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Brief communication

Modeling energy and reproductive costs in caribou exposed to low flying military jet aircraft

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Abstract: We used simulation modeling to estimate the effect of low-flying military jet aircraft on the productivity of caribou. The base model (CARIBOU, CWS Whitehorse, Yukon Territory) uses daily intake and expenditure of energy to assess the condition of female caribou throughout the annual cycle. The activity budget of the model caribou was adjusted based on field observations of responses to noise disturbance. A subroutine was added that predicted the likelihood of conception based on fall body fat weight. Caribou responses to overflights were evaluated by equipping free-ranging caribou with radio collars and activity sensors that could distinguish between resting and active periods. Collared animals were exposed to 110 overflights by A-10, F-15 and F- 16 jet aircraft during late-winter, post-calving and the insect season. Noise exposure levels for individual animals either were measured directly with collar-mounted dosimeters or were estimated based on the proximity of the caribou to the aircraft during the overflight. A Time-averaged Sound Level (L_T) was calculated from the total daily noise exposure for each animal and linear regression was used to evaluate the influence of daily noise exposure on daily hours spent resting. Results of these analyses then were used to modify the time budgets in the CARIBOU model. That is, if time spent resting declined, then time spent in the two rest classes (lying and standing) were proportionately redistributed into the three active classes (foraging, walking and running). Model simulations indicated that caribou increased forage intake in response to increased noise exposure, but it also predicted that increased noise exposure would cause a reduced accumulation of body fat. Because body fat in fall has successfully been used to predict the probability of pregnancy (see Gerhart *et al.*, 1993), this relationship was used in the model. Preliminary model simulations indicate that increased noise exposure decreases the probability of pregnancy and that unfavorable environmental conditions (e.g., deep snow and severe insect harassment) exacerbate the situation. The threshold at which point the caribou fail to conceive has not been determined at this time, but appears to be well beyond the exposure to aircraft that caribou in the Delta herd are currently experiencing.

Key words: energetics, noise, model, reproduction

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Introduction

This report describes the use of the computer simulation model CARIBOU (Kremsater *et al.,* 1989) to estimate the effects of low flying military jet aircraft on the breeding success of a female caribou (*Rangifer tarandus granti*). Use of lowflying jet aircraft associated with military training has associated concern for the effects of these overflights on wildlife. Northern residents and resourcemanagment agencies have concern for the effects these training exercises may have on productivity of caribou (Wadden, 1989). Some energy expenditures (Fancy & White, 1985; Luick & White, 1986; White & Fancy, 1986) and seasonal energy budgets (Russell *et al.,* 1993) have been documented for caribou and effects of energy and nutrition on fecundity have been estimated (Cameron *et al.,* 1993; Gerhart *et al.,* 1993). The Delta Caribou Herd (DCH) of interior Alaska was selected for the study of short temm effects of noise disturbance on activity budgets because of its proximity to Eielson Air Force Base. Long term effects including fecundity were then predicted using computer simulation. The current version of CARIBOU was developed as part of a contract to the United States Air Force (USAF) in connection with the USAF Noise and Sonic Boom Impact Technology (NSBIT) program.

CARIBOU has both energy and growth modules that work sequentially to simulate growth of a caribou at a daily time step throughout a year. The model begins an execution cycle by calculating daily interpolated values from seasonally corrected tables of activity budgets, forage quality and quantity, and environmental parameters such as snow depth and insect harassment of a free ranging female caribou. For the purposes of modeling, it was assumed that noise disturbance influenced the activity budget. In CARIBOU, forage class intake is determined as a product of time and efficiency of foraging and prevalence of forage class. Likewise, nutrient absorption is determined as a product of forage class intake, digestibility and composition. Considerations of nutrient efficiency of utilization are employed by CARIBOU to calculate a daily energy credit against which daily energy demands are drawn. These demands may include resting metabolic rate, gestation, lactation, and physical activity. An energy credit surplus can result in growth and fattening, a deficit in sacrifice of body fat and protein. Constraints limiting the model include availability of forage and availability of time for foraging, rumen capacity and metabolic demands on energy supplies. The model produces 83 output variables including body, fat, muscle, calf and fetus weights and milk production for each day simulated.

Materials and methods

The simulation model CARIBOU was obtained from the Canadian Wildlife Service, Whitehorse, YT Canada. Initial condition variables such as body weight and seasonal dates were adjusted to resemble animals of the DCH. The program was modified to read a schedule of jet aircraft overflights and associated sound exposure levels (SEL, dB) and then calculate a noise adjusted daily activity budget. The noise adjustment was based on the observed daily hours spent resting in free ranging caribou exposed to varying intensities jet aircraft overflights. Briefly, up to ten DCH caribou were fitted with *Wildlink* Inc. radio collars bearing recording activity monitors (mercury tip switch) and sometimes a noise dosimeter from which an SEL was determined. In cases where a collared animal either did not have a dosimeter or the dosimeter was not triggered, an empiracally derived estimated SEL was provided by the USAF. A ground crew directed jet aircraft to the precise location of the animals under observation and recorded visual observations of the overflown animals. Evaluation of the direct observations of overflown caribou has been summarized elsewhere (Murphy *et al.*, 1993). Since individual activity classes (foraging, lying, standing, walking, running) could not be identified from the activity monitors, the existing emperically determined activty distributions of the control animals were applied to the overflown animals. That is, motion detected in connection with noise disturbance was assumed to have the same relative distribution of foraging, walking and running as motion recorded for undisturbed animals (Kitchens *et al.*, 1993). All SELS from each day for a given animal were combined to estimate a time averaged sound level (L_T, ANSI S 12.40-1990). A regression of daily hours spent resting on L_T was used to make adjustments to the default activity budget of CARIBOU for noise exposure simulations.

Results and discussion

The SELS experienced by caribou as generated by jet aircraft noise were measured or estimated from near zero for animals located a great distance from the jets, to 130 dB. Overflights occurred in three seasons of the year, late winter (early April), post-calving (early June) and insect season (late July/early August). Separate regressions of time averaged sound level (L_T) on hours spent resting were developed for all seasons, but only post-calving had a significant slope (0.03 L_T, n= 50, P= 0.03, S.E.=), therefore modeling was limited to this time of year. The range of L_Ts extended from near zero to 84. The current simulations employed the relatively high L_T of 80 in order to generate a detectable yet realistic response by the model. Consecutive simulation exposure days were set from O (control) to 40 in 5 day increments. The simulations were repeated with the environmental variables set to poor conditions (deep snow, poor forage, heavy insect harassment). A probability of pregnancy prediction was made for each simulation based on fall fat weight (Gerhart *et al.*, 1993) arbitrarily taken as the mid-rut date of October 15 as shown in Table 1. The control runs of CARIBOU indicated that energy demands on a lactating cow were not being

Table 1. A tabulation of body (BW) and fat weights (FW) and probability of pregnancy (PP) as predicted by the computer model CARIBOU when increasing consecutive days of a single event noise disturbance are simulated under both good and poor environmental conditions.

Days	Good year			Bad year		
	BW kg	FW kg	PP %	BW kg	FW kg	PP %
0	76.1	6.52	70.2	65.2	3.59	47.7
5	76.0	6.48	70.0	65.1	3.56	47.5
10	75.9	6.45	69.8	64.9	3.52	47.2
15	75.7	6.41	69.5	64.7	3.46	46.7
20	75.5	6.35	69.0	64.4	3.37	46.0
25	75.3	6.30	68.7	64.1	3.30	45.5
30	75.1	6.25	68.3	63.8	3.21	44.7
35	74.9	6.18	67.9	63.3	3.09	43.8
40	74.6	6.11	67.4	62.8	2.95	42.7

met over the course of the summer. The overflight simulation produced a downward shift in the time course of total body and fat weights which indicated that the "cow" did not completely compensate for the additional energy demands.

The predicted likelihood of conception declined with increasing noise exposure with an accelerated effect as the duration of exposure increased. Plots of body and fat weight (not shown) revealed the same relationship, indicating that the model increasingly drew on body reserves to meet the demands of lactation and increased physical activity. Simulations of a non-pregnant/non-lactating cow predicted that a caribou is capable of increasing body weight and fat over the same period with these levels of noise exposure.

As noise exposure increased, the calculated pregnancy rate under poor environmental conditions fell off more sharply than under good environmental conditions. The model attempted to maintain milk production in the face of a declining energy balance, ultimately resulting in the "cow" attaining a low probability of conceiving. Simulations of a non-pregnant cow predicted a rapid recovery of body condition at the end of lactation and based on predicted fat weight, the animal would be likely to conceive the following year.

The effects of disturbance on caribou varies depending on the type of disturbance, time of year and group composition (nursery bands, bull groups, mixed aggregations) (Gunn *et al.*, 1985; Murphy & Curatolo, 1987; Harrington & Veitch, 1991; 1992). The current implementation of CARIBOU predicts a minimal effect of jet aircraft overflight on caribou fecundity. In the unlikely event of 40 consecutive days of severe noise exposure a caribou is predicted to have a 4 or 5 % decrease in the probability of becoming pregnant under normal or poor environmental conditions, respectively.

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