite of 60 categories until 30 minutes had elapsed. For the purposes of this report, these data were collated into 15 general behavioural categories (Table 1). In order to maximize independence of behavioural data, a new bird was selected for observation or observers shifted locations to find other birds after each 30-minute watch was completed. In a few cases, two standardized watches were conducted in succession.

Instantaneous data recorded every 15 seconds were not statistically independent within each 30 minute watch. Therefore frequencies in behavioural categories were summed over each watch, and these summaries were converted to proportions, i.e., one data entry per behavioural watch (Martin and Bateson 1986). Proportions represented the primary unit for general data presentation, e.g. time-activity budgets. Further statistical analyzes applied the Generalized Linear Model, using The GENMOD Procedure of SAS (SAS Institute Inc. 1993). The response variable was modeled using a binomial distribution with a logit function because each data entry were binomial in nature, i.e., the individual bird either exhibited a given behaviour or it did not.

Undisturbed Versus Disturbed Categories

Behavioural watches were segregated into disturbed and undisturbed categories. We considered a standardized watch to be disturbed if the focal birds were over-flown by an aircraft during the 30-minute period. Our ability to coordinate and coincide standardized behavioural watches with aircraft over-flights was dependent on the knowledge that aircraft would be transiting the study area during specific time windows.

Coordination of Aircraft Over-flights

Military Jets

Our ability to coordinate and coincide standardized behavioural watches with aircraft over-flights was dependent on the knowledge that aircraft would be transiting the study area during specific time windows. Operational staff at 5-Wing Goose Bay relayed time on target (TOT) of military jet over-flights to field staff via satellite phone following the submission of daily flight plans by allied pilots that indicated their intent to register the target located at Fig Lake. In 2002, mock army tank targets were airlifted and placed on peatlands within 300m of the outlet of Fig Lake in an effort to increase low-level military jet flights there. Having a formal military target at the study site was beneficial because pilots had to file daily flight plans indicating intent to over-fly target sites.

Aircraft over-flights of the study area were recorded to time of day and aircraft type whenever possible. If aircraft was visible, we recorded the direction of transit, altitude, and whether the aircraft transited over the Fig Lake outlet where the digital time-logging Larson Davis Model 820 Sound Level Meter was deployed. Study site information related to military jet over-flights was relayed to DND 5 Wing Goose Bay on a daily basis.

Civilian Aircraft

In addition to military aircraft, we also attempted to collect behavioural data associated with civilian aircraft, and these generally related to helicopter and/or floatplane logistical support for the camp at Fig Lake. We generally had prior knowledge of the approximate time of arrival of these aircraft from communication with the charter company dispatcher. It was felt appropriate to use civilian aircraft because other researchers have demonstrated that noise generated by helicopters was the primary stressor affecting response in waterfowl (Ward *et al.* 1994, 2001).

Sound and Noise Measurements

Sound Data

Collected sound data were primarily A-weighted because this scale approximates the hearing sensitivity of most birds (Meyer 1986), and is a standard scale generally used to quantify aircraft noise in avian studies (Brown 1990). A continuous digital time logging Larson Davis Model 820 Sound Level Meter was programmed and deployed at the outlet of Fig Lake in the area of maximum use by Harlequin Ducks. Data collected included L_{max}, L_{min}, L_{eq}, Sound Exposure Level (SEL), Peak, unweighted Peak, L1, L3, L5, L10, L25, and L90 every 60 seconds and as mean values every 30 minutes. Data were logged daily from 0500 to 2100 in an effort to coincide with activity by Harlequin Ducks at the outlet, and also encompass the time window for military over-flights. This level of coverage of sound measurements required that we downloaded the LD820 onto a data logger every 2 to 4 days.

Behavioural data were also collected at other sites along Fig River and Fig Lake, and we recorded sound during those 30-minute watches using hand-held digital Larson Davis Model DSP80 Sound Level Meter (Larson Davis Laboratories 1998). This sound meter recorded $L_{max\ (A\text{-weighted})}$, $L_{eq(A\text{-weighted})}$, and peakC values integrated over the 30-minute standardized behavioural watch.

Aircraft Over-flight Noise

The *Passby* function is a special exceedance event detector on the LD820 Sound Level Meter that measures the L_{max}, L_{eq}, and Sound Exposure Level, weighted Peak Level, Unweighted Peak Level, Symmetry and Decay of the highest event to raise and lower $\geq$ 10 dB in Sound Pressure Level. It is used to capture single event noises such as vehicle or aircraft passby (Larson Davis Laboratories 1997). In addition to the levels measured, the date and time of the L_{max} and the duration of the event are recorded. The recorded maximum duration of the passby event is 64 or 128 seconds depending on whether a 0.5 or 1.0 second time history period is selected. Ten samples before and after the exceedance are normally stored up to a maximum of 255 samples with each sample period being 1/32 seconds; equivalent to 8 seconds before and after. For the Fig River study, we set a time history period to 0.5 seconds triggered for events with a minimum duration of 3 seconds and exceedance threshold of 75 dBA.

CONTROL OF WIND NOISE

We reduced/eliminated wind noise by locating the LD820 Sound Level Meter in a leeward site protected from the predominant westerly winds. We placed a two-layered baffle over the microphone and wind shroud consisting of an inner layer of silk, an outer layer of burlap, and an outer covering of plastic (A. Bowles and S. Insley, pers. comm.). The LD820 Sound Level Meter was assessed for calibration with and without the baffle, and readings were not significantly different (Paired t-test, $P > 0.40$); the background degradation due to the baffle averaged less that 0.3 dB).

EXPERIMENTAL DESIGN

An optimal environmental impact study design was applied using a Before After Control Impact (BACI) statistical approach. This experimental design has controls in both space and time**,** and the General Linear Model for BACI is a two-way ANOVA, i.e., an areas by times 2 X 2 factorial design whereby the evidence for impact effects is a significant interaction term (Green 1979) (Figure 2):

$$\textit{Behaviour} = \beta_o + \beta_{ba} * B\text{-}A + \beta_{ci} * C\text{-}I + \beta_{ba \times ci} * B\text{-}A \times C\text{-}I + \textit{residual}$$

$$\text{F-ratio} = MS_{ba \times ci} / MS_{Error}$$

The behavioural data collected every 15 sec. during a 30-minute watch were binomial in nature, i.e., the birds either responded with a given behaviour or they did not. Therefore response was modeled using a binomial distribution with a logit link in the GENMOD Procedure of program SAS (SAS Institute Inc. 1993).

<u>Results</u>

Military Jet Over-flights

COORDINATION AND FREQUENCY

The coordination by the Military Control Centre (MCC) at 5 Wing Goose Bay resulted in low-level over-flights of the Fig River study site by 94 military jets between 19 May and 18 June 2002. Approximately 2/3 of over-flights occurred in early to mid June and 1/3 occurred on 2 days (Fig. 3). Approximately ½ of over-flights occurred in the 10:00 – 10:30 time window and about 1/3 in the 16:00 – 17:00 period (Fig. 4). Over-flights at Fig River related to sortie times to and from 5 Wing Goose Bay. Briefings and up-datings of field crew at Fig Lake by DND from the MCC at 5 Wing Goose Bay of anticipated military jet sorties to Fig River were excellent. Regular contact with MCC staff was by satellite phone, and resulted in accurate forecasting of Time On Target (TOT) by military jets.

BACKGROUND SOUND AND JET NOISE

Noise generated by military jets was dramatically higher than background sound levels near the outlet of Fig Lake (40 – 50 dBA) and along the rapids and riffles of Fig River (60 – 70 dBA) (Fig. 5). Noise events related to military jet over-flights were sudden onset (Appendix 1) and loud (Lmax: mean 91.4 dBA ± 11.69 SD, PEAK: mean 101.9 dBA ± 13.27 SD) but of short duration (mean = 6.1 sec ± 3.67 SD). The maximum PEAK noise level (A-weighted) registered during an over-flight by a military jet was 129.3 dBA (Table 2).

Behaviours

UNDISTURBED BEHAVIOURS

At Fig River in 2002, undisturbed Harlequin Ducks spent about 40 % of the day feeding, and this was very similar to other years ($F = 0.136$; $P > 0.95$). In undisturbed conditions, only about 0.1% of the time was related to alert behaviours (Fig. 6).

BEHAVIOURS DURING DISTURBANCE

We were successful at completing a full BACI experimental design. There was a significant impact of military jet over-flights on behaviours of paired Harlequin Ducks breeding on the Fig River study site in central Labrador. Harlequin Ducks responded to over-flights by increasing ALERT behaviours (females – ba x ci : $X^2 = 38.79$, $P < 0.0001$; males – ba x ci : $X^2 = 31.21$, $P < 0.0001$) (Fig. 6). Results of the BACI model for other behaviours were more ambiguous, for example, there was a significant interaction term for VIGILANT behavious (females - $X^2 = 5.08$, $P = 0.024$; males - $X^2 = 26.14$, $P < 0.0001$) which may support that paired female Harlequin Ducks increased VIGILANCE during over-flights by military jets however the significant ba*ci interaction for paired males was not intuitive, i.e., no difference between before and after treatment at Fig River (Fig. 8) There was a possible year effect on COURTSHIP, at least for paired females, but the ba*ci interaction terms were not significant (females - $X^2 = 0.33$, $P = 0.5631$; males - X^2 0.40, $P = 0.5258$) (Fig. 9).

There was evidence of short-term behavioural habituation as during successive jet over-flights (< 1 min apart) ALERT behaviours waned, and by the third successive jet over-flight there was no detectible behavioural response (females - $X^2 = 0.016$, $P = 0.90$; males - X^2 0.102, $P = 0.75$).

DOSE – RESPONSE RELATIONSHIPS

There was a highly significant dose – response relationship of ALERT behaviours to noise levels generated by military jets (Figs. 10, 11), and the relationship was stronger for paired females ($X^2 = 21.42$, df = 1, $P < 0.0001$; $ß_{Lmax} = 0.0287$, 95% CI = 0.0166 – 0.0409) than paired males ($X^2 = 13.25$, df = 1, $P = 0.0003$; $ß_{Lmax} = 0.0215$, 95% CI = 0.0099 – 0.0331).

RESIDUAL EFFECTS

There was evidence to support possible residual effects of noise generated by military jet on AGONISTIC behaviours (for paired females: $X^2 = 67.27$, df = 6, $P < 0.0001$; for paired males $X^2 = 50.77$, df = 6, $P < 0.0001$) (Figs. 12) and COURTSHIP behaviours (for paired females: $X^2 = 60.09$, df = 6, $P < 0.0001$; for paired males $X^2 = 57.05$, df = 6, $P < 0.0001$) (Fig. 13) of Harlequin Ducks at Fig River. Aggressive behaviours appeared to be higher up to 1 h following over-flights, and courtship behaviours appeared to remain lower up to 1.5 h following over-flights than levels of these behaviours exhibited prior to over-flights of paired Harlequin Ducks by military jets at Fig River.

Mark-Resighting

Bandings

There were 4 new bandings (3 ASY males, 1 L female) and 5 recaptures (2 males, 3 females) of Harlequin Ducks in 2002. An ATY male banded in Forillon National Park, Gaspé Peninsula in 1997 was re-captures at Crooked River, and received the new numeric-alpha band yellow 7Y (original blueE8 had been lost since 2001 re-sighting). The successful continuation of the banding program increased the total marked individuals at Fig River (Treatment Site) as: Adult Male – 20, Juvenile Male – 33, Adult Female – 18, Juvenile Female – 24; at Crooked River (Control Site): Adult Male – 16, Juvenile Male – 4, Adult Female – 19, Juvenile Female – 4. Recaptures included ATY females ye3K, ye3P and FY female ye4R, a recruit from the 1999 young cohort. For the fourth consecutive year, ye3P bred successfully at Fig River, and we were successful at capturing a local female from this brood (ye8K). Morphometrics were collected on all captured individuals (Appendix 2).

Return Rates and Apparent Survival

Return rates to the study areas were high for adult Harlequin Ducks, i.e., Fig River: ATYF –10 of 18 (0.556), ASYM – 13 of 21 (0.619), LF – 7 of 24 (0.292), and LM – 0 of 33 (0), and Crooked River: ATYF – 5 of 19 (0.263), ASYM – 6 of 16 (0.375), LF – 0 of 4 (0), LM – 0 of 4 (0). As expected, the adult return rates were lower than those presented for 2001 (Goudie and Jones 2002) because they combine all Harlequin Ducks marked to date. Sample sizes of local birds at Crooked River were very small. Returns of females born at Fig River have been higher than expected, i.e., 6 of 8 for the 1999 cohort thus far whereas no local males have been re-sighted on their natal areas. We noted the return of ye9B, a juvenile from the 2000 cohort, for the second consecutive year. In contrast to previous years, none of the 12 juveniles marked in 2001 were re-sighted in 2002.

Apparent survival rates for adult females were high, i.e., Fig River – 0.795 $\pm$ 0.065 SE and Crooked River – 0.857 $\pm$ 0.132 SE whereas there was more spatial variation evidenced for adult males, i.e., Fig River 0.874 $\pm$ 0.089 SE and Crooked River - 0.500 $\pm$ 0.112 SE. Re-sighting probabilities were generally very high and the most parsimonious models supported a constant survival rate with time variation in probability of re-sight for females and males at Crooked River (Table 3). We felt that our timings plus variation in spring chronology affected the re-sight probabilities at Crooked River, and therefore forced time variation on re-sighting probability even when model selection did not support it (e.g. adult males). We only considered the model incorporating a constant survival and time variation in re-sighting for recruiting females as temporal heterogeneity in re-sighting rates was intuitively expected.

At Crooked River, we re-sighted a lone male banded with metal only that was recaptured, and discovered to be the same male (blE8) that had been re-sighted there in 2001. This male was originally banded at the coast of the Gaspé Peninsula in Forillon National Park in April 1997 (P. Thomas, pers. comm.). There were no other ‘foreign’ re-sighting/recaptures at Fig River or Crooked River in 2002. During observations of male Harlequin Ducks moulting at the Gannet Islands off Cartwright in coastal Labrador in 2002 there were re-sightings of ye5S, an ASY male banded at Fig Lake in 2003 and ye8P, a juvenile female banded at Fig River in 2001. These re-sightings were the first to connect the population of Harlequin Ducks at Fig River with moulting concentrations at the Gannet Islands. Complete Capture-Mark-Recapture arrays are presented by cohorts in Appendix 3.

Body Condition

There was little evidence of inter-year variation in body condition of Harlequin Ducks breeding in central Labrador. In 2000, females at Crooked River may have been below average condition. The predominance of positive residuals for the adult male Harlequin Ducks at Fig River in 2000 suggested that these birds were in better than average body condition that year whereas male Harlequin Ducks were in poorer body condition at Crooked River in 2001. There was no evidence that the noise treatment resulting from the over-flights of military jets affected body condition of adults up to 7 June 2002, although the majority of over-flights occurred after this date (Fig. 14).

We were unable to test the prediction for impact of noise treatment on body condition of juvenile Harlequin Ducks at Fig River because only 1 local female was successfully captured in 2002. Nevertheless, we found no evidence of inter-year or inter-site variation in body condition of juvenile Harlequin Ducks produced in central Labrador over the 4 years of our study (Fig. 15).

Productivity

At Fig River, 4 broods were observed in 2002. Brood size averaged 4.75 $\pm$ 1.26 SD, (range 3 – 6 young at classes 2c to 3). At least 10 pairs were present on the study area in 2002 yielding a productivity of 0.4 broods per female or 1.9 young per female. We observed that ye3P successfully produced a brood (5 young) for the fourth consecutive year, and ye3L who failed due to depredation in 2001was successful in 2002 (6 young), representing success in 3 out of 4 years. Overall production of young on the Fig River study area from 1999 to 2002 was influenced strongly by a few experienced hens. Of the 2 remaining hens and broods, band status was unknown for one, and the remainder was banded (yellow) but not deciphered.

Small rodent populations were indexed at 2 indicating that they had recovered to some degree in comparison to 2001. A regression of productivity on our small rodent population index indicated a strong relationship although this is only based on 4 years of data (Fig. 16).

Habitat Use

We experienced very high water levels in 2002. In spring-early summer, the melt was protracted and water levels remained high because of the large amount of accumulated snow from the previous winter. Harlequin Ducks made extensive use of the inundated shorelines of Fig Lake and lagoons of Nipisish Lake from late May to early June. Following this, there was substantial use of the 2^{nd} Steady ~ 0.5 km below Fig Lake, a pattern similar to 2000.

Heavy rains maintained unusually high water levels throughout late summer. There was consistent use of Fig Lake outlet by females with broods. A banded female with a brood of 3 young observed at the outlet of Kakopoe Lake (Hiding Porcupine Lake) was never re-sighted at the outlet of Fig River.

Discussion

Completion of the BACI Design

We were successful at completing the optimal experimental design (Green 1979) in order to test for a statistical effect of military jet over-flights on behaviours of Harlequin Ducks breeding at Fig River in the Military Training Area. The treatment of military jets at Fig Lake had been problematic in previous years but was accomplished in 2002 because of:

i. The direct liaison between IEMR and 5 Wing Goose Bay in order to develop a strategy to attract military jets into the general area.
ii. Placement of mock army tanks on peatlands adjacent to the Fig River study site in early spring.
iii. Daily liaison between the MCC staff at 5 Wing Goose Bay and the Allied forces squadrons in order to encourage them to register the targets established adjacent to Fig Lake.
iv. The filing of daily flight plans by Allies that were required to indicate intent to register targets such as Fig Lake.
v. Daily liaison between the MCC staff at 5 Wing Goose Bay and the field crew at Fig River via satellite telephone and e-mail predicting time on target of military jets. Phone calls were usually in early morning and after lunch to mid afternoon depending on anticipated sortie times. Forecast sortie times for the following day were provided late each day via e-mail.

The demonstration of an effect of military jet noise on behaviours of Harlequin Duck was not surprising giving that response to aircraft noise had been demonstrated previously (Goudie and Jones 2001, 2002). Clearly, the inclusion of the control site at Crooked River strengthened our inferences as we did note that some apparent before-after effects at Fig River were likely related to temporal effects.

Effects of Jet Noise on Behaviours

Direct Behavioural Responses

Adult Harlequin Ducks breeding at Fig River responded to noise generated from low-flying military jets. This is not surprising given that the noise is sudden onset, very loud, and substantially above background levels of the riverine environment of the Harlequin Ducks. In spring, when breeding pairs were intact, Harlequin Ducks increased alert behaviours during military jet over-flights including flushing, panic diving, head-up orientation, and general agitation related to this sudden onset noise. Loud noise (> 70 dBA) generated by low-level military jets generally lasted less than 15 seconds, and subsequent behavioural responses by Harlequin Ducks lasted less than 60 seconds.

In the context of time-activity budgets, alert behaviours comprise a small fraction of the daily activity in undisturbed (~0.1%) and disturbed (~1.0%) scenarios. Critical behaviours that consume a significant portion of the time-activity budget include feeding which averaged about 40% of the day (Fig. 19). It appears unlikely that direct (ALERT) response to military jets could jeopardize the ability of adult Harlequin Ducks to budget sufficient time to feeding unless the frequency of over-flights was considerably greater than the 94 registered over the 3 + weeks of this study. There is ample flexibility in the time-activity budget for compensatory adjustments for critical behaviours such as feeding, and it is known that Harlequin Ducks and other sea ducks can spend much higher proportions of the day in feeding if necessary (Goudie and Ankney 1986). Some species of birds can also increase the intensity of feeding (Swennen *et al.* 1989).

It is worth noting that the frequency of over-flights by military jets at the Fig River study area in 2002 was considerably higher than that experienced across many of the watersheds occupied by Harlequin Ducks in the MTA. Potential for a high frequency of military jet over-flights coinciding with significant concentrations of Harlequin Ducks is currently limited in the MTA to only a few watersheds, most notably the Nauskapi - Red Wine Rivers because of the heavy transiting use of these valleys for sorties to and from the northern portions of the MTA.

Residual Behavioural Responses

Implications of potential residual effects on behaviour are more difficult to interpret. If aggression increases following over-flights then some interference with feeding and resting could be implied. Whether increased aggression could affect the stability of the long-term pair bonds of this species is unknown. It is evident at Fig River that the older experienced females are the ones that breed successfully, supporting that experience is a very important factor. Reduced courtship following over-flights by military jets could be of concern because courtship serves important functions related to the maintenance of the strong pair bonds, and especially the continued fertilization of sequential eggs that are laid every other day until the clutch is complete (about a 2 week period) (Williams 1999). Because increased agonistic behavious and decreased courtship appeared to last up to an hour or more following over-flights by military jets, the implications to time-activity budgets of adult Harlequin Ducks is potentially more serious than the demonstrated short-term immediate alert responses.

Dose Response Relationship

A dose-response relationship of alert behaviours to noise levels generated by military jet over-flights has important implications for impact mitigation. The results demonstrated that alert responses especially intensify when noise levels reach and or exceed about 80 dBA. Because noise at ground level is strongly affected by altitude of aircraft, potential exists to maintain specific thresholds in altitudes that reduce noise exposure on critical habitats for Harlequin Ducks.

Body Condition

We found no compelling evidence to support inter-year variation in body condition of Harlequin Ducks breeding in central Labrador. This was especially the case for females as they didn't corroborate any patterns evident in body condition of males. For example, adult males may have been in better body condition at Fig River in 2000 than other years whereas the females did not show this pattern. A possible explanation for this difference is that the body condition could be strongly affected by when the males are captured because body condition deteriorates due to their increased vigilant behaviours associated with the strong pair bonds.

Body condition of juveniles was similar across years and sites. Although we could not test for an effect of military over-flights on body condition, we noted that the one local female captured at Fig River was in above-average body condition. Interpretation of an effect, or lack of, by military jets on body condition of adult Harlequin Ducks at Fig Lake is not possible because most adults were captured on or before 7 June 2002, by which time only about half (48) of the 94 military jet over-flights had occurred. Female (ye3P) was successfully recaptured with one of the 5 young of her brood on 23 August 2002. There was no indication that this female was below average body condition.

Productivity and Recruitment

Production (by marked hens) was relatively low on Fig River for the third consecutive year. We have demonstrated a relationship between an index of small rodent populations and productivity of Harlequin Ducks**.** The proximate factor(s) limiting production of young Harlequin Ducks in central Labrador appears to be nest predation. Eggs are removed from nests sometimes before incubation commences and there is no apparent re-nesting. Goudie and Jones (2002) proposed a pure reciprocal model of population limitations as proposed by Krebs *et al.* (2001) for Harlequin Ducks where cyclic herbivore populations (hares and/or small rodents) affect the levels of predation experienced because predators switch to alternative prey such as waterfowl during declines in herbivore populations. This model contrasts sharply with the long-held food-limiting paradigm developed by Bengtson and Ulfstrand (1971) in Iceland for Harlequin Ducks.

Recruitment to the breeding population in this species appears more prolonged than originally speculated (Robertson and Goudie 1999) because no subadult females, i.e., 2 years old, attempted to nest in our study. In 2002, we recaptured ye4R and confirmed that she was egg laden. Hence our first confirmed recruitment to breeding by a juvenile Harlequin Duck was at 3 years of age. It is significant to note that this individual was the only juvenile of the 8 females from the 1999 juvenile cohort that returned to Fug River at 1 year of age. She and other individuals returned as 2 year olds but none attempted to breed (Goudie and Jones 2002). Of the 8 females from the 1999 juvenile cohort, 6 have been re-sighted at Fig River to date, and only ye4R has attempted to nest. This suggests that: (i) survival to recruitment may be quite high for juvenile Harlequin Ducks at or near fledging age, (ii) recruitment into the breeding population may require a number of years at natal areas in order to gain experience, and (iii) recruitment into breeding cohorts may be protracted over a 3 to 5 + year period, a pattern demonstrated for Common Eiders (*Somateria mollissima*) in the Netherlands (Goudie *et al.* 2000).

Habitat Use

Especially with the high water levels experienced in 2002 due to protracted run-off, we reaffirmed the extensive use of inundated lake backshores by paired Harlequin Ducks. The extensive feeding observed at these locations likely related to the high abundance of Ephemoptera (Mayfly) larvae evident at these sites. Harlequin Ducks feed by gleaning (similar to dabbling) as well as diving which contrasted with the strictly diving mode evident during foraging on riverine habitats in spring. Therefore lake and pond networks along rivers may be critical habitat for sustaining breeding populations of Harlequin Ducks. Furthermore, it is well established that larval insect epibenthos are especially concentrated at lake outlets (Larson and Colbo 1983). The extensive and protracted run-off evident for many of these watersheds in the Labrador – Quebec region render riverine habitats largely unusable in spring-early summer.

The extensive use of inundated lake and pond backshores by Harlequin Ducks in spring is an important consideration for aerial surveys. In the past, mitigation measures related to Harlequin Ducks have been site specific and dependent on detecting Harlequin Ducks annually. Our experience is that high water levels can render such surveys to useless, i.e., detection rates that are normally 50 to 60% can be extremely low or zero. Further considerations related to the high annual site fidelity of the long-term pair bonds support that repeating annual surveys over the same sites is probably not appropriate, i.e., it should not be necessary to re-sight Harlequin Ducks each year. In 1998, additional coverage extending higher into the watersheds of central Labrador virtually doubled the previous estimate by Jacques Whitford Environment Ltd. on behalf of DND of numbers of Harlequin Ducks breeding in the MTA (AGRA Earth and Environmental and Harlequin Enterprises 1998). Hence effective mitigation measures must be developed with an integrated understanding of the species' life history while acknowledging the limitations to detection imposed by survey coverage and field methodologies.

Conclusions and Recommendations

Coordination of military jet over-flights in the cooperative application of a Before After Control Impact (BACI) scientific study design was demonstrated for the Military Training Area (MTA) in central Labrador. Noise generated from low-level military jet over-flights at Fig River was loud (> 80 dBA), and greatly exceeded the background level of the Lake (~40-50 dBA) and river environments (60 – 70 dBA) where Harlequin Ducks occurred in spring.

There was a positive dose-response relationship as adult Harlequin Ducks increased Alert behaviours with increasing noise levels from military jets. Reponses to military jet over-flights were of short duration, i.e., < 60 sec., and overall these alert behaviours accounted for about 1% of the daily time-activity budgets for the 94 events that we recorded in late May to 18 June 2002. This level of direct response is unlikely to have detrimental effects on the time budgeted to critical behaviours such as feeding. Residual effects were indicated by increased aggression up to 1 hour following over-flights, and decreased courtship up to 1.5 h following jet over-flights. Residual effects were potentially more problematic because aggression could affect stability of pair bonds, and decreased courtship might affects the fertility rate of eggs that are laid sequentially every 2 to 3 days during the spring period.

We found no evidence of annual variation in body condition of adults or young Harlequin Ducks. There was no inter-year variation in apparent survival rates for 1999-2000, 2000-

2001 and 2001-2002, i.e., Adult female: 0.795 + 0.065 SE, Adult male: 0.874 + 0.089 SE, and these were similar to studies elsewhere in North America. The first estimate of survival to recruitment age of female Harlequin Ducks was possible (0.876 ± 0.212 SE), and this was considerably higher than previous guestimates (e.g. 0.50). A formal test of the hypothesis of effects of military jet over-flights on adult survival in 2002 will potentially be possible in spring 2003.

Recommendations noted were:

1. The continued application of the Before After Control Impact (BACI) scientific study design to address questions of the impact of military jet noise on wildlife.

2. Continuation of the mark-resighting program into 2003 in order to:
    i. Refine estimates of apparent survival of juvenile female Harlequin Ducks to recruitment age.
    ii. Formally test the research hypothesis of the effects of military jet over-flights on apparent survival rates of adult Harlequin Ducks at Fig River in central Labrador.

3. Conduct further treatment studies of behaviours of Harlequin Ducks in order to substantiate the residual effects on aggression and courtship supported by our data.

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Table 1. General categories used to summarize behaviours of Harlequin Ducks.

BEHAVIOUR	DESCRIPTION
AGONISM	Agonistic interactions among conspecifics
AGONISM (HO)	Agonistic interactions while hauled out
COURTSHIP	All courtship behaviour (on the water), e.g., prone, copulate
FEED	All aspects of feeding (on the water), e.g. dip, dive, pause, glean
PEER	Looking into water (maybe associated with food seeking)
LOCOMOTION	All types of movements, e.g., swim, scoot, fly
LOCOMOTION (HO)	All types of movements while hauled out
PREEN	Feather maintenance while on water
PREEN (HO)	Feather maintenance while hauled out
REST	Rest while on water, including sleeping, head down
REST (HO)	Rest while hauled out, including sleeping, head down, sitting, standing
SOCIAL	Directed calls and head nods
VIGILANT	Maintaining a look-out (vigil) while on water
VIGILANT (HO)	Maintaining a look-out (vigil) while hauled out
ALERT	Head stretched upward and agitated while on water, often accompanied with locomotion.
ALERT (HO)	Head stretched upward and agitated while hauled out, usually accompanied with movement to water.

Table 2. General statistics for noise related to military jet events registered at Fig River, central Labrador, 19 May – 18 June 2002.

Parameter	N	Min	Max	Mean	SE	SD
Duration	133	1	16	6.1	.32	3.67
Leq	133	58.4	113.2	94.2	.94	10.78
SEL	133	57.8	115.5	101.3	.92	10.64
Lmax	133	65.6	116.5	91.4	1.01	11.69
PEAK	133	75.7	129.3	101.9	1.15	13.27
UWPK	133	0	128	101.0	2.23	25.77
SYM	133	12.5	92.6	52.5	1.90	21.96

Table 3. Apparent survival and resighting probabilities for Harlequin Ducks at Fig River and Crooked River in central Labrador.

Cohort	Model	Local Survival	Prob of Re-sight	AIC Wt.	Model Strength
Fig R.					
ATYF	Phi (.)P(.)	0.795 ± 0.065	1.00	0.543	2.8x
ASYM	Phi (.)P(.)	0.874 ± 0.089	0.817 ± 0.109	0.523	2.1x
LF	Phi (.) P (age*t)				
1999-2000		0.876 ± 0.212	0.0999 ± 0.124	0.2256	
2000-2001			0.5824 ± 0.366		
2001-2002			0.8843 ± 0.525		
Crooked R.					
ATYF	Phi (.)P(t)				
1999-2000		0.857 ± 0.132	0.45 ± 0.000	0.244	1x
2000-2001			1.0 ± 0.000		
2001-2002			0.32 ± 0.133		
ASYM	Phi (.)P(t)	0.571 ± 0.187	0.450 ± ob	0.131	-3.6x
			1.0 ± 0.000		
			0.808 ± 0.358		

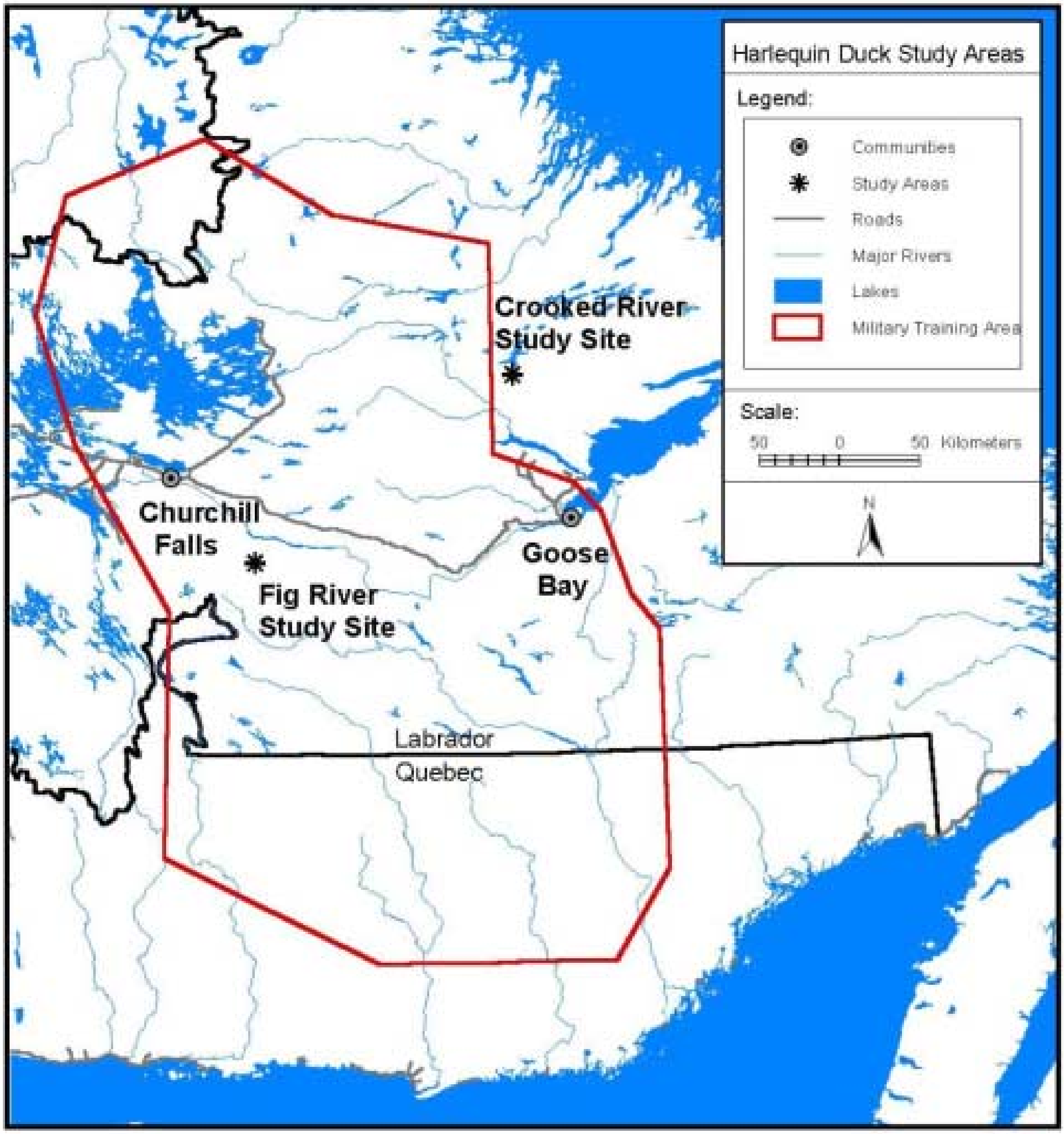


Figure 1. Fig River and Crooked River study areas and Military Training Area in central Labrador.

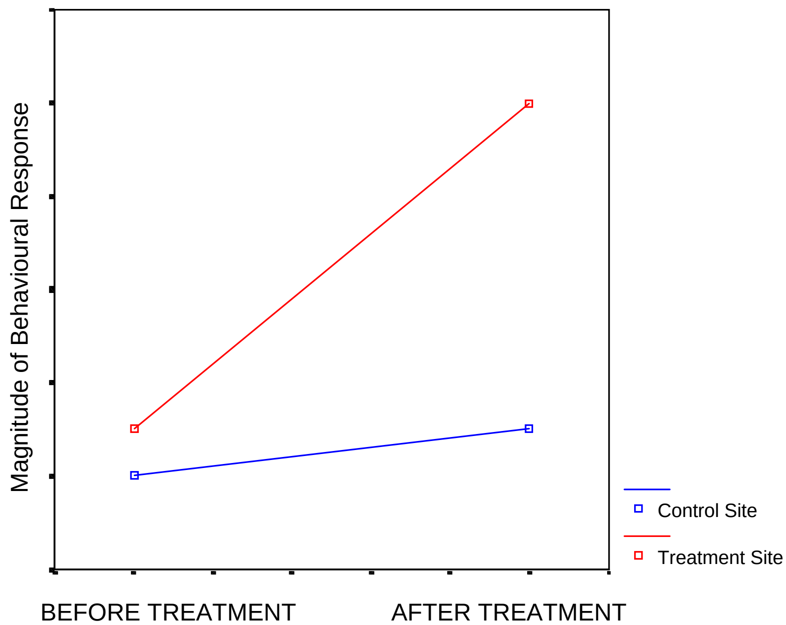


Figure 2. Conceptual statistical 2-Way ANOVA model for testing for effects of military jet over-flights on behaviour of Harlequin Ducks in central Labrador.

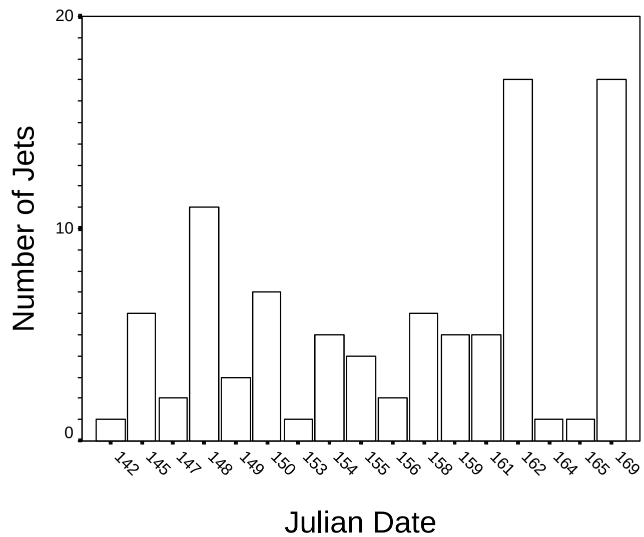


Figure 3. Distribution of 94 military jet over-flights registered at the Fig River study site in Labrador, 19 May – 18 June 2002.

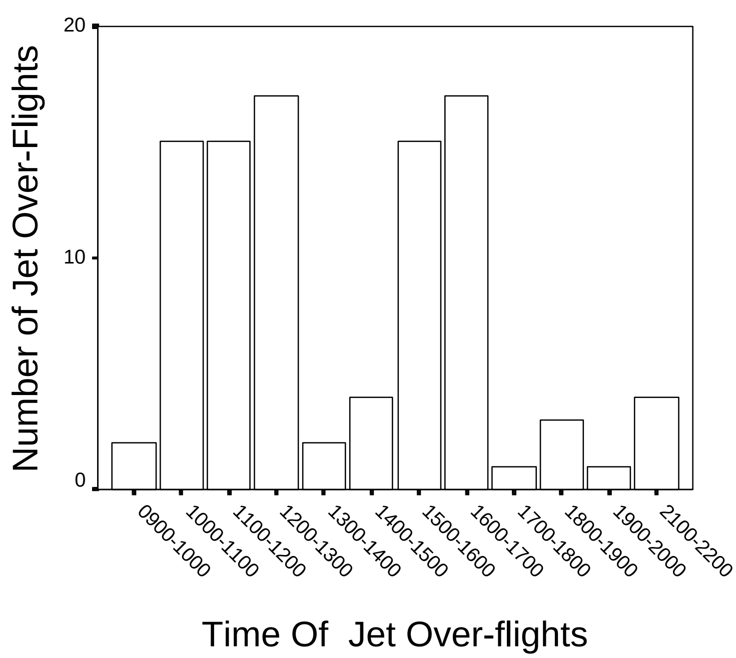


Figure 4. Time periods of military jet over-flights registered at the Fig River study site in Labrador, 19 May – 18 June 2002.

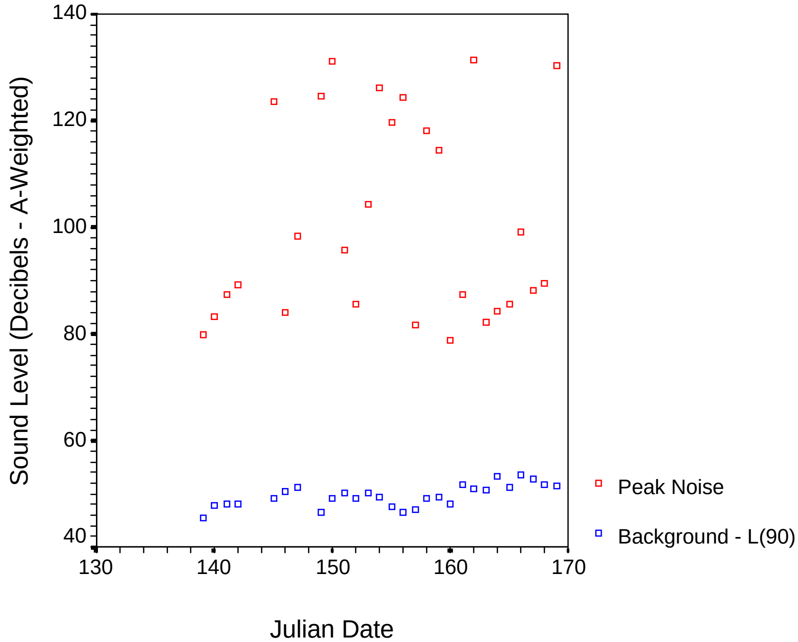


Figure 5. Background sound levels (L90) and peak noise levels registered during military jet over-flights near Fig Lake outlet, Labrador, 19 May – 18 June 2002.

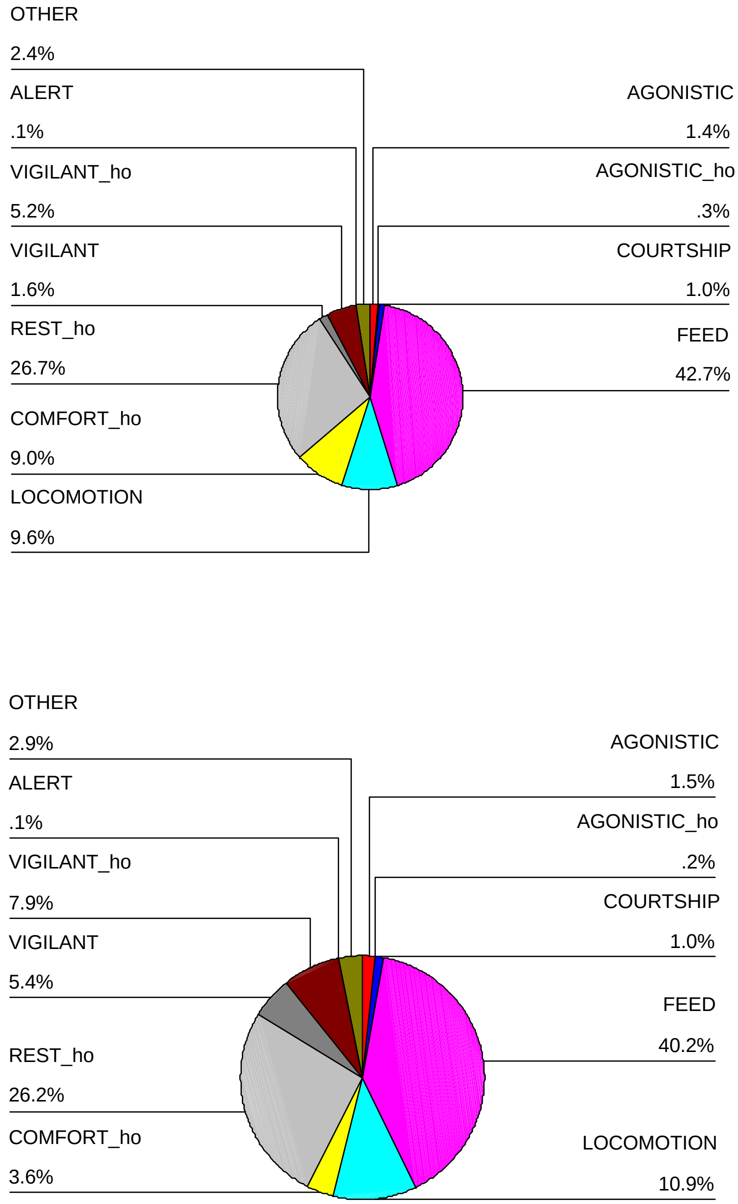
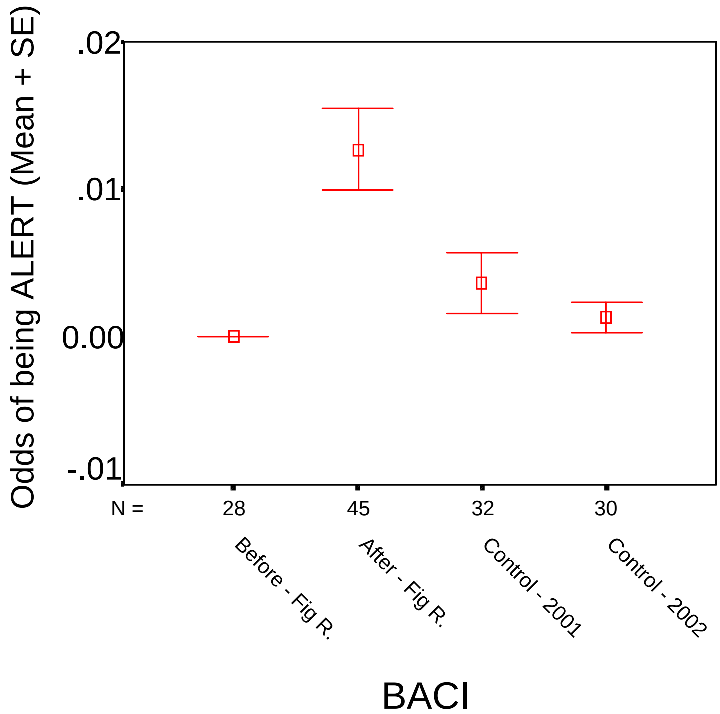


Figure 6. Behaviours of paired females (top) and paired males (below) at Fig River, central Labrador, 2002.



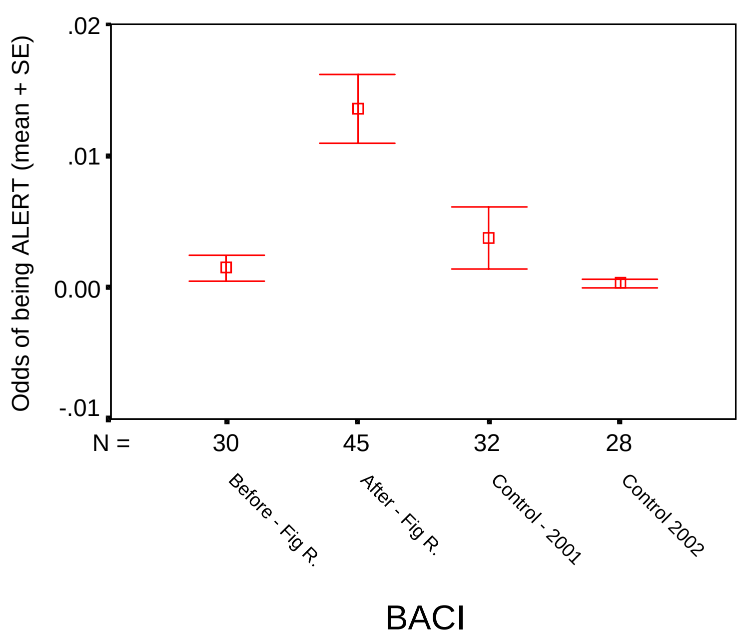
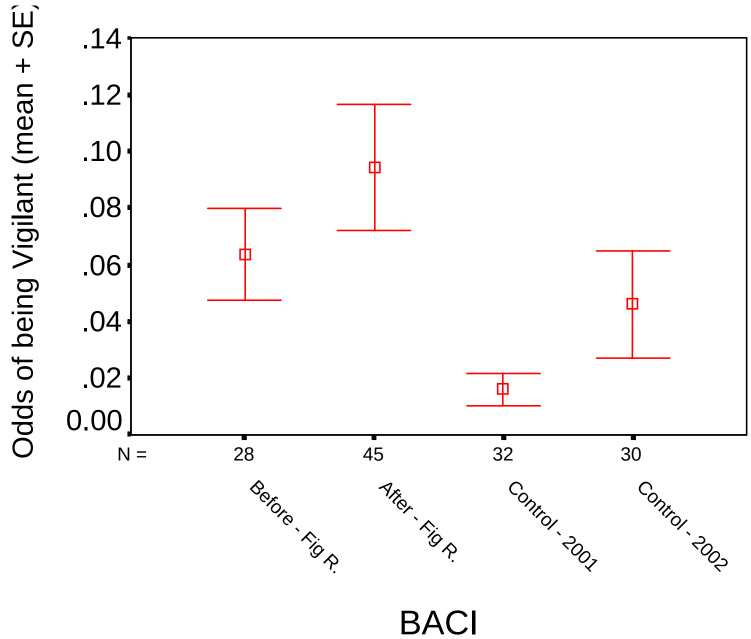


Figure 7. Odds of being ALERT by paired female (above) and paired male (below) Harlequin Ducks in treatment and control locations before and after military jet over-flights.



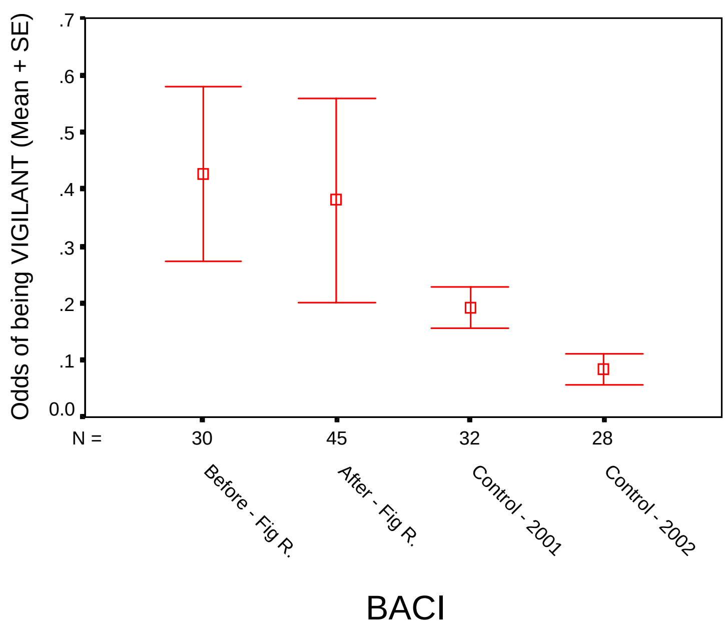
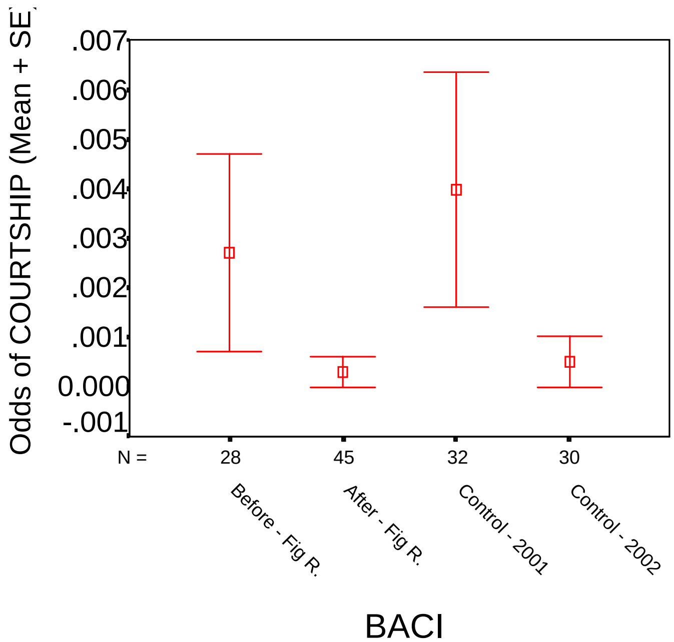


Figure 8. Odds of being VIGILANT for paired female (above) and paired male (below) Harlequin Ducks in treatment and control locations before and after military jet over-flights.



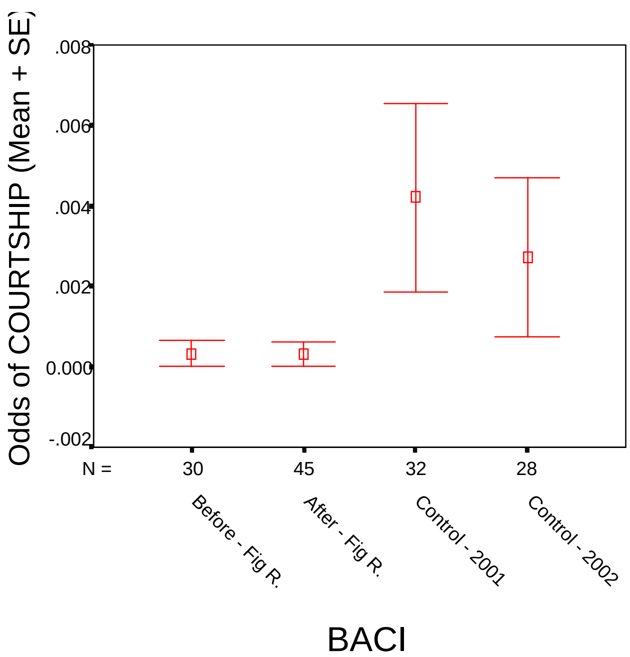


Figure 9. Odds of COURTSHIP by paired female (above) and paired male (below) Harlequin Ducks in treatment and control locations before and after military jet over-flights.

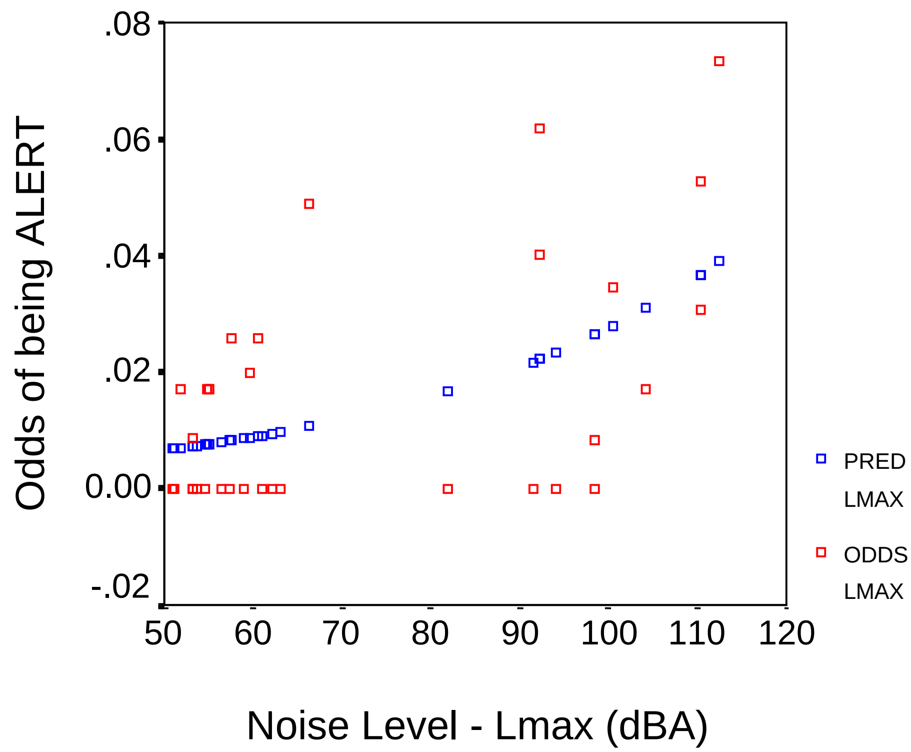


Figure 10. Odds of being ALERT versus noise level for paired female Harlequin Ducks at Fig River, central Labrador, 2002.

Odds of ALERT (paired female) = $e^{(ßo + ßi\ Lmax)} + €$

ßo = - 6.437 $\pm$ 0.549 (SE) ; 95% CI = -7.512 to -5.361; X^2 = 137.51, P < 0.0001

ßi = 0.0287 $\pm$ 0.0062 (SE); 95% CI = 0.0166 to 0.0404; X^2 = 21.42, P < 0.0001

Difference in Deviance ratio = 25.1%

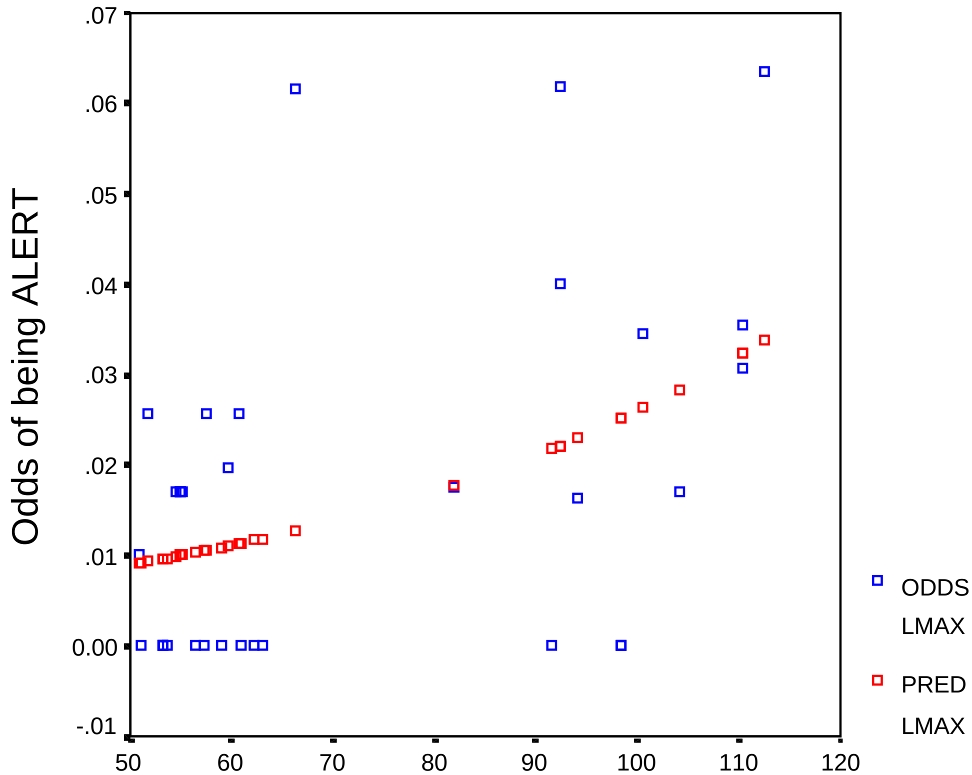


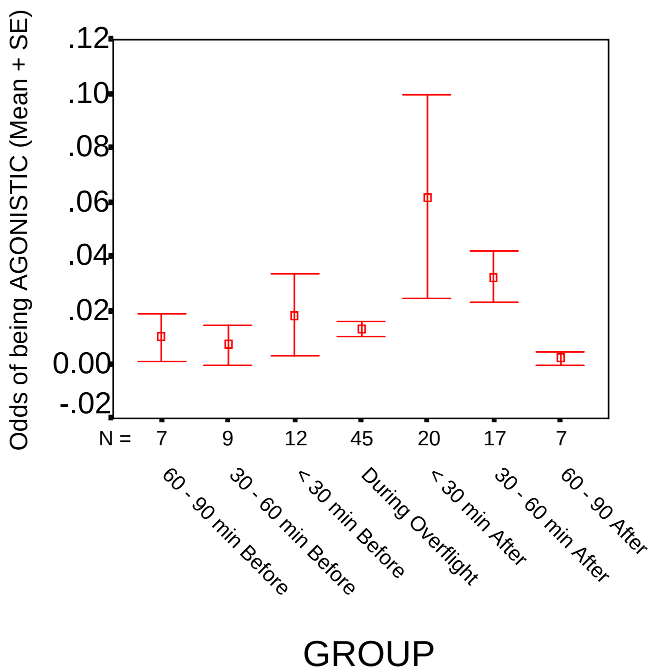
Figure 11. Odds of being ALERT versus noise level for paired male Harlequin Ducks at Fig River, central Labrador, 2002.

Odds of ALERT (paired male) = e $^{(ßo + ßi\ Lmax)}$ + €

ßo = - 5.775 ± 0.503 (SE) ; 95% CI = -6.760 to -4.789; X^2 = 137.89, P < 0.0001

ßi = 0.0215 ± 0.0059 (SE); 95% CI = 0.0099 to 0.0331; X^2 = 13.25, P = 0.0003

Difference in Deviance ratio = 16.7%



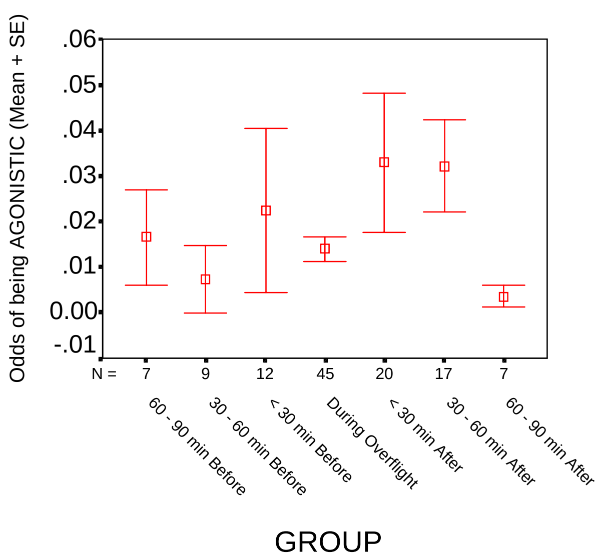


Figure 12. Odds of being AGONISTIC for paired female (above) and paired male (below) Harlequin Ducks before, during and after over-flights by military jets at Fig River, central Labrador.

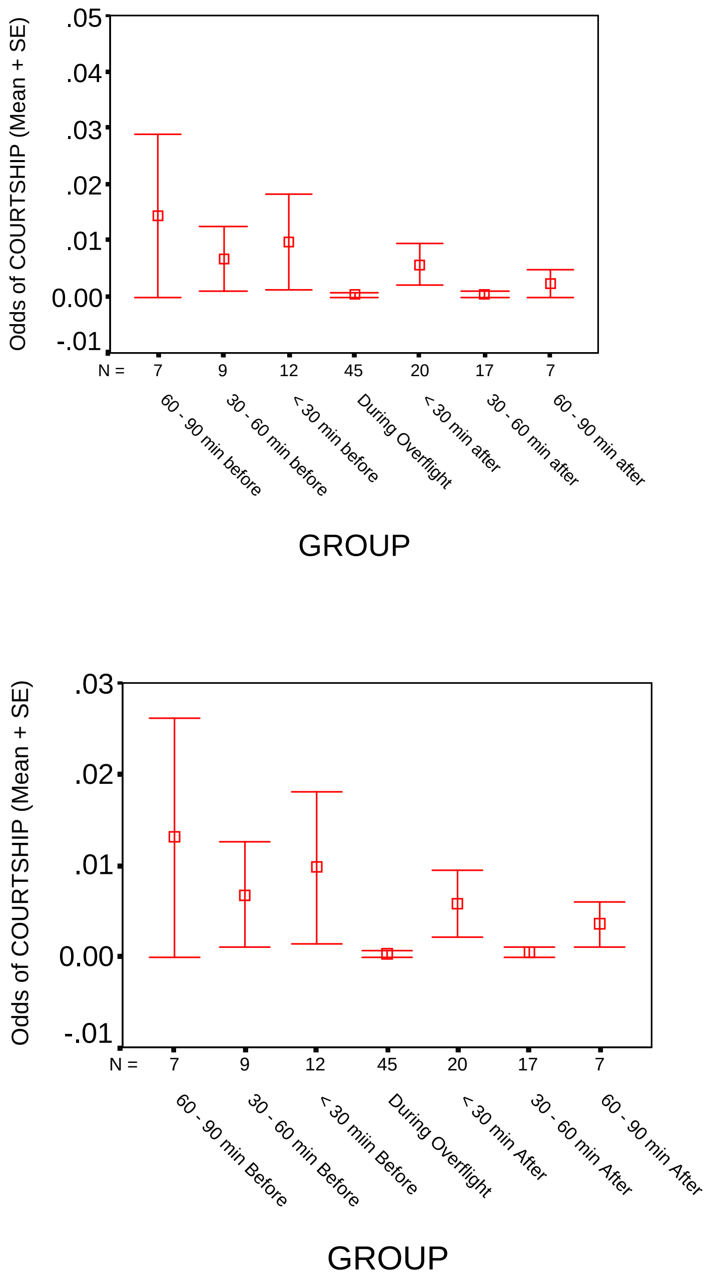
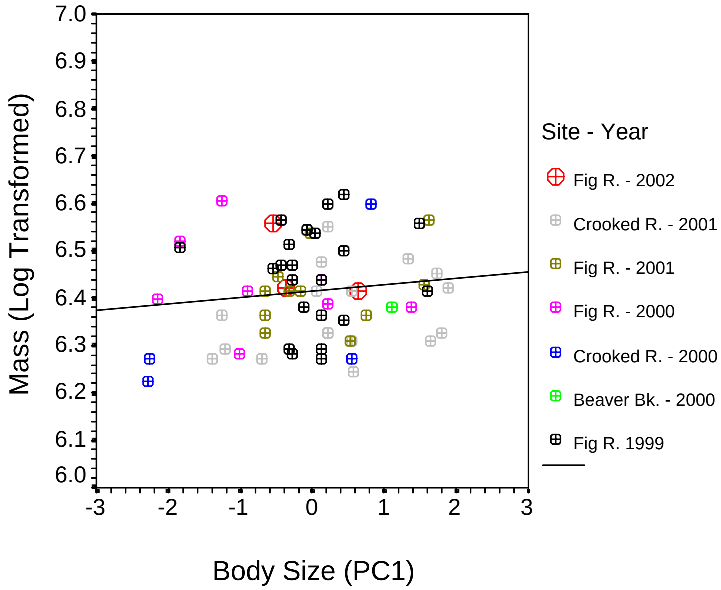


Figure 13. Odds of COURTSHIP for paired female (above) and paired male (below) Harlequin Ducks before, during and after over-flights by military jets at Fig River, central Labrador.



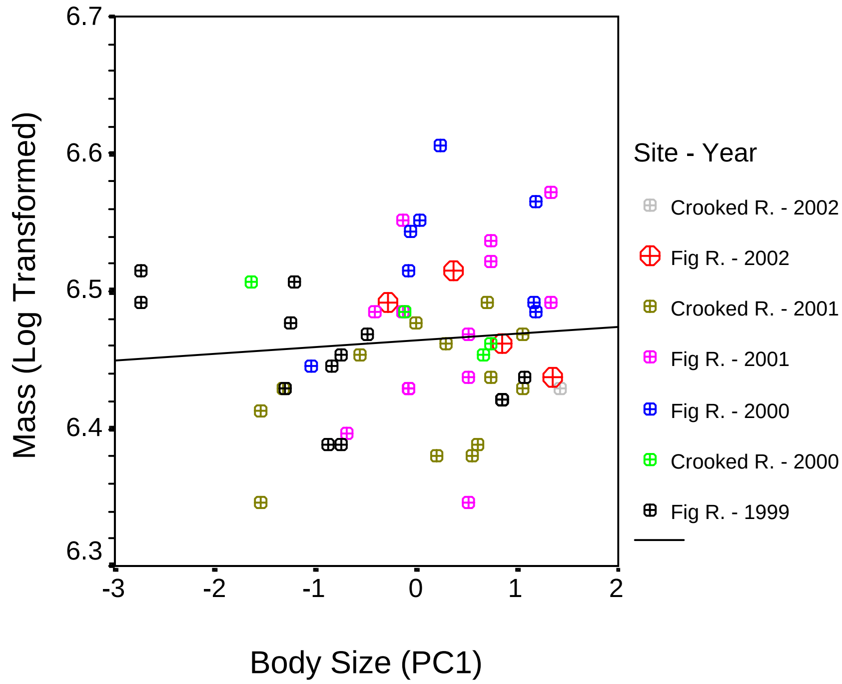


Figure 14. Body condition of adult female (above) and adult male (below) Harlequin Ducks in central Labrador, 1999 – 2002. Birds above and below the regression line are above and below average body condition, respectively.

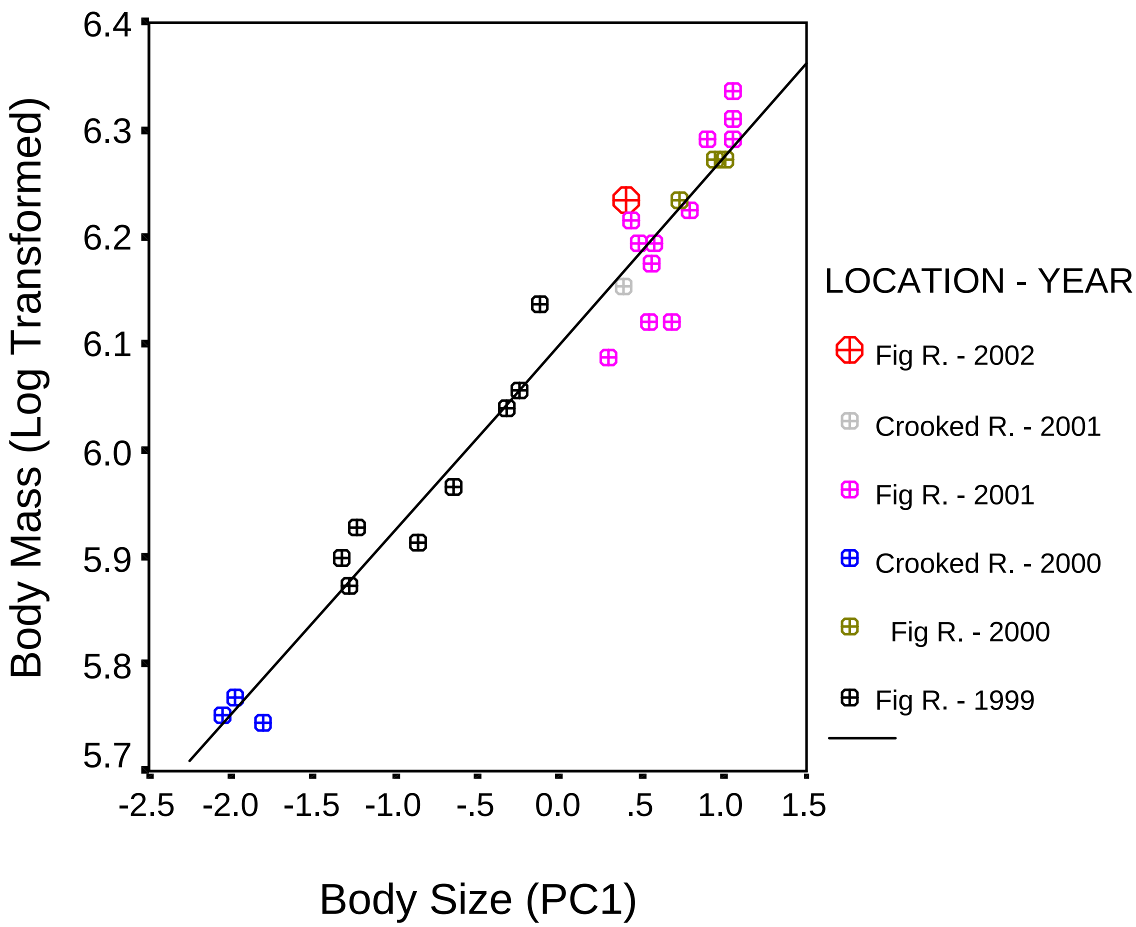


Figure 15. Body condition of juvenile (local) female Harlequin Ducks in central Labrador, 1999 – 2002. Birds above and below the regression line are above and below average body condition, respectively.

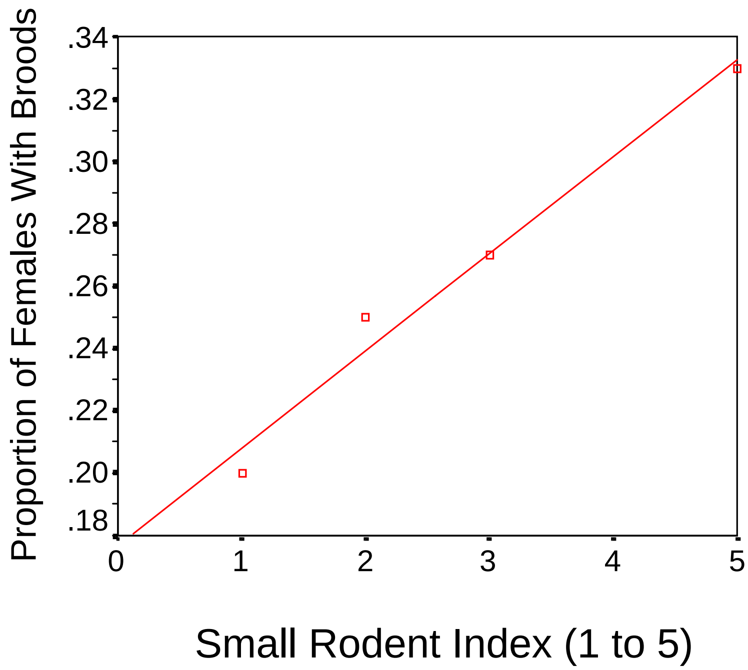
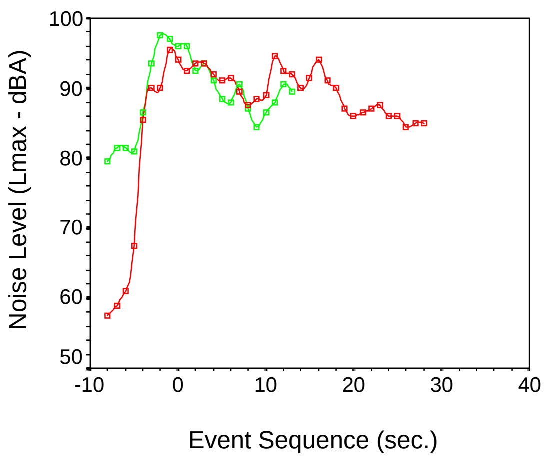


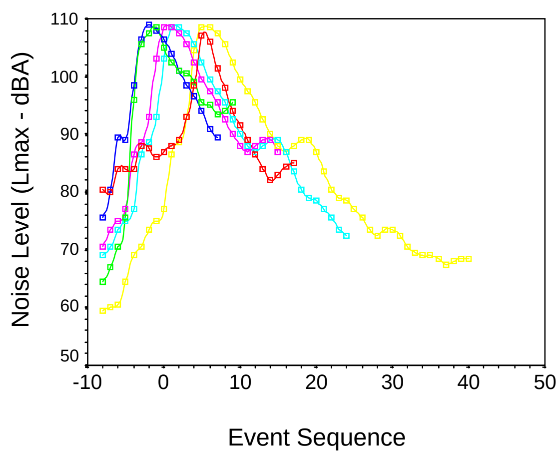
Figure 16. The relationship of the proportion of female Harlequin Ducks producing broods with the index of small rodents at Fig River, central Labrador.

Appendix 1. Noise profiles for military jet over-flight events at Fig River, 22 May – 18 June 2002.

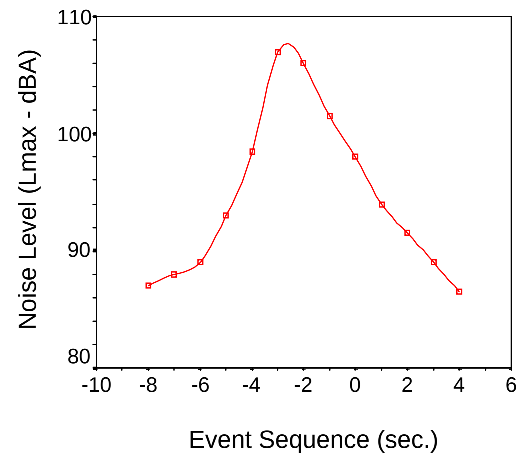
May 25, 2002



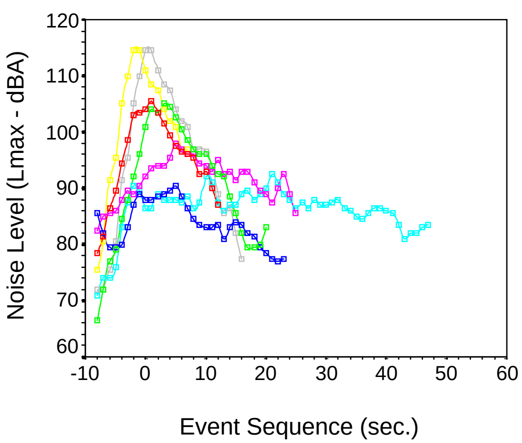
May 30, 2003



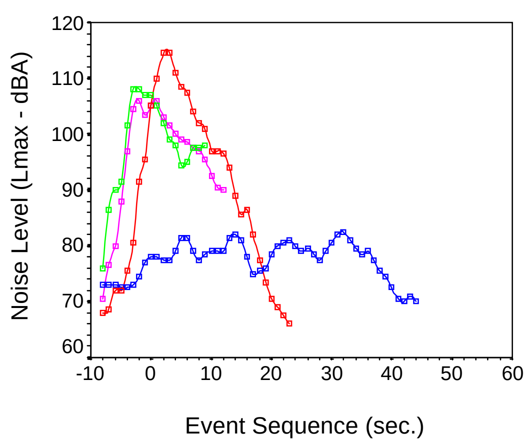
May 29, 2002



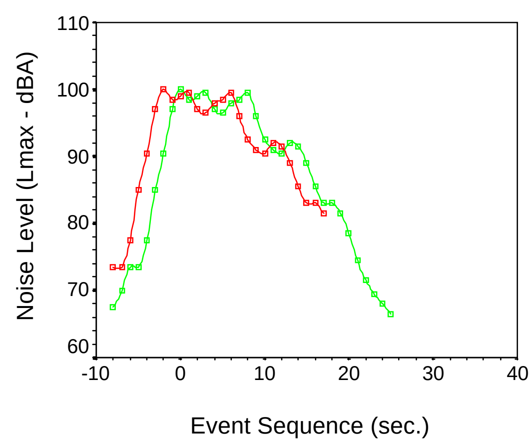
June 3, 2002



June 7, 2002

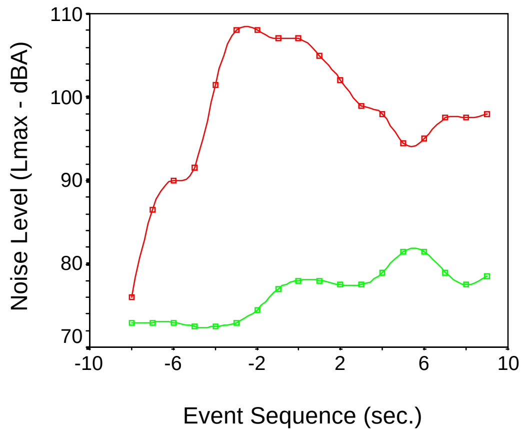


June 8, 2002

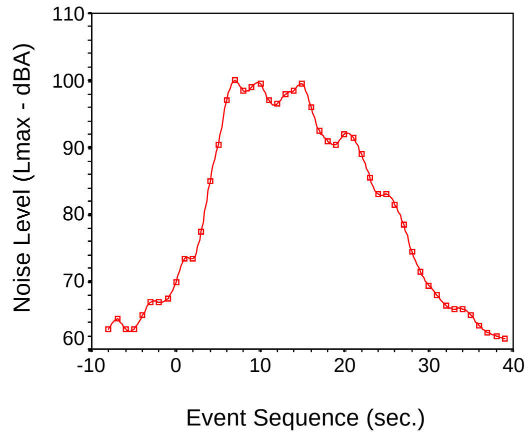


Appendix 1 (cont.). Noise profiles for military jet over-flight events at Fig River, 22 May – 18 June 2002.

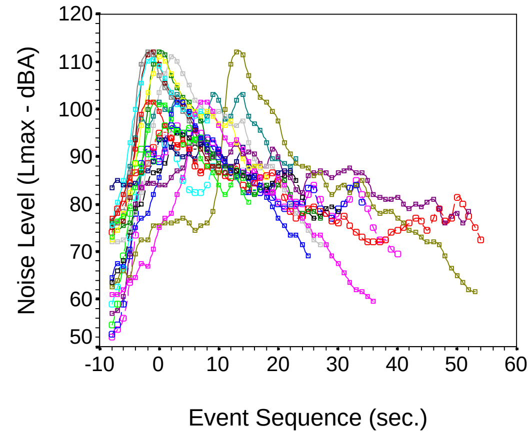
June 5, 2002



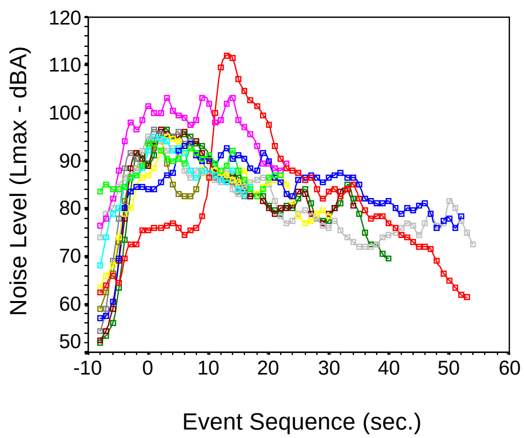
June 10, 2002



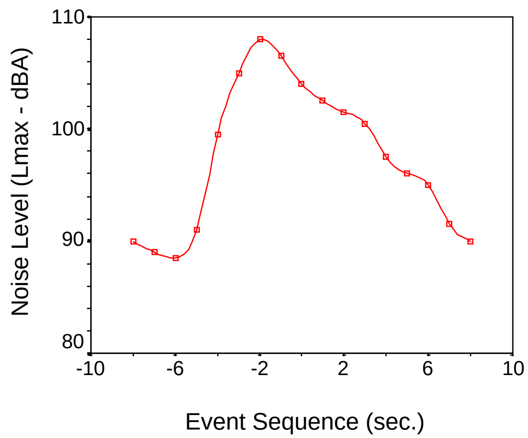
June 11, 2002



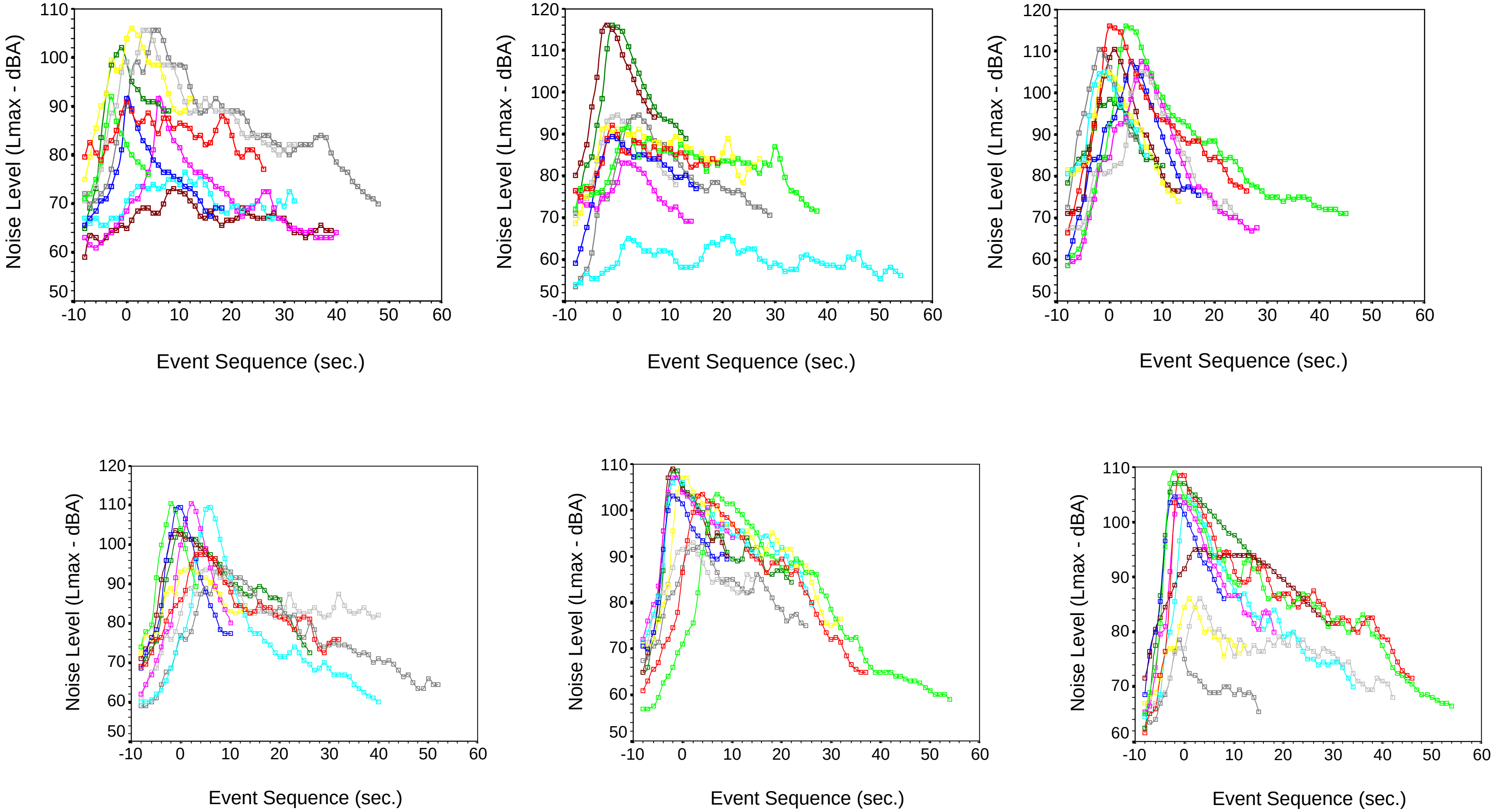
June 11, 2002 (cont.)



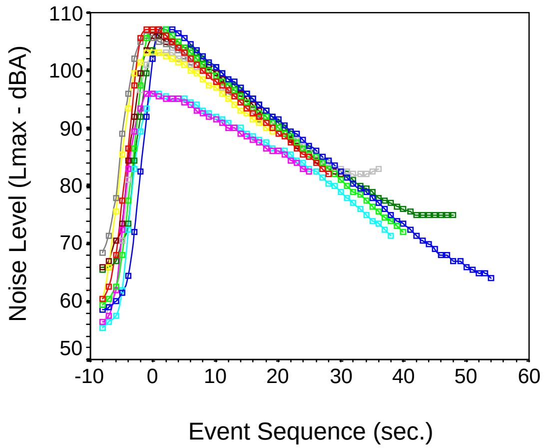
June 15, 2002

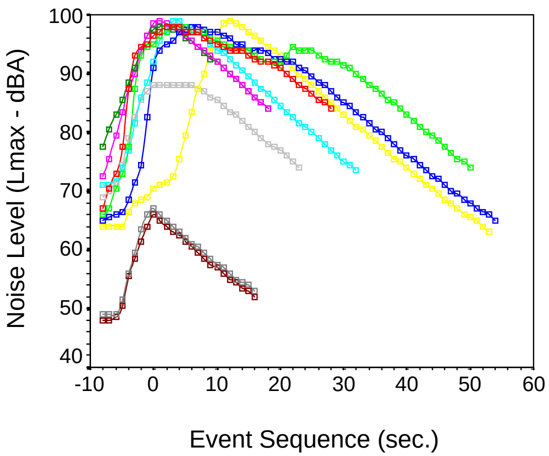


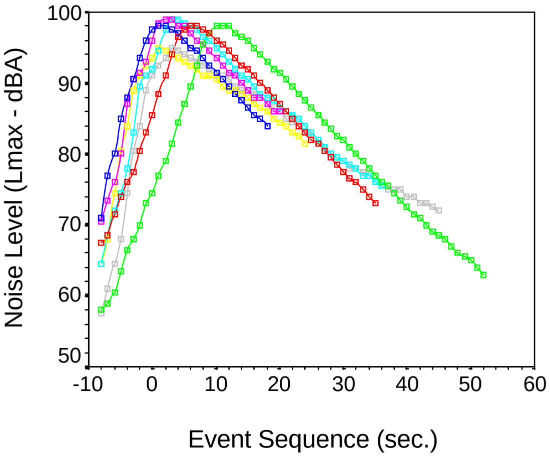
Appendix 1 (cont.). Noise profiles for military jet over-flight events at Fig River, 22 May – 18 June 2002.



Appendix 1 (cont.). Noise profiles for military jet over-flight events at Fig River, 22 May – 18 June 2002.







Appendix 2 . Bandings and morphometrics of newly captured and recaptured Harlequin Ducks at Fig River and Crooked River, Labrador 2002. All measures are in mm unless otherwise specified.

Date	Loc	Metal	Color	Sex	Age	Mate	Wt (g)	Wg_Cd	10_prim	9_prim	Tar_Bo	Cul_ml	Cul_ex	Ster	Tail	Head	Body	Bld	Fea	Old	Stat
7-Jun-02	Fig L.	705-71357	ye5I	M	ASY	ye3K	660	210	130	136	38.5	25.1	34.8	86	93	80.0	427	y	y		N
7-Jun-02	Fig L.	705-71311	ye5K	F	ATY	ye5I	615	201	125	129	35.4	24.4	31.5	77	82	75.5	410	y	y		R
7-Jun-02	Fig L.	705-71358	ye5S	M	ASY	ye4R	640	211	130	136	37.0	26.5	33.1	86	99	78.2	433	y	y		N
7-Jun-02	Fig L.	705-71320	ye4R	F	FY	ye5S	705	195	117	121	36.6	24.2	31.0	77	83	74.0	400	y	y		R
7-Jun-02	Fig L.	705-71359	ye5D	M	ASY	lone	625	206	125	131	38.4	25.5	34.0	86	102	80.1	440	y	y		N
7-Jun-02	Fig L.	705-71427	ye5P	M	ATY	lone	675	212	128	134	38.4	24.8	33.1	86	96	82.0	436	y	y		R
19-Jun-02	Cro.R.	785-40163	ye7Y	M	ATY	lone	620	213	133	135	38.1	25.1	32.2		101	76.0		n	n	blE8	R
23-Aug-02	Fig R.	935-91881	ye3P	F	ATY	ye5P	610	201	118	126	36.7	24.1	30.3		86	73.0	385	n	n		R
23-Aug-02	Fig R.	705-71360	ye8K	F	L	ye3P	510	175	86	92	40.6	23.1	27.6		75		349	n	n		N

Appendix 2 (cont.)

Date	Loc	Metal	Color	Sex	Age	Mate	Comment
7-Jun-02	Fig L.	705-71311	ye5K	F	ATY	ye5I	Sunken Abdomen/splayed pelvis
7-Jun-02	Fig L.	705-71320	ye4R	F	FY	ye5S	Splayed Pelvis, missing 1 central rectrice
19-Jun-02	Cro.R.	785-40163	ye7Y	M	ATY	lone	banded blE8 - 28 April 97 at coast of Forillon NP, Qe
23-Aug-02	Fig R.	705-71360	ye8K	F	L	ye3P	blood in outer 3 primaries

Appendix 3. Capture – Mark – Recapture Array for adult female Harlequin Ducks at Fig River, central Labrador, 1999-2002.

Colour Code	Sex and Age	Paired to	Banded in 1999	Resight or banded in 2000	Resight or banded in 2001	Resight or banded in 2002	1999 Comments	2000comments	2001 Comments	2002 Comments
ye3C	ATYF	unpaired	1	1	0	0				
ye3L	ATYF	unpaired	1	1	1	1	brood, subsequently paired to ye3B	brood	Failed nester	brood
ye3U	ATYF	ye3E	1	1	1	1	brood	Failed nester	Failed nester	
ye3H	ATYF	ye3I	1	1	1	1	Failed nester	Failed nester	Failed nester	Failed nester
ye3V	ATYF	unpaired	1	1	1	0	unpaired	Paired to ye0K	Paired to u/b male	
ye3K	ATYF	ye5U	1	1	1	1	unpaired	Paired to ye5K, failed nester	Paired to ye5U, failed nester	Paired to ye5I, failed nester
ye3T	ATYF	unpaired	1	1	1	1	unpaired	Paired to ye3R, failed nester	Paired to ye3R, failed nester	Paired to ye3R, failed nester
ye3Z	ATYF	ye3Y	1	1	1	1	Failed nester	brood	Failed nester	Failed nester?
ye0J	ATYF	ye0J	1	0	0	0				
ye3P	ATYF	ye3B	1	1	1	1	brood	brood, arrived with ye3B-repair with an ub m	brood, paired to ye5P	brood, paired toye5P
ye0S	ATYF	ye0T	1	1	0	0	brood	brood		
ye5G	ATYF	unknown	1	1	1	0	Failed nester	Failed nester	brood	
ye5C	ATYF	ye5B	0	0	1	1			failed nester	paired to ub male
Ye5R	TYF	u/b	0	1	1	1		unpaired TY female	Paired to ub	Paired to ub

ye5V	ATYF	unknown	0	0	1	0
ye5H	ATYF	unknown	0	0	1	0
ye5X	ATYF	unknown	0	0	1	1
ye5T	ATYF	unknown	0	0	1	0

Appendix 3 (cont.). Capture – Mark – Recapture Array for adult male Harlequin Ducks at Fig River, central Labrador, 1999-2002.

Code	Sex	Paired to	Banded in 1999	Resight or banded in 2000	Resight or banded in 2001	Resight or banded in 2002	1999 Comments	2000comments	2001 Comments	2002 Comments
Ye5L	ASYM	ye0H	1	1	1	0		arrived with ye0H but alone after 1 week	unpaired	
ye3E	ASYM	ye3U	1	1	1	1				
ye3I	ASYM	ye3H	1	1	1	1				
ye3J	ASYM	u/b female	1	1	1	0				
ye3N	ASYM	unpaired	1	0	1	1			unpaired	unpaired
ye3S	ASYM	unpaired	1	1	0	0	unpaired	Paired to u/b female in 2000		
ye0K	ASYM	ye0J	1	1	1	0		Paired to ye3V in 2000		
ye0T	ASYM	ye0S	1	1	0	0				
ye3Y	ATYM	ye3Z	1	1	1	1				
ye3R	ASYM	ye3T	0	1	1	1	unpaired	paired to ye3T	paired to ye3T	paired to ye3T
ye5A	ASYM	u/b male	0	1	1	1		lone	Paired to ye3L	
Ye5K	ASYM	ye3K	0	1	0	0				
Ye5N	ASYM	ye3L	0	1	0	1				unpaired
ye5J	ASYM	ye4J	0	0	1	1				
ye5P	ASYM	ye3P	0	0	1	1				
ye5U	ASYM	ye3K	0	0	1	0				
ye5B	ASYM	ye5C	0	0	1	0				
ye5I	ASYM	ye3K	0	0	0	1				

ye5S	ASYM	ye4R	0	0	0	1		
ye5D	ASYM		0	0	0	1		unpaired
ye5P	ASYM	ye3P	0	0	1	1		

Appendix 3 (cont.). Capture – Mark – Recapture Array for juvenile female Harlequin Ducks at Fig River, central Labrador, 1999-2002.

Code	Sex	Banded in 1999	Resight or banded in 2000	Resight or banded in 2001	Resight or banded in 2001	1999 Comments	2000comments	2001 Comments	2002 Comments
ye4B	LF	1	0	0	1	Young of ye0S			Unpaired
ye4N	LF	1	0	0	0	Young of ye0S			
ye4R	LF	1	1	1	1	Young of ye0S			paired to ye5S
ye4S	LF	1	0	1	0	Young of ye3L			
ye4T	LF	1	0	0	0	Young of ye3L			
ye4Z	LF	1	0	0	1	Young of ye3L			paired to ub
ye4E	LF	1	0	1	1	Young of ye3L			loosely paired with 3Y
ye4J	LF	1	0	1	1	Young of ye3U			assumed paired to ye5J
ye4H	LF	0	1	0	0		Brood of ye3P		
ye9B	LF	0	1	1	1		Brood of ye3L		loosely paired with ub
ye9F	LF	0	1	0	0		Brood of ye3Z		
ye9V	LF	0	0	1	0			brood of ye5V	
ye9J	LF	0	0	1	0			brood of ye5V	
ye9K	LF	0	0	1	0			brood of ye5H	
ye9R	LF	0	0	1	0			brood of ye5H	
ye9L	LF	0	0	1	0			brood of ye5H	

ye9Z	LF	0	0	1	0	brood of ye5X
ye9U	LF	0	0	1	0	brood of ye5X
ye9T	LF	0	0	1	0	brood of ye5X
ye9P	LF	0	0	1	0	brood of ye5G
ye8T	LF	0	0	1	0	brood of ye5T
ye8P	LF	0	0	1	0	brood of ye5T
ye8R	LF	0	0	1	0	brood of ye5T
ye8K	LF	0	0	0	1	brood of ye3P

Appendix 3 (cont.). Capture – Mark – Recapture Array for juvenile male Harlequin Ducks at Fig River, central Labrador, 1999-2002.

Code	Sex	Banded in 1999	Resight or banded in 2000	Resight or banded in 2001	Resight or banded in 2002	1999 Comments	2000comments	2001 Comments
ye4K	LM	1	0	0	0	Young of ye3P		
ye4I	LM	1	0	0	0	Young of ye0S		
ye4L	LM	1	0	0	0	Young of ye0S		
ye4C	LM	1	0	0	0	Young of ye3L		
ye4A	LM	1	0	0	0	Young of ye3L		
ye4P	LM	1	0	0	0	Young of ye3P		
ye4G	LM	1	0	0	0	Young of ye3U		
ye4W	LM	1	0	0	0	Young of ye3U		
ye4D	LM	1	0	0	0	Young of ye3U		
ye4Y	LM	0	1	0	0		brood of ye3P	
ye4X	LM	0	1	0	0		Brood of ye3P?	
ye4F	LM	0	1	0	0		Brood of ye3P	
ye4U	LM	0	1	0	0		Brood of ye3P	
ye4V	LM	0	1	0	0		Brood of ye3P	
ye9A	LM	0	1	0	0		Brood of ye3L	
ye9C	LM	0	1	0	0		Brood of ye3L	
ye9D	LM	0	1	0	0		Brood of ye3L	

ye9E	LM	0	1	0	0	Brood of ye3L	
ye9G	LM	0	1	0	0	Brood of ye3Z	
ye9H	LM	0	1	0	0	Brood of ye3Z	
ye9Y	LM	0	0	1	0		brood of ye5H
ye9N	LM	0	0	1	0		brood of ye5H
ye9S	LM	0	0	1	0		brood of ye5H
ye9I	LM	0	0	1	0		brood of ye5H
ye9M	LM	0	0	1	0		brood of ye5X
ye9W	LM	0	0	1	0		brood of ye5X
ye9X	LM	0	0	1	0		brood of ye5G
ye8I	LM	0	0	1	0		brood of ye5G
ye8B	LM	0	0	1	0		brood of ye5G
ye8S	LM	0	0	1	0		brood of ye5G
ye8Y	LM	0	0	1	0		brood of ye5V
ye8G	LM	0	0	1	0		brood of ye5T
ye8A	LM	0	0	1	0		brood of ye5T

Appendix 3 (cont.). Capture – Mark – Recapture Array for adult female Harlequin Ducks at Crooked River, central Labrador, 1999-2002.

Location	Color Band	Sex	Age	1999	2000	2001	2002	Comments 2001	Comments 2002
Crooked R.	ye6H	F	ATY	0	0	1	1	paired to ye6J	paired to ub male
Crooked R.	ye6F	F	ATY	0	0	1	0		
Crooked R.	ye6C	F	ATY	0	0	1	0		
Crooked R.	ye6P	F	ATY	0	0	1	1	paired to ye6M	paired to ub male, brood
Crooked R.	ye6U	F	ATY	0	0	1	1		paired to ub male
Crooked R.	ye6R	F	ATY	0	0	1	0		
Crooked R.	ye6I	F	ATY	0	0	1	0		
Crooked R.	ye7A	F	ATY	0	0	1	0		
Crooked R.	ye7L	F	ATY	0	0	1	1		paired to ub male
Crooked R.	ye7P	F	TY	0	0	1	0		
Crooked R	ye6X	F	ATY	0	1	1	0		
Crooked R	ye6K	F	ATY	0	1	0	0		
Crooked R	ye6V	F	TY	0	1	1	1	paired to ye6B	paired to ub male, brood
Crooked R.	ye7X	F	ATY	0	0	1	0		
Crooked R.	ye7C	F	ATY	0	0	1	0		
Crooked River	ye2W	F	ATY	0	1	1	0		
Crooked River	ye2R	F	TY	0	1	1	0		
Crooked River	ye2Y	F	ATY	0	1	1	0		
Crooked River	ye2E	F	ATY	0	1	1	0		

Appendix 3 (cont.). Capture – Mark – Recapture Array for adult male Harlequin Ducks at Crooked River, central Labrador, 1999-2002.

Location	Color Band	Sex	Age	1999	2000	2001	2002	comments
Crooked R.	ye6J	M	ASY	0	0	1	1	
Crooked R.	ye6G	M	ASY	0	0	1	1	
Crooked R.	ye6B	M	ASY	0	0	1	0	
Crooked R.	ye6W	M	ASY	0	0	1	0	
Crooked R.	ye6N	M	ASY	0	0	1	0	
Crooked R.	ye6E	M	ASY	0	0	1	1	
Crooked R.	ye6D	M	ASY	0	0	1	0	
Crooked R.	ye6M	M	ASY	0	0	1	0	
Crooked R	ye6Y	M	ASY	0	1	1	0	
Crooked R	ye6S	M	ASY	0	1	1	1	
Crooked R	ye6L	M	ASY	0	1	0	0	
Crooked R	ye6T	M	ASY	0	1	0	0	
Crooked River	ye2Q	M	ASY	0	1	0	0	
Crooked River	ye2X	M	ASY	0	1	1	1	
Crooked River	ye2J	M	ASY	0	1	1	0	
Crooked River	ye7Y	M	ASY	0	0	1	1	formerly blE8

Appendix 3 (cont.). Capture – Mark – Recapture Array for juvenile female Harlequin Ducks at Crooked R., central Labrador, 1999-2002.

Location	Color Band	Sex	Age	1999	2000	2001	2002
Crooked R	ye7V	F	L	0	1	0	0
Crooked R	ye7I	F	L	0	1	0	0
Crooked R	ye7H	F	L	0	1	0	0
Crooked R.	ye7B	F	L	0	0	1	0

Appendix 3 (cont.). Capture – Mark – Recapture Array for juvenile male Harlequin Ducks at Crooked R., central Labrador, 1999-2002.

Location	Color Band	Sex	Age	1999	2000	2001	2002
Crooked R	ye7G	M	L	0	1	0	0
Crooked R.	ye7T	M	L	0	0	1	0
Crooked R.	ye7F	M	L	0	0	1	0
Crooked R.	ye7E	M	L	0	0	1	0