ARCTIC
VOL. 45, NO. 3 (SEPTEMBER 1992) P. 213-218

Calving Success of Woodland Caribou Exposed to Low-Level Jet Fighter Overflights

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(*Received 1 October 1990; accepted in revised form 12 October 1991*)

ABSTRACT. Effects on woodland caribou (*Rangifer tarandus caribou*) of low-level military jet training at Canadian Forces Base – Goose Bay (Labrador) were studied during the 1986-88 training seasons. Calf survival was periodically monitored during 1987 and 1988 in a sample of 15 females wearing satellite-tracked radiocollars. During 1987, each female's exposure to low-level overflights was experimentally manipulated on a daily basis. In 1988, daily exposure was determined by analyzing jet flight tracks following the low-level flying season. Calf survival was monitored by survey flights every 3-4 weeks. A calf survival index, the number of survey periods (maximum = 4) that a cow was accompanied by a calf, was negatively correlated with the female's exposure to low-level jet overflights during the calving and immediate post-calving period and again during the period of insect harassment during summer. No significant relationship between calf survival and exposure to low-level flying was seen during the pre-calving period, during the late post-calving period prior to insect harassment, and during fall. In view of the continued depression of population growth in the woodland caribou population within the low-level training area, jets should avoid overflying woodland caribou calving range at least during the last week of May and the first three weeks of June.

Key words: caribou, *Rangifer tarandus caribou*, calf survival, low-level flying, jet aircraft, disturbance, Labrador

RÉSUMÉ. Au cours des saisons d'entraînement de 1986 à 1988, à la base des Forces armées canadiennes de Goose Bay au Labrador, on a étudié les retombées sur le caribou des bois (*Rangifer tarandus caribou*) de l'entraînement à basse altitude sur des avions militaires à réaction. En 1987 et 1988, on a observé périodiquement la survie des veaux dans un échantillon de 15 femelles équipées de colliers émetteurs suivis par satellite. En 1987, on a manipulé quotidiennement de façon expérimentale l'exposition de chaque femelle à des survols à basse altitude. En 1988, on a déterminé l'exposition quotidienne en analysant le parcours des avions à réaction après la saison de vol à basse altitude. On a observé la survie des veaux en effectuant des relevés en vol toutes les 3 ou 4 semaines. Un index de survie des veaux — le nombre de fois (maximum = 4) durant les relevés où une femelle était accompagnée d'un petit — a été corrélé négativement à l'exposition de la femelle au survol à basse altitude des avions à réaction au cours de la mise bas et de la période lui faisant immédiatement suite, ainsi que durant la saison estivale de harcèlement par les insectes. On n'a observé aucun lien significatif entre la survie des veaux et l'exposition aux vols à basse altitude au cours de la période précédant la mise bas, au cours de la période tardive suivant la mise bas et précédant celle du harcèlement par les insectes, ainsi que durant l'automne. Vu la baisse continue de la croissance de population du caribou des bois à l'intérieur de la zone d'entraînement à basse altitude, les avions à réaction devraient éviter de survoler le territoire de mise bas du caribou des bois au moins durant la dernière semaine de mai et les trois premières semaines de juin.

Mots clés: caribou, *Rangifer tarandus caribou*, survie des veaux, vol à basse altitude, avion à réaction, perturbation, Labrador

Traduit pour le journal par Nésida Loyer.

INTRODUCTION

Most studies of aircraft impacts on caribou (*Rangifer tarandus*) have focused on the short-term effects of overflights (Klein, 1974; Calef *et al.*, 1976; Surrendi and DeBock, 1976; Miller and Gunn, 1979; Gunn *et al.*, 1985). Although knowledge of the nature of these short-term effects and the variables influencing their severity is important, these studies fall short in terms of answering a more fundamental question: does aircraft disturbance have a negative impact on population dynamics in the long term (Bergerud *et al.*, 1984). The validity of extrapolating from short-term reactions of individuals to long-term impacts at the level of the population has not been proven. For example, 5 minutes of hard running in response to an overflight may appear to have a greater potential long-term impact than a brief startle followed by several minutes of alert behaviour. But if the energy expended in running can be recouped the same day by extending a foraging bout, whereas the physiological depression of lactation caused by the startle reduces the calf's milk intake by 25%, then the impact on population growth may be the reverse. Consequently, both short-term and long-term effects must be monitored to more fully assess the impacts of aircraft disturbance on caribou.

In our study of the short-term effects on woodland caribou (*R. t. caribou*) of low-level flying activity by fighter-type jet aircraft in Labrador (Harrington and Veitch, 1991), we also investigated the potential for long-term effects on population dynamics and behaviour. Previously, Davis *et al.* (1985) assessed the long-term impacts of jet aircraft activity through population-wide habitat use and demographics. We assessed long-term effects on an individual level by determining the relationship between an animal's exposure to low-level flying and its corresponding calf survival. An individual's exposure to low-level overflights was assessed on a daily basis, whereas calf survival was determined every 3-4 weeks. We hypothesized that frequent overflights during the calving and immediate post-calving periods would reduce calf survival as a consequence of the startle responses caused by low-level overpasses (Harrington and Veitch, 1991).

STUDY AREA

The study area encompasses the ranges of two woodland caribou populations (Fig. 1). The Red Wine Mountain population of about 700 animals (Veitch, 1990) inhabits a 23 000 km^2 area that includes a heavily overflown portion of the northern low-level training area. Several NATO-member air forces engage in low-level jet fighter training there between April and November each year. During winter, most Red Wine Mountain caribou can be found within the training area, whereas a portion of the population migrates out prior to calving and remains to the south or west of the training area until after the fall rut. The Mealy Mountain population of about 2000 animals (Hearn and Luttich, 1987) inhabits a 22 000 km^2

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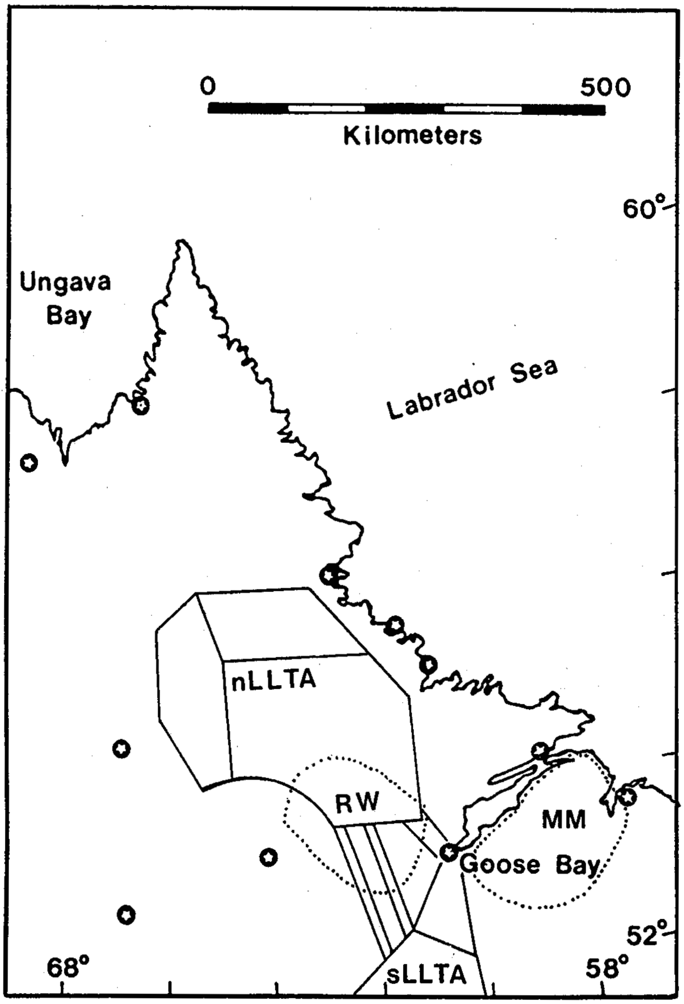

FIG. 1. The study area and approximate ranges of two woodland caribou populations in Labrador. The ranges of each population are denoted by dotted lines: RW = Red Wine Mountain population; MM = Mealy Mountain population. nLLTA = the northern low-level training area; sLLTA = the northernmost portion of the southern low-level training area. The three units of the nLLTA are indicated, as are the corridors between the LLTAs and CFB Goose Bay. Permanent communities are indicated by circled stars.

area east of Goose Bay and is removed from both training areas. Topography, climate and vegetation are generally similar for the ranges of both caribou populations. Each range includes an area of rounded, barren hills supporting alpine tundra, providing late-winter forage when deep snow in the surrounding lichen-conifer forest plateau limits foraging opportunities and impedes travel (Brown, 1986).

METHODS

We used satellite telemetry, Platform Transmitter Terminals (PTT), to manipulate and/or measure the daily frequency of exposure to low-level flying of each study animal (Harrington and Veitch, 1991). Satellite telemetry allowed us to locate each animal as often as daily without disturbance. Using these locations, jet aircraft (Alpha-jet, F4, F16, F18, and Tornadoes) were directed either toward or away from an animal's location. By manipulating exposure frequency among animals, we could then determine the relationship between exposure to aircraft and a caribou's subsequent calving success.

Adult female caribou were captured prior to the beginning of the low-level flying season each spring by darting from helicopter (Bell 206B, 206L). Each animal was outfitted with a satellite collar containing a PTT (Generation ST-2 or ST-3; Telonics, Inc., Mesa, Arizona). These collars were retrieved in winter for refurbishment.

Locations obtained from Service Argos (Landover, Maryland) through satellite telemetry vary in accuracy. Three levels of "guaranteed" locations average within 1 km of the true location (Harrington *et al.*, 1987; Fancy *et al.*, 1988), which is similar to the accuracy of locations we obtain using VHF radiotelemetry. To minimize locational error, only the best location obtained each day was used. This was chosen first on the basis of the quality index assigned by Service Argos and second on the number of messages received during the overpass (more messages = better signal). Locations were not obtained on all days. The percentage of days with locations (Location-days) varied among PTTs and tended to decline several months after a PTT was deployed (Harrington *et al.*, 1987). During the calving and immediate post-calving periods, however, locations were obtained on 93% of days in 1987 and 98% of days in 1988.

In 1987, the 10 satellite-collared caribou were all obtained from the Red Wine Mountain population. These were divided into exposure and control groups. Each day, the most current location was obtained for each animal and relayed to each participating NATO air force prior to that day's flying as either Target (exposure group) or Avoidance (control group) coordinates. Each Target coordinate was accompanied by a request for as many overflights as possible. Avoidance coordinates, on the other hand, were to be avoided by jets by at least 9.2 km. We received a report back indicating the number of times each day that a Target animal's coordinates were overflown. Field-truthing exercises, in which we were stationed at dummy target or avoidance coordinates, indicated a high degree (90%+) of accuracy in these reports (Harrington and Veitch, 1991). The number of reported overflights each day was used as the measure of an animal's exposure to low-level jet activity.

In 1988, our study animals were taken from both the Red Wine Mountain and Mealy Mountain populations. Red Wine Mountain caribou were used as exposure animals, whereas Mealy Mountain caribou served as controls. We placed the control animals outside the Red Wine Mountain population because 1) it ensured the military completely avoided the control animals, 2) all control animals in the Red Wine Mountain population have had prior exposure to overflights and thus constitute a biased sample, and 3) under the 1988 study procedures, it was simply not possible to avoid specific caribou in the Red Wine Mountain population. The Mealy Mountain population was chosen for its proximity to Goose Bay, its similar characteristics, and its position outside the present and historical range of low-level flying aircraft.

Records of all flight tracks flown by jets during 1988 were collected. Each flight track consisted of a list of coordinates that represented turning points during the flight. For some aircraft (F16, F18, Tornado) these were generated by onboard computers, whereas for other aircraft (F4, RF4) these were recorded by hand from topographic maps. From these coordinates, flight lines were constructed from which indices of exposure were generated. An overflight was considered to be a jet within 1 km of the caribou's location. This radius was chosen to account for the inherent error in the caribou's location, any movement that occurred since that location had been fixed, and navigational error on the part of the pilot and is similar to the accuracy of reported overflights in 1987.

Calf Survival

Calf survival was determined by periodic aerial surveys starting in mid-June (Fig. 2). Every 3-4 weeks each female was visually located by helicopter so that any accompanying calf could be detected. A calf's survival was measured as the number of survey periods (0-4) during which her calf was observed. These periods included survival to mid-June (1), to mid-July (2), to mid-August (3), and throughout the entire low-level flying season (4). No direct observations of calving were available, but declines in 24 h activity indices and daily movements (Harris *et al.*, 1991) were used to estimate the calving period. Females never seen with calves were treated in two ways. First, we assumed they lost their calves between birth and the first survey. Second, we assumed they were never pregnant and therefore deleted them from the sample.

Statistical Analyses

We divided the low-level flying season into seven biologically relevant seasons (Fig. 2). The pre-calving period began with the initiation of low-level flying during the third week of April and ended with the beginning of the calving period. The calving period (23 May – 5 June) included all but one of the suspected calving dates. The initial post-calving period (6–19 June) included the remaining calving date (8 June) as well as the first one or two weeks post-calving. The pre-insect post-calving period (20 June – 3 July) ended when both temperature indices and 24 h activity indices indicated that insect harassment had become extreme. Two equal-length summer insect periods ended with the first day of sub-freezing weather (as determined by Environment Canada at Goose Bay and Churchill Falls). Insect activity is expected to be high during the first of these periods and to continue periodically throughout the second. A fall period followed from 17 September to the end of the low-level flying season. For each period, the mean number of low-level overflights per day was determined for each animal. In addition, the overall mean number of overflights per day was calculated for the entire period a female's calf was presumed to be alive. For this latter analysis, we presumed a calf was lost at the mid-point of the interval during which it disappeared.

Once a calf was determined lost, its mother's data were deleted from the analyses of subsequent periods. Because females were dropped from the sample as the season progressed, we computed separate Spearman correlation coefficients for each period between a calf's survival index and the mean number of overflights it was exposed to during that period. Our hypothesis predicted a negative effect of exposure frequency on calf survival; therefore one-tailed probability values were used.

Two females were followed during both years. To avoid "pseudo-replication" (Hurlbert, 1984; Machlis *et al.*, 1985), we represented each female by her mean values over the two years. Both females held the same ranks among all females each year in terms of frequency of exposure to flying.

RESULTS

Of the ten Red Wine Mountain females outfitted with PTTs in early April 1987, eight provided calf survival and satellite data throughout the entire low-level flying season and a ninth provided satellite data through the end of September and calf survival data throughout. The tenth animal's PTT failed in late April, and thus was deleted from the study. In 1988, five female caribou were initially collared on the Red Wine Mountains in early April and one in early May. Two of these animals were deleted from the sample after they emigrated from the Red Wine Mountain population range in May and were assumed to have been George River caribou. Exposure to

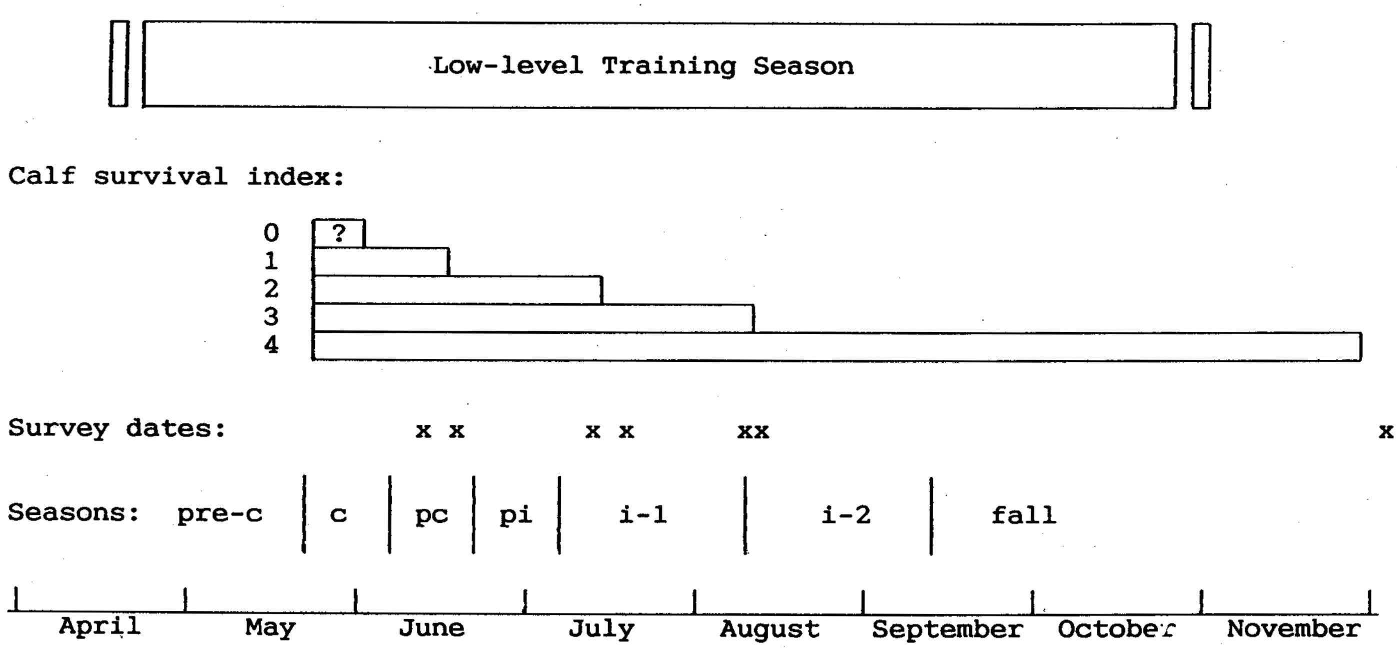

FIG. 2. The temporal relationships among the variables used in the data analyses. The upper box indicates the approximate period of low-level flying activity in 1987 and 1988. The closed bars of the calf survival index indicate the minimum period that a calf was known to survive, except for index = 0, when the presence of a calf was unknown. The timing of survey dates in 1987 and 1988 is indicated by an "x". The biological seasons are: pre-c = pre-calving period; c = calving period; pc = immediate post-calving period; pi = pre-insect post-calving period; i-1 = first summer insect period; i-2 = second summer insect period; and fall = fall period.

TABLE 1. Calf survival and frequency of exposure to low-level jet overflights of satellite-collared female woodland caribou in Labrador

Population	Year	n	Calves surviving to:[a] June	July	August	October	Frequency of overflights[b] Mean±SD	(range)	n
Red Wine	1987	9	7	7	4	4	1.0 ± 1.6	(0-4.5)	1857
Red Wine	1988	4	1	1	1	1	0.8 ± 0.7	(0.1-1.7)	716
Mealy Mtn.	1988	4	3	3	2	2	—	no overflights	—

[a]Number of calves (of maximum n) alive during surveys in the months noted.
[b]Frequency of overflights is the number of jet overflights reported <1 km from an animal's location within each 24 h period.

low-level flying aircraft varied greatly among Red Wine Mountain caribou (Table 1). In each year, some animals had virtually no exposure whereas others were exposed to several low-level passes each day, on average.

Four Mealy Mountain females were also followed by satellite telemetry during the 1988 season, after the early failure of a fifth PTT in April (Table 1). One of these animals died on 11 August but was never seen with a calf, and thus is included in the sample. None of the four Mealy Mountain caribou was exposed to low-level jet activity, as these animals did not inhabit the low-level training area and flight tracks indicated that no jets strayed over the area.

Calf Survival

Calf survival was negatively correlated with exposure to low-level flying activity for all periods analyzed (Table 2). This relationship was significant during the calving and immediate post-calving periods (23 May – 19 June) for the subset of females known to have calved and was marginally significant (.05 < P < .10) during the calving period for the entire sample of females. The relationship was also significant during both of the summer insect periods. Deleting the Mealy Mountain caribou from the sample did not change the results; Red Wine Mountain caribou still showed significant negative correlations between mean exposure frequency and calf survival during the same four periods.

Five females successfully brought their calves through the entire low-level flying season. Two of these were Mealy Mountain caribou and thus were never exposed to low-level overflights. Of the three successful Red Wine Mountain females, one was never known to have been overflown, another experienced overflights only during the pre-calving period and again briefly during the fall period, while the last was exposed to overflights only during the calving period.

TABLE 2. Survival of caribou calves as a function of exposure to low-level jet training activity during 1987 and 1988

Period	Dates	Sample[a]	N	r_s[b]	$[r_s]^2$
Pre-calving	18/4-22/5	All	15	–.252	.05
Pre-calving	18/4-22/5	w/calf	11	–.212	.06
Calving	23/5-05/6	All	15	–.414	.17
Calving	23/5-05/6	w/calf	11	–.567*	.32
Post-calving	06/6-19/6	w/calf	11	–.727*	.53
Pre-insect	20/6-03/7	w/calf	11	–.441	.19
Insect I	04/7-09/8	w/calf	10	–.653*	.43
Insect II	10/8-15/9	w/calf	9	–.735*	.54
Fall	16/9-20/10	w/calf	8	–.221	.05

[a]All = entire sample of females; w/calf = only those females known to have produced a calf.
[b]Spearman correlation coefficient.
*P < 0.05.

The frequency of exposure that individual caribou experienced throughout the low-level flying season remained relatively consistent for most caribou. For example, the mean correlation for exposure frequency from one period to the next was 0.910. However, changes in the frequency or distribution of jet activity over the season, as well as caribou movements into or away from areas of jet activity, did result in substantial changes for some animals, reducing the overall correlation among periods to 0.694. When the mean exposure frequency for the entire period the calf survived was used, the correlation between calf survival and exposure to low-level flying was not significant (all females: n = 15, r_s = –.312; females known to have calved: n = 11, r_s = –.553; Red Wine females: n = 11, r_s = –.418).

DISCUSSION

We have shown a significant negative correlation between a female caribou's exposure to low-level jet training activity and her calf's subsequent survival. The magnitude of this effect was substantial; during the two calving periods considered, 42% of the variance in calf survival was explained by exposure level to low-level overflights, and for the summer insect periods this proportion increased to 48%. The robustness of our finding is strengthened by the fact that it was shown for each subsample of females analyzed. That this relationship was significant only during the calving and immediate post-calving periods, and again during the summer periods of insect activity, further indicates the biological reality of this relationship. In fact, the lack of a significant relationship during the pre-calving, pre-insect, and fall periods may be as important a finding as the significant relationship during the other periods.

The effects of disturbance on calf survival should vary in magnitude as a function of season. The greatest effects would be expected during critical stages in the animal's development or during periods when other stressors are also acting. The calving period is one such critical period, as disturbance during this period may result in stillbirths, injuries, or cow-calf separations (Banfield, 1974; Cowan, 1974; Miller and Broughton, 1974; Miller *et al.*, 1988). Within a week of birth a calf's lactation demands are greatest (Parker *et al.*, 1990), and any reduction in lactation caused by disturbance (i.e., Ely and Peterson, 1941) may have long-term consequences for growth and survival. In particular, failure to develop sufficiently prior to the onset of the insect harassment season may jeopardize later survival. Reduction in feeding rates, movement to insect relief habitat at the expense of forage quality, the energetic costs of insect avoidance behaviour, and simple loss of blood may increase the calf's susceptibility to other stressors during the summer insect period. For these reasons, significant negative effects of disturbance from low-level overflights would be expected during the above periods and were found.

On the other hand, the calf is well protected *in utero* during the pre-calving period, when most females migrate substantial distances over rugged terrain to calving areas. During the period just prior to the emergence of insects as major pests, the calf is being weaned to solid food, which it may find in sufficient quantity and can eat in relative peace. Finally, during fall the disappearance of insects frees the cow and calf to exploit better resource habitat and forage without disturbance. The short-term effects of low-level overflights may be relatively benign during these periods, as other stressors on the animals have been removed and critical stages have been passed.

The exposure of an individual to low-level flying often did not change greatly during the low-level flying season; correlations among the periods analyzed were relatively high. For this reason, it is unknown whether each of the significant correlations between exposure to low-level flying and calf survival represents an effect from that period or from another period in which exposure frequency was similar. For example, a strong effect during the calving period will also be reflected in every subsequent period in which the distribution of exposure among females remains the same. Thus, the relationship between calf survival and exposure to flying found for the summer insect period could represent a spurious correlation as a result of a real effect from the calving period, coupled with similar exposure frequency during the summer periods. If our data do record such spurious correlations, however, they are more likely to be seen for the latter periods. Correlations seen during the earlier periods are based on a larger sample of animals and thus are not likely to be the result of effects acting later in the season. By the beginning of the summer insect period, one-third of the calves had already been lost, and data from their mothers had been dropped from the analyses.

Both the boundaries of the low-level training area and the topography constrain the distribution of low-level training activity. In particular, areas near the transit corridors leading to CFB-Goose Bay and deep river valleys receive a disproportionate amount of flying activity (Harrington and Veitch, 1990). In our requests for target coordinate overflights in 1987, we found that targets in some areas were readily overflown whereas targets in other areas were seldom overflown. This same bias in the distribution of overflight activity was seen in 1988, when pilots were permitted to fly wherever they wished. If an unknown mortality factor, such as predation by wolves or black bears, was distributed in a similar manner (e.g., along valleys, nearer Goose Bay, etc.), the relationship seen between calf survival and overflight frequency may be spurious.

In an earlier, unpublished report of these findings (Harrington and Veitch, 1990), we used a mean exposure index that was based on the animals' exposure to overflights throughout the entire flying season and found a non-significant negative correlation between overflight exposure and calf survival. Because relative exposure did change throughout the low-level flying season, using a season-long mean exposure index was a serious flaw in our earlier analysis, as the ability to detect important but short-lived effects during sensitive periods was lost.

Management Implications

Through 1987, the Red Wine Mountain population has shown no growth, despite a ban on hunting since 1972 (Veitch, 1990), whereas the Mealy Mountain population has more than doubled during the same period (Hearn and Luttich, 1987). Veitch (1990) suggested that high adult mortality from predation may have been an important factor limiting the growth of the population during that time. The early loss of calves in this study is also consistent with predation mortality, as both black bears and wolves are relatively common in the study area and have been shown to be responsible for three-quarters of the adult mortalities of known cause (Veitch, 1990). In the present study, we have shown that calf survival is also negatively correlated with exposure to low-level flying, which indicates that current levels of training activity may have reached a level where negative impacts on calf survival will become noticeable. Together, the impacts of predators and disturbance from low-level training activity may be preventing the recovery of the Red Wine Mountain population, despite over 15 years of protection from human hunting.

The most conservative conclusion from the results presented here is that calf survival is affected by frequency of exposure to low-level overflights during and immediately after calving. Thus we recommend that calving areas of Red Wine Mountain caribou not be overflown at altitudes below 300 m above ground level during the last week of May and the first three weeks of June. If it is not possible to avoid all areas of the calving range, then corridors of permitted training activity should be designed to minimize the number of females being overflown. In addition, further study of the potential link between low-level flying and calf survival is necessary to firmly establish the relationship and, in particular, to determine its temporal properties.

ACKNOWLEDGEMENTS

We owe a special thanks to Stu Luttich (Regional Wildlife Biologist, Labrador) for all his support and assistance. We are also grateful to the other members of the project's steering committee: J. Hancock, J. Inder, E. Mercer (Newfoundland-Labrador Wildlife Division); A. Noseworthy (Intergovernmental Affairs Secretariat); B. Moores (Environment Canada); C. MacNeil and J. Rowell (Labrador Inuit Association); and their alternates.

We thank the following for their valuable contributions to field work: B. Baikie, D. Baikie, M. Berger, D. Blake, C. Butler, B. Chaulk, B. Dalton, B. Hearn, K. Hollett, N. Hughes, T. Kent, F. Phillips, H. Supper, R. Trask, and Z. Tooze. We thank the staffs at Sealand (Canadian) and Universal Helicopters, Goose Bay Air Services (Labrador Airways) and Air Northland, and their pilots: H. Blake, P. Bradford, H. Day, C. House, B. Kendall, K. Loder, W. Massie, W. Mitchell, G. Nuttall, G. Penny, B. Raymond, B. Smith, H. Supper, and R. Taylor. We thank T. Downs and his staff (Department of National Defence, Ottawa) for their continued assistance. At CFB Goose Bay, the staff of the Military Coordinating Centre deserve a special thanks, especially Major D. Ghyselinks. We thank the officers, squadron leaders, and operations personnel in the German Air Force, Royal Air Force, and Royal Netherlands Air Force for their cooperation.

D. Decker, J. Russell, and S. Tomkiewicz, of Telonics, Inc., and Service Argos staff in Toulouse, France, and Landover, Maryland, especially L. Morakis and H. Sparks, provided help and advice. S. Fancy, through the Alaska Fish and Wildlife Research Center (U.S. Fish and Wildlife Service) and Alaska Department of Fish and Game, provided computer programs used in the analyses of the satellite data. T. Barrett, R. Kafer, F. Messier and J. Reid provided advice on statistical matters.

Funding and other support for this study were provided by the Newfoundland-Labrador Wildlife Division, the Department of National Defence, the Natural Sciences and Engineering Research Council, and Mount Saint Vincent University.

F. Miller, D. Russell, and an anonymous reviewer provided very helpful suggestions to greatly strengthen this paper.

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