Frank L. Miller
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Responses of Peary caribou and muskoxen to helicopter harassment

Environment Canada Environnement Canada

0016388A S

OCCASIONAL PAPER (CANADIAN WILDLIFE SERVICE)

SCF

Occasional Paper
Number 40
Canadian Wildlife Service

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Environment Canada Wildlife Service
Environnement Canada Service de la Faune

0016388A S

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Responses of Peary caribou and muskoxen to turbo-helicopter harassment, Prince of Wales Island, Northwest Territories, 1976–77

Occasional Paper
Number 40
Canadian Wildlife Service

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471
C33
NO. 40

SCF

*CWS, Edmonton T5K 2J5

Issued under the authority of the Minister
of the Environment
Canadian Wildlife Service

©Minister of Supply and Services Canada 1979
Catalogue No. CW69-1/40
ISBN-0-662-10400-5
ISSN-0576-6370

Design: Rolf Harder & Associates

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Abstract

Acknowledgements

The project was funded by Arctic Islands Pipeline Program (AIPP), Polar Continental Shelf Project (PCSP) and Canadian Wildlife Service (CWS). We especially thank G.D. Hobson and F.P. Hunt of PCSP for their support which was critical for the project. We are also indebted to PCSP for logistical and technical assistance from A. Alt and W. Presley. We thank the other field observers: D.B.M. Lamperd in 1976; S. Hall, B.K. Herbert and D. Myers in 1977; A.J. Kennedy, K.E. Smyth and R.G. Thomson were also field observers and compiled data in 1977. We thank M.C.S. Kingsley for computer analyses and statistical help, and B. Chubb for drafting the figures. C. Larsen and K.E. Smyth helped with the final stages of report production. We also would like to thank L. Harder for statistical advice, editing and his analyses of group activities.

This report provides information on overt behavioural responses of Peary caribou (*Rangifer tarandus pearyi*) and muskoxen (*Ovibos moschatus*) to simulations of three likely categories of helicopter activity that would be associated with construction of a gas pipeline in arctic Canada. The study was carried out on Prince of Wales and Russell islands, Northwest Territories, in summers 1976 and 1977. One three-man team and a Bell 206B turbo-helicopter were used in July and August 1976, and four two-man teams and a Bell 206B were used in June–August 1977. All helicopter harassment overflights were flown at less than 400 m above ground level (m agl): mostly below and above 200 m agl in 1976 and 1977, respectively. The maximum response of an animal during an overflight was taken as a measure of harassment. In total, 3939 individual maximum response samples (IRS) of Peary caribou were obtained during 671 harassment overflights and 4011 IRS of muskoxen during 315 overflights: 64.0% of the Peary caribou samples and 43.6% of the muskox samples responded overtly to the helicopter overflights. It was judged that the 12.1% (477) of the Peary caribou samples and the 21.0% (841) of the muskox samples that were still responding at the extreme level after completion of the overflights represented the animals most seriously affected by the helicopter harassment. Helicopter landings were made on 116 occasions near 736 Peary caribou samples and 69 touchdowns near 1192 muskox samples. In total, 28.7% (211) of the Peary caribou IRS and 12.3% (147) of muskox IRS responded at the extreme level to the harassment. Our results indicated that (*a*) the responsiveness of cows and calves of both species and solitary bull muskoxen, (*b*) group size and type, (*c*) number of calves in a group, (*d*) the position of the sun and direction of the wind relative to the helicopter flight, (*e*) previous activity of the animals and (*f*) the terrain where the animals were sampled are all factors contributing to the level of response exhibited by harassed animals. There was an inverse relationship between response level and the altitude of the helicopter overflights or the distance away for a helicopter landing and our recommendations were based on that relationship. Evidence for habituation was detected within but not between sets of passes simulating cargo slinging. The levels of harassment did not cause any visible pathological conditions or lead to group splintering or calf desertion. It is not known, however, what the actual short-term costs of harassment to the individuals were in energy, or what are the potential long-term effects to the populations. If we are to advise wisely on the conservation of Peary caribou and muskoxen, there is a vital need for additional baseline data, especially on affinities for and locations of critical areas such as calving grounds, post-calving areas, rutting areas and migratory routes.

Résumé

Le présent rapport fournit des renseignements sur les réactions manifestes du caribou de Peary (*Rangifer tarandus pearyi*) et du boeuf musqué (*Ovibos moschatus*) lorsqu'ils sont mis en présence de trois manoeuvres possibles d'helicoptères associées à la construction d'un gazoduc dans l'Arctique canadien. L'étude a été réalisée sur les îles Prince-de-Galles et Russell, dans les Territoires du Nort-Ouest, pendant les étés de 1976 et de 1977. En juillet et août 1976, on a utilisé une équipe de trois hommes et un hélicoptère turbopropulsé Bell 206B et, de juin à août 1977, quatre équipes de deux hommes et un Bell 206B. Tous les survols de harcèlement ont été effectués à moins de 400 m de hauteur; surtout au-dessous de 200 m en 1976 et au-dessus en 1977. La réaction maximal d'un animal pendant un tel survol a été considérée comme une mesure du harcèlement. On a obtenu au total 3939 réactions maximales individuelles (R.M.I.) de caribous de Peary à l'occasion de 671 survols de harcèlement, et 4011 R.M.I. de boeufs musqués pendant 315 survols: 64% des caribous et 43,6% des boeufs musqués ont réagi de façon manifeste aux survols de harcèlement. On a jugé que les 477 (12,1%) caribous et les 841 (21%) boeufs musqués qui montraient toujours une réaction extrême après les survols étaient les sujets les plus sérieusement touchés par ce type de harcèlement. L'hélicoptère a atterri 116 fois près de 736 caribous et 69 fois près de 1192 boeufs musqués. Au total, 28,7% (211) des R.M.I. de caribous et 12,3% (147) R.M.I. de boeufs musqués étaient encore observables à la fin des survols. Nos résultats ont démontré que: a) la réaction des femelles et des petits des deux espèces ainsi que des boeufs musqués mâles solitaires; b) l'effectif et le type du groupe; c) le nombre de petits dans un groupe; d) la position du soleil et la direction du vent par rapport à l'hélicoptère en survol; e) l'activité préalable des animaux; et f) la configuration du terrain étaient tous des facteurs influant sur le degré de réaction des animaux harcelés. Le degré de réaction des sujets était inversement proportionnel à la hauteur des hélicoptères en survol ou à la distance séparant les animaux des appareils lors des atterrissages, et nos recommandations s'appuient sur cette observation. On a décelé une certaine accoutumance à l'intérieur d'une même série de passages, mais pas entre les passages simulant un transport de marchandises. Le harcèlement n'a entraîné aucune condition pathologique visible et n'a jamais provoqué la division des groupes ou l'abandon des petits. Toutefois, nous ne connaissons pas le coût énergétique réel à court terme de ces harcèlements pour un sujet particulier, pas plus que leurs effets possibles à long terme pour les populations. Si nous voulons porter un jugement éclairé sur la conservation du caribou de Peary et du boeuf musqué, il nous faut absolument obtenir des données fondamentales supplémentaires portant notamment sur l'emplacement des régions essentielles comme les aires de mise bas, d'élevage et de reproduction et les routes de migration, ainsi que sur les affinités des animaux pour ces régions.

Introduction

The construction and maintenance of a gas pipeline in the High Arctic will lead to great increases in aircraft activity along the route of the pipeline. Polar Gas propose in total the use of 19 aircraft including five light- and two heavy-lift helicopters. The helicopters will be turbine powered and used for such routine operations as pipeline inspections and close-in support of contingency operations.

The proposed pipeline routes and supply lines of the Polar Gas project in the High Arctic (eastern Melville, Byam Martin, Bathurst, Cornwallis, Prince of Wales and Somerset islands) cross habitats used by about 6000–7000 Peary caribou (*Rangifer tarandus pearyi*) and 1000–1500 muskoxen (*Ovibos moschatus*) (1974 estimates). Our concern was the effects of the aircraft traffic associated with the pipeline on the Peary caribou and muskoxen. More specifically, our objectives were to determine the responses of the two ungulate species to helicopter-induced harassment.

As the state of telemetry of physiological parameters such as heartbeat was not advanced enough for use under field conditions, and knowledge of physiology and energetics is limited, especially for muskoxen, we did not measure the cost of harassment in physiological or psychological terms. Instead we noted only observable responses or apparent lack of responses in behavioural terms. Any harassing stimulus causes a change in an animal's environment and the animal will respond in an attempt to adapt to the change. Therefore, the apparent lack of response during some harassments is, in fact, a reflection of our inability to detect a response.

In the 1976 field season our objectives were (*a*) to develop techniques for observation of animals harassed by a helicopter simulating likely categories of helicopter activity, and (*b*) to describe the responses of harassed animals by direct observation from the ground and air.

For the 1977 field season our objectives were to further examine (*a*) the effect of the aircraft's altitude on the animals' responses, (*b*) the possibility of habituation to overflights and (*c*) the possibility of delayed responses to helicopter harassment. We flew simulations of cargo-slinging at relatively high altitudes (200–400 m above ground level) with ground observers. Our fourth goal was to examine the animals' responses to helicopter landings and to the subsequent activities of either work parties or amateur photographers.

Literature review

Knowledge of the effects of harassment on Peary caribou and muskoxen is limited and has to be largely drawn from parallels with other ungulates and predicted from descriptions of caribou and muskox behaviour. Most of the concern about potential wildlife problems that industrial exploration and development activities have brought to the Arctic has been for caribou, still an integral part of native culture.

The literature on harassment of ungulates is scattered among different subjects such as animal husbandry, ethology, range and wildlife management, physiology and psychology. Geist (1975) and Mair (1976) compiled partial general bibliographies of harassment. Hudson and Stelfox (1976) emphasized the physiological aspect of harassment in their bibliography. We have emphasized cervids in our preliminary bibliography (Gunn and Miller 1977).

There are four main categories of industrial development likely to have an impact on caribou populations, and these categories have been the basis for several recent studies. The potential of pipelines, roads, railways and hydroelectric lines as barriers to caribou have been described by Klein (1971), Miller *et al.* (1972, 1977a), Child (1973), Banfield (1974), Bergerud (1974), Cowan (1974), LeResche (1975), LeResche and Linderman (1975), Villmo (1975), Cameron and Whitten (1977) and Roby (1976). The effects of on-going and completed seismic lines were observed by Riewe (1973), Urquhart (1973), Banfield (1974), Beak Consultants (1975), Freeman (1975) and Slaney (1975). The third category of industrial development is the great increase in the use of aircraft associated with industrial exploration and development. Espmark (1972), Thomson (1972), Klein (1973), McCourt and Horstman (1974), McCourt *et al.* (1974), Surrendi and DeBock (1976) and Calef *et al.* (1976) have described caribou responses to fixed wing aircraft and helicopters. Finally, Calef and Lortie (1973) McCourt *et al.* (1974) and Surrendi and DeBock (1976) describe some caribou responses to permanent installations such as construction camps, oil rigs and compressor stations.

Geist (1971, 1975) in his discussion of harassment has argued for a physiological approach to harassment studies with emphasis on the energetic cost of harassment. So far, all published accounts of caribou harassment have depended on observations of behavioural responses. The reliance on behavioural responses was partly the result of most harassment studies being secondary to other projects, such as studies of sex and age composition, but also was the result of the current state of remote monitoring of physiological parameters.

Although techniques for measuring metabolic rates of unrestrained large mammals are being developed (Young and McEwan 1975), the need for a portable infusion apparatus to monitor the flux of radioactive tracers prohibits the use of the method for harassment studies. A more promising approach employs radio-telemetry to monitor parameters such as heartbeat. Skutt *et al.* (1973) developed an implanted transmitter to monitor heartbeat of white-tailed deer (*Odocoileus virginianus*) and Holter *et al.* (1976) further refined the technique to measure metabolic rate under laboratory conditions. Moen and Chevalier (1977) and Geist (pers. comm.) have used external electrodes to record heartbeat on unrestrained white-tailed deer and domestic sheep (*Ovis aires*), respectively.

General descriptions of caribou behaviour (Pruitt 1960, Kelsall 1968 and Skoog 1968) have been supplemented by detailed treatments of calving behaviour and cow–calf relationships (Lent 1966, de Vos 1960, Ericson 1972 and Miller and Broughton 1973), rutting behaviour (Lent 1965, Espmark 1964, Bergerud 1974) and movements (Kelsall 1968, Pruitt 1959 and Curatolo 1975). Previous behavioural studies have emphasized two critical aspects of caribou behaviour that increase their susceptibility to harassment, namely migrations and the synchronized breeding and calving on discrete traditional areas (Miller *et al.* 1972, Miller 1974a, Dauphiné and McClure 1974 and Bergerud 1974). Espmark (1970), Thomson (1972) and Miller *et al.* (1972) have also emphasized the importance of socialization in maintaining traditional migrations.

These harassment studies demonstrated that caribou responded differently to harassment that coincided with the identified critical phases of their life cycle. Observations of responses to both pipeline simulations and aircraft harassment identified a cow–calf pair as the most responsive sex/age group. The studies of aircraft harassment critically reviewed in Geist (1975) all agreed that altitude of the aircraft was one of the determinants of the responses, but previous activity, sex and age class, group size, season, surrounding terrain and aircraft type were all considered important.

Most studies of harassment have considered barren-ground caribou. Peary caribou are the least known caribou subspecies (Jakimchuk 1975): recent data on numbers and movements (Miller *et al.* 1977a and b, Miller and Gunn 1978b) suggest this subspecies may be particularly vulnerable to harassment.

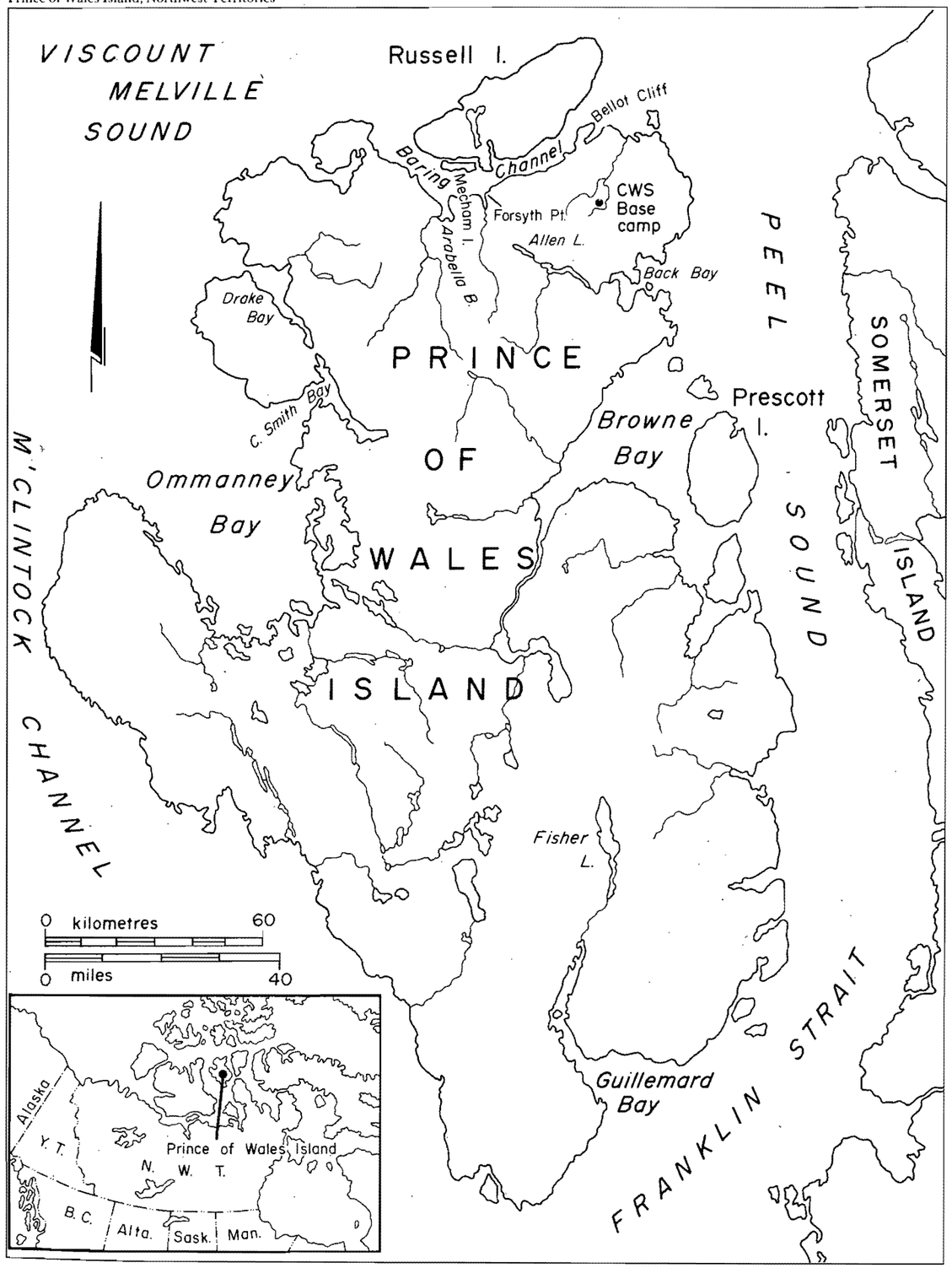
There have been to date no specific studies on harassment of muskoxen by aircraft and only one study on the effects of seismic activity on muskoxen (Beak Consultants 1975). There are some descriptive accounts of responses to isolated harassments by aircraft (Gray 1974), seismic activity (Urquhart 1973, Riewe 1973, Slaney 1975) and human activity (Hone 1934, Tener 1965).

Tener (1965) outlined the biology of the species and noted some of the adaptations of this unique species to the Arctic. Gray (1973) wrote a descriptive account of muskox behaviour and Smith (1976) described rutting behaviour. In a subsequent paper, Gray (1974) described the characteristic defense formation of muskoxen which, although often caused by low-flying aircraft, probably originated as a defense mechanism against wolf attack. Other studies of muskoxen have examined productivity (Hubert 1974), range relationships (Wilkinson and Shank 1974), numbers and distributions (Tener 1958, 1963, Fischer and Duncan 1976 and Miller *et al.* 1977a) and domestication (Wilkinson 1974).

Geist (1971, 1975) outlined some effects of harassment primarily on ungulates and noted (1971:419) that "Another serious consequence of persistent disturbance is voluntary withdrawal from available habitat." Beak Consultants (1975) suggested that seismic activity subtly modified muskox distribution on Banks Island but both Urquhart (1973) and Riewe (1973) could ascribe no major changes of distributions to seismic activities. Gray (pers. comm.) has suggested that aircraft activities will drive muskoxen from an area. However, as almost nothing is known about the factors influencing muskox distribution, it is difficult to evaluate such suggestions.

At present, knowledge of possible effects of harassment on muskoxen has to be largely drawn from parallels with other ungulates and predicted from descriptions of muskox behaviour. Lent (1974) predicted from his observations of muskox calving that calves would be particularly vulnerable to aircraft disturbance.

Figure 1
Prince of Wales Island, Northwest Territories



Study area

Prince of Wales Island is about 32 000 km² in size and lies between 71 and 74°N and 96 and 103° W (Fig. 1). Our aerial reconnaissance included all of Prince of Wales Island (except the extreme south) and a southern coastal strip (3 x 42 km) on Russell Island between 98°00'W and 99°20'W. Ground work was restricted to the northeastern portion of Prince of Wales, including the north coast from Cape Hardy (73°53'N, 97°36'W) west to Forsyth Point (73°44'N, 98°50'W), the Allen Lake drainage from Forsyth Point southeast to Back Bay (73°32' N, 97°41'W) and the "Russell" (unnamed) River from Back Bay north past our base camp at 73°41'N, 97°41' W to the mouth of the drainage east of Cape Hardy and west of Lyons Point (73°51'N, 97°25'W).

Dunbar and Greenaway (1956), Bird (1967) and Blackadar (1967) described the physiography of Prince of Wales Island and Netterville *et al.* (1976) have recently described the terrain and geology. Craig (1963) discussed some of the glacial features of the island. Woo and Zoltai (1977) classified regions and districts of Prince of Wales using physiographic, soil and plant distribution characteristics. Russell and Edmonds (1977) give botanical information and further descriptions of range types for the island.

Inuit are not known to have settled on Prince of Wales, but Inuit from Resolute Bay and Spence Bay have travelled there to hunt Peary caribou. Dunbar and Greenaway (1956) in their account of the history of exploration stated "No trading post or other settlement have ever been established on the island."

We selected Prince of Wales Island for our study area because it lies along a potential route for the proposed eastern Arctic pipeline, at the junction of the high- and mid-arctic regions (Polunin 1948, Woo and Zoltai 1977). It also has characteristics in common with other high- and mid-arctic islands along the proposed pipeline routes. In addition, present distributions and numbers of both muskoxen and caribou are more favourable for study on Prince of Wales than on adjacent islands (Fischer and Duncan 1976, Miller *et al.* 1977a, Russell and Edmonds 1977).

Methods and sources of data

1. Experimental field techniques

In 1976 we established a base camp in the "Russell" (unnamed) River valley which we shared with field parties of AIPP project 6123. Our party of three observers used a Bell 206B "Jet Ranger" turbo-helicopter as a harassment agent from 5 July to 15 August and flew 49.9 and 33.7 h in July and August respectively. In 1976 we varied our daily distributions and directions of flights according to suitability of weather for flying, aircraft maintenance, requirements of the other field party and the exploratory nature of our first field season.

On 29 May 1977 we returned with six observers to the 1976 base camp. Two observers left 4 August and the camp was removed 25 August. In June we flew 97.2 h in a Bell 206B helicopter on exclusive contract to our project (Miller and Gunn 1978b: Appendix I). In July and August we flew 42.3 and 65.5 h, respectively, on a casual contract when the helicopter was available from Resolute Bay, Cornwallis Island.

Our helicopter harassment simulated three likely categories of activity that will probably be associated with construction and maintenance of an oil or gas pipeline in the Arctic. Our work in 1976 emphasized the development of techniques and an opportunistic approach prevailed. In 1977, we restricted our work to a more detailed look at the effect of relatively high altitude simulated cargo slinging and simulated work parties. We also concentrated on maximum use of ground crews to record behaviour prior and subsequent to harassment overflights.

1.1. Reconnaissance and search flights

We flew reconnaissance flights only in 1976 to obtain information on relative numbers and distributions of Peary caribou and muskoxen and their overt responses to the helicopter. Subsequently we carried out search and harassment flights in July and August over the areas that groups of Peary caribou and/or muskoxen frequented. Occasionally, we returned to areas that previously had carried low numbers to determine whether animals had moved into those areas. The altitude of the helicopter was partly determined by the weather, but we flew at all 30-m intervals below 325 m agl (above ground level) altitude. Some flights were flown at 20–70 m agl to simulate aerial inspection of pipelines.

We searched for groups within 2–4 km of the helicopter. When we spotted a group or an individual, the helicopter flew past them, turning if necessary to have the animals on the same side of the helicopter as the two observers. In 1976, we recorded helicopter speed (km/h) and altitude (m asl) and, using a clinometer, the actual (diagonal) distance (m) to

the first animal to respond and to the animals when the helicopter approached them most closely. In addition we recorded sex, age and overt responses of individual animals and shot Kodachrome 40 or Ectachrome 40 Super 8 film, when conditions allowed, with a Braun 800 movie camera at 54 frames/sec through the open window of the helicopter rear door. We located the observation on a 1:250 000 topographical map and also noted the terrain and direction of wind and position of sun relative to the helicopter for each observation. We tape recorded all observations on Phillips LFH 0085/25 cassette recorders and subsequently transcribed them onto data sheets.

We recognized the following categories and overt behavioural responses: (*a*) bedded, (*b*) foraging, (*c*) standing alerted, (*d*) walking, (*e*) trotting or cantering and (*f*) galloping. We noted the relative position of individual muskoxen to each other and whether the locomotary activities of the individuals were directed toward taking up a group defense formation. We recorded the type of group defense formation and the subsequent response of the group to the harassment. We divided our observations into three periods: approach, closest contact with the animals (opposite helicopter) and departure of helicopter. Other overt responses including calves moving to cows, bolting, milling, aggressive and grooming behaviours were also recorded in our tape-recorded narratives of observations.

1.2. Simulated cargo slinging flights

In 1976 and 1977 we flew a series of five or more passes over a group at relatively low speeds (less than 100 km/h) to simulate the slinging of cargo by helicopter. We were able to make those simulations when animals were in areas that allowed observation from nearby high ground. During searches for groups for simulated slinging, we flew at high altitudes (200–400 m agl) and on spotting a group in a suitable location we turned away and landed out of sight of the group 0.4–1.6 km away, depending on cover afforded by surrounding terrain. Two observers walked to a prominence and used 15 x 60 zoom spotting scopes and 10 x 40 binoculars to observe the animals. If the group was less than 0.8 km from the observers, one observer shot Super 8 movie film on timed single frames or continuous footage. Immediately after the two observers had deplaned, the helicopter took off and flew away from the group taking advantage of suitable terrain to remain out of sight. We started flying passes over the group either immediately or within 4 h after observer placement, depending on helicopter availability and the suitability of the location for the observers maintaining contact with the group. An observer remained in the helicopter and recorded the time, altitude (m asl), speed and direction of each pass. He also located the observation on a 1:250 000 topographical map and noted the direction of wind and position of the sun relative to the helicopter for each pass.

The observers on the ground divided their observations into three periods: pre-harassment (undisturbed), harassment and post-harassment (recovery). The duration of the three periods varied according to weather, helicopter availability and movements of the animals under observation. We recorded behaviour at 10-min intervals of all individuals in the group by sex/age class during pre- and post-harassment periods, and continuously during periods of harassment. In 1977, one observer attempted to maintain a continuous record of the behaviour of an individual cow–calf pair while the second observer concentrated on the entire group. We used the same categories as we had used for aerial observations and also recognized other specific types of adaptive behaviour. In our examination of the possible behavioural repertoires we used as guides descriptions of specific behavioural patterns of North American ungulates: Pruitt (1960), Cowan and Geist (1961), Geist (1963, 1966), Thomas *et al.* (1965), Lent (1966), Prenzlow *et al.* (1968), DeBock (1970), Gray (1973), Miller (1974b, 1975) and Smith (1976).

In 1976 the use of a shared helicopter on a daily basis restricted our simulated cargo slinging flights. The sets of passes were flown at either constant altitudes or descending altitude with each pass from 305 to 30 m agl. In 1977 we only flew simulated cargo slinging flights using sets of six passes at relatively high altitudes (270–400 m agl). When distribution of the animals permitted, we positioned two teams of observers watching different groups 1–5 km apart and flew one set of passes over both groups. The helicopter flew at about 80 km/h and turned at 8 km on either side of the group. If weather permitted and the observers had maintained contact with the group, we flew a second set of six passes over the group within 2–6 h of the first set.

1.3. Inspection flights, simulated work parties and simulated amateur photography

In 1976 we simulated inspection flights by flying low-level passes or circles at hovering speeds. In 1976 we simulated the placement of work parties by helicopter as a likely type of harassment associated with survey and inspection crews. The helicopter landed and shut down within 20–800 m of the animals. The observers left the helicopter but remained in its immediate vicinity with no attempt at concealment. The observers recorded on tape and Super 8 film overt behavioural responses using the categories for ground observation already described. We also recorded terrain, distance to the animals and wind direction in relation to ourselves and the animals.

Although we did not simulate inspection flights in 1977, we did simulate work parties by landing within 200–800 m of groups of animals. In 1977 we also simulated the type of activity we would anticipate from amateur photographers. These simulations were the same as for the work parties except that we approached the group and recorded the animals' overt responses to the approach at 2-min intervals.

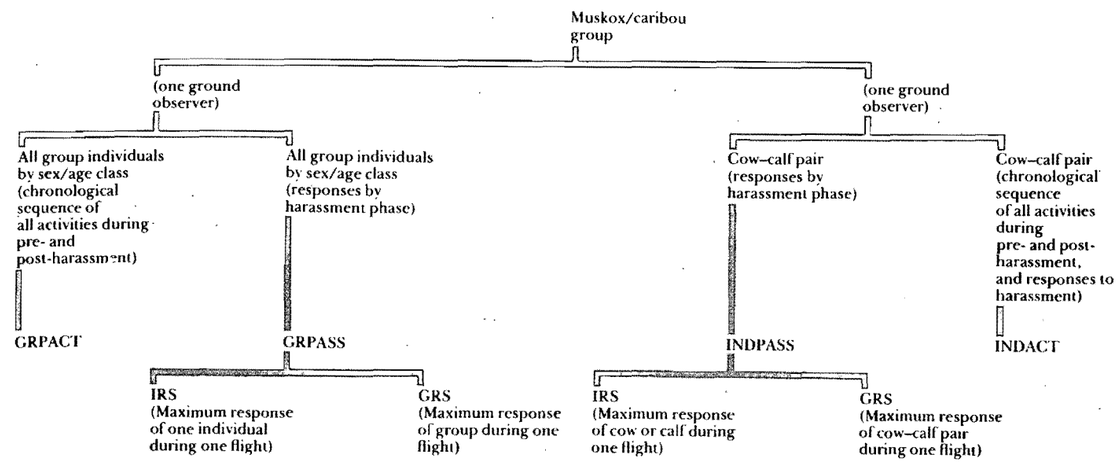
2. Data analyses

2.1 Computer analyses

In 1977 all field observations were numerically coded and transcribed onto computer sheets at the field camp and subsequently key punched on our return to the office. All files (Table 1) were edited and checked for any spurious values and cross-checks were run. The 1976 caribou computer data files were overlaid with the 1977 format and the 1976 muskox data sheets were transferred to files.

We recorded our observations of responses to harassment into several phases (response pattern) according to the type of harassment, and those phases were maintained throughout analyses. During harassment flights, we recorded the minimum (A) and maximum (B) response of an individual during approach of the helicopter. As the helicopter was overhead, the departure phase began; a maximum (C), a minimum (D) and, in 1977 only, a last response while the helicopter was last audible (E) were recorded (in our overlay of 1976 data we arbitrarily assigned E response to equal D). During landings, we recorded responses of individuals at specific phases or times: when first sighted, during approach, as we touched down, as the blades wound down, at 2-min intervals until we returned to the helicopter, as it started up, during take off and when the animals were last seen. The use of discrete phases during the recording of overt responses permitted standardization of observations and allowed us to

Table 1
Schema of collection of data obtained during helicopter harassment study, Prince of Wales Island, NWT, 1977



compare both specific responses and response sequences at different times during harassments.

We have analyzed one type of response sample in this report. The maximum response of one individual during one flight (or landing) is referred to as an individual response sample (IRS). The number of groups sampled is equivalent to the number of flights.

2.2. Categorization of responses

We have assumed in our work that the most extreme response that a Peary caribou or muskox could exhibit would be flight by galloping away from the harassing stimuli. In an attempt to make our analyses of IRS more meaningful, however, we have identified the following categories as responses at the extreme level: (*a*) Peary caribou that trotted or galloped; (*b*) muskoxen that walked, cantered or galloped together to form tight and loose group defense formations; (*c*) muskoxen that stood in tight or loose group defense formations and (*d*) muskoxen that cantered or galloped. Although trotting and cantering are defined as controlled gaits, they are responses that demand energy expenditures beyond the level normally associated with ongoing maintenance activities. We have, therefore, judged that they should also be categorized as extreme level responses.

We have also assumed that although walking is part of foraging activity, deliberate walking in apparent response to harassing stimuli may at times be excessive to the demands of maintenance and so we have categorized walking and alarm (alert) behaviour as moderate level responses. We have further assumed that as long as these moderate level responses are short-lived and infrequent, as they appeared to be in our work, they do not in themselves constitute serious extra demands on the harassed animals.

If the harassed animals remained engaged in maintenance activities (bedded or foraging) and exhibited no apparent responses to harassing stimuli, we considered the lack of observable responses as an indication that the animals were not harassed to a level that would elicit an overt response. Such a condition was recorded as a maintenance level activity or maintenance activity. We have avoided any consideration of psychological or internal physiological problems in this approach because we could not measure them.

We analyzed IRS in relation to measured variables by observed/expected (O/E) indices. O/E indices indicated whether observed values were occuring as often as expected (O/E = 1.00), more frequently than expected (O/E = > 1.00) or were less frequent than expected (O/E = < 1.00). Statistical significances of the observed values (Hypothesis of independence, Freund 1960) were measured by contributions to Chi-square (χ_n^2) values calculated from O/E indices and expected values: where $\chi_n^2 = E\,(1\text{-}I)^2$, where I = O/E.

When calculating the O/E ratios, a "class" should be thought of as an "independent variable" composed of "values": e.g. the sex/age class is composed of the values Bull, Cow, Juvenile, Yearling and Calf which constitute the independent variable — the sex/age class. In the tables, we presented two-way contingency tables of tabulations of response levels against the independent variables (e.g. sex/age, group size, group type classes) for each altitude class (<200, >200 and <400 m agl) separately. In the text, we discuss results obtained by calculating two-way contingency tables of altitude against response levels, looked at separately for each value of each independent variable (e.g. the sex/age class, Bull; group size class, 2–5; and the group type class, Cow–calf pairs) and those results are presented in the text and are not tabulated. The reader

should note, that the O/E ratios in the tables reflect only the relative responsiveness of each value to each other value of an independent variable while the O/E ratios in the text indicate the responsiveness of only that particular value of an independent variable in isolation. Consideration of only the O/E ratios in the tables or in the text would permit only a partial understanding of the subject matter and could often provide misleading evalutions of the data. Therefore, the reader must consider both sets (tables and text) of O/E ratios to truly understand the distribution and contribution of each value of each independent variable to the analyses of responses induced by turbo-helicopter harassment.

We use "predicted" to mean the assumed inverse altitudinal relationship of harassing agent to harassed animals: the closer the two entities are to each other the more frequent the extreme level of responses. That is, we predicted that the lower the helicopter harassment flight, the more frequent the extreme level of the responses and the less frequent the apparent lack of responses (remaining bedded or foraging). We also predicted the converse for extreme level and maintenance activities during harassment overflights at higher altitudes.

Three stepwise multiple regressions were used for analyses of the variance of measured variables obtained for all helicopter harassment overflights < 200 m agl, > 200 m agl and < 400 m agl with levels of responses used as the dependant variable. The critical proportion for exclusion of variables was set at < 0.5%.

2.3. Definitions of terms

Alerted. An animal was alerted when it took a "head high" or "head low" stance. Such alerted positions were more stereotyped for caribou than muskoxen and more easily recognized. Animals "standing alerted" or bedded and "alerted" usually looked toward the harassing agent. Animals that became "alerted" while bedded received the same response rating as animals standing "alerted."

Bedded. A "bedded" animal is one that was in a resting or ruminating position either upright on its brisket or lying on its side, and showing no apparent signs of alertness to changes in its environment.

Canter. A "canter" is a slow galloping assymetrical gait (Bullock 1974) employed by muskoxen during periods of apparently restrained flight behaviour.

Circle (helicopter harassment flight pattern). A "circle" was a more or less constant radius flight pattern flown at a given altitude around the harassed animals.

Defense circle (also defense formation or defense ring). The classical grouping of muskoxen in a circle, crescent, line or ring-like formation practised as a mutual defense maneuver during flight behaviour. We refer to mutual group defense by members of single-sex groups of bulls as "defense formations", and by members of mixed-sex groups as "defense circles". We make the distinction as it is difficult to conceive of two or three muskoxen as forming a circle. A "loose" group was one with some animals one body length or more apart and group members could be readily counted. In a "tight" group the animals were compacted together, calves and juveniles were difficult to identify and it was not easy to count group members.

Defense position. "Defense position" is the stance assumed by a solitary muskox bull against or close to a topographical feature (gully bank, hummock or stream) seemingly as a defense aid during his flight behaviour.

Expected (expected cell frequencies). We use the word "expected" in the sense of a mathematical expectation. "Under the hypothesis of independence, the expected frequencies for any cell can thus be obtained by multiplying the total of the row to which the cell belongs by the total of the column to which it belongs and then dividing by the grand total" (Freund 1960:277).

Foraging. An animal was "foraging" when it appeared to be feeding while standing in place or walking and not showing alertness to changes in its surroundings.

Galloping. A "gallop" is the most rapid assymetrical gait employed during apparently unrestrained flight behaviour.

Group. A "group" identifies a gathering of animals as a seemingly discrete closed social unit at the time of our contact with them.

Habituation. The adjustment, affected in a cell or an organism, by which subsequent contacts of the same stimulus produce diminishing effects (Henderson and Henderson 1963:232).

Harassing stimuli. "Harassing stimuli" were changes (visual, auditory or olfactory) of unknown intensity in the animal's environment brought about by a harassing agent (helicopter). We recorded the changes only as overt responses made seemingly in attempts to adapt to those changes.

Harassment. "Harassment" is assumed to be the phenomenon which resulted from the introduction of unidentified stimuli into an animal's environment. Our only measure of harassment was through overt responses by the supposedly harassed animals. Therefore, its presence would have been undetected in cases where animals did not respond in an observable manner. A good analysis of the meaning of harassment is given by Geist (1971).

Harassment flight. "Harassment flight" means a single flight of the helicopter (regardless of pattern: pass, circle or land) over and near an animal or group for the purpose of causing a harassment.

Head high alert position. An animal with a "head high alert position" held its head and neck erect above shoulder height to look in the direction of the harassing agent.

Head low alert position. An animal with a "head low alert position" was usually an animal which had been foraging and raised its head but with the head and neck below or level with shoulder height to look in the direction of the harassing agent.

Head-tracking. An animal was "head-tracking" when it rotated its head, usually on a horizontal plane but also sometimes vertically, to maintain visual contact with the harassing agent while keeping the remainder of the body stationary. Both standing and bedded animals performed "head-tracking."

Herd bull. A "herd bull" is the dominant bull of a mixed sex group whom we recognized by his size, aggressive behaviour, apparent leadership and apparent defense of the group during harassments. The herd bull often assumed a defensive stance on or slightly beyond the periphery of the group defense circle.

"Intruder" bull. An "intruder bull" is a bull that has made contact with and seemingly is attempting to associate with a mixed sex group, apparently for the potential to mate. His presence is, however, noticeably intolerable to the herd bull and leads to aggressive acts and a degree of excitability within the group.

Observation. An "observation" is an overall discrete period of harassment(s) regardless of the number of harassment flights and animals involved. For example: One pass over 10 animals in one observation (composed of 10 samples). Ten consecutive passes and/or circles over one animal is also one observation (composed of 10 samples). Ten consecutive passes and/or circles over 10 animals is also one observation (composed of 100 samples). Note: "observation" and "occasion" are synonomous.

Pass. A single helicopter flight "pass" is a straight-line flight alongside the animal or group, and a "multi-pass" is a compressed elliptical pattern flown over animals for the purpose of harassment. The primary axis of the multi-pass was varied from 1.6 to 32 km during each harassment flight (0.8 to 16 km equally on each side of the harassed animal or group).

Repeat sampling. "Repeat sampling" is two or more observations of harassments of an animal or group that we assumed was the same animal or group.

Response. A "response" is an attempt by a harassed animal to adapt to a change in its environment caused by the harassment. The rating that we gave for an "individual response" (IRS) was determined directly by the animal's behaviour.

Response pattern. The "response pattern" consisted of four parts (A, B, C, D): A = minimum response during initial stage of approach; B = maximum response during approach before point of closest contact with the animals; C = maximum response during departure after point of closest contact; D = minimum response during departure.

Sample. A "sample" is the smallest unit that we recognized; it is the response of one animal during one harassment flight. For example, one harassment flight over 10 animals equals 10 samples, 10 harassment flights over 10 animals equals 100 samples and over one animal equals 10 samples.

Solitary muskox bull. A "solitary muskox bull" is an animal that appears to have no association (at that point in time) with other muskoxen. His flight behaviour reflects apparent awareness of his lack of companion animals.

Stress. "Stress" in this report is an unknown entity. We assume that all of our helicopter-induced harassments resulted in some degree of stress to the harassed animals. "Stress" was defined by Selye (1950) as the action of nervous and emotional stimuli elicited by an animal's environment on the nervous, circulatory, endocrine, respiratory and digestive systems to produce measurable changes in the functional levels of those systems.

Trot. A "trot" is a two-timed symmetrical gait of medium speed (Bullock 1974) employed by caribou during periods of apparently restrained flight behaviour.

Unharassed (undisturbed). An "unharassed" animal is an individual that has not been deliberately disturbed by us and showed no escape behaviour in our presence. In reality, the animal may have been stressed by us but we could not detect any responses other than occasional alarm behaviour that might have been directed at us.

Walking. A "walk" is the slowest gait employed during feeding activities and unharassed movements. The "walk" usually at a faster or more deliberate tempo is also the slowest gait during periods of restrained flight behaviour.

Results and discussion

In total, we obtained 8607 response samples during 1102 helicopter harassment overflights: 4358 from Peary caribou during 751 overflights and 4249 from muskoxen during 351 overflights. As we have deleted all circle-type overflights (see next paragraph) from the analyses in this report, the total samples used are 3939 from Peary caribou obtained during 671 pass-type overflights and 4011 from muskoxen obtained during 315 pass-type overflights. Data obtained at the time of helicopter harassment landings involved 736 Peary caribou samples during 116 landings and 1192 muskox samples at 69 touchdowns. More detailed considerations of season, wind, sun and terrain classes, and regression analyses are given in Miller and Gunn (1978b) as are discussions of cargo-slinging, analyses of muskox group defense formations and responses of four muskox herds to repeated harassment.

We believe that the greater duration of the circle-type helicopter harassment overflights is the principal reason for greater responses during those overflights. When we maintained a more or less fixed-radius, circle-type overflight around the animals, we were probably subjecting them to a similar level of harassing stimuli but for about three times the duration of a helicopter pass. Also, if the animals moved on a course that would cross ahead on the circumference of the helicopter flight path, the helicopter would often overtake them or come closer to them as they passed beyond the circle. On some occasions the helicopter may have caused the animals to turn back within this circle several times in their attempts to escape. This behaviour was apparently more intensified during single and first circles than during subsequent circles. Such conditions would probably lead to reinforcing the escape drives of the animals and, therefore, to more extreme responses during circle-type rather than pass-type overflights.

Analyses of IRS of Peary caribou and muskoxen obtained during single, first and subsequent circle-type harassment overflights in 1976 could not, however, be directly compared to pass-type harassment overflights obtained in 1976 and 1977 because few circles were flown in altitude classes > 200 m agl. Therefore, we have deleted 419 Peary caribou samples obtained during 80 circle-type overflights and 238 muskox samples obtained during 36 circle-type overflights.

1. Peary caribou, IRS

1.1. Altitude classes

Of the 3939 IRS obtained for Peary caribou during all pass-type harassment overflights, 35.1% (1382) were extreme level responses (ELIRS), 28.9% (1139) were moderate level responses (MLIRS) and 36.0% (1418) were maintenance activities (MAIRS) (Tables 2, 3 and 4; Fig. 2). The distributions of IRS during overflights at < and >200 m agl varied significantly (χ^2 = 991.18, 2 df, P<0.005). ELIRS represented 53.6% (1068) of the 1992 IRS obtained during flights at <200 m agl and exceeded the expected value by 53.0%. The ELIRS obtained during flights at >200 m agl equalled only 16.1% (314) of 1947 IRS and represented only 46.0% of the expected ELIRS at >200 m agl. The difference in the contributions of MLIRS during flights at < and > 200 m agl is relatively weak, but moderate level responses did follow the predicted pattern with altitude: <200 m agl exceeded the expected value by 14.0% and >200 m agl was only 85.0% of the expected value. The strongest difference between altitude classes was observed for the MAIRS which represented only 13.4% (266) of 1992 IRS at <200 m agl or 37.0% of the expected value and 59.2% of the 1947 IRS at >200 m agl or 64.0% more than the expected value.

The occurrence of observable responses by Peary caribou to helicopter harassment overflights varied from 90.4% for flights at <50 m agl to 40.4% for flights between 201 and 300 m agl and 47.4% for flights between 301 and 400 m agl. Peary caribou responded more at the extreme level, 74.1%, when the overflights were at <50 m agl, followed by 55.6% at 51–100 m agl, 44.1% at 101–200 m agl, 15.2% at 201–300 m agl and 29.3% at 301–400 m agl. The greater percentage of observable responses and the higher proportion of extreme level of responses from the 201–300 m agl class relative to the 301–400 m agl class is significant (χ^2 = 20.24, 2 df, P <0.005). When IRS from the two higher altitude classes are compared, the O/E index for extreme level responses to flights at 301–400 m agl exceeds the expected rate by 86.0%. The O/E index for extreme level responses to 201–300 m agl flights only realized 94.0% of the expected rate. O/E indices for MLIRS and MAIRS were both lower than expected for the 301–400 m agl class and greater than expected for the 201–300 m agl class.

A test of independence between distributions of the IRS obtained during single passes and first passes of multi-pass overflights (Table 5) and passes subsequent (Table 6) to the first passes of multi-pass overflights indicates that the levels of the IRS were partly dependent on the sequence of passes. That is, Peary caribou responded more at the extreme and moderate levels and were engaged in maintenance activities less frequently than expected during single and first passes than during subsequent passes (χ^2 = 522.79, 2 df, P<0.005).

Distribution of IRS within the single and first passes (χ^2 = 314.16, 2 df, P<0.005) and the subsequent passes (χ^2 = 256.36, 2df, P<0.005) followed the predicted pattern. Extreme and moderate responses occurred more often than expected during flights below 200 m agl and less often during higher flights. Maintenance activities were observed less frequently than expected during low level flights and more often than expected during flights at >200 m agl. These conditions may be partially attributable to the contagious nature of the IRS data.

Examination of the IRS distribution by altitude for single and first passes and for subsequent passes (Tables 5 and 6) indicates that the apparent habituation may actually be a reflection of the indirect relationship between response level and altitude. Overflights at <200 m agl account for 82.5% (1608) of the IRS obtained during single passes and first passes. Overflights during subsequent passes account for only 19.3% (384) of the IRS obtained at <200 m agl (4.27 times fewer than in single and first passes).

The percentage of Peary caribou responding to flights <200 m agl at the extreme level (55.5% versus 45.8%) and moderate level (32.3% versus 36.2%) for single and first passes and subsequent passes, respectively, appeared similar. However, those percentages are misleading as the response frequencies were less than expected for ELIRS and greater than expected for MAIRS for subsequent passes at <200 m agl when compared with ELIRS and MAIRS for single and first passes at <200 m agl (χ^2 = 14.29, 2 df, P<0.005). Only MLIRS occurred at significantly greater frequencies than expected when IRS distributions for samples obtained during passes at >200 m agl were compared between single and first passes and subsequent passes (χ^2 = 9.73, 2 df, P<0.01).

The percentage contribution by altitude to any one level of response can be misleading and must be related to the relative sampling intensities. For example, during subsequent passes only 40.9% (176) of the ELIRS were obtained during overflights at <200 m agl while 59.1% (254) ELIRS were obtained at >200 m agl. Those absolute values suggest that Peary caribou were more responsive during subsequent passes above 200 m agl. If we examine the O/E indices (Table 5), however, the 40.9% represents 212.0% of the expected rate and 59.1% equals only 73.2% of the expected rate. This condition suggests that Peary caribou were really more responsive in the ELIRS category at <200 m agl. Similarly at the moderate level, only 26.9% (139) and 73.1% (378) MLIRS were obtained during subsequent passes at < and >200 m agl, respectively. The relative contributions of MLIRS were, however, 139.0% of the expected for subsequent passes at <200 m agl and only 90.6% of the expected for subsequent passes at >200 m agl.

Distributions of IRS of Peary caribou obtained during all pass-type overflights (<400 m agl) were significantly different (χ^2 = 1109.68, 8 df, P<0.005). The greatest significant difference was between distributions of IRS obtained during passes at <200 m agl versus higher passes (χ^2 = 991.18, 2 df, P<0.005). Contributions were greater than expected for ELIRS and MLIRS during low altitude (<200 m agl) passes, and less than expected for passes >200 m agl. Maintenance activities were less common than expected during passes <200 m agl and more common than expected during higher passes. All IRS distributions indicated that Peary caribou were significantly more responsive to harassment by the helicopter flying at <200 m agl. Therefore, we will consider Peary caribou responses to helicopter harassment by all IRS during passes at <200 m agl (1992), all IRS during passes at >200 m agl (1947) and all IRS obtained during passes at <400 m agl (3939).

Table 2
Distribution of Peary caribou individual response samples, by level of response and altitude class (metres above ground level), during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Trot	Extreme Gal.
1–50	8	22	38	13	199	33
51–100	46	48	183	89	324	135
101–200	49	93	183	152	310	67
201–300	355	727	317	140	222	53
301–400	2	68	17	7	12	27
<200	103	163	404	254	833	235
>200	357	795	334	147	234	80
<400	460	958	738	401	1067	315

Figure 2
Distribution of Peary caribou individual response samples, by level of response and altitude class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77

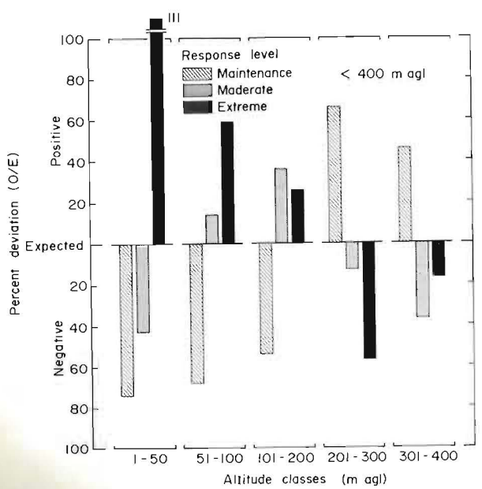


Table 3
Distribution of Peary caribou individual response samples, by level of response and variable classes, during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 3939)

Variable class	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Trot	Extreme Gal.
Sex/age						
Bull	197	421	252	91	171	62
Cow	89	251	283	172	478	137
Juv	82	115	74	39	148	26
Yr	28	30	10	7	22	14
Calf	64	141	119	92	248	76
Group size						
Solitary caribou	1	9	36	13	26	9
Cow–calf pair	0	4	9	8	9	6
2–5 caribou	77	179	237	112	304	88
6–9 caribou	83	313	252	124	396	74
10–19 caribou	294	286	176	91	244	55
20–27 caribou	5	167	28	53	88	83
Group type						
Bull	73	161	146	60	89	43
Bull–cow–juv–yr–calf	89	231	69	44	39	17
Bull–juv–yr	148	267	139	52	160	36
Juv–yr	6	6	15	5	22	8
Cow–juv–yr–calf	108	70	106	60	222	32
Cow–calf	24	186	199	138	418	146
Cow–juv–yr	12	37	64	42	117	33

Table 4
Distribution of Peary caribou individual response samples, by level of response, altitude class (metres above ground level) and type of helicopter harassment overflight, Prince of Wales Island, NWT, 1976–77

Altitude class m agl, by flight type	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Trot	Extreme Gal.
Single passes and first passes of multi-passes (n = 1948)						
1–50	7	18	15	7	153	22
51–100	29	37	132	66	263	102
101–200	38	68	165	134	290	62
201–300	52	102	55	41	58	2
301–400	0	23	3	4	0	0
Subsequent passes of multi-passes (n = 1991)						
1–50	1	4	23	6	46	11
51–100	17	11	51	23	61	33
101–200	11	25	18	18	20	5
201–300	303	625	262	99	164	51
301–400	2	45	14	3	12	27

Table 5
Distribution of Peary caribou individual response samples (IRS), by level of response and altitude class (metres above ground level) during single and first passes of helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
1–50	25	22	175	222
51–100	66	198	365	629
101–200	106	299	352	757
201–300	154	96	60	310
301–400	23	7	0	30
Total	374	622	952	1948
Observed/expected indices				
1–50	0.59	0.31	1.61	
51–100	0.55	0.99	1.19	
101–200	0.73	1.24	0.95	
201–300	2.59	0.97	0.40	
301–400	3.99	0.73	0.00	
Chi-square contributions				
1–50	7.29	33.71	40.77	81.77
51–100	24.83	0.04	10.79	35.67
101–200	10.65	13.58	0.87	25.10
201–300	149.99	0.09	55.26	205.34
301–400	51.60	0.69	14.66	66.96
Total	244.36	48.12	122.36	414.83

Table 6
Distribution of Peary caribou individual response samples (IRS), by level of response and altitude class (metres above ground level) during subsequent passes of helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
1–50	5	29	57	91
51–100	28	74	94	196
101–200	36	36	25	97
201–300	928	361	215	1504
301–400	47	17	39	103
Total	1044	517	430	1991
Observed/expected indices				
1–50	0.10	1.23	2.90	
51–100	0.27	1.45	2.22	
101–200	0.71	1.43	1.19	
201–300	1.18	0.92	0.66	
301–400	0.87	0.64	1.75	
Chi-square contributions				
1–50	38.24	1.22	70.97	110.43
51–100	54.40	10.49	63.07	127.96
101–200	4.34	4.64	0.78	9.77
201–300	24.63	2.23	37.13	63.99
301–400	0.91	3.55	12.62	17.08
Total	122.52	22.14	184.57	329.23

1.2. Sex/age classes

We obtained 30.3% (1194) of the IRS from Peary caribou bulls (Tables 7, 8 and 9; Figs. 3, 4 and 5). In total 47.2% (563) of the above IRS were from overflights at <200 m agl. There was a significant difference in the relative frequencies of the three levels of responses exhibited by bulls during passes at < and >200 m agl ($\chi^2 = 287.84$, 2 df, $P<0.005$). The observed ELIRS totalled 19.5% (233): 35.7% (201/563) for ELIRS during passes at <200 m agl and only 5.1% (32/631) for ELIRS during higher passes. O/E indices for IRS at <200 m agl were the greatest for extreme level responses (O/E = 1.83) and lowest for maintenance activities (O/E = 0.53), which was the reverse order for those O/E indices at >200 m agl.

We obtained 35.8% (1410) of the IRS from Peary caribou cows (Tables 7, 8 and 9). In total 63.0% (888) of the above IRS were from overflights at <200 m agl. There was a significant difference in the relative frequencies of the three levels of responses exhibited by cows during passes at < and >200 m agl ($\chi^2 = 277.04$, 2 df, $P<0.005$). The observed ELIRS totalled 43.6% (615): 54.4% (483/888) for ELIRS during passes at <200 m agl and 25.3% (132/522) for ELIRS during higher passes. O/E indices for IRS at <200 m agl were greatest for extreme level responses (O/E = 1.25) and lowest for maintenance activities (O/E = 0.41), which was the reverse order for those O/E indices at >200 m agl.

We obtained 12.3% (484) of the IRS from juvenile Peary caribou (Tables 7, 8 and 9). In total 44.0% (213) of the above IRS were from overflights at <200 m agl. There was a significant difference in the relative frequencies of the three levels of responses exhibited by juveniles during passes < and >200 m agl ($\chi^2 = 221.97$, 2 df, $P<0.005$). The observed ELIRS totalled 36.0% (174): 69.5% (148/213) for ELIRS during passes at <200 m agl and only 9.6% (26/271) for ELIRS during higher passes. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.93) and lowest for maintenance activities (O/E = 0.18), which was the reverse order for those O/E indices at >200 m agl.

We obtained only 2.8% (111) of the IRS from yearling Peary caribou (Tables 7, 8 and 9). In total 36.0% (40) of the above IRS were from overflights at <200 m agl. There was a significant difference in the relative frequencies of the three levels of responses exhibited by yearlings during passes at < and >200 m agl ($\chi^2 = 59.10$, 2 df, $P<0.005$). The observed ELIRS totalled 32.4% (36): 75.0% (30/40) for ELIRS during passes at <200 m agl and only 8.5% (6/71) for ELIRS during higher passes. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 2.31) and lowest for maintenance activities (O/E = 0.14), which was the reverse order for those O/E indices at >200 m agl.

We obtained 18.8% (740) of the IRS from Peary caribou calves (Tables 7, 8 and 9). In total 38.9% (288) of the above IRS were from overflights at <200 m agl. There was a significant difference in the relative frequencies of the three levels of responses exhibited by calves during passes at < and >200 m agl ($\chi^2 = 198.17$, 2 df, $P<0.005$). The observed ELIRS totalled 43.8% (324): 71.5% (206/288) for ELIRS during passes at <200 m agl and 26.1% (118/452) for ELIRS during higher passes. O/E indices for IRS during passes at <200 m agl were the greatest for extreme level responses (O/E = 1.63) and lowest for maintenance activities (O/E = 0.06), which was the reverse order for those O/E indices at >200 m agl.

In total, harassment overflights elicited observable responses from 75.9% of the cow samples, 72.3% of the calf samples, 59.3% of the juvenile samples, 48.2% of the bull samples and 47.7% of the yearling samples. On a percentage basis, calves (43.8%) and cows (43.6%) contributed more to the ELIRS than all other sex/age classes. Juveniles (36.0%) and yearlings (32.4%) contributed less and bulls (19.5%) the least to ELIRS. Cows also contributed the greatest percentage (32.3%) to MLIRS, followed by bulls (28.7%), calves (28.5%), juveniles (23.3%) and yearlings (15.3%). Cows were the most responsive sex/age class and maintenance activities were observed during only 24.1% of the passes. Calves were almost as responsive as cows as only 27.7% of their activities during harassment overflights involved bedding or foraging. Juveniles, bulls and yearlings were less responsive and contributed 40.7%, 51.8% and 52.3% of their sex/age classes, respectively, to MAIRS.

All sex/age classes responded more during overflights at <200 m agl than at >200 m agl. Yearlings, calves and juveniles were more responsive and bulls less responsive than the other sex/age classes during overflights at <200 m agl (Table 7). Yearlings contributed the greatest proportion to ELIRS, followed by greater than expected contributions by calves, juveniles and cows, and lower than expected contributions by bulls. Bulls contributed the greatest proportion to MLIRS, followed by a greater than expected contribution by cows and less than expected contributions by calves, juveniles and yearlings. Calves contributed the least to MAIRS, followed by lower than expected contributions by yearlings, juveniles and cows and a greater than expected contribution by bulls.

Table 7
Distribution of Peary caribou individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights <200 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	155	207	201	563
Cow	87	318	483	888
Juv	16	49	148	213
Yr	3	7	30	40
Calf	5	77	206	288
Total	266	658	1068	1992
Observed/expected indices				
Bull	2.06	1.11	0.67	
Cow	0.73	1.08	1.01	
Juv	0.56	0.70	1.30	
Yr	0.56	0.53	1.40	
Calf	0.13	0.81	1.33	
Chi-square contributions				
Bull	84.75	2.38	33.69	120.82
Cow	8.41	2.08	0.10	10.59
Juv	5.44	6.48	10.00	21.93
Yr	1.03	2.92	3.41	7.36
Calf	29.11	3.46	17.24	49.80
Total	128.73	17.31	64.45	210.50

Table 8
Distribution of Peary caribou individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights >200 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	463	136	32	631
Cow	253	137	132	522
Juv	181	64	26	271
Yr	55	10	6	71
Calf	200	134	118	452
Total	1152	481	314	1947
Observed/expected indices				
Bull	1.24	0.87	0.31	
Cow	0.82	1.06	1.57	
Juv	1.13	0.96	0.59	
Yr	1.31	0.57	0.52	
Calf	0.75	1.20	1.62	
Chi-square contributions				
Bull	21.53	2.54	47.83	71.89
Cow	10.10	0.50	27.16	37.76
Juv	2.66	0.13	7.17	9.96
Yr	4.02	3.24	2.59	9.85
Calf	17.01	4.47	27.91	49.38
Total	55.31	10.88	112.66	178.85

Figure 3
Distribution of Peary caribou individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <200 m above ground level, Prince of Wales Island, NWT, 1976–77

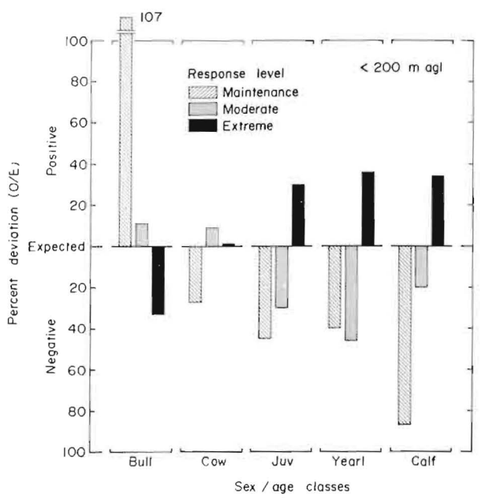


Table 9
Distribution of Peary caribou individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights <400 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	618	343	233	1194
Cow	340	455	615	1410
Juv	197	113	174	484
Yr	58	17	36	111
Calf	205	211	324	740
Total	1418	1139	1382	3939
Observed/expected indices				
Bull	1.44	0.99	0.56	
Cow	0.67	1.12	1.24	
Juv	1.13	0.81	1.02	
Yr	1.45	0.53	0.92	
Calf	0.77	0.99	1.25	
Chi-square contributions				
Bull	82.38	0.01	82.51	164.90
Cow	55.33	5.48	29.25	90.07
Juv	2.97	5.19	0.10	8.27
Yr	8.15	7.10	0.22	15.47
Calf	14.15	0.04	15.96	30.15
Total	162.98	17.83	128.05	308.86

Figure 4
Distribution of Peary caribou individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at >200 m above ground level, Prince of Wales Island, NWT, 1976–77

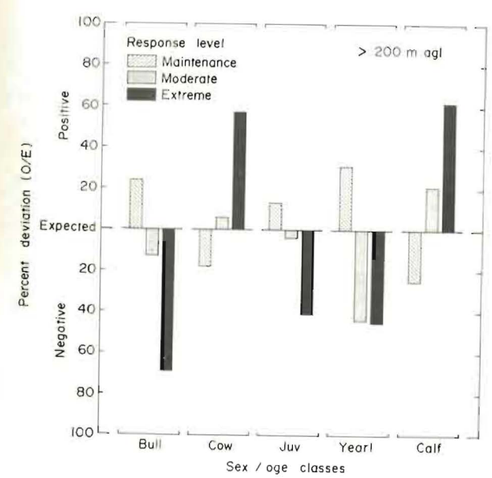
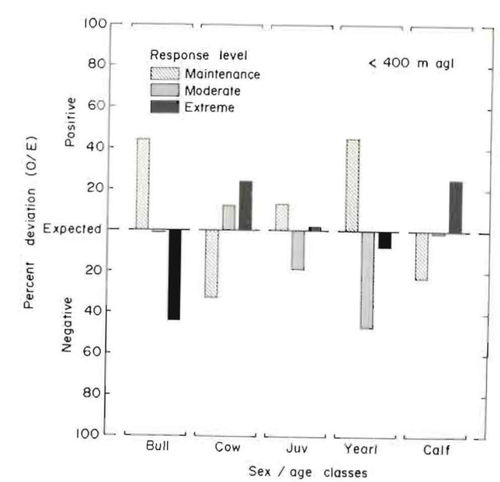


Figure 5
Distribution of Peary caribou individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



All sex/age classes responded less during overflights at > 200 m agl than at < 200 m agl, but calves and cows were more responsive than bulls, yearlings and juveniles during overflights at > 200 m agl (Table 8). Calves contributed most to ELIRS, followed by a greater than expected contribution by cows and less than expected contributions by juveniles, yearlings and bulls. Calves and cows also made the largest contributions to MLIRS, followed by less than expected contributions by juveniles, bulls and yearlings. Calves and cows contributed the least to MAIRS, followed by greater than expected contributions by yearlings, bulls and juveniles.

Cows and calves were more responsive and bulls and yearlings less responsive than the other sex/age classes during all (< 400 m agl) overflights (Table 9). Calves contributed the most to ELIRS, followed by greater than expected contributions by cows and juveniles, and less than expected contributions by yearlings and bulls. Only cows responded at moderate levels more often than expected. Calves, bulls, juveniles and yearlings contributed less than expected to MLIRS. Cows and calves contributed the least to MAIRS, followed by greater than expected contributions by yearlings, bulls and juveniles.

The data indicated that cows and calves remain more responsive than other sex/age classes as altitudes of the helicopter increase. Therefore, we must consider cows and calves more susceptible to helicopter harassment than the other sex/age classes. The relatively high contributions to ELIRS by yearlings and juveniles during overflights at < 200 m agl probably reflects a form of investigative behaviour often exhibited by those sex/age classes when foreign stimuli were introduced to them. When alerted, yearlings and juveniles often moved at a trot or gallop in the direction of the harassing agent (especially during helicopter landings). Such responses are, we believe, often just expressions of the inquisitive nature of juveniles and yearlings and not a true measure of stress as identified by a form of flight behaviour.

Special constraints should be placed on aircraft activities during calving (May–June) and post-calving (July–August) periods if Peary caribou are to be afforded the proper degree of protection during construction and maintenance of a pipeline. The mother–young bond most likely contributes to the relatively high level of excitability by lactating cows. In turn, calves are dependent upon their maternal cows for sustenance and protection for at least the first 3 months of life. Any harassment that disrupts the mother–young bond has a potential for causing mortality to calves. Such mortality over the long-term could seriously reduce the capacity of the population to reproduce and maintain its numbers.

1.3. Group size classes

We obtained only 2.4% (94) of the IRS from solitary Peary caribou (Tables 10 and 12; Figs. 6 and 8). All of the above IRS were from overflights at < 200 m agl. ELIRS comprised 37.2% (35) of all responses by solitary animals.

We obtained only 0.9% (36) of the IRS from lone cow–calf pairs of Peary caribou (Tables 10, 11 and 12; Figs. 6, 7 and 8). In total, 94.4% (34) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the three levels of responses exhibited by cow–calf pairs at < and > 200 m agl ($\chi^2 = 16.94$, 2 df, $P < 0.005$). The observed ELIRS totalled 41.7% (15): 100% for ELIRS during passes at < 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.06) and lowest for maintenance activities (O/E = 0.53), which was the reverse order for those O/E indices at > 200 m agl. No IRS occurred at the moderate level nor at the extreme level during passes at > 200 m agl.

We obtained 25.3% (997) of the IRS from Peary caribou in groups of 2–5 (Tables 10, 11 and 12). In total 87.3% (870) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the three levels of responses exhibited by Peary caribou in groups of 2–5 at < and > 200 m agl ($\chi^2 = 73.41$, 2 df, $P < 0.005$). The observed ELIRS totalled 39.3% (392): 44.1% (384/870) for ELIRS during passes at < 200 m agl and only 6.3% (8/127) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.13) and lowest for maintenance activities (O/E = 0.87), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 31.5% (1242) of the IRS from Peary caribou in groups of 6–9 individuals (Tables 10, 11 and 12). In total 44.8% (556) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the three levels of responses exhibited by Peary caribou in groups of 6–9 during passes at < and > 200 m agl ($\chi^2 = 337.03$, 2 df, $P < 0.005$). The observed ELIRS totalled 37.8% (470): 62.2% (346/556) for ELIRS at < 200 m agl and only 18.1% (124/686) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.64) and lowest for maintenance activities (O/E = 0.25), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 29.1% (1146) of the IRS from Peary caribou in groups of 10–19 individuals (Tables 10, 11 and 12). In total 25.2% (289) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the three levels of responses exhibited by Peary caribou in groups of 10–19 during passes at < and > 200 m agl ($\chi^2 = 330.92$, 2 df, $P < 0.005$). The observed ELIRS totalled 26.1% (299): 55.0% (159/289) for ELIRS during passes at < 200 m agl

Table 10
Distribution of Peary caribou individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights < 200 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary caribou	10	49	35	94
Cow–calf pair	2	17	15	34
2–5 caribou	195	291	384	870
6–9 caribou	45	165	346	556
10–19 caribou	14	116	159	289
20–27 caribou	0	20	129	149
Total	266	658	1068	1992
Observed/expected indices				
Solitary caribou	0.80	1.58	0.69	
Cow–calf pair	0.44	1.51	0.82	
2–5 caribou	1.68	1.01	0.82	
6–9 caribou	0.61	0.90	1.16	
10–19 caribou	0.36	1.22	1.03	
20–27 caribou	0.00	0.41	1.61	
Chi-square contributions				
Solitary caribou	0.52	10.38	4.70	15.60
Cow–calf pair	1.42	2.96	0.57	4.96
2–5 caribou	53.48	0.05	14.57	68.10
6–9 caribou	11.52	1.90	7.70	21.11
10–19 caribou	15.67	4.42	0.11	20.19
20–27 caribou	19.90	17.34	30.20	67.44
Total	102.51	37.04	57.85	197.40

Figure 6
Distribution of Peary caribou individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77

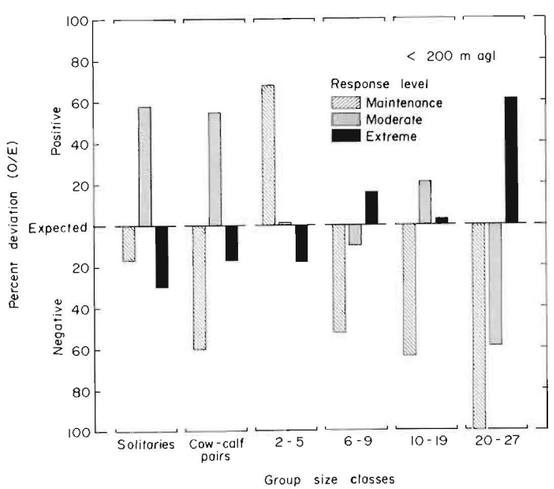


Table 11
Distribution of Peary caribou individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights > 200 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Cow–calf pair	2	0	0	2
2–5 caribou	61	58	8	127
6–9 caribou	351	211	124	686
10–19 caribou	566	151	140	857
20–27 caribou	172	61	42	275
Total	1152	481	314	1947
Observed/expected indices				
Cow–calf pair	1.69	0.00	0.00	
2–5 caribou	0.81	1.85	0.39	
6–9 caribou	0.86	1.25	1.12	
10–19 caribou	1.12	0.71	1.01	
20–27 caribou	1.06	0.90	0.95	
Chi-square contributions				
Cow–calf pair	0.56	0.49	0.32	1.38
2–5 caribou	2.66	22.59	7.61	32.86
6–9 caribou	7.42	10.17	1.61	19.21
10–19 caribou	6.85	17.41	0.02	24.29
20–27 caribou	0.53	0.71	0.12	1.36
Total	18.03	51.39	9.69	79.11

Figure 7
Distribution of Peary caribou individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77

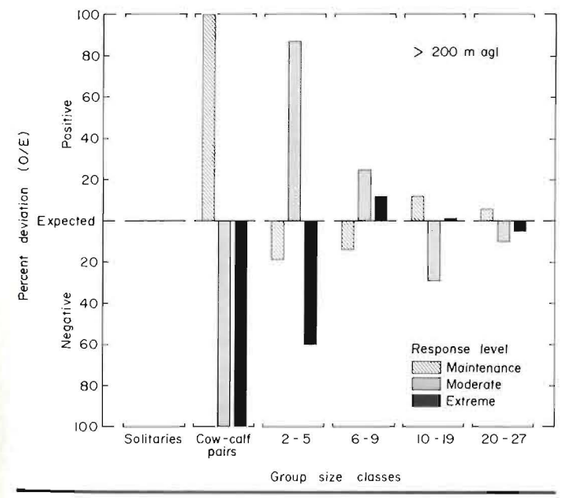
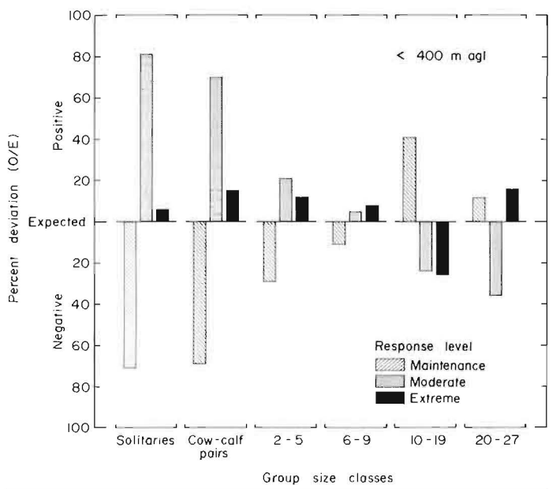


Table 12
Distribution of Peary caribou individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary caribou	10	49	35	94
Cow–calf pair	4	17	15	36
2–5 caribou	256	349	392	997
6–9 caribou	396	376	470	1242
10–19 caribou	580	267	299	1146
20–27 caribou	172	81	171	424
Total	1418	1139	1382	3939
Observed/expected indices				
Solitary caribou	0.30	1.80	1.06	
Cow–calf pair	0.31	1.63	1.19	
2–5 caribou	0.71	1.21	1.12	
6–9 caribou	0.89	1.05	1.08	
10–19 caribou	1.41	0.81	0.74	
20–27 caribou	1.13	0.66	1.15	
Chi-square contributions				
Solitary caribou	16.79	17.51	0.12	34.43
Cow–calf pair	6.19	4.17	0.44	10.81
2–5 caribou	29.51	12.78	5.09	47.38
6–9 caribou	5.84	0.79	2.69	9.32
10–19 caribou	67.97	12.51	26.42	106.90
20–27 caribou	2.46	14.12	3.32	19.90
Total	128.76	61.89	38.10	228.75

Figure 8
Distribution of Peary caribou individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 400 m above ground level, Prince of Wales Island, NWT, 1976–77



and only 16.3% (140/857) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 2.11) and lowest for maintenance activities (O/E = 0.10), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 10.8% (424) of the IRS from Peary caribou in groups of 20–27 individuals (Tables 10, 11 and 12). In total 35.1% (149) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the three levels of responses exhibited by Peary caribou in groups of 20–27 during passes at < and > 200 m agl (χ^2 = 218.90, 2 df, P < 0.005). The observed ELIRS totalled 40.3% (171): 86.6% (129/149) for ELIRS during passes at < 200 m agl and only 15.3% (42/275) for ELIRS during passes at > 200 m agl. O/E indices for IRS at < 200 m agl were greatest for extreme level responses (O/E = 2.15) and lowest for maintenance activities (O/E = 0.00), which was the reverse order for those O/E indices at > 200 m agl.

The percentage of observable responses to harassment overflights at < 200 m agl varied from 77.6% for groups of 2–5 animals to 100% for Peary caribou in groups of 20–27 animals (Table 10). Individuals in groups of 20–27 also contributed the greatest percentage (86.6%) to extreme level responses, followed by individuals in groups of 6–9 (62.2%), 10–19 (55.0%), cow–calf pairs (44.1%), 2–5 (44.1%) and solitary animals (37.2%).

Examination of O/E indices in Table 10 indicates that Peary caribou in groups of 20–27 individuals responded more at the extreme level during passes at < 200 m agl than did individuals in other group sizes. Solitary Peary caribou responded more at the moderate level during harassment than did individuals in groups. No Peary caribou in groups of 20–27 remained engaged in maintenance activities when harassed.

During passes at > 200 m agl, Peary caribou in groups of 6–9 responded more at the extreme level than did individuals in other group sizes (Table 11). Peary caribou in groups of 2–5 responded more at the moderate level and less at the maintenance level than did individuals in other group sizes.

Examination of O/E indices in Table 12 indicates that for all overflights (< 400 m agl) cow–calf pairs of Peary caribou responded more at the extreme level and less (except for solitaries) at the maintenance level than did individuals in other group sizes. Solitary Peary caribou responded more at the moderate level and less at the maintenance level during periods of harassment than did individuals in all other group sizes.

1.4. Group type classes

We obtained 14.5% (572) of the IRS from bull-only groups of Peary caribou (Tables 13, 14 and 15; Figs. 9, 10 and 11). In total 70.6% (404) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups with only bulls present during passes at < and > 200 m agl (χ^2 = 102.62, 2 df, P < 0.005). The observed ELIRS totalled 23.1% (132): 32.7% (132/404) for ELIRS during passes at < 200 m agl and 0.0% (0/168) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.42) and lowest for maintenance activities (O/E = 0.71), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 12.4% (489) of the IRS from Peary caribou bull–cow–juvenile–yearling–calf groups (Tables 13, 14 and 15). In total 12.1% (59) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups with all sex/age classes present during passes at < and > 200 m agl (χ^2 = 139.79, 2 df, P < 0.005). The observed ELIRS totalled 11.5% (56): 45.8% (27/59) for ELIRS during passes at < 200 m agl and only 6.7% (29/430) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 4.00) and lowest for maintenance activities (O/E = 0.03), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 20.4% (802) of the IRS from Peary caribou bull–juvenile–yearling groups (Tables 13, 14 and 15). In total 34.8% (279) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the rates of contributions to the three levels of responses exhibited by individuals in groups with bulls, juveniles and yearlings present during passes at < and > 200 m agl (χ^2 = 284.84, 2 df, P < 0.005). The observed ELIRS totalled 24.4% (196): 57.0% (159/279) for ELIRS during passes at < 200 m agl and only 7.1% (37/523) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 2.33) and lowest for maintenance activities (O/E = 0.33), which was the reverse order for those O/E indices at > 200 m agl.

We obtained only 1.6% (62) of the IRS from Peary caribou juvenile–yearling groups (Tables 13, 14 and 15). In total 67.7% (42) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups with juveniles and yearlings present during passes at < and > 200 m agl (χ^2 = 11.97, 2 df, P < 0.005). The observed ELIRS totalled 48.4% (30): 61.9% (26/42) for ELIRS during passes at < 200 m agl and 20.0% (4/20) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.28) and lowest for maintenance activities (O/E = 0.49), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 15.2% (598) of the IRS from Peary caribou cow–juvenile–yearling–calf groups (Tables 13, 14 and 15). In total 46.3% (277) of the above IRS were from over-

Table 13
Distribution of Peary caribou individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights < 200 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	118	154	132	404
Bull–cow–juv–yr–calf	1	31	27	59
Bull–juv–yr	48	72	159	279
Juv–yr	4	12	26	42
Cow–juv–yr–calf	21	90	166	277
Cow–calf	25	194	409	628
Cow–juv–yr	49	105	149	303
Total	266	658	1068	1992
Observed/expected indices				
Bull	2.19	1.15	0.61	
Bull–cow–juv–yr–calf	0.13	1.59	0.85	
Bull–juv–yr	1.29	0.78	1.06	
Juv–yr	0.71	0.86	1.15	
Cow–juv–yr–calf	0.57	0.98	1.12	
Cow–calf	0.30	0.94	1.21	
Cow–juv–yr	1.21	1.05	0.92	
Chi-square contributions				
Bull	76.05	3.16	33.04	112.26
Bull–cow–juv–yr–calf	6.01	6.80	0.68	13.48
Bull–juv–yr	3.10	4.41	0.59	8.10
Juv–yr	0.46	0.25	0.54	1.25
Cow–juv–yr–calf	6.91	0.02	2.06	9.00
Cow–calf	41.31	0.87	15.53	57.71
Cow–juv–yr	1.80	0.24	1.11	3.16
Total	135.64	15.76	53.55	204.96

Figure 9
Distribution of Peary caribou individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77

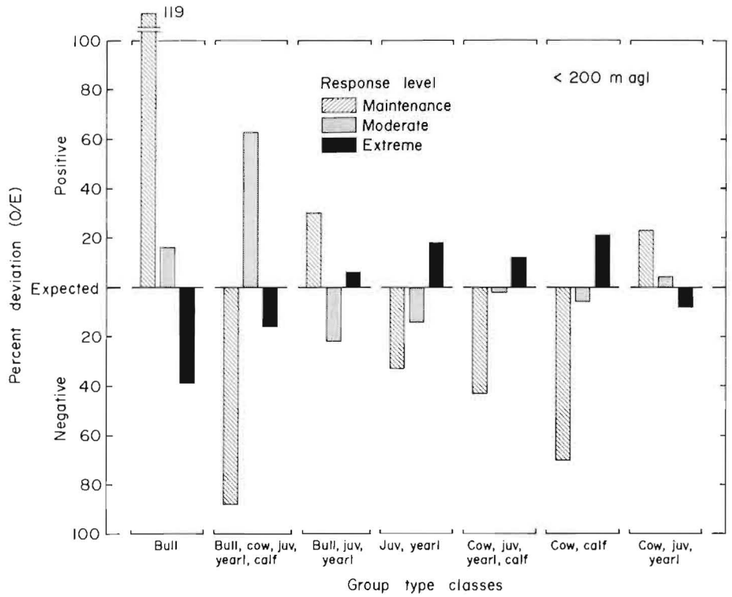


Table 14
Distribution of Peary caribou individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights > 200 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	116	52	0	168
Bull–cow–juv–yr–calf	319	82	29	430
Bull–juv–yr	367	119	37	523
Juv–yr	8	8	4	20
Cow–juv–yr–calf	157	76	88	321
Cow–calf	185	143	155	483
Cow–juv–yr	0	1	1	2
Total	1152	481	314	1947
Observed/expected indices				
Bull	1.17	1.25	0.00	
Bull–cow–juv–yr–calf	1.25	0.77	0.42	
Bull–juv–yr	1.19	0.92	0.44	
Juv–yr	0.68	1.62	1.24	
Cow–juv–yr–calf	0.83	0.96	1.70	
Cow–calf	0.65	1.20	1.99	
Cow–juv–yr	0.00	2.02	3.10	
Chi-square contributions				
Bull	2.77	2.65	27.09	32.52
Bull–cow–juv–yr–calf	16.39	5.53	23.47	45.39
Bull–juv–yr	10.70	0.81	26.58	38.09
Juv–yr	1.24	1.89	0.19	3.32
Cow–juv–yr–calf	5.71	0.14	25.36	31.20
Cow–calf	35.54	4.70	76.32	116.56
Cow–juv–yr	1.18	0.52	1.42	3.12
Total	73.54	16.23	180.43	270.21

Table 15
Distribution of Peary caribou individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	234	206	132	572
Bull–cow–juv–yr–calf	320	113	56	489
Bull–juv–yr	415	191	196	802
Juv–yr	12	20	30	62
Cow–juv–yr–calf	178	166	254	598
Cow–calf	210	337	564	1111
Cow–juv–yr	49	106	150	305
Total	1418	1139	1382	3939
Observed/expected indices				
Bull	1.14	1.25	0.66	
Bull–cow–juv–yr–calf	1.82	0.80	0.33	
Bull–juv–yr	1.44	0.82	0.70	
Juv–yr	0.54	1.12	1.38	
Cow–juv–yr–calf	0.83	0.96	1.21	
Cow–calf	0.53	1.05	1.45	
Cow–juv–yr	0.45	1.20	1.40	
Chi-square contributions				
Bull	3.83	9.97	23.51	37.31
Bull–cow–juv–yr–calf	117.74	5.70	77.84	201.29
Bull–juv–yr	55.24	7.22	25.91	88.36
Juv–yr	4.77	0.24	3.13	8.14
Cow–juv–yr–calf	6.45	0.28	9.31	16.04
Cow–calf	90.21	0.77	77.85	168.84
Cow–juv–yr	33.66	3.60	17.27	54.53
Total	311.91	27.77	234.82	574.50

Figure 10
Distribution of Peary caribou individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77

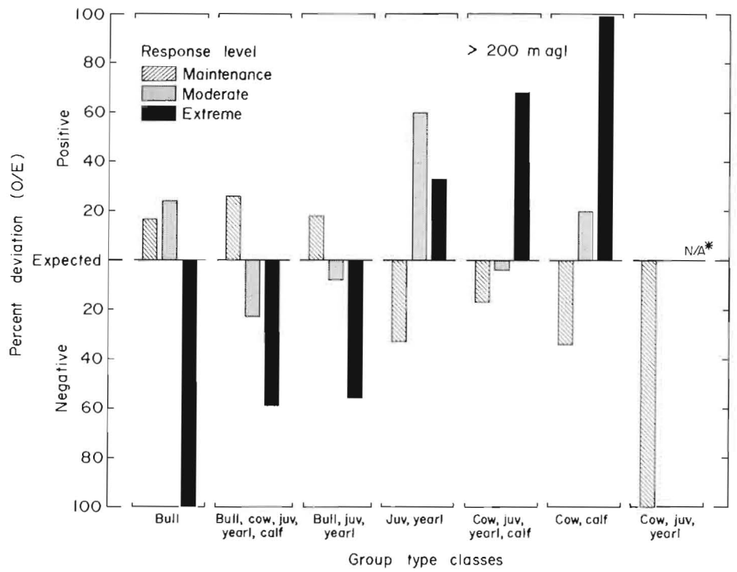
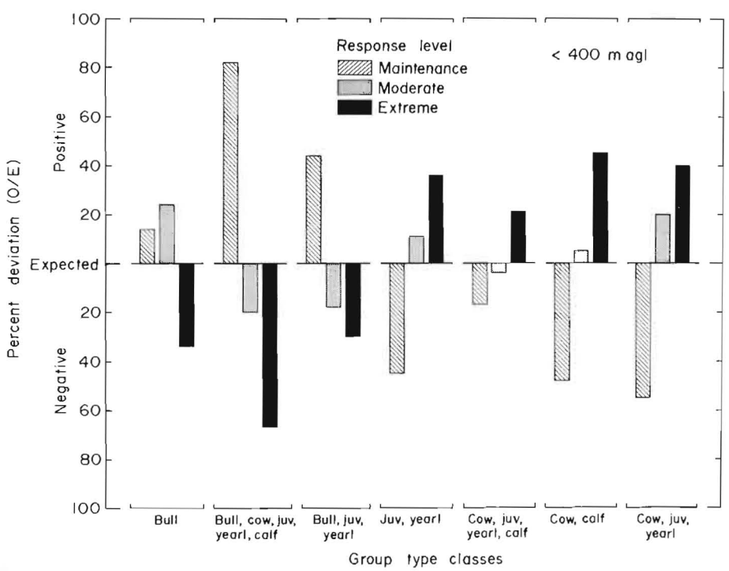


Figure 11
Distribution of Peary caribou individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



flights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups with cows, juveniles, yearlings and calves present during passes at < and > 200 m agl (χ^2 = 126.49, 2 df, P < 0.005). The observed ELIRS totalled 42.5% (254): 59.9% (166/277) for ELIRS during passes at < 200 m agl and 27.4% (88/321) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.41) and lowest for maintenance activities (O/E = 0.25), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 28.2% (1111) of the IRS from Peary caribou cow–calf groups (Tables 13, 14 and 15). In total 56.5% (628) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individual cows and calves in pairs during passes at < and > 200 m agl (χ^2 = 228.99, 2 df, P < 0.005). The observed ELIRS totalled 50.8% (564): 65.1% (409/628) for ELIRS during passes at < 200 m agl and 32.1% (155/483) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.28) and lowest for maintenance activities (O/E = 0.21), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 7.7% (305) of the IRS from Peary caribou cow–juvenile–yearling groups (Tables 13, 14 and 15). In total 99.3% (303) of the above IRS were from overflights at < 200 m agl. There was no significant difference in the contributions to the three levels of responses exhibited by individuals in groups with cows, juveniles and yearlings present during passes at < and > 200 m agl (χ^2 = 0.46, 2 df, P > 0.5). The observed ELIRS totalled 49.2% (150): 49.2% (149/303) for ELIRS during passes at < 200 m agl and 50.0% (1/2) for ELIRS during passes at > 200 m agl. The small sample size from > 200 m agl distorted the calculations of O/E indices for IRS: < 200 m agl, extreme level responses (O/E = 1.00) and maintenance activities (O/E = 1.01); > 200 m agl, extreme level (O/E = 1.02) and maintenance activities (O/E = 0.0).

The percentage of observable responses varied from 34.6% for Peary caribou individuals in the bull–cow–juvenile–yearling–calf group type to 83.9% for individuals in the cow–juvenile–yearling group type (Tables 13, 14 and 15). Cow–calf pairs of Peary caribou contributed the most (50.8%) to extreme level responses followed by individuals in the cow–juvenile–yearling group type (49.2%), juvenile–yearling group type (48.4%), cow–juvenile–yearling group type (42.5%), bull–juvenile–yearling group type (24.4%), bull group type (23.1%) and the bull–cow–juvenile–yearling–calf group type (11.5%).

Examination of O/E indices in Table 13 indicates that cow–calf pairs of Peary caribou responded more at the extreme level during passes at < 200 m agl than did individuals in other group types. Peary caribou in the bull–cow–juvenile–yearling–calf group type responded more at the moderate level and less at the maintenance level during periods of harassment than did individuals in other group types.

During passes at > 200 m agl, Peary caribou in the cow–juvenile–yearling group type responded more at the extreme and moderate levels than did individuals in other group types. Also, fewer Peary caribou in the cow–juvenile–yearling group type remained engaged in maintenance activities during periods of harassment than did individuals in other group types.

Examination of O/E indices in Table 15 indicates that for all overflights (< 400 m agl) cow–calf pairs of Peary caribou responded more at the extreme level than did individuals in other group types. Peary caribou in the bull-only group type responded more at the moderate level during periods of harassment than did individuals in other group types. Fewer Peary caribou in the cow–juvenile–yearling group remained engaged in maintenance activities when harassed than did individuals in other group types.

1.5. Calf classes

We obtained 44.5% (1752) of the IRS from Peary caribou in groups without calves (Tables 16, 17, 18 and 19; Figs. 12, 13 and 14). In total 59.3% (1039) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups without calves during passes at < and > 200 m agl (χ^2 = 473.11, 2 df, P < 0.005). The observed ELIRS totalled 29.3% (514): 45.4% (472/1039) for ELIRS at < 200 m agl and only 5.9% (42/713) for ELIRS at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.55) and lowest for maintenance activities (O/E = 0.52), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 8.1% (318) of the IRS from Peary caribou in groups with one calf (Tables 16, 17, 18 and 19). In total 77.4% (246) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals in groups with one calf present during passes at < and > 200 m agl (χ^2 = 148.26, 2 df, P < 0.005). The observed ELIRS totalled 46.2% (147): 58.1% (143/246) for ELIRS during passes at < 200 m agl and only 5.6% (4/72) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.26) and lowest for maintenance activities (O/E = 0.29), which was the reverse order for those O/E indices at > 200 m agl.

Table 16
Distribution of Peary caribou individual response samples (IRS), by level of response and calf class during all pass-type helicopter harassment overflights < 200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
No. calves	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	219	348	472	1039
1	15	88	143	246
2	18	50	204	272
3	1	104	83	188
4	0	31	46	77
5	13	17	15	45
6	0	20	6	26
8	0	0	99	99
Total	266	658	1068	1992
Observed/expected indices				
0	1.58	1.01	0.85	
1	0.46	1.08	1.08	
2	0.50	0.56	1.40	
3	0.04	1.67	0.82	
4	0.00	1.22	1.11	
5	2.16	1.14	0.62	
6	0.00	2.33	0.43	
8	0.00	0.00	1.87	
Chi-square contributions				
0	46.43	0.07	12.99	59.48
1	9.70	0.56	0.94	11.19
2	9.24	17.67	23.20	50.12
3	23.14	28.27	3.14	54.56
4	10.28	1.22	0.54	12.04
5	8.13	0.31	3.45	11.89
6	3.47	15.16	4.52	23.16
8	13.22	32.70	39.73	85.65
Total	123.62	95.96	88.51	308.09

We obtained 7.3% (289) of the IRS from Peary caribou with two calves in each group (Tables 16, 17, 18 and 19). In total 94.1% (272) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals with two calves present in each group during passes at < and > 200 m agl ($\chi^2 = 20.88$, 2 df, $P < 0.005$). The observed ELIRS totalled 72.3% (209): 75.0% (204/272) for ELIRS during passes at < 200 m agl and 29.4% (5/17) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.04) and lowest for moderate level responses (O/E = 0.87), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 10.1% (397) of the IRS from Peary caribou with three calves in each group (Tables 16, 17, 18 and 19). In total 47.4% (188) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals with three calves present in each group during passes at < and > 200 m agl ($\chi^2 = 216.05$, 2 df, $P < 0.005$). The observed ELIRS totalled 29.7% (118): 44.1% (83/188) for ELIRS during passes at < 200 m agl and 16.7% (35/209) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for moderate level responses (O/E = 1.72) and lowest for maintenance activities (O/E = 0.01), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 10.5% (413) of the IRS from Peary caribou with four calves in each group (Tables 16, 17, 18 and 19). In total 18.6% (77) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals with four calves present in each group during passes at < and > 200 m agl ($\chi^2 = 45.52$, 2 df, $P < 0.005$). The observed ELIRS totalled 35.8% (148): 59.7% (46/77) for ELIRS during passes at < 200 m agl and 30.4% (102/336) for ELIRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.67) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 6.0% (237) of the IRS from Peary caribou with five calves in each group (Tables 16, 17, 18 and 19). In total 19.0% (45) of the above IRS were from overflights at

Table 17
Distribution of Peary caribou individual response samples (IRS), by level of response and calf class during all pass-type helicopter harassment overflights > 200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
No. calves	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	491	180	42	713
1	51	17	4	72
2	1	11	5	17
3	150	24	35	209
4	127	107	102	336
5	117	45	30	192
6	39	25	8	72
7	4	11	46	61
9	108	39	3	150
12	64	22	39	125
Total	1152	481	314	1947
Observed/expected indices				
0	1.16	1.02	0.37	
1	1.20	0.96	0.34	
2	0.10	2.62	1.82	
3	1.21	0.46	1.04	
4	0.64	1.29	1.88	
5	1.03	0.95	0.97	
6	0.92	1.41	0.69	
7	0.11	0.73	4.68	
9	1.22	1.05	0.12	
12	0.87	0.71	1.93	
Chi-square contributions				
0	11.33	0.08	46.33	57.74
1	1.66	0.03	4.99	6.68
2	8.16	11.01	1.86	21.03
3	5.61	14.79	0.05	20.45
4	25.93	6.93	42.19	75.06
5	0.10	0.12	0.03	0.26
6	0.30	2.92	1.12	4.35
7	28.54	1.10	132.93	162.56
9	4.17	0.10	18.56	22.84
12	1.34	2.55	17.61	21.50
Total	87.14	39.66	265.67	392.47

Table 18
Distribution of Peary caribou individual response samples (IRS), by level of response and calf class during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
No. calves	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	710	528	514	1752
1	66	105	147	318
2	19	61	209	289
3	151	128	118	397
4	127	138	148	413
5	130	62	45	237
6	39	45	14	98
7	4	11	46	61
8	0	0	99	99
9	108	39	3	150
12	64	22	39	125
Total	1418	1139	1382	3939
Observed/expected indices				
0	1.13	1.04	0.84	
1	0.58	1.14	1.32	
2	0.18	0.73	2.06	
3	1.06	1.12	0.85	
4	0.85	1.16	1.02	
5	1.52	0.90	0.54	
6	1.11	1.59	0.41	
7	0.18	0.62	2.15	
8	0.00	0.00	2.85	
9	2.00	0.90	0.06	
12	1.42	0.61	0.89	
Chi-square contributions				
0	9.97	0.90	16.49	27.37
1	20.53	1.85	11.25	33.63
2	69.51	6.09	114.19	189.79
3	0.46	1.52	3.25	5.23
4	3.16	2.89	0.07	6.12
5	23.40	0.62	17.50	41.53
6	0.39	9.80	12.08	22.27
7	14.69	2.50	28.27	45.46
8	35.64	28.63	118.91	183.17
9	54.00	0.44	46.80	101.24
12	8.02	5.54	0.54	14.10
Total	239.77	60.78	369.36	669.91

Table 19
Distribution of Peary caribou individual response samples, by number of calves, during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 3939)

	Level of response					
	Maint.		Moderate		Extreme	
No. calves	Bed	For.	Alert	Walk	Trot	Gal.
0	239	471	369	159	394	120
1	12	54	75	30	112	35
2	9	10	41	20	183	26
3	75	76	88	40	110	8
4	12	115	69	69	121	27
5	96	34	39	23	45	0
6	12	27	18	27	14	0
7	0	4	11	0	30	16
8	0	0	0	0	45	54
9	3	105	13	26	1	2
12	2	62	15	7	12	27

Figure 12
Distribution of Peary caribou individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O – E/E), obtained during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77

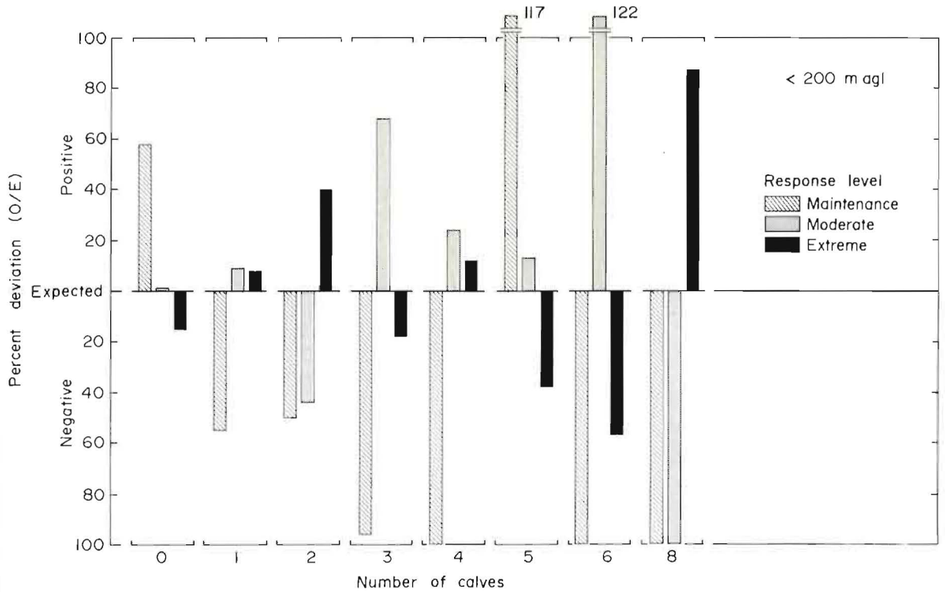


Figure 13
Distribution of Peary caribou individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O—E/E), obtained during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77

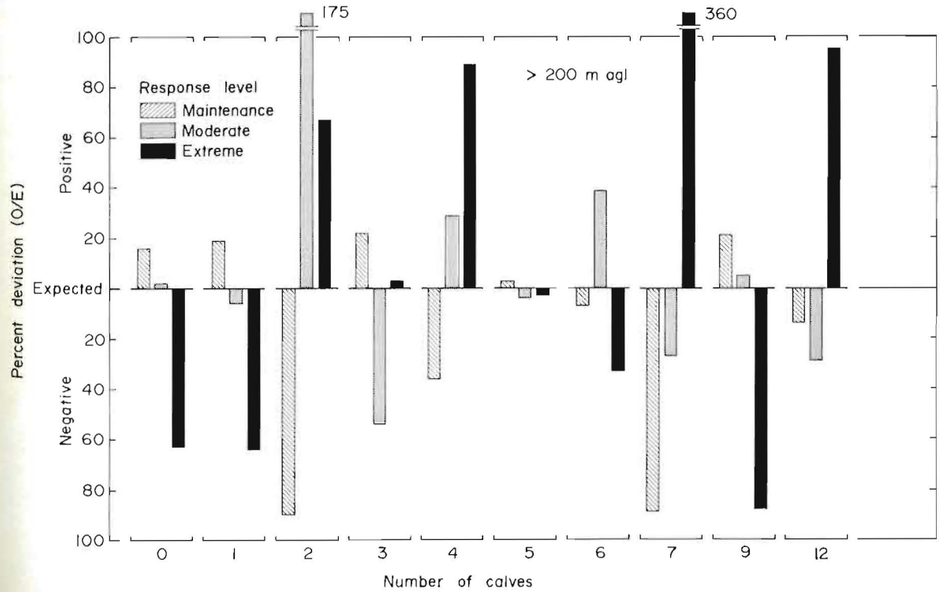
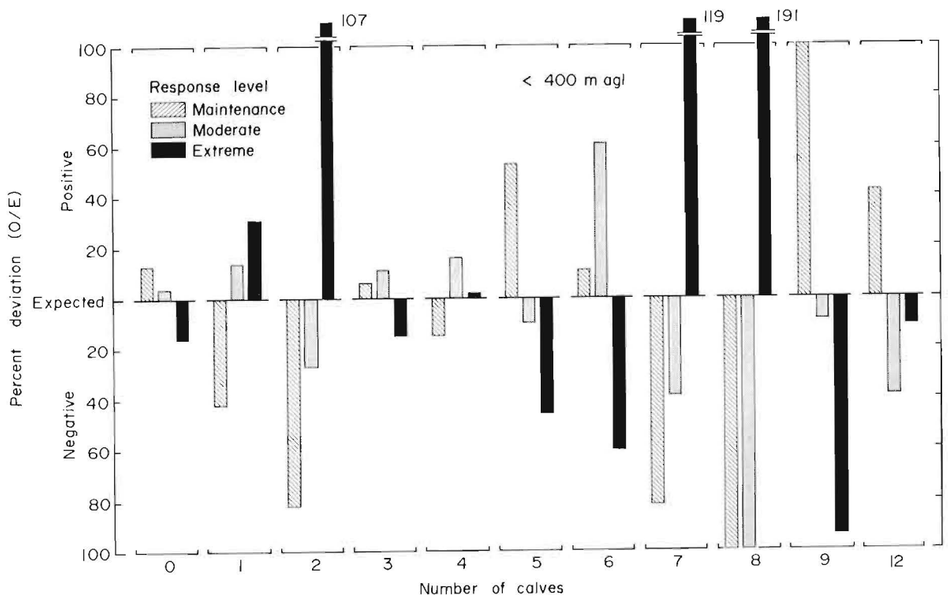


Figure 14
Distribution of Peary caribou individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



<200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals with five calves present in each group during passes at < and >200 m agl (χ^2 = 15.71, 2 df, P<0.005). The observed ELIRS totalled 19.0% (45): 33.3% (15/45) for ELIRS during passes at <200 m agl and 15.6% (30/192) for ELIRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.76) and lowest for maintenance activities (O/E = 0.53), which was the reverse order for those O/E indices at >200 m agl.

We obtained 2.5% (98) of the IRS from Peary caribou with six calves in each group (Tables 16, 17, 18 and 19). In total 26.5% (26) of the above IRS were from overflights at <200 m agl. There was a significant difference in the contributions to the three levels of responses exhibited by individuals with six calves present in each group during passes at < and >200 m agl (χ^2 = 23.41, 2 df, P<0.005). The observed ELIRS totalled 14.3% (14): 23.1% (6/26) for ELIRS during passes at <200 m agl and 11.1% (8/72) for ELIRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for moderate level responses (O/E = 1.68) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

The distributions of IRS from Peary caribou associated with 7, 8, 9 and 12 calves in each group (Tables 16, 17, 18 and 19) were too fragmentary to allow tests of independence by altitude or calculation of meaningful O/E indices. Contributions to extreme level responses of individuals in groups with 7, 8, 9 and 12 calves were as follows: 7 calves in each group, 75.4% (46); 8 calves, 100% (99); 9 calves, 2.0% (3); and 12 calves, 31.2% (39).

Calves represented 18.8% (740) of the Peary caribou samples (Table 3). In total, 44.5% (1752) of the Peary caribou sampled were not in the company of calves and 36.7% (1447) of the Peary caribou sampled were in groups with 1 to 12 calves each (Table 19). The IRS contributions did not follow a continuous pattern of increasing responsiveness by individuals in groups with increasing number of calves. Although there was an indication of increasing responsiveness with the number of calves present, not all groups with calves responded at the expected rates for ELIRS: 1 calf in each group, 51–100 m agl; 5 calves in each group, 51–100 m agl, <400 m agl; 6 calves in each group, <200 m agl, <400 m agl; and 9 calves in each group, 201-300 m agl, >200 m agl and <400 m agl.

IRS distributions relative to the number of calves present varied within and by altitude class. A comparison of the IRS distributions for individuals in groups with no calves present to the IRS distributions for caribou in groups with calves present, however, indicated that individuals were relatively more responsive when calves were present (χ^2 = 48.61, 2 df, P<0.005). Those IRS distributions also indicated that there were differences between responses by individuals when calves were present or absent for both ELIRS and MAIRS (Table 20).

IRS distributions for individuals in groups without calves during overflights at <200 m agl (Table 21) accounted for 44.2% of the ELIRS, but only 13.2% of the ELIRS during overflights at >200 m agl (Table 22). This condition suggests that even though individuals associated with calves responded more than individuals in groups without calves during passes at <200 m agl, the difference was less at lower altitudes due to the effects of harassment on all individuals. It seems calves influenced the level of responses more at higher altitudes.

Table 20
Distribution of Peary caribou individual response samples (IRS), by level of response and the absence or presence of calves in the groups sampled during all pass-type helicopter harassment overflights at <400 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
Calves in group	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	710	528	514	1752
1–12	708	611	868	2187
Total	1418	1139	1382	3939
Observed/expected indices				
0	1.13	1.04	0.84	
1–12	0.90	0.97	1.13	
Chi-square contributions				
0	10.66	0.81	15.72	27.19
1–12	7.87	0.57	12.98	21.42
Total	18.53	1.38	28.70	48.61

Table 21
Distribution of Peary caribou individual response samples (IRS), by level of response and the absence or presence of calves in the groups sampled during all pass-type helicopter harassment overflights at <200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
Calves in group	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	219	348	472	1039
1–8	47	310	596	953
Total	266	658	1068	1992
Observed/expected indices				
0	1.58	1.01	0.85	
1–8	0.37	0.99	1.17	
Chi-square contributions				
0	46.76	0.03	12.53	59.32
1–8	50.41	0.03	14.77	65.21
Total	97.17	0.06	27.30	124.53

Table 22
Distribution of Peary caribou individual response samples (IRS), by level of response and the absence or presence of calves in the groups sampled during all pass-type helicopter harassment overflights at >200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
Calves in group	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	491	180	42	713
1–12	661	301	272	1234
Total	1152	481	314	1947
Observed/expected indices				
0	1.16	1.02	0.37	
1–12	0.91	0.99	1.37	
Chi-square contributions				
0	10.80	0.07	45.64	56.51
1–12	5.91	0.03	27.24	33.18
Total	16.71	0.10	72.88	89.69

1.6. Season classes

The distribution of IRS of Peary caribou followed the pattern established for IRS by altitude classes: greater than expected rates during passes at <200 m agl for ELIRS and MLIRS and less for MAIRS and the reverse for IRS obtained during passes at >200 m agl (Table 2). The distributions for IRS in all altitude classes indicate that caribou were more responsive between 15 July and 7 August than at other times (χ^2 = 359.00, 4 df, P<0.005). This relationship held for the distribution obtained during overflights at <200 m agl (χ^2 = 70.28, 4 df, P<0.005) but switched to 24 June – 15 July for flights at >200 m agl (χ^2 = 17.93, 4 df, P<0.005).

1.7. Wind classes

Peary caribou were most responsive when the helicopter was flying into the wind and least responsive when the helicopter was flying in calm weather during all overflights at <400 m agl. Peary caribou were also most responsive when the helicopter was flying into the wind during overflights at <200 m agl. No IRS were obtained in calm weather during overflights at <200 m agl. Contributions of IRS when the helicopter was flying with the wind or at >60° to the wind at <200 m agl appeared similar and were at lower response levels. A considerable shift in the responsiveness of Peary caribou by wind classes was indicated by IRS distributions during overflights at >200 m agl. Peary caribou were most responsive to overflights during calm weather and least responsive when the helicopter was flying with the wind. Peary caribou did not show a high level of responsiveness when the helicopter was flying into the wind during overflights at >200 m agl. IRS contributions obtained during helicopter overflights at >200 m agl and into the wind were greater than expected for MLIRS but less than expected for ELIRS.

1.8. Sun classes

More Peary caribou responded during all overflights at the extreme level when the animals were "between" the sun and the helicopter than did individuals harassed during different sun class conditions. Peary caribou responded more at the moderate level when the sun was obscured than did individuals overflown under different sun class conditions. Fewer Peary caribou remained at the maintenance level when the harassed animals were "between" the sun and the helicopter than did individuals overflown under different sun class conditions.

1.9. Terrain classes

During all overflights Peary caribou responded more at the extreme level when on sites that constituted physical barriers than did individuals in all other terrain classes. Peary caribou on plateaus responded more at the moderate level and less at the maintenance level than did individuals in all other terrain classes.

2. Muskoxen, IRS

2.1. Altitude classes

Only 43.6% (1748) of the muskox IRS obtained were observable responses to the helicopter overflights (Tables 23, 24 and 25; Fig. 15): 31.0% (1243) responded by walking, cantering or galloping and 12.5% (505) alerted to the harassing stimuli. In total 28.6% of the IRS were muskoxen exhibiting extreme level responses, 15.0% were individuals responding at the moderate level and 56.4% were individuals that remained engaged in maintenance activities during periods of harassment (Tables 23, 24 and 25). Observable responses approximated the predicted trend of decreasing contributions of IRS to moderate and extreme responses with increasing altitude of the helicopter during overflights but they did not vary monotonically with changes in altitudes: 92.4% during passes at <50 m agl, 96.1% during passes at 51–100 m agl, 61.9% during passes at 101–200 m agl, 36.8% during passes at 201–300 m agl and 49.8% during passes at 301–400 m agl. Extreme level responses varied from 68.4% during passes at <50 m agl to 24.0% during passes at 201–300 m agl, then an unpredicted rise to 32.0% during passes at 301–400 m agl.

Although the percentages of MLIRS were exceeded by ELIRS in each altitude class, the percentage of MLIRS

Table 23
Distribution of muskox individual response samples, by altitude class (metres above ground level) during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Can.	Extreme Gal.	Extreme Walk tog.	Extreme Can. tog.	Extreme Gal. tog.
1–50	2	4	13	6	0	8	25	2	19
51–100	4	0	34	8	0	23	16	0	18
101–200	41	53	37	5	0	21	52	17	21
201–300	835	919	296	61	5	52	335	188	85
301–400	121	284	125	18	8	0	90	101	59
<200	47	57	84	21	0	52	93	19	58
>200	956	1203	421	77	13	52	425	289	144
<400	1003	1260	505	98	13	104	518	308	202

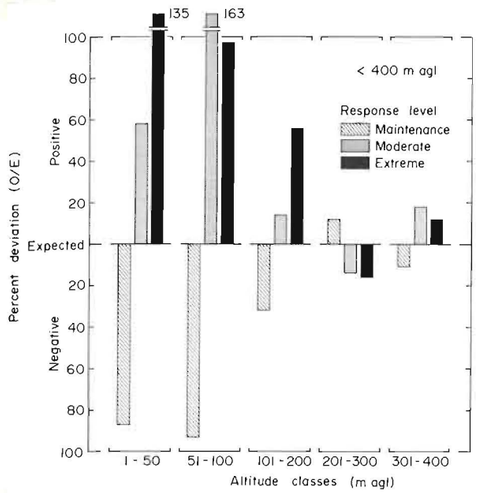
Table 24
Distribution of muskox individual response samples, by level of response and variable classes during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 4011)

Variable class	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Can.	Extreme Gal.	Extreme Walk tog.	Extreme Can. tog.	Extreme Gal. tog.
Sex/age									
Bull	270	310	144	44	7	27	97	44	59
Cow	273	395	152	21	0	31	178	107	63
Juv	65	107	37	2	0	14	31	21	21
Yr	119	154	34	6	1	11	57	39	15
Calf	276	294	138	25	5	21	155	97	44
Group size									
Solitary bull	0	4	2	10	0	7	2	2	11
Bull pair	2	1	31	9	0	8	18	0	9
Single sex, 3+	0	2	13	2	2	0	2	2	9
Mixed sex, 2–5	0	0	11	1	0	0	0	0	3
Mixed sex, 6–9	40	66	62	9	0	3	49	2	20
Mixed sex, 10–19	271	310	156	19	7	72	308	74	95
Mixed sex, 20–29	623	705	199	45	4	12	101	222	26
Mixed sex, 40+	67	172	31	3	0	2	38	6	29
Group type									
Solitary bull	0	4	2	10	0	7	2	2	11
Single sex	2	3	44	11	2	8	20	2	18
Mixed sex	1001	1253	459	77	11	89	496	304	173

Table 25
Distribution of muskox individual response samples, by response, sex/age class and type of helicopter harassment overflight, Prince of Wales Island, NWT, 1976-77

Sex/age	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Can.	Extreme Gal.	Extreme Walk tog.	Extreme Can. tog.	Extreme Gal. tog.
Single passes and first passes of multi-passes (n = 864)									
Bull	29	55	38	19	3	12	34	15	35
Cow	17	69	26	2	0	14	55	45	35
Juv	3	23	7	1	0	6	10	11	11
Yr	9	33	3	1	0	4	9	15	7
Calf	11	60	14	4	2	8	46	41	22
Subsequent passes of multi-passes (n = 3147)									
Bull	241	255	106	25	4	15	63	29	24
Cow	256	326	126	19	0	17	123	62	28
Juv	62	84	30	1	0	8	21	10	10
Yr	110	121	31	5	1	7	48	24	8
Calf	265	234	124	21	3	13	109	56	22

Figure 15
Distribution of muskox individual response samples, by level of response and altitude class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



also decreased with increasing altitude of the helicopter over the muskoxen. MLIRS accounted for 33.5% of the responses during overflights at < 100 m agl and 24.0% for passes at < 200 m agl. MLIRS occurred as frequently during passes at > 100 m agl (14.2%) as during passes at > 200 m agl (13.9%). MAIRS were infrequent (5.5%) during overflights at < 100 m agl and relatively infrequent (24.2%) during passes at < 200 m agl. MAIRS were more common during passes at > 100 m agl (58.8%) and during passes at > 200 m agl (60.3%).

We have also used the < and > 200 m agl altitude classes as a division for the analyses of responses by muskoxen to harassment, mainly because of the relatively larger number of IRS during passes at < 200 m agl than at < 100 m agl (429 versus 182) and the contributions of IRS at < and > 200 m agl. Most (69.2%) of the IRS (2776) were obtained during overflights between 201–300 m agl. Therefore, the number of IRS during overflights at > 200 m agl is disproportionately high (3582) and division between altitudinal categories < and > 200 m agl serves best for a comparison of IRS ($\chi^2 = 204.49$, 2 df, $P < 0.005$).

A test of independence between the number of IRS that we obtained during single passes and first passes of multi-pass overflights and passes subsequent to the first passes of multi-pass overflights indicates that the level of response was partly dependent on the sequences of passes within each set of overflights (Table 26). Muskoxen responded more at the extreme level and less than expected at the moderate and maintenance levels during single and first passes than during subsequent passes ($\chi^2 = 276.00$, 2 df, $P < 0.005$).

We broke the IRS down by altitude categories to control the effect of altitude on the relationship between first and single and subsequent passes. The distribution of levels of response during both single and first passes ($\chi^2 = 50.30$, 2 df, $P < 0.005$) and subsequent passes ($\chi^2 = 91.00$, 2 df, $P < 0.005$) followed the predicted pattern of more ELIRS and MLIRS than expected during flights at < 200 m agl and fewer observable responses during higher passes (Tables 27 and 28). MAIRS were observed less frequently than

Table 26
Comparison of muskox individual response samples (IRS), by single and first passes versus subsequent passes during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

Pass sequence	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Single and first	299	125	440	864
Subsequent	1954	488	705	3147
Total	2253	613	1145	4011
Observed/expected indices				
Single and first	0.62	0.95	1.78	
Subsequent	1.11	1.01	0.79	
Chi-square contributions				
Single and first	70.03	0.33	150.27	220.63
Subsequent	21.39	0.05	39.60	61.04
Total	91.42	0.38	189.87	281.67

Table 27
Distribution of muskox individual response samples (IRS), by level of response and altitude classes (metres above ground level) during single and first passes of helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
1–50	6	7	28	41
51–100	0	13	55	68
101–200	24	17	52	93
201–300	231	48	223	502
301–400	48	30	82	160
Total	309	115	440	864
Observed/expected indices				
1–50	0.41	1.28	1.34	
51–100	0.00	1.44	1.59	
101–200	0.72	1.37	1.10	
201–300	1.29	0.72	0.87	
301–400	0.84	1.41	1.01	
Chi-square contributions				
1–50	5.12	0.44	2.43	7.98
51–100	24.32	1.72	11.98	38.02
101–200	2.58	1.73	0.45	4.76
201–300	14.75	5.30	4.17	24.22
301–400	1.49	3.56	0.00	5.05
Total	48.26	12.74	19.04	80.03

Table 28
Distribution of muskox individual response samples (IRS), by level of response and altitude class (metres above ground level) during subsequent passes of helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
1–50	0	12	26	38
51–100	4	29	2	35
101–200	70	25	59	154
201–300	1523	309	442	2274
301–400	357	113	176	646
Total	1954	488	705	3147
Observed/expected indices				
1–50	0.00	2.04	3.05	
51–100	0.18	5.34	0.26	
101–200	0.73	1.05	1.71	
201–300	1.08	0.88	0.87	
301–400	0.89	1.13	1.22	
Chi-square contributions				
1–50	23.59	6.33	35.92	65.85
51–100	14.47	102.38	4.35	121.20
101–200	6.86	0.05	17.40	24.32
201–300	8.73	5.40	8.92	23.06
301–400	4.85	1.64	6.76	13.25
Total	58.51	115.80	73.36	247.67

expected during overflights at <200 m agl and more often than expected during higher flights, as predicted (Tables 27 and 28).

There were differences in the distributions of IRS during first and single passes and subsequent passes at < and > 200 m agl. Unlike Peary caribou, IRS from harassment over muskoxen at <200 m agl accounted for only a small percentage (10.7%, 429/4011) of the total IRS. In total, however, 23.4% (202/864) of the IRS from single and first passes and only 7.2% (277/3147) of the IRS from subsequent passes were obtained during passes at <200 m agl, a ratio of 3.25 to 1. The O/E indices for IRS at the extreme level do, however, indicate that the muskoxen that responded during single and first passes (O/E = 1.78) did so at a much greater rate than those individuals that responded during subsequent passes (O/E = 0.79).

We then examined the response levels of muskoxen during first and single passes relative to subsequent passes within the altitude categories of < and > 200 m agl. The tests of independence for single and first passes versus subsequent passes at <200 m agl and at >200 m agl both give a significant difference (<200 m agl, $\chi^2 = 34.08$, 1 df, $P<0.005$ and >200 m agl, $\chi^2 = 171.99$, 1 df, $P<0.005$). O/E indices for IRS obtained from first and single passes at <200 m agl and >200 m agl both indicate that muskoxen responded at the extreme level more often than expected (O/E = 1.29 and 1.78 respectively) and at other levels less often than expected (O/E = 0.69 and 0.73, respectively). The converse was true for responses at extreme and other levels during subsequent passes at <200 m agl and >200 m agl (extreme, O/E = 0.74 and 0.82; other O/E = 1.27 and 1.06).

The IRS distributions of levels of response for overflights between 51–100 m agl could not be tested because there were only two IRS at the extreme level observed during subsequent passes. A test of independence between IRS obtained during passes at <100 m agl during single and first passes versus subsequent passes did, however, give a significant difference ($\chi^2 = 28.26$, 1 df, $P<0.005$) and indicates that some degree of habituation had occurred during some sets: ELIRS single and first passes, O/E = 1.26, ELIRS subsequent passes, O/E = 0.62. A final test of independence between IRS obtained during passes at <50 m agl during single and first passes versus subsequent passes was not significant ($\chi^2 = 0.00$, 1 df, $P>0.995$) which indicates that during such low flights the altitudinal effect was probably too strong to allow any degree of habituation during sets of passes. Therefore, the above conditions suggest the following: (*a*) muskoxen did not habituate during sets of helicopter harassment overflights at <50 m agl; (*b*) muskoxen appeared to habituate to some degree during sets of helicopter harassment overflights at >50 m agl; (*c*) muskoxen continued to habituate to a greater degree during sets of passes as the altitudes of the harassment overflights by the helicopter increased >100 m agl.

2.2. Sex/age classes

We obtained 25.0% (1002) of the IRS from muskox bulls (Tables 29, 30 and 31; Figs. 16, 17 and 18). In total 19.4% (194) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by bulls during passes at < and >200 m agl ($\chi^2 = 106.94$, 2 df, $P<0.005$). Of the IRS observed for bulls, 23.4% (234) were at the extreme level. ELIRS made up 44.3% (86/194) of the IRS observed during passes at <200 m agl and 18.3% (148/808) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.90) and lowest for maintenance activities (O/E = 0.44), which was the reverse order for those O/E indices at >200 m agl.

We obtained 30.4% (1220) of the IRS from muskox cows (Tables 29, 30 and 31). In total 8.6% (105) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by cows during passes at < and >200 m agl ($\chi^2 = 52.41$, 2 df, $P<0.005$). Of the IRS observed for cows, 31.1% (379) were at the extreme level. ELIRS made up 58.1% (61/105) of the IRS observed during passes at <200 m agl and 28.5% (318/1115) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.87) and lowest for maintenance activities (O/E = 0.40), which was the reverse order for those O/E indices at >200 m agl.

We obtained 7.4% (298) of the IRS from muskox juveniles (Tables 29, 30 and 31). In total 15.4% (46) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by juveniles during passes at < and >200 m agl ($\chi^2 = 32.50$, 2 df, $P<0.005$). Of the IRS observed for juveniles, 25.9% (87) were at the extreme level. ELIRS made up 56.5% (26/46) of the IRS observed during passes at <200 m agl and 24.2% (61/252) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.94) and lowest for maintenance activities (O/E = 0.34), which was the reverse order for those O/E indices at >200 m agl.

We obtained 10.9% (436) of the IRS from muskox yearlings (Tables 29, 30 and 31). In total 4.8% (21) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by yearlings during passes at < and >200 m agl ($\chi^2 = 11.00$, 2 df, $P<0.005$). Of the IRS observed for yearlings, 28.2% (123) were at the extreme level. ELIRS made up 52.4% (11/21) of the IRS observed during passes at <200 m agl, and 27.0% (112/415) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.86) and lowest for maintenance activities (O/E = 0.46). The highest and lowest rates of response levels during passes at >200 m agl were for the maintenance activities (O/E = 1.03) and moderate level responses (O/E = 0.95).

We obtained 26.3% (1055) of the IRS from muskox calves (Tables 29, 30 and 31). In total 6.0% (63) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by calves during passes at < and >200 m agl ($\chi^2 = 28.89$, 2 df, $P<0.005$). Of the IRS observed for calves, 30.5% (322) were at the extreme level. ELIRS made up 60.3% (38/63) of the IRS observed during passes at <200 agl and 28.6% (284/992) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl

Table 29
Distribution of muskox individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights <200 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	49	59	86	194
Cow	23	21	61	105
Juv	9	11	26	46
Yr	6	4	11	21
Calf	17	8	38	63
Total	104	103	222	429
Observed/expected indices				
Bull	1.04	1.27	0.86	
Cow	0.90	0.83	1.12	
Juv	0.81	1.00	1.09	
Yr	1.18	0.79	1.01	
Calf	1.11	0.53	1.17	
Chi-square contributions				
Bull	0.08	3.31	2.06	5.46
Cow	0.24	0.70	0.82	1.76
Juv	0.42	0.00	0.20	0.62
Yr	0.16	0.22	0.00	0.38
Calf	0.20	3.36	0.89	4.45
Total	1.09	7.59	3.98	12.66

Figure 16
Distribution of muskox individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <200 m above ground level, Prince of Wales Island, NWT, 1976–77

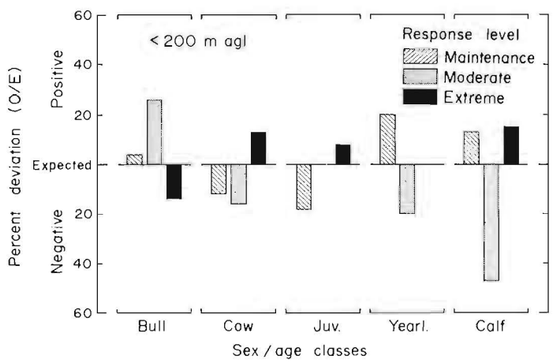


Table 30
Distribution of muskox individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights >200 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	531	129	148	808
Cow	645	152	318	1115
Juv	163	28	61	252
Yr	267	36	112	415
Calf	553	155	284	992
Total	2159	500	923	3582
Observed/expected indices				
Bull	1.09	1.14	0.71	
Cow	0.96	0.98	1.11	
Juv	1.07	0.80	0.94	
Yr	1.07	0.62	1.05	
Calf	0.92	1.12	1.11	
Chi-square contributions				
Bull	3.97	2.33	17.41	23.71
Cow	1.09	0.09	3.28	4.45
Juv	0.81	1.46	0.24	2.52
Yr	1.14	8.30	0.24	9.68
Calf	3.37	1.97	3.15	8.50
Total	10.39	14.15	24.32	48.86

Figure 17
Distribution of muskox individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at >200 m above ground level, Prince of Wales Island, NWT, 1976–77

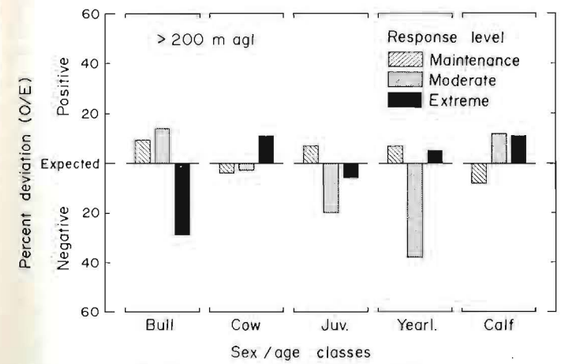
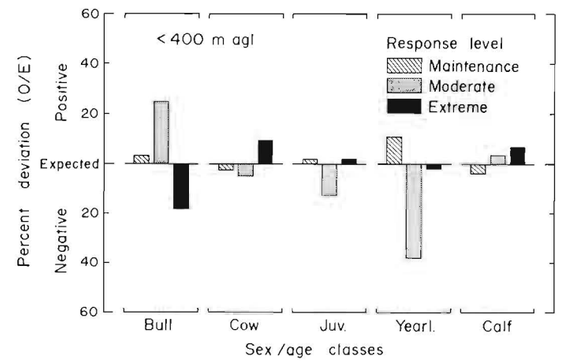


Table 31
Distribution of muskox individual response samples (IRS), by level of response and sex/age class during all pass-type helicopter harassment overflights <400 m agl, Prince of Wales Island, NWT, 1976–77

Sex/age class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Bull	580	188	234	1002
Cow	668	173	379	1220
Juv	172	39	87	298
Yr	273	40	123	436
Calf	570	163	322	1055
Total	2263	603	1145	4011
Observed/expected indices				
Bull	1.03	1.25	0.82	
Cow	0.97	0.94	1.09	
Juv	1.02	0.87	1.02	
Yr	1.11	0.61	0.99	
Calf	0.96	1.03	1.07	
Chi-square contributions				
Bull	0.38	9.27	9.47	19.11
Cow	0.60	0.59	2.71	3.90
Juv	0.09	0.75	0.04	0.88
Yr	2.97	9.96	0.02	12.94
Calf	1.07	0.12	1.44	2.63
Total	5.10	20.69	13.68	39.47

Figure 18
Distribution of muskox individual response samples, by level of response and sex/age class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



were greatest for extreme level responses (O/E = 1.98) and lowest for maintenance activities (O/E = 0.50), which was the reverse order for those O/E indices at > 200 m agl.

The frequency of observable responses to helicopter harassment overflights ranged from 37.4% for yearlings to 46.0% for calves (Tables 29, 30 and 31). Muskox cows responded most frequently at the extreme level (31.1%), followed closely by calves (30.5%), then by juveniles (29.2%), yearlings (28.2%) and bulls (23.4%).

The distributions of IRS of muskoxen by sex/age classes during overflights at < 200 m agl were not significantly different (χ^2 = 12.66, 8 df, P > 0.1; Table 29). O/E indices for ELIRS (Table 29) during passes at < 200 m agl suggest that muskox calves responded most frequently at the extreme level, followed by cows and juveniles. Yearlings responded at about the expected rate at the extreme level and bulls responded less frequently than expected at the extreme level (Table 29).

The distributions of IRS of muskoxen by sex/age classes during overflights at > 200 m agl were significantly different (χ^2 = 48.86, 8 df, P < 0.005; Table 30). O/E indices for ELIRS (Table 30) during passes at > 200 m agl indicate that muskox cows and calves again responded at the extreme level more often than expected, followed by yearlings. Juveniles and bulls responded less frequently than expected at the extreme level (Table 30).

The distributions of IRS of muskoxen by sex/age classes during all overflights at < 400 m agl were significantly different (χ^2 = 39.47, 8 df, P < 0.005; Table 31). O/E indices for ELIRS (Table 31) observed during passes at < 400 m agl indicate that muskox cows and calves responded more at the extreme level than expected. Juveniles and yearlings responded about as frequently as expected at that level and observations of extreme responses by bulls were less frequent than expected (Table 31).

2.3. Group size classes

We obtained only 0.9% (38) of the IRS from solitary muskox bulls (Tables 32, 33 and 34; Figs. 19, 20 and 21). In total 84.2% (32) of the above IRS were from overflights at < 200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by solitary bulls during passes at < and > 200 m agl (χ^2 = 24.33, 2 df, P < 0.005). Of the IRS observed for solitary bulls, 57.9% (22) were at the extreme level. ELIRS made up 62.5% (20/32) of the IRS observed during passes at < 200 m agl and 33.3% (2/6) of the IRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.08) and lowest for maintenance activities (O/E = 0.0). The highest and lowest rates of response levels during passes at > 200 m agl were for the maintenance activities (O/E = 6.33) and the moderate level responses (O/E = 0.0).

We obtained only 1.9% (78) of the IRS from pairs of muskox bulls (Tables 32, 33 and 34). In total 59.0% (46) of the above IRS were from overflights at < 200 m agl. There was no significant difference in the frequencies of the three levels of responses exhibited by pairs of bulls during passes at < and > 200 m agl (χ^2 = 5.01, 2 df, P < 0.05). Of the IRS observed for bull pairs, 44.9% (35) were at the extreme level. ELIRS made up 50.0% (23/46) of the IRS observed during passes at < 200 m agl and 37.5% (12/32) of the IRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.11) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at > 200 m agl.

Table 32
Distribution of muskox individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights < 200 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	0	12	20	32
Bull pair	0	23	23	46
Bulls, 3+	0	5	11	16
Mixed sex, 2–5	0	12	3	15
Mixed sex, 6–9	31	32	35	98
Mixed sex, 10–19	73	19	130	222
Total	104	103	222	429
Observed/expected indices				
Solitary bull	0.00	1.56	1.21	
Bull pair	0.00	2.08	0.97	
Bulls, 3+	0.00	1.30	1.33	
Mixed sex, 2–5	0.00	3.33	0.39	
Mixed sex, 6–9	1.30	1.36	0.69	
Mixed sex, 10–19	1.36	0.36	1.13	
Chi-square contributions				
Solitary bull	7.76	2.43	0.71	10.90
Bull pair	11.15	12.94	0.03	24.12
Bulls, 3+	3.88	0.35	0.89	5.12
Mixed sex, 2–5	3.64	19.59	2.92	26.14
Mixed sex, 6–9	2.21	3.05	4.87	10.13
Mixed sex, 10–19	6.84	22.07	1.99	30.90
Total	35.47	60.43	11.42	107.31

Figure 19
Distribution of muskox individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77

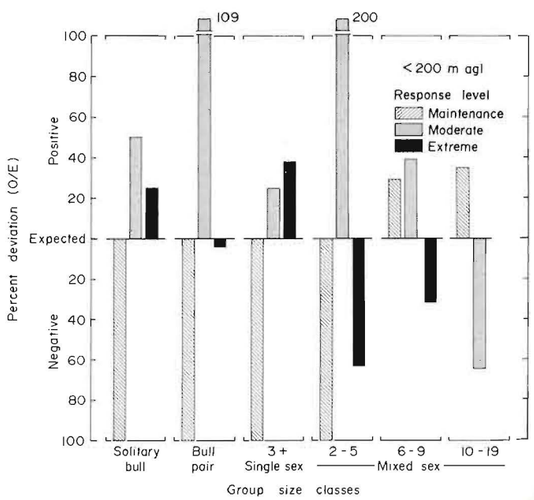


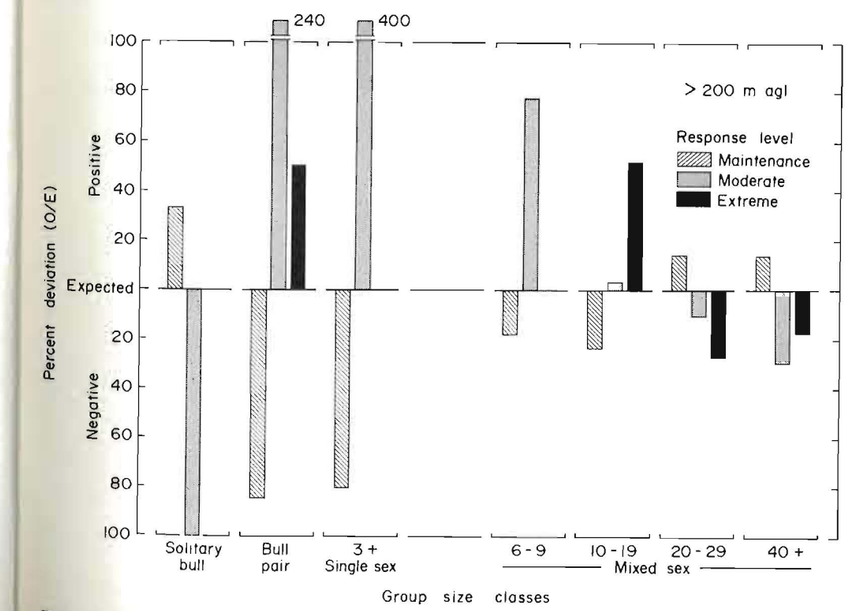
Table 33
Distribution of muskox individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights > 200 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	4	0	2	6
Bull pair	3	17	12	32
Bulls, 3+	2	10	4	16
Mixed sex, 6–9	75	39	39	153
Mixed sex, 10–19	508	156	426	1090
Mixed sex, 20–29	1328	244	365	1937
Mixed sex, 40+	239	34	75	348
Total	2159	500	923	3582
Observed/expected indices				
Solitary bull	1.11	0.00	1.29	
Bull pair	0.16	3.81	1.46	
Bulls, 3+	0.21	4.48	0.97	
Mixed sex, 6–9	0.81	1.83	0.99	
Mixed sex, 10–19	0.77	1.03	1.52	
Mixed sex, 20–29	1.14	0.90	0.73	
Mixed sex, 40+	1.14	0.70	0.84	
Chi-square contributions				
Solitary bull	0.04	0.84	0.13	1.01
Bull pair	13.75	35.17	1.71	50.63
Bulls, 3+	6.06	27.01	0.00	33.07
Mixed sex, 6–9	3.21	14.58	0.00	17.79
Mixed sex, 10–19	33.78	0.10	74.99	108.87
Mixed sex, 20–29	22.06	2.57	36.04	60.68
Mixed sex, 40+	4.08	4.37	2.40	10.85
Total	83.00	84.63	115.28	282.91

Table 34
Distribution of muskox individual response samples (IRS), by level of response and group size class during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

Group size class	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	4	12	22	38
Bull pair	3	40	35	78
Bulls, 3+	2	15	15	32
Mixed sex, 2–5	0	12	3	15
Mixed sex, 6–9	106	71	74	251
Mixed sex, 10–19	581	175	556	1312
Mixed sex, 20–29	1328	244	365	1937
Mixed sex, 40+	239	34	75	348
Total	2263	603	1145	4011
Observed/expected indices				
Solitary bull	0.19	2.10	2.03	
Bull pair	0.07	3.41	1.57	
Bulls, 3+	0.11	3.12	1.64	
Mixed sex, 2–5	0.00	5.32	0.70	
Mixed sex, 6–9	0.75	1.88	1.03	
Mixed sex, 10–19	0.78	0.89	1.48	
Mixed sex, 20–29	1.22	0.84	0.66	
Mixed sex, 40+	1.22	0.65	0.75	
Chi-square contributions				
Solitary bull	14.19	6.92	11.47	32.57
Bull pair	38.21	68.17	7.28	113.67
Bulls, 3+	14.28	21.58	3.77	39.62
Mixed sex, 2–5	8.46	42.11	0.38	50.96
Mixed sex, 6–9	8.96	29.33	0.08	38.36
Mixed sex, 10–19	34.25	2.51	87.93	124.69
Mixed sex, 20–29	50.60	7.65	63.88	122.13
Mixed sex, 40+	9.27	6.41	5.96	21.65
Total	178.21	184.68	180.75	543.64

Figure 20
Distribution of muskox individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77



We obtained only 0.8% (32) of the IRS from individuals in groups of three or more muskox bulls (Tables 32, 33 and 34). In total 50.0% (16) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals during passes at < and >200 m agl (χ^2 = 6.93, 2 df, $P<0.05$). Of the IRS observed for bull groups with more than two animals, 46.9% (15) were at the extreme level. ELIRS made up 68.8% (11/16) of the IRS observed during passes at <200 m agl and 25.0% (4/16) of the IRS during passes at >200 m agl. O/E indices for the IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.47) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained only 0.4% (15) of the IRS from individual muskoxen in mixed sex groups of 2–5 animals (Tables 32 and 34). All of the above IRS were from overflights at <200 m agl. The observed ELIRS totalled 20.0% (3).

We obtained 6.3% (251) of the IRS from individual muskoxen in groups of 6–9 animals (Tables 32, 33 and 34). In total 39.0% (98) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in groups of 6–9 individuals during passes at < and >200 m agl (χ^2 = 7.48, 2 df, $P<0.025$). Of the IRS observed for groups of 6–9 muskoxen, 29.5% (74) were at the extreme level. ELIRS made up 35.7% (35/98) of the IRS observed during passes at <200 m agl and 25.5% (39/153) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.21) and lowest for maintenance activities (O/E = 0.75), which was the reverse order for those O/E indices at >200 m agl.

We obtained 32.7% (1312) of the IRS from individual muskoxen in groups of 10–19 animals (Tables 32, 33 and 34). In total 16.9% (222) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in groups of 10–19 individuals during passes at < and >200 m agl (χ^2 = 28.93, 2 df, $P<0.005$). Of the IRS observed for groups of 10–19 muskoxen, 42.4% (556) were at the extreme level. ELIRS made up 58.6% (130/222) of the IRS observed during passes at <200 m agl and 39.1% (426/1090) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.38) and lowest for maintenance activities(O/E = 0.74). The highest and lowest rates of response levels during passes at >200 m agl were for the moderate level (O/E = 1.07) and the extreme level (O/E = 0.92).

We obtained 48.3% (1937) of the IRS from individual muskoxen in groups of 20–29 animals (Tables 33 and 34). None of the above IRS were from overflights at <200 m agl. The observed ELIRS totalled 18.8% (365).

We obtained 8.7% (348) of the IRS from individual muskoxen in a group of 58 animals (Tables 33 and 34). None of the above IRS were from overflights at <200 m agl. The observed ELIRS totalled 21.6% (75).

The frequency of observable responses to helicopter harassment overflights ranged from 31.3% for a mixed sex group of 58, to 100% for mixed sex groups of 2–5 animals (Table 34). Solitary bull muskoxen responded most frequently at the extreme level during helicopter harassment overflights, followed by single sex bull groups of 3–5 (46.9%); bull pairs (44.9%); mixed sex groups of 10–19 animals (42.4%); 6–9 animals (29.5%); 58 animals (21.6%); 2–5 animals (20.0%); and 20–29 animals (18.8%).

The distributions of IRS of muskoxen by group size classes during overflights at <200 m agl were significantly different (χ^2 = 107.31, 10 df, $P<0.005$; Table 32). O/E indices for ELIRS (Table 32) during passes at >200 m agl indicate that bulls in single sex groups of 3–5 animals were most responsive followed by solitary bulls, then individuals in mixed sex groups of 10–19 animals. Pairs of muskox bulls responded at about the expected rate at the extreme level (Table 32). Muskoxen in mixed sex groups of 6–9 and 2–5 individuals responded less frequently than expected at the extreme level (Table 32).

The distributions of IRS of muskoxen by group size classes during overflights at >200 m agl were also significantly different (χ^2 = 282.90, 10 df, $P<0.005$; Table 33). O/E indices for ELIRS during passes at >200 m agl (Table 33) indicate that muskoxen in mixed sex groups of 10–19 individuals responded more frequently than expected at the extreme level. Pairs of muskox bulls and solitary bulls also responded more frequently than expected at the extreme level of response (Table 33). Individuals in mixed sex groups of 6–9 animals and bulls in single sex groups of 3–5 responded more or less frequently as expected at the extreme level whereas individuals in the mixed sex group of 58 animals and mixed sex groups of 20–29 animals less frequently than expected at the extreme level (Table 33).

The distributions of IRS of muskoxen by group size classes during all overflights <400 m agl were significantly different (χ^2 = 543.64, 10 df, $P<0.005$; Table 34). O/E indices for ELIRS observed during passes at <400 m agl (Table 34) indicate that solitary muskox bulls responded more at the extreme level, followed by bulls in single sex groups of 3–5 and pairs of bulls. Mixed sex groups of 10–19 muskoxen were the most responsive of all the mixed sex groups (Table 34). Mixed sex groups of 6–9 individuals responded more or less as expected and the mixed sex group of 58 and groups of 2–5 and 20–29 responded less frequently than expected (Table 34).

Figure 21
Distribution of muskox individual response samples, by level of response and group size class, expressed as percentage deviations of observed from expected values (O−E /E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77

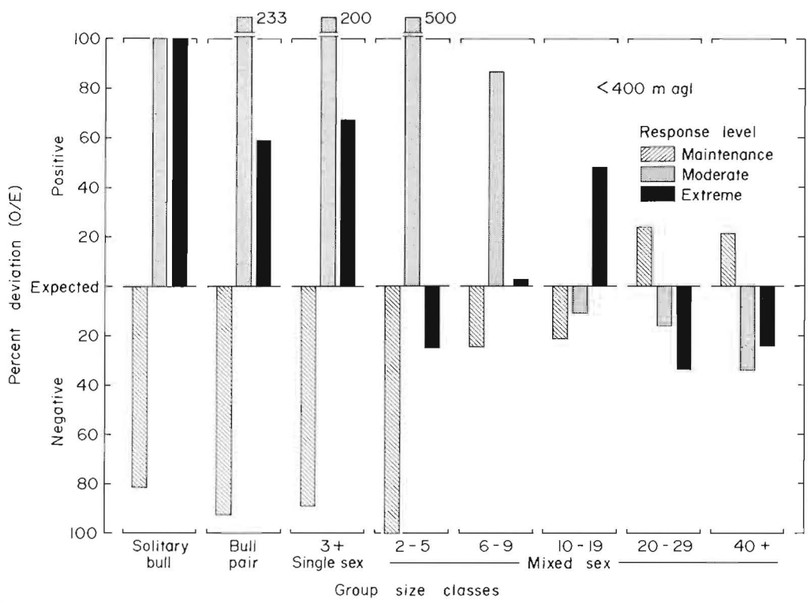


Table 36
Distribution of muskox individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights >200 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response			
	Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	4	0	2	6
Single sex	5	27	16	48
Mixed sex	2150	473	905	3528
Total	2159	500	923	3582
Observed/expected indices				
Solitary bull	1.11	0.0	1.29	
Single sex	0.17	4.03	1.29	
Mixed sex	1.01	0.96	1.00	
Chi-square contributions				
Solitary bull	0.04	0.84	0.13	1.01
Single sex	19.80	61.50	1.07	82.37
Mixed sex	0.26	0.77	0.02	1.05
Total	20.10	63.11	1.22	84.42

Table 37
Distribution of muskox individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights <400 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response			
	Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	4	12	22	38
Single sex	5	55	50	110
Mixed sex	2254	536	1073	3863
Total	2263	603	1145	4011
Observed/expected indices				
Solitary bull	0.19	2.10	2.03	
Single sex	0.08	3.33	1.59	
Mixed sex	1.03	0.92	0.97	
Chi-square contributions				
Solitary bull	14.19	6.92	11.47	32.57
Single sex	52.46	89.46	11.02	152.94
Mixed sex	2.55	3.45	0.80	6.80
Total	69.20	99.83	23.28	192.31

2.4. Group type classes

We obtained only 0.9% (38) of the IRS from the solitary muskox bull group type class (Tables 35, 36 and 37; Figs. 22, 23 and 24). In total 84.2% (32) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by solitary bulls during passes at < and >200 m agl (χ^2 = 24.33, 2 df, $P<0.005$). Of the IRS observed for solitary bulls, 57.9% (22) were at the extreme level. ELIRS made up 62.5% (20/32) of the IRS observed during passes at <200 m agl and 33.3% (2/6) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.08) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained 2.8% (110) of the IRS from muskox bulls in single sex groups (Table 35, 36 and 37). In total 56.4% (62) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by bulls in single sex groups during passes at < and >200 m agl (χ^2 = 9.99, 2 df, $P<0.01$). Of the IRS observed for bulls in single sex groups, 45.5% (50) were at the extreme level. ELIRS made up 54.8% (34/62) of the IRS observed during passes at <200 m agl and 33.3% (16/48) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.21) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained 96.3% (3863) of the IRS from individual muskoxen in mixed sex groups (Tables 35, 36 and 37). In total 8.7% (335) of the above IRS were from overflights at

Table 35
Distribution of muskox individual response samples (IRS), by level of response and group type class during all pass-type helicopter harassment overflights <200 m agl, Prince of Wales Island, NWT, 1976–77

Group type class	Level of response			
	Maint.	Mod.	Ext.	Totals
Observed IRS				
Solitary bull	0	12	20	32
Single sex	0	28	34	62
Mixed sex	104	63	168	335
Total	104	103	222	429
Observed/expected indices				
Solitary bull	0.00	1.56	1.21	
Single sex	0.00	1.88	1.06	
Mixed sex	1.28	0.78	0.97	
Chi-square contributions				
Solitary bull	7.76	2.43	0.71	10.90
Single sex	15.03	11.55	0.11	26.70
Mixed sex	6.39	3.78	0.17	10.34
Total	29.18	17.76	0.99	47.93

Figure 22
Distribution of muskox individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <200 m above ground level, Prince of Wales Island, NWT, 1976–77

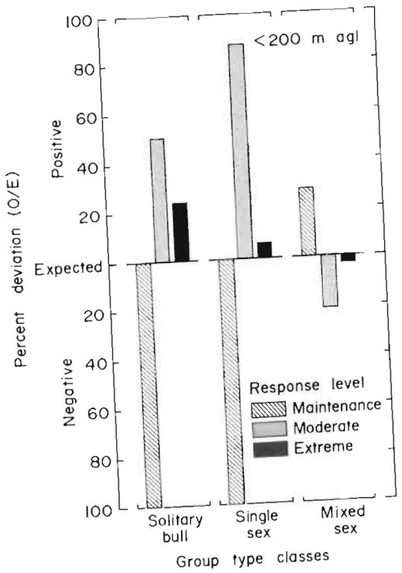
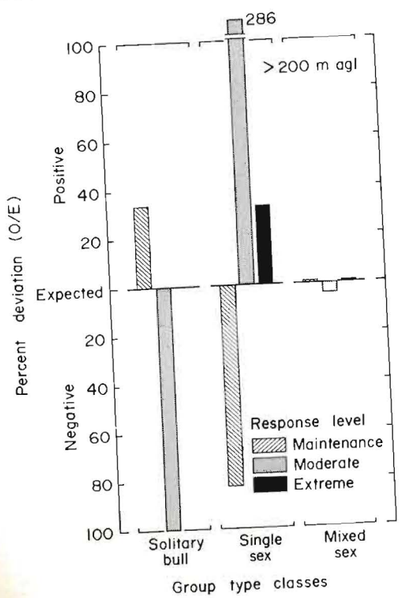


Figure 23
Distribution of muskox individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at >200 m above ground level, Prince of Wales Island, NWT, 1976–77

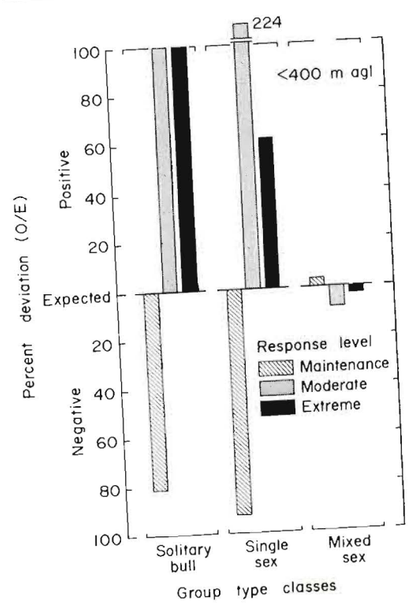


<200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in mixed sex groups during passes at < and > 200 m agl ($\chi^2 = 119.39$, 2 df, $P < 0.005$). Of the IRS observed for mixed sex groups, 27.8% (1073) were at the extreme level. ELIRS made up 50.1% (168/335) of the IRS observed during passes at <200 m agl and 25.7% (905/3528) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.81) and lowest for maintenance activities (O/E = 0.53), which was the reverse order for those O/E indices at >200 m agl.

The frequency of observable responses to helicopter harassment overflights ranged from 41.7% for mixed sex groups to 95.5% for single sex bull groups (Table 37). The solitary bull group type responded most frequently at the extreme level (57.9%), followed by the single sex bull group type (45.5%) and the mixed sex group type (27.8%).

The distributions of IRS of muskoxen by group type classes during overflights within all altitude categories were significantly different ($\chi^2 = 47.93$, 4 df, $P < 0.005$ during passes at <200 m agl; $\chi^2 = 84.42$, 4 df, $P < 0.005$ during passes at >200 m agl and $\chi^2 = 192.31$, 4 df, $P < 0.005$ during passes at <400 m agl, Tables 35, 36 and 37). O/E indices for ELIRS within all three altitude categories (Tables 35, 36 and 37) indicate that solitary muskox bulls responded the most, followed by bulls in the single sex group type and then by individuals in the mixed sex group type.

Figure 24
Distribution of muskox individual response samples, by level of response and group type class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77



2.5. Calf classes

We obtained 3.7% (148) of the IRS from muskoxen in groups without calves present; 63.5% (94) of the above IRS were from overflights at <200 m agl (Tables 38, 39, 40 and 41; Figs. 25, 26 and 27). There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in groups without calves during passes at < and >200 m agl ($\chi^2 = 20.19$, 2 df, $P < 0.005$). Of the IRS observed for muskoxen unaccompanied by calves, 49.1% (72) were at the extreme level. ELIRS made up 57.4% (54/94) of the IRS observed during passes at <200 m agl and 33.3% (18/54) of the IRS during passes at >200 m agl. O/E indices for the IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.18) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained 7.1% (284) of the IRS from muskoxen in groups with one calf (Tables 38, 39, 40 and 41). In total 46.8% (133) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of response exhibited by individuals in groups with one calf during passes at < and >200 m agl ($\chi^2 = 33.27$, 2 df, $P < 0.005$). Of the IRS observed for muskoxen in groups with one calf, 28.5% (81) were at the extreme level. ELIRS made up 38.3% (51/133) of the IRS observed during passes at <200 m agl and 19.9% (30/151) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for extreme level responses (O/E = 1.34) and lowest for maintenance activities (O/E = 0.57), which was the reverse order for those O/E indices at >200 m agl.

We obtained 17.7% (708) of the IRS from muskoxen in groups with two calves (Tables 38, 39, 40 and 41). In total 8.5% (60) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in groups with two calves during passes at < and >200 m agl ($\chi^2 = 17.06$, 2 df, $P < 0.005$). Of the IRS observed for muskoxen in groups with two calves, 17.4% (123) were at the extreme level. ELIRS made up 0.0% (0/60) of the IRS observed during passes at <200 m agl and 19.0% (123/648) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for maintenance activities (O/E = 1.32) and lowest for extreme level responses (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained 1.5% (62) of the IRS from muskoxen in groups with three calves (Tables 38, 39, 40 and 41). In total 32.3% (20) of the above IRS were from overflights at <200 m agl. There was a significant difference in the frequencies of the three levels of responses exhibited by individuals in groups with three calves during passes at < and >200 m agl ($\chi^2 = 16.29$, 2 df, $P < 0.005$). Of the IRS observed for muskoxen in groups with three calves, 59.7% (37) were at the extreme level. ELIRS made up 65.0% (13/20) of the IRS observed during passes at <200 m agl and 57.1% (24/42) of the IRS during passes at >200 m agl. O/E indices for IRS during passes at <200 m agl were greatest for moderate level responses (O/E = 2.41) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at >200 m agl.

We obtained 4.5% (179) of the IRS from muskoxen in groups with four calves (Tables 38, 39, 40 and 41). In total 59.8% (107) of the above IRS were from overflights at <200 m agl. There was a significant difference in the rates of contributions to the three levels of responses exhibited

Table 38
Distribution of muskox individual response samples (IRS), by level of response and calf class during all pass-type helicopter harassment overflights <200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
No. calves	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	0	40	54	94
1	31	51	51	133
2	55	5	0	60
3	0	7	13	20
4	18	0	89	107
5	0	0	15	15
Total	104	103	222	429
Observed/expected indices				
0	0.00	1.77	1.11	
1	0.96	1.60	0.74	
2	3.78	0.35	0.00	
3	0.00	1.46	1.26	
4	0.69	0.00	1.61	
5	0.00	0.00	1.93	
Chi-square contributions				
0	22.79	13.46	0.59	36.84
1	0.05	11.39	4.62	16.05
2	112.51	6.14	31.05	149.70
3	4.85	1.01	0.68	6.53
4	2.43	25.69	20.42	48.54
5	3.64	3.60	6.75	13.99
Total	146.26	61.29	64.11	271.66

Table 39
Distribution of muskox individual response samples (IRS), by level of response and calf class obtained during all pass-type helicopter harassment overflights >200 m agl, Prince of Wales Island, NWT, 1976–77

	Level of response			
No. calves	Maint.	Mod.	Ext.	Totals
Observed IRS				
0	9	27	18	54
1	86	35	30	151
2	438	87	123	648
3	16	2	24	42
4	0	0	72	72
5	20	24	184	228
6	23	47	32	102
8	1328	244	365	1937
18	239	34	75	348
Total	2159	500	923	3582
Observed/expected indices				
0	0.28	3.58	1.29	
1	0.94	1.66	0.77	
2	1.12	0.96	0.74	
3	0.63	0.34	2.22	
4	0.00	0.00	3.88	
5	0.15	0.75	3.13	
6	0.37	3.30	1.22	
8	1.14	0.90	0.73	
18	1.14	0.70	0.84	
Chi-square contributions				
0	17.04	50.25	1.20	68.49
1	0.28	9.20	2.04	11.51
2	5.76	0.13	11.58	17.47
3	3.43	2.54	16.05	22.02
4	43.40	10.05	153.97	207.42
5	100.33	1.92	267.02	369.28
6	24.08	75.39	1.24	100.71
8	22.06	2.57	36.04	60.68
18	4.08	4.37	2.40	10.85
Total	220.46	156.43	491.54	868.43

Table 40
Distribution of muskox individual response samples (IRS), by level of response and calf class during all pass-type helicopter harassment overflights < 400 m agl, Prince of Wales Island, NWT, 1976–77

No. calves	Level of response: Maint.	Mod.	Ext.	Totals
Observed IRS				
0	9	67	72	148
1	117	86	81	284
2	493	92	123	708
3	16	9	37	62
4	18	0	161	179
5	20	24	199	243
6	23	47	32	102
8	1328	244	365	1937
18	239	34	75	348
Total	2263	603	1145	4011
Observed/expected indices				
0	0.11	3.01	1.70	
1	0.73	2.01	1.00	
2	1.23	0.86	0.61	
3	0.46	0.97	2.09	
4	0.18	0.00	3.15	
5	0.15	0.66	2.87	
6	0.40	3.07	1.10	
8	1.22	0.84	0.66	
18	1.22	0.65	0.75	
Chi-square contributions				
0	66.47	90.00	20.95	177.43
1	11.66	43.92	0.00	55.59
2	21.91	1.96	30.96	54.83
3	10.30	0.01	21.05	31.36
4	68.20	26.91	236.38	331.49
5	100.02	4.30	242.25	346.57
6	20.74	65.39	0.29	86.42
8	50.60	7.65	63.88	122.13
18	9.27	6.41	5.96	21.65
Total	359.16	246.56	621.72	1227.45

Figure 25
Distribution of muskox individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77

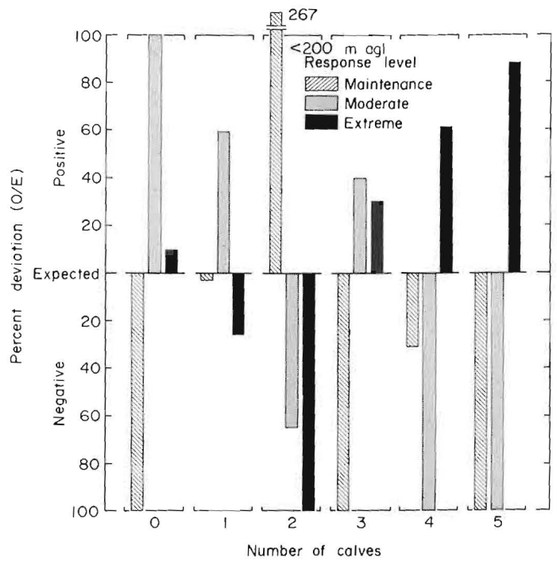


Table 41
Distribution of muskox individual response samples, by number of calves, during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–1977 (n = 4011)

No. calves	Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Can.	Extreme Gal.	Extreme Walk tog.	Extreme Can. tog.	Extreme Gal. tog.
0	2	7	46	21	2	15	22	4	29
1	40	77	76	10	0	3	57	2	19
2	254	239	77	15	7	0	83	7	26
3	0	16	9	0	0	0	21	0	16
4	4	14	0	0	0	72	18	17	54
5	6	14	24	0	0	0	162	35	2
6	7	16	43	4	0	0	16	15	1
8	623	705	199	45	4	12	101	222	26
18	67	172	31	3	0	2	38	6	29

Figure 26
Distribution of muskox individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77

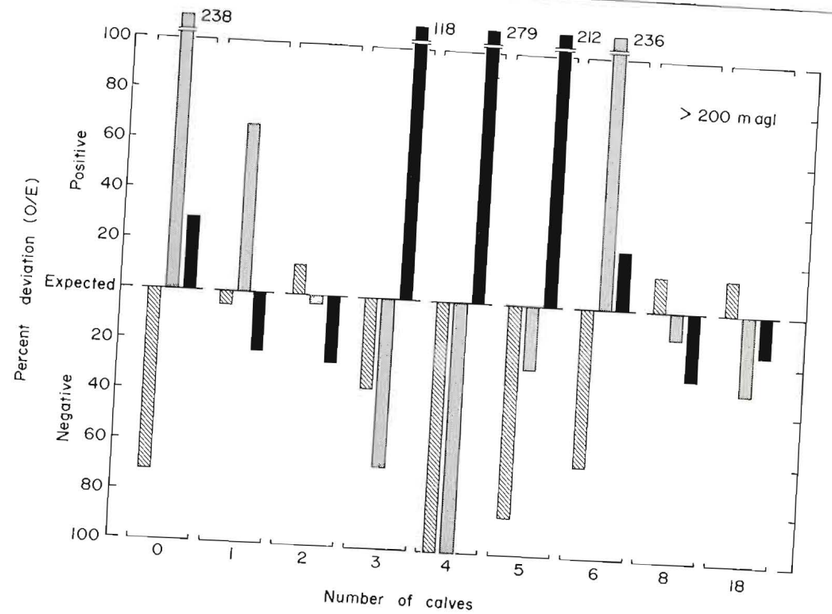
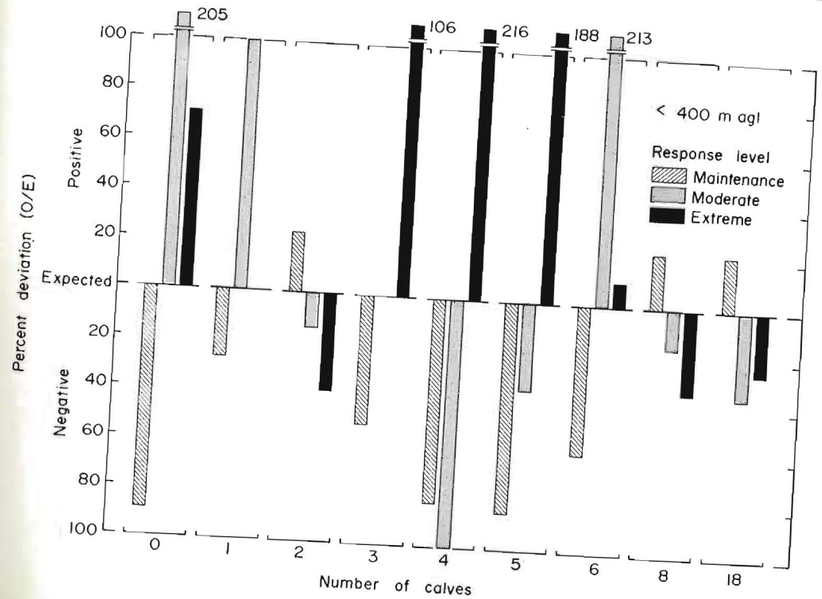


Figure 27
Distribution of muskox individual response samples, by level of response and calf class, expressed as percentage deviations of observed from expected values (O−E/E), obtained during helicopter harassment overflights at < 400 m above ground level, Prince of Wales Island, NWT, 1976–77



by individuals in groups with four calves during passes at < and > 200 m agl ($\chi^2 = 13.47$, 2 df, $P < 0.005$). Of the IRS observed for muskoxen in groups with four calves, 89.9% (161) were at the extreme level. ELIRS made up 83.2% (89/107) of the IRS observed during passes at < 200 m agl and 100.0% (72) of the IRS during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for maintenance activities (O/E = 1.67) and lowest for moderate level responses (O/E = 0.0). The highest and lowest rates of response levels during passes at > 200 m agl were for the extreme level (O/E = 1.10) and for the moderate level (O/E = 0.0) and maintenance level (O/E = 0.0).

We obtained 6.0% (243) of the IRS from muskoxen in groups with five calves (Tables 38, 39, 40 and 41). In total 6.2% (15) of the above IRS were from overflights at < 200 m agl. There was no significant difference in the frequencies of the three levels of responses exhibited by individuals in groups with five calves during passes at < and > 200 m agl ($\chi^2 = 3.53$, 2 df, $P > 0.1$). Of the IRS observed for muskoxen in groups with five calves, 81.9% (199) were at the extreme level. ELIRS made up 100.0% (15) of the IRS during passes at < 200 m agl and 80.7% (184/228) of the IRS observed during passes at > 200 m agl. O/E indices for IRS during passes at < 200 m agl were greatest for extreme level responses (O/E = 1.22) and lowest for maintenance activities (O/E = 0.0), which was the reverse order for those O/E indices at > 200 m agl.

We obtained 2.5% (102) of the IRS from muskoxen in groups with six calves (Tables 39, 40 and 41). None of the above IRS were from overflights at < 200 m agl. The observed ELIRS totalled 31.4% (32).

We obtained 48.3% (1937) of the IRS from muskoxen in groups with eight calves (Tables 39, 40 and 41). None of the above IRS were from overflights at < 200 m agl. The observed ELIRS totalled 18.8% (365).

We obtained 8.7% (348) of the IRS from muskoxen in a group with 18 calves (Tables 39, 40 and 41). None of the above IRS were from overflights at < 200 m agl. The observed ELIRS totalled 21.6% (75).

The frequency of observable responses to helicopter harassment overflights ranged from 30.4% for mixed sex groups with two calves present in each group to 93.9% for solitary bulls and single sex groups of 2–5 bulls unaccompanied by calves (Tables 40 and 41). Muskoxen in mixed sex groups that contained five calves were the most responsive (91.8%). Muskoxen in groups with four calves contributed the greatest percentage to ELIRS (89.4%), followed closely by individuals in groups with five calves (81.9%). There was no continuous pattern in the percentage contributions by individuals to the extreme level of responses and the number of calves present in each group: 1st and 2nd as above; 3rd, 3 calves (59.7%); 4th, no calves (48.6%); 5th, 6 calves (31.4%); 7th, 18 calves (one group – 21.6%); 8th, 8 calves (18.4%); and 9th, 2 calves (17.4%).

The distributions of IRS of muskoxen by number of calves present (calf classes) during overflights at < 200 m agl were significantly different ($\chi^2 = 271.66$, 10 df, $P < 0.005$; Table 38). O/E indices for ELIRS during passes at < 200 m agl (Table 38) indicate that muskoxen in groups with five calves were the most responsive to helicopter harassment. Individuals in groups that contained four calves, three calves and no calves also responded at the extreme level more often than expected. Individuals in groups that contained two calves responded less frequently than expected at the extreme level (Table 38).

The distributions of IRS of muskoxen by number of calves present during overflights at > 200 m agl were significantly different ($\chi^2 = 868.43$, 16 df, $P < 0.005$; Table 39). O/E indices for ELIRS observed during passes at > 200 m agl (Table 39) indicate that muskoxen in groups with four calves were the most responsive to helicopter harassment. Individuals in groups that contained 5 calves, 3 calves, no calves and 6 calves also responded at the extreme level more often than expected. Individuals in groups that contained 18 calves (one group), 1 calf, 2 calves and 8 calves were less responsive than expected at the extreme level (Table 39).

The distributions of the IRS of muskoxen by number of calves present during all overflights at < 400 m agl were significantly different ($\chi^2 = 1227.45$, 16 df, $P < 0.005$; Table 40). O/E indices for ELIRS observed during passes at < 400 m agl (Table 40) indicate that muskoxen in groups with four calves were the most responsive to helicopter harassment. Individuals in groups that each contained 5 calves, 3 calves, no calves and 6 calves also responded at the extreme level more often than expected. Individuals in groups that contained 18 calves (one group), 8 calves and 2 calves were less responsive than expected at the extreme level (Table 40).

There is no clear pattern of increasing responsiveness by muskoxen in groups with more calves than in groups with fewer calves (Table 41). There is, however, a significant difference between the distribution of IRS for muskoxen in groups with no calves and individuals in groups with 1–18 calves ($\chi^2 = 186.91$, 2 df, $P < 0.005$). O/E indices for muskoxen in groups without calves indicate that those individuals (all bulls) were more responsive at the extreme (O/E = 1.71) and moderate (O/E = 3.05) levels and remained less frequently at the maintenance (O/E = 0.11) level than individuals in mixed sex groups with calves present. This condition probably reflects sex/age (bull versus all other sex/age classes) and group type (solitary bulls and single sex bull group types versus the mixed sex group type) differences as much as the presence or absence of calves in groups. At any rate, the pattern of responses in relation to absence or presence of muskox calves is the reverse of that for caribou calves.

2.6. Season classes

The distribution of IRS of muskoxen by sampling period (season classes) during overflights within all altitude categories were significantly different ($\chi^2 = 186.48$, 4 df, $P < 0.005$, during passes at < 200 m agl; $\chi^2 = 507.68$, 4 df, $P < 0.005$, during passes at > 200 m agl and $\chi^2 = 510.42$, 4 df, $P < 0.005$, during passes at < 400 m agl). O/E indices for ELIRS within all three altitude categories indicate that muskoxen sampled between 16 July – 7 August were always the most responsive at the extreme level. Muskoxen sampled during overflights at > 200 m agl were second most responsive at the extreme level of response between 4–24 June: no individuals were sampled in that period during overflights at < 200 m agl. Muskoxen sampled during 24 June – 15 July and 8–24 August were less responsive than expected during overflights within all altitude categories. It is probable that the greater than expected responsiveness of muskoxen during overflights at > 200 m agl between 16 July – 7 August reflects the influence of male behaviour during the early stages of the rut. The presence of "intruder" bulls and responses to them by herd bulls tended to cause more activity within the groups during harassments. This supposition is, however, contradicted by the reduced responses of muskoxen during 8–24 August when rut was more fully advanced. One possible explanation for this apparent contradiction is that the bulls sampled between 8–24 August had sorted themselves out to a degree that allowed more close contact during periods of harassment without the higher levels of excitability being transformed into aggressive behaviour. Also, some herd bulls appeared to be more antagonistic than others, perhaps, partly for the above reason.

2.7. Wind classes

No pattern for IRS distributions by wind classes could be discerned for muskoxen. No explanation can be offered for the greatest responsiveness during passes at > 200 m agl being when overflights were at > 60° to the wind. But we do speculate that there was often an element of surprise associated with overflights at < 200 m agl into winds with speeds in excess of 16 km per hour. That is, the sound of the helicopter is muffled to the animals by the wind flow against the oncoming helicopter until it is relatively close to the muskoxen, then the sound suddenly becomes loud (at least, to the ground observers). This condition often seemed to startle the muskoxen into brief but strong responses to the helicopter.

2.8. Sun classes

No pattern for the distribution of IRS by sun classes could be discerned. We can offer no explanation for the greater responsiveness of muskoxen during overflights at < 200 m agl when the sun was obscured. But we can offer the following supposition for the greater contribution to ELIRS during passes at > 200 m agl when the helicopter passed "between" the sun and the animals. It is possible that when the helicopter is back lighted and the side facing the animals is in shadow, that the helicopter stands out more in the sky and its visual discreteness along with the sound stimuli adds to the strength of the harassing stimuli. At least this is the impression that we received during ground observations under such conditions. Perhaps, the line-of-sight from the animals to the helicopter to the sun has to approach a straight line to maximize impact of this condition.

2.9. Terrain classes

No pattern for the distribution of IRS by terrain classes could be discerned. Most (94.0%) of the IRS were obtained from muskoxen on lowland flats (2347) and intermediate slopes (1424). Only 6.0% (240) of the muskoxen sampled were on ridges and plateaus. Perhaps, muskoxen on plateaus and ridges responded more at the extreme and moderate levels because the helicopter harassment was compounded psychologically by those muskoxen being on sites not often occupied by them. This assumption is, however, seemingly in contradiction with the fact that muskoxen often flee to high ground when disturbed. At any rate, the small sample (11) of muskoxen on ridges during overflights at < 200 m agl probably explains much of the results as given in Miller and Gunn (1978b) for that altitude category.

3. Peary caribou, multiple regression analyses (IRS)

We ran a multiple regression analysis for each of the three altitude categories: < 200 m agl, > 200 m agl and < 400 m agl. Nine variables explained a significant proportion of the variation in responses during both passes at < 200 m agl (17.9%) and at > 200 m agl (18.0%) (Tables 42 and 43). Only six variables were significant contributors to the regression for all passes at < 400 m agl and together they explained 27.9% of the variation in response (Table 44).

Only the negative contributions by the bull sex/age class were common to all three regressions. Four variable classes were common to regressions for passes at < 200 m agl and < 400 m agl: group sizes of 2 to 19 animals, negative; calves present, positive; altitude > 50 m agl, negative; and season class 2 (24 June – 15 July), negative.

A comparison of the three regressions allows us to make some assumptions about the responses of Peary caribou during helicopter harassment overflights at < 400 m agl.

Table 42
Stepwise multiple regression analysis for 1992 individual response samples of Peary caribou, during helicopter harassment overflights at < 200 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
– Bulls	6.4	– 1.118	– 0.241	124.00
– 24 June – 15 July	4.7	– 0.474	– 0.110	22.47
– Group sizes 2–19 (excluding cow–calf pairs)	2.4	– 1.614	– 0.203	84.39
– Altitude > 50 m agl	1.3	– 0.678	– 0.118	30.36
– Plateaus	0.7	– 1.373	– 0.110	26.12
+ Calves	0.7	+ 0.500	+ 0.084	15.86
– Ridges	0.6	– 0.441	– 0.082	14.02
+ Sun–helicopter–caribou (helicopter backlighted)	0.6	+ 0.365	+ 0.083	15.98
+ Sites that constituted physical barriers	0.5	+ 1.102	+ 0.074	13.04

Table 43
Stepwise multiple regression analysis for 1947 individual response samples of Peary caribou, during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
– Lowland flats	4.7	– 1.274	– 0.228	102.65
– Bulls	4.0	– 1.056	– 0.243	97.21
– Juveniles	2.5	– 1.100	– 0.187	71.56
+ Group sizes 2–9 (excluding cow–calf pairs)	2.3	+ 0.414	+ 0.100	19.03
+ Altitude > 300 m agl	0.9	+ 0.814	+ 0.101	20.81
+ Helicopter flying at > 60° to the wind	0.7	+ 0.591	+ 0.138	36.39
+ Group sizes 2–5 (excluding cow–calf pairs)	0.8	+ 1.832	+ 0.222	51.41
– Bull group type	1.5	– 1.321	– 0.182	34.65
– Yearlings	0.6	– 0.860	– 0.079	13.77

Table 44
Stepwise multiple regression analysis for 3939 individual response samples of Peary caribou, during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
– Altitude > 200 m agl	19.8	–1.822	–0.395	703.04
– Bulls	4.4	–1.016	–0.203	183.84
– 24 June – 15 July	1.5	–0.546	–0.118	62.30
– Group sizes 2–19 (excluding cow–calf pairs)	1.0	–0.703	–0.095	46.29
+ Calves	0.6	+0.511	+0.087	35.77
– Altitude > 50 m agl	0.6	–0.710	–0.083	33.24

On the basis of all overflights, responses by Peary caribou to harassing stimuli waned during passes at > 200 m agl. Bulls came in as the least responsive sex/age class in all regressions. The effect of season class 2 on levels of IRS during passes at < 200 m agl was not apparent during passes at > 200 m agl but was regained during passes at < 400 m agl. The lack of responsiveness by Peary caribou in groups of 2–19 animals during passes at < 200 m agl shifted to more responsiveness by individuals in small groups of 2–9 at > 200 m agl then shifted back at < 400 m agl. The influence of the < 50 m agl altitude class in the regression for passes at < 200 m agl was replaced by the impact of the > 300 m agl altitude class in the regression for > 200 m agl but then reappeared during passes at < 400 m agl. Lack of responsiveness by Peary caribou sampled on plateaus and ridges during passes at < 200 m agl was not apparent during passes at > 200 m agl and individuals sampled on lowland flats were the least responsive. No Peary caribou were sampled during passes at > 200 m agl on sites that constituted physical barriers, so that the influence of such conditions could not be considered. The effect on response when the helicopter passed "between" the sun and the animals during overflights at < 200 m agl was not apparent during higher passes. Finally, the responsiveness of calves during passes at < 200 m agl was lost during passes at > 200 m agl but regained during passes at < 400 m agl.

We must conclude that the relationship between the altitude of the harassing agent and the levels of responses exhibited by the Peary caribou sampled is the most manageable finding of these regression analyses. Secondly, that the greater responsiveness of calves followed by cows, yearlings, juveniles and bulls, warrants special consideration in any implementation of constraints on aircraft activities during calving and post-calving periods.

4. Muskoxen, multiple regression analyses (IRS)

We ran a multiple regression analysis for each of the three altitude categories: < 200 m agl, > 200 m agl and < 400 m agl. Eleven variable classes explained a significant proportion of the variation in responses during passes at < 200 m agl (58.7%; Table 45) and nine variable classes were significant contributors to the regression for passes at > 200 m agl (25.6%; Table 46). Thirteen variable classes accounted for 27.4% of the variation in IRS obtained during passes flown at < 400 m agl (Table 47).

Only two variable classes were common to all three regressions (Tables 45, 46 and 47): (*a*) single and first passes versus single and first circles, 3rd at < 200 m agl, 2nd at > 200 m agl and 1st at < 400 m agl; and (*b*) terrain class 3, ridges, 10th at < 200 m agl, 4th at > 200 m agl and 5th at < 400 m agl. Only one variable class was common to the regressions for passes at < and > 200 m agl (Tables 45 and 46): season class 4, 8–24 August, 5th at < 200 m agl and 9th at > 200 m agl. Five variable classes were common to the regressions for passes at > 200 m agl and < 400 m agl (Tables 46 and 47): season class 2, 24 June – 15 July, 1st and 2nd; sun class 3, sun obscured, 3rd and 6th; wind class 1, flying into wind, 5th and 7th; mixed sex group sizes 2–19, 6th and 4th; and bull sex/age class, 8th and 9th, respectively.

We conclude that the relationship between the altitude of the harassing agent and response is not as definite for muskoxen as it was for Peary caribou. Such a continuing relationship was demonstrated, however, and we believe that the minimum altitudes of aircraft flights above muskoxen is a primary consideration in the development of potential constraints. Any added stress to cows and calves, as was demonstrated for Peary caribou, was probably masked in muskoxen by their common participation in group defense formation during the most extreme level responses. The mortality of muskoxen is

Table 45
Stepwise multiple regression analysis for 429 individual response samples of muskoxen, during helicopter harassment overflights at <200 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
+ Intermediate slopes	16.7	+2.013	+0.273	62.29
– Altitude > 100 m agl	11.9	–1.480	–0.263	38.10
– Single and 1st passes vs. single and 1st circles	2.7	–0.596	–0.107	6.61
+ Bull group type	2.2	+7.764	+1.155	82.70
+ 8 – 24 August	3.8	+4.451	+0.762	163.00
– Group sizes 2–9	4.3	–3.552	–0.638	142.92
+ Plateaus	6.7	+9.468	+0.782	150.44
+ 16 July – 7 August	6.1	+2.966	+0.531	72.01
– Group sizes 2–5	2.9	–4.331	–0.678	30.77
+ Ridges	0.8	+1.756	+0.100	9.10
+ Solitary bulls	0.6	+1.048	+0.099	6.24

Table 46
Stepwise multiple regression analysis for 3582 individual response samples of muskoxen, during helicopter harassment overflights at > 200 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
– 24 June – 15 July	7.8	–1.591	–0.308	374.62
+ Single and 1st passes vs. single and 1st circles	6.9	+1.596	+0.278	364.17
– Sun obscured during overflights	2.5	–1.417	–0.260	160.86
+ Ridges	3.7	+1.476	+0.154	98.72
– Helicopter flying into wind	1.4	–0.448	–0.092	30.55
+ Group sizes 2–19	1.3	+0.935	+0.202	132.15
+ Helicopter flying at > 60° to the wind	0.9	+0.659	+0.142	57.69
– Solitary bulls	0.6	–0.417	–0.078	27.66
+ 8 – 24 August	0.5	+0.561	+0.107	24.88

Table 47
Stepwise multiple regression analysis for 4011 individual response samples of muskoxen, during helicopter harassment overflights at <400 m above ground level, Prince of Wales Island, NWT, 1976–77
(+ = positive influence, – = negative influence)

Independent variable affecting maximum level of responses	% variation estimated by each variable	Regression coefficient	Standardized regression coefficient	F value
+ Single and 1st passes vs. single and 1st circles	9.1	+1.547	+0.270	369.45
– 24 June – 15 July	6.5	–1.423	–0.253	230.42
– Altitude > 100 m agl	2.7	–1.272	–0.112	41.64
+ Group sizes 2–19	1.6	+0.900	+0.189	132.58
+ Ridges	1.5	+1.198	+0.115	60.34
– Sun obscured during overflights	1.7	–1.191	–0.209	139.88
– Helicopter flying into the wind	0.9	–0.523	–0.103	53.29
– Lowland flats	0.7	–0.210	–0.044	6.81
– Solitary bulls	0.5	–0.579	–0.106	52.80
+ Bull group type	0.6	+2.376	+0.190	102.03
+ Altitude > 300 m agl	0.5	+0.533	+0.091	38.55
– Group sizes 2–9	0.5	–0.966	–0.125	41.72
+ Plateaus	0.6	+2.754	+0.090	34.64

highest during the first year of life and any additional stress may lessen their chances of survival.

5. Peary caribou, strength and intensities of IRS

Each helicopter harassment overflight was divided into four stages, A, B, C and D (see "Response patterns" in definitions section) in an attempt to better quantify the sequences of responses and to measure the intensities of the various responses to harassing stimuli (Tables 48 and 49). The intensity of an activity or response is defined as the retention and/or change in the strength of activity or response throughout the four stages of the helicopter harassment overflight. A group of animals that galloped throughout an overflight exhibited extreme level response while a group of animals that walked throughout an overflight exhibited a moderate level response but individuals in both groups exhibited the same intensity of response in all four stages of each overflight. Only 10.5% (411) of the IRS from Peary caribou were seemingly already responding to the approaching helicopter in stage A of the overflights: 3.9% (16) were galloping, 38.7% (159) were trotting, 10.9% (45) were walking and 46.5% (191) were alerted, but remaining in place.

We assumed that the greatest intensity of a response after the initial approach of the helicopter during stage A at any response level would be when B=C=D and lower levels of intensity in descending order would be when B=C>D, B>C=D, B<C=D, B>C>D and B<C>D. Therefore, the most extreme and intense response would be when a caribou was galloping in stage A and continued to gallop throughout the entire overflight in stages B, C and D. This condition occurred for only 0.3% (10) of the 3939 IRS of Peary caribou obtained during helicopter harassment overflights.

There was a direct relationship between the level of responses exhibited by Peary caribou during the initial approaches of the helicopter, stage A of the overflight, and the rates of contributions to subsequent IRS at higher levels (Table 48). Only 0.4% (16) of the Peary caribou galloped during stage A and 4.0% (159) trotted. Of those caribou trotting in stage A, 26.4% (42) subsequently galloped during later stages of the overflight. Of the 1.1% (45) Peary caribou that walked in stage A, 44.4% (20) subsequently trotted and 15.6% (7) galloped. Of the 4.9% (191) Peary caribou that were alerted in stage A, 42.9% (82) subsequently trotted and 21.0% (40) galloped. Of the 65.8% (2593) Peary caribou that were foraging in stage A, 29.7% (770) subsequently trotted and only 7.5% (195) galloped. Of the 23.7% (935)

Table 48
A summary of Peary caribou individual response samples by initial and subsequent activity during helicopter harassment, Prince of Wales Island, NWT, 1976–77*

Subsequent activity (stages B, C and D)†	Initial activity (stage A)						Totals (stages B, C and D)
	Bed	For.	Alert	Walk	Trot	Gal.	
Bed	460						460
Forage	50	908					958
Alert	229	461	48				738
Walk	103	259	21	18			401
Trot	78	770	82	20	117		1067
Gallop	15	195	40	7	42	16	315
Totals (stage A)	935	2593	191	45	159	16	3939

* Read down the initial activity column, then to the extreme left to find out the subsequent activity, e.g. in the alert column, 48 samples were from caribou that were alerted in stage A and remained alerted; 21 samples were from caribou that were alerted in stage A and subsequently walked at some time in stage B, C or D.
† See "response patterns" in definition section for explanation of stages.

Table 49
Distribution by levels of intensity of Peary caribou individual response samples, Prince of Wales Island, NWT, 1976–77

Max. act. in all stages*	Act. in stage A	Levels of intensity: 1st (B=C=D)†	2nd (B=C>D)	3rd (B<C=D)	4th (B>C=D)	5th (B>C>D)	6th (B<C>D)	Totals
Bed	Bed	460						460
Forage	Bed	10	9	5	6		20	50
	Forage	887	12		9			908
Alert	Bed	48	51	31	17	3	79	229
	Forage	98	132	31	68		132	461
	Alert	42	4		2			48
Walk	Bed	1	10	3	16		73	103
	Forage	16	42	10	29	39	123	259
	Alert	1	7		9	2	2	21
	Walk	17				1		18
Trot	Bed	11	5	7	10	5	40	78
	Forage	159	163	62	76	76	234	770
	Alert	10	37	2	6	6	21	82
	Walk	8	7	1	1		3	20
	Trot	92	13		3	9		117
Gallop	Bed						15	15
	Forage	1	29	2	47	12	104	195
	Alert		2			3	35	40
	Walk	1				5	1	7
	Trot		30		2	1	9	42
	Gallop	10			1	5		16

* See "response patterns" in definitions section for explanation of stages.
† B,C,D refer to level of response during stages B,C,D.

Peary caribou that were bedded in stage A, 8.3% (78) subsequently trotted and only 1.6% (15) galloped.

Peary caribou that were alerted or walking in stage A of the overflights contributed ELIRS about as often as expected (O/E = 1.01 vs. 0.96). There was no significant difference ($\chi^2 = 0.12$, 1 df, $P > 0.9$) between the proportion of ELIRS from caribou that were alerted and those that were walking in stage A. There was a significant difference ($\chi^2 = 243.74$, 1 df, $P < 0.005$) between the proportion of ELIRS from caribou that were foraging and those that were bedded in stage A of the overflights. Peary caribou that were foraging in stage A later responded at an extreme level more often than expected (O/E = 1.24), unlike individuals that were bedded (O/E = 0.33) in stage A. Peary caribou responded more at the extreme level during later phases of harassment overflights if they had already responded at the moderate level (O/E = 1.96) than if they had only responded at the maintenance level (O/E = 0.94) in stage A ($\chi^2 = 110.13$, 1 df, $P < 0.005$).

There were significant differences ($\chi^2 = 65.00$, 3 df, $P < 0.005$) between the distributions of IRS from Peary caribou that remained bedded, foraging, alerted or walking throughout periods of harassment (stages A, B, C and D of overflights) during passes at < and > 200 m agl. A comparison of O/E indices for the above IRS indicate the following. (*a*) More caribou than expected remained bedded (O/E = 1.05) and fewer caribou than expected remained foraging (O/E = 0.84) during all phases of overflights at < 200 m agl. These conditions suggest that fewer bedded caribou and more foraging caribou would respond during helicopter overflights at < 200 m agl. (*b*) About the expected number of caribou remained bedded (O/E = 0.99) and slightly more caribou than expected remained foraging (O/E = 1.04) during all phases of overflights at > 200 m agl. These conditions suggest that bedded caribou would not be overly responsive and foraging caribou only slightly more responsive to helicopter overflights at > 200 m agl. (*c*) More caribou than expected remained alerted (O/E = 3.00) and walking (O/E = 2.25) during all phases of overflights at < 200 m agl and fewer remained alerted (O/E = 0.47) and walking (O/E = 0.64) at > 200 m agl. These conditions suggest that caribou that are already responding at a moderate level (alert or walk) to the initial approach of a helicopter are less likely to respond at the extreme level during overflights at < 200 m agl than they are during overflights at > 200 m agl.

The intensity of the responses by Peary caribou obtained by division of IRS into four stages A, B, C and D is given in Table 49. Only 0.3% (10) of the total IRS reached the most extreme and intense level possible (galloped in A, B, C and D). At the extreme level of response, only 2.6% (102) of the total IRS reached the first level of intensity (B=C=D) (10 galloped and 92 trotted); 1.5% (59) at the moderate level of response (42 alerted and 17 walked); and 34.2% (1347) at the maintenance level (460 remained bedded and 887 remained foraging). There was a significant difference ($\chi^2 = 170.78$, 1 df, $P < 0.005$) between the relative frequencies of the first level of intensity and the remaining five intensity levels combined, during overflights at < and > 200 m agl. IRS at the first level of intensity occurred more often than expected during passes at < 200 m agl (O/E = 1.35) and less often than expected at > 200 m agl (O/E = 0.24). IRS at one of the five lower levels of intensity occurred at a less than expected rate during passes at < 200 m agl (O/E = 0.91) and a greater than expected rate during passes at > 200 m agl (O/E = 1.19). These conditions suggest that responses by Peary caribou to helicopter overflights at the first level of intensity would be more common during overflights at < 200 m agl than at > 200 m agl. Also, less intense responses would occur more during helicopter overflights at > 200 m agl.

First level intensity samples of Peary caribou equalled 47.5% (1872) of the total IRS obtained (Table 49): (*a*) 75.6% (1416) were from individuals that had reached their maximum responses to helicopter harassment during initial approaches in stage A of the overflights and maintained those responses throughout stages B, C and D; and (*b*) 24.4% (456) were from individuals that had increased their responses from stage A to maximum responses in stage B which were maintained throughout stages C and D. Second level intensity samples were from Peary caribou that reached their maximum responses in stage B and maintained them through stage C, then returned to lesser responses during the last part of the departure phase of the overflights, stage D, and accounted for 14.0% (553) of the total IRS. Third level intensity samples were from Peary caribou that had not reached their maximum responses until after the point of closest approach with the animals (stage C) and maintained those responses throughout the departures and accounted for only 3.9% (154) of the total IRS. Fourth level intensity samples were from Peary caribou that had reached their maximum responses in stage B of the approaches, but retained them for only stage B, then returned to lesser responses after point of closest contact with the animals and maintained them throughout the departure (stages C and D) and accounted for 7.7% (302) of the total IRS. Fifth level intensity samples were from Peary caribou that had reached their maximum responses in stage B of the approaches and retained them for only stage B, then returned to lesser responses in stage C at the beginning of the departures and then became even less responsive in stage D of the last part of the departures and accounted for 4.2% (167) of the total IRS. The sixth and final level intensity samples were from Peary caribou that had not reached their maximum responses until the beginning of the departure after point of closest contact with the animals (stage C) and then returned to lesser responses in the last part of the departures and accounted for 22.6% (891) of the total IRS.

Only 6.0% (210/3528) of the Peary caribou samples of individuals engaged in maintenance activities during initial approaches (stage A) of the helicopter subsequently galloped, and 24.0% (848/3528) trotted. In total, 19.9% (47/236) of the Peary caribou samples of individuals already responding at the moderate level during stage A of the overflights subsequently galloped and 43.2% (102/236) trotted. The analysis of the six intensity levels indicates, however, that of the 65.8% (2592) IRS of Peary caribou that responded to helicopter harassment overflights, only 20.3% (525) did so at the first level of intensity. Therefore, we must assume that 86.7% (3414/3939) of the time Peary caribou did not respond at the most intense level possible for the responses that they exhibited and 92.0% (3624) of the IRS did not respond as extremely as possible.

In total 89.6% (3528) of the IRS of Peary caribou were from individuals that were engaged in maintenance activities during stage A of the helicopter harassment overflights. Of those caribou samples, 40.2% (1418) remained engaged in maintenance activities and were never observed to respond to the harassment overflights; 29.8% (1052) subsequently responded in stages B and/or C at the moderate level and 63.4% (667) of those caribou returned to maintenance activities during stage D; 30.0% (1058) subsequently responded in stages B and/or C at the extreme level, 25.1% (266) of those caribou returned to maintenance activities whereas 45.1% (477) returned to the moderate level in stage D.

In total only 6.0% (236) of the IRS of Peary caribou were from individuals that responded at the moderate level during stage A of the helicopter harassment overflights. Of those caribou samples, 63.1% (149) subsequently responded in stage B and/or C at the extreme level of which 63.8% (95) returned to the moderate level and 18.1% (27) lessened their responses to the maintenance level in stage D of the overflights; 31.8% (75) remained at the moderate level throughout the overflights; and 5.1% (12) lessened their responses from the moderate level to the maintenance level in stage D of the overflights.

In total only 4.4% (175) of the IRS of Peary caribou were from individuals that were responding at the extreme level during stage A of the helicopter harassment overflights. Of those samples, 77.1% (135) remained at the extreme level throughout the overflights, 12.0% (21) decreased their responses to the moderate level and 10.9% (19) to the maintenance level during stage D of the overflights.

When the helicopter harassment overflights were completed at the end of stage D, 61.2% (2409) of the Peary caribou sampled were engaged in maintenance activities, 26.7% (1053) were still responding at the moderate level and 12.1% (477) were responding at the extreme level.

We suggest that the caribou that continued to respond at the extreme level throughout stage D would probably be most seriously affected by helicopter harassment. In total 92.0% (439) of those samples of caribou still responding at the extreme level during stage D of the overflights were obtained during passes at < 200 m agl. Thus, we further suggest that if helicopters (at least, Bell 206B helicopters) fly over Peary caribou at < 200 m agl about 11.0% of the Peary caribou would be seriously harassed. If the overflights were at > 200 m agl only about 1.0% of the caribou would be seriously harassed.

6. Muskoxen, strength and intensities of IRS

It became evident during our first season in 1976 that solitary muskox bulls were more overtly responsive to helicopter harassment than other muskoxen, including bulls in single sex groups and especially bulls in mixed sex groups. A solitary bull is aware of his lack of companion animals and his response to a given kind of harassment may be more intense than the responses elicited from a group of muskoxen under similar conditions. The muskox group has evolved to find security in mutual defense and the lone bull must take advantage of natural features such as gully banks, hummocks and streams for added protection against predator attack. The use of natural features for added protection is, however, apparently in the repertoires of behaviour for all or almost all muskoxen of both sexes and all ages.

As for Peary caribou, the helicopter harassment overflight was divided into four stages, A, B, C and D, in an attempt to better quantify the sequences of responses and to measure the intensities of the various responses to harassing stimuli (Tables 50 and 51). Again, the intensity of an activity or response is defined as the retention of and/or change in the strength of the activity or response throughout the four stages of the helicopter harassment overflight. The stages of the overflight (A, B, C and D) are described in the definition section, under "response patterns." Only 8.9% (357) of the IRS from muskoxen were, seemingly, already responding to the approaching helicopter in stage A of the overflights: 85.4% (305) of those IRS were at the moderate level and 14.6% (52) at the extreme level.

As before, we assumed that the greatest intensity of a response after the initial approach of the helicopter during stage A at any response level would be when B=C=D and lower levels of intensity in descending order would be when B=C>D, B>C=D, B<C=D, B>C>D and B<C>D. Therefore, the most extreme and intense responses would be when (*a*) muskoxen were galloping in stage A and continued to gallop throughout the entire overflight in stages B, C and D; (*b*) muskoxen were in a tight group defense formation in stage A and remained in that formation throughout stages B, C and D; or (*c*) muskoxen exhibited any combination of the above. These conditions never occurred in 4011 IRS of muskoxen during helicopter harassment overflights. Also, no muskoxen were galloping in stage A of the overflights (Table 50).

In total 55.7% (170/305) of the muskoxen that were alerted or walking during the initial approaches, stage A, of

Table 50
A summary of muskox individual response samples, by initial and subsequent activity, helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77*

Subsequent activity (stages B, C and D)†	Initial activity (stage A)								
	Bed	For.	Alert	Walk	Can.	Gal.	Walk tog.	Can. tog.	Gal. tog.
Bed	1008								
Forage	99	1161							
Alert	210	215	80						
Walk	11	32	20	35					
Canter	4	6	1				2		
Gallop	20	34	30	19			1		
Walk tog.	128	317	52	2			19		
Canter tog.	16	278	1	1	11			1	
Gallop tog.	6	114	64						18
Totals (stage A)	1497	2157	248	57	11	0	22	1	18

* Read down the initial activity column, then to the extreme left to find out the subsequent activity, e.g. in the alert column, 80 samples were from muskoxen that were alerted in stage A and remained alerted through stages B, C and D; 20 samples were from muskoxen that were alerted in stage A and subsequently walked at some time in stages B, C and D.
† See "response patterns" in definition section for explanation of stages.

Table 51
Distribution by levels of intensity of muskox individual response samples, Prince of Wales Island, NWT, 1976–77

Max. act. in all stages*	Act. in stage A	Levels of intensity						
		1st (B=C=D)†	2nd (B=C>D)	3rd (B<C=D)	4th (B>C=D)	5th (B>C>D)	6th (B<C>D)	Totals
Bed	Bed	1003						1003
Forage	Bed	29	12	26	1		31	99
	Forage	1111	29		21			1161
Alert	Bed	18	53	15	34	4	86	210
	Forage	25	64	32	45	2	47	215
	Alert	73	5		2			80
Walk	Bed		1		2	4	4	11
	Forage		1		12	5	14	32
	Alert	2	2	4	8		4	20
	Walk	22	11		1	1		35
Canter	Bed				3	1	2	6
	Forage				3	1	2	6
	Alert						1	1
	Canter							
	Walk tog.			1			1	2
Gallop	Bed		2				18	20
	Forage				3	2	29	34
	Alert	1	20		2	2	5	30
	Walk		18				1	19
	Walk tog.					1		1
Walk tog.	Bed		18		43	13	54	128
	Forage	7	20		154	96	40	317
	Alert		16		22	11	3	52
	Walk				2			2
	Walk tog.	2			15	2		19
Can. tog.	Bed				11	4	1	16
	Forage		23		146	38	71	278
	Alert						1	1
	Walk				1			1
	Canter				11			11
	Can. tog.					1		1
Gal. tog.	Bed				5	1		6
	Forage		1		32	41	40	114
	Alert		1		11	47	5	64
	Gal. tog.				6	12		18

* See "response patterns" in definitions section for explanation of stages.
† B, C, D refer to level of response during stages B, C, D.

the helicopter overflights subsequently responded at the extreme level during later stages of the passes. Only 25.3% (923/3654) of the individuals that were bedded or foraging during the initial approaches of the helicopter subsequently responded at the extreme level. There was a significant difference ($\chi^2 = 8.65$, 1 df, $P < 0.005$) between the proportion of IRS of muskoxen that were alerted and those that were walking during stage A of the overflights. More muskoxen than expected (O/E = 1.07) that were alerted during stage A subsequently responded at the extreme level and fewer than expected (O/E = 0.97) responded at the moderate and maintenance levels. Fewer muskoxen than expected (O/E = 0.69) that were walking during stage A subsequently responded at the extreme level and more than expected (O/E = 1.40) responded at the moderate and maintenance levels. There was a significant difference between the proportion of IRS of muskoxen that were bedded and those that were foraging during stage A of the overflights ($\chi^2 = 248.33$, 1 df, $P < 0.005$). More muskoxen than expected (O/E = 1.37) that were foraging during stage A subsequently responded at the extreme level and fewer than expected (O/E = 0.87) responded at the moderate and maintenance levels. Fewer muskoxen than expected (O/E = 0.46) that were bedded during stage A subsequently responded at the extreme level and more than expected (O/E = 1.18) responded at the moderate and maintenance levels. As with Peary caribou, bedded muskoxen were less responsive to helicopter harassment overflights than individuals that were foraging when subjected to harassing stimuli.

There was a significant difference ($\chi^2 = 296.95$, 1 df, $P < 0.005$) between the relative frequencies of IRS of muskoxen that remained engaged in maintenance activities or at the moderate level of responses throughout periods of harassment (stages A, B, C and D of overflights) during passes at < and > 200 m agl. A comparison of O/E indices for the above IRS indicates the following. (*a*) More muskoxen than expected (O/E = 7.67) remained at the moderate level of responses during overflights at < 200 m agl and fewer than expected (O/E = 0.55) at > 200 m agl. (*b*) Fewer muskoxen than expected (O/E = 0.72) remained engaged in maintenance activities throughout the harassments when the helicopter overflights were at < 200 m agl. (*c*) About the expected number (O/E = 1.02) of muskoxen remained engaged in maintenance activities during overflights at > 200 m agl. Only 3.8% (2) of the 52 ELIRS during stage A of the overflights continued to respond at that level throughout all stages of the overflights (A=B=C=D).

There was no significant difference ($\chi^2 = 1.13$, 1 df, $P > 0.1$) between the distributions of ELIRS from muskoxen that were already responding at the extreme level during stage A of the overflights and individuals that were responding at maintenance or moderate levels during stage A and subsequently responded at the extreme level. A comparison of O/E indices for the above ELIRS indicates that muskoxen responding at the extreme level did so less often than expected (O/E = 0.70) during stage A of the overflights at < 200 m agl and more often than expected (O/E = 1.07) during passes at > 200 m agl. Also, muskoxen that responded at the maintenance and moderate levels during stage A subsequently responded at the extreme level at the expected rates (O/E = 1.01 and 1.00). These conditions suggest that altitude did not have an inverse effect on the rate of ELIRS in stage A (responses become stronger as altitudes become lower).

The intensity of the responses by muskoxen obtained by division of IRS into four stages A, B, C and D is given in Table 51. None of the IRS reached the most extreme and intense levels possible (galloping or in tight defense formation in A, B, C and D). At the extreme level of responses only 0.05% (2) of the total reached the first level of intensity by walking together throughout the harassment period to apparently form a group defense formation; 2.4% (95) at the moderate level of responses (73 alerted and 22 walked); and 52.7% (2114) at the maintenance level (1003 remained bedded and 1111 remained foraging).

There was a significant difference ($\chi^2 = 100.36$, 1 df, $P < 0.005$) between the relative frequencies of the first level of intensity and the remaining five levels combined, during overflights at < and > 200 m agl. O/E indices for the above IRS indicate that (*a*) muskoxen were more responsive than expected (O/E = 2.75) at the extreme level of intensity during overflights at < 200 m agl and less responsive than expected (O/E = 0.84) during passes at > 200 m agl and (*b*) fewer muskoxen than expected (O/E = 0.60) responded at the extreme level of intensity during overflights at > 200 m agl and slightly more than expected (O/E = 1.04) at lesser levels of intensity.

A comparison of responses at the first level of intensity with responses at the five lower levels of intensity by ELIRS and MLIRS gave a significant difference ($\chi^2 = 248.71$, 1 df, $P < 0.005$). O/E indices for the above IRS indicate that (*a*) muskoxen responded at the first level of intensity more frequently than expected (O/E = 2.69) and less frequently at the five lower levels of intensity at the moderate levels of response; (*b*) muskoxen were less responsive than expected (O/E = 0.10) at the first level of intensity and more responsive than expected (O/E = 1.08) at the five lower levels of intensity at the extreme level of responses.

First level intensity samples of muskoxen equalled 57.2% (2293) of the total IRS obtained (Table 51): (*a*) 87.6% (2009) were from individuals that had reached their maximum responses to helicopter harassment during initial approaches of the helicopter and maintained those responses throughout stages B, C and D; and (*b*) 12.4% (284) were from individuals that had increased their responses from stage A to maximum responses in stage B which were maintained throughout stages C and D. Second level intensity samples were from muskoxen that reached their maximum responses in stage B and maintained them through stage C, then returned to lesser responses during stage D, and accounted for only 7.4% (297) of the total IRS. Third level intensity samples were from muskoxen that had not reached their maximum responses until stage C, after the point of closest approach with the animals, and maintained those responses throughout the departures, stages C and D, and accounted for only 1.9% (78) of the total IRS. Fourth level intensity samples were from muskoxen that had reached their maximum responses in stage B of the approaches, but retained them for only stage B, then returned to lesser responses for stages C and D, and accounted for 14.9% (596) of the total IRS. Fifth level intensity samples were from muskoxen that had reached their maximum responses in stage B of the approaches and retained them for only stage B, then returned to lesser responses in stage C at the beginning of the departures and then became even less responsive in stage D of the last part of the departures and accounted for only 7.2% (288) of the total IRS. Sixth, and final level intensity samples were from muskoxen that had not reached their maximum responses until the beginning of the departure after the point of closest contact with the animals (stage C) and then returned to lesser responses in the last part of the departures and accounted for 11.4% (459) of the total IRS.

Only 25.3% (923/3654) of the muskox samples of individuals engaged in maintenance activities during initial

approaches (stage A) of the helicopter overflights subsequently responded at the extreme level: 1.5% (54) galloped away from the helicopter; 3.3% (120) galloped together to form group defense formations; 0.3% (10) cantered away from the helicopter; 8.0% (294) cantered together to form group defense formations; and 12.2%(445) walked together to form group defense formations. Subsequent responses at the extreme level for the 305 muskox samples of individuals already responding at the moderate level during stage A of the overflights were 16.1% (49) galloped away from helicopter; 21.0% (64) galloped together to form group defense formations; 0.3% (1) cantered away from the helicopter; 0.6% (2) cantered together to take up a group defense formation and 17.7% (54) walked together to form group defense formations. The analysis of the six levels of intensity indicates, however, that of the 43.6% (1748) IRS of muskoxen that responded to helicopter harassment overflights, only 8.6% (150) did so at the first level of intensity. Therefore, we must assume that 96.3% (3861) of the time muskoxen did not respond at the most intense level possible for the responses that they exhibited and 97.4% (3907) of the IRS did not respond as extremely as possible (gallop at some time in stages A, B, C and D).

In total 91.1% (3654) of the IRS of muskoxen were from individuals that were engaged in maintenance activities during stage A of the helicopter harassment overflights. Of those muskox samples, 61.9% (2263) remained engaged in maintenance activities and were never observed to respond to the harassment overflights; 12.8% (468) subsequently responded in stages B and/or C at the moderate level and 78.6% (368) of those muskoxen returned to the maintenance level during stage D; 25.3% (923) subsequently responded in stage B and/or C at the extreme level and 31.1% (287) of them returned to the maintenance level whereas only 1.8% (17) of them returned to the moderate level — alerted but out of group defense formation.

In total 7.6% (305) of the IRS of muskoxen were from individuals that responded at the moderate level in stage A of the helicopter harassment overflights. Of those muskox samples, 55.7% (170) subsequently responded in stages B and/or C at the extreme level, only 0.7% (1) of those ones returned to the moderate level and 2.4% (4) lessened their responses to the maintenance level in stage D of the overflights; 38.4% (117) remained at the moderate level throughout the overflights; and 5.9% (18) lessened their responses from the moderate level to the maintenance level in stage D of the overflights.

In total only 1.3% (52) of the IRS of muskoxen were from individuals that responded at the extreme level during stage A of the helicopter harassment overflights. Of those samples, 73.1% (38) remained at the extreme level throughout the overflights, only 1.9% (1) reduced their responses to the moderate level and 25.0% (13) were engaged in maintenance activities during stage D of the overflights.

When the helicopter harassment overflights were completed at the end of stage D, 73.6% (2954) of the muskoxen sampled were engaged in maintenance activities, only 5.4% (216) were still responding at the moderate level and 21.0% (841) were responding at the extreme level. In total, 902 muskox samples from groups of two or more individuals had taken up group defense formations at some time during the harassment overflights. Subsequently, 13.0% (117) of them had left the group defense formations before the harassment overflights were completed.

Only 21.0% (841) of the muskoxen sampled were still responding at the extreme level at the end of stage D. We suggest, therefore, that those muskoxen would be most seriously affected by helicopter harassment. Unlike Peary caribou, there was no strong relationship between the percentage of muskoxen still responding at the extreme level at the end of stage D of the overflights and lower altitudes — only 39.7% (334) during passes at <200 m agl.

7. Peary caribou, helicopter landings

In 1976, we obtained 91 IRS during 14 landings (Miller and Gunn 1977b). The responses to the touchdowns were 26.4% at the extreme level, 46.1% at the moderate level and 27.5% at the maintenance level. As our activities after the touchdown varied with each group, and the sample size was small, we have not analysed the results further. Our impressions were that after landings the caribou responded more to our activities on the ground than to the presence of the helicopter.

In 1977, we made 116 landings near Peary caribou and classified those landings into three types depending on our activity subsequent to the actual landing (touchdown) and prior to the take-off. As the approaches, touchdowns and take-offs were similar for the three types of landings, we have not separated the results for those phases. In 1976, we did not classify the landings into these three types, and as we recorded the responses without division by phase, we have not included them in the analyses.

The 116 landings involved a varying number of IRS for each phase (first seen, maximum approach, touchdown and shutdown) as Peary caribou were sometimes moving in or out of our sight depending on the terrain where we had touched down. We chose the IRS recorded during approach as our sample size for the distributions by variables and responses as that phase was the first phase during which caribou responded. We recorded 736 IRS at the touchdown compared to 764 IRS for first seen on approach and 456 IRS for last seen after the helicopter took off (Table 52).

There was a significant difference in the distribution of response levels between the phases preceding and including shutdown ($\chi^2 = 988.49$, 6 df, $P < 0.005$). As, however, the high percentage of Peary caribou not responding to the approaching helicopter (initial phase) may have masked differences among the other three phases, we excluded it. The difference among response level distributions by maximum approach, landing, and shutdown remained significant ($\chi^2 = 14.36$, 4 df, $P < 0.01$).

During the initial phase 96.3% of the IRS were from Peary caribou that were not apparently responding to the harassing stimuli, 1.5% of the IRS were from Peary caribou responding at the moderate level and 2.2% at the extreme level. The maximum responses at the extreme level were as expected during the approach (O/E = 1.00), more frequent than expected during the touchdown (O/E = 1.13) and less frequent than expected during shutdown (O/E = 0.82). The distributions of MAIRS followed a reverse trend and emphasized the touchdown phase as the phase that elicited the most overt responses. MAIRS occurred more often than expected during maximum approach (O/E = 1.06) and shutdown (O/E = 1.08) and less often than expected during the touchdown (O/E = 0.87). MLIRS were observed less often than expected during maximum approach (O/E = 0.96) and slightly more often than expected during both touchdown and shutdown (O/E = 1.01 and 1.05, respectively).

The observed pattern of responses supported our empirical impressions, if the caribou did not leave the immediate vicinity as the helicopter landed, they would usually remain alerted as the helicopter wound down. Our activities around the helicopter after touchdown determined the responses of the caribou.

Table 52
Distribution of individual response samples by landing phases during helicopter landings and take-offs near Peary caribou during the helicopter harassment study, Prince of Wales Island, NWT, 1977

Landing phase	Level of response		
	Maint.	Mod.	Ext.
First seen	736	11	17
Approach	246	325	194
Touchdown	195	330	211
Shutdown	175	249	112
Power-on	145	165	40
Take-off	125	204	123
Last seen	203	171	82

The attention of the caribou was again focused on the helicopter when we returned to it and the power was increased or switched on. After 1–2 min, the helicopter took off and we tried to avoid flying toward the caribou unless forced to do so by the wind conditions. The distributions of response levels differed significantly during the three take-off phases ($\chi^2 = 49.77$, 4 df, $P < 0.005$). ELIRS were observed less often than expected during both power-on (O/E = 0.59) and when the caribou were last visible (O/E = 0.92), but more often than expected (O/E = 1.40) during take-off. MAIRS followed a reverse pattern to ELIRS as MAIRS were observed less frequently than expected during take-off (O/E = 0.74) and more frequently than expected during power-on (O/E = 1.10) and during the last sighting (O/E = 1.18). MLIRS occurred at a slightly greater rate than expected during power-on and take-off (O/E = 1.10 and 1.05, respectively) and less often than expected during the last sighting (O/E = 0.87).

As with the landing phases, the observed pattern of response levels during take-off phases also supports our impressions from the field. Caribou in the immediate vicinity of the helicopter tended to respond at the moderate level to the changes in sound of the helicopter (power-on or shutdown), but at more extreme levels when the helicopter was moving.

There was a strong significant relationship between response levels and the distance of the helicopter from the Peary caribou ($\chi^2 = 235.26$, 6 df, $P < 0.005$) at touchdown. During landings that were <200 m and 201–500 m from the caribou ELIRS occurred more often than expected (O/E = 1.25 and 1.02, respectively) as did MLIRS (O/E = 1.15 and 1.29, respectively). MAIRS occurred less frequently than expected (O/E = 0.47 and 0.49) during landings at <200 m and within 201–500 m from the caribou. Both ELIRS and MLIRS occurred less frequently than expected during landings >501 m away from the caribou (O/E = 1.02 and 1.29, respectively) and MAIRS were more frequent than expected during landings that occurred at those greater distances (>500 m) from the caribou (O/E = 2.64).

We also found a significant difference between response levels and the distance of the helicopter from the Peary caribou at the time of take-off ($\chi^2 = 42.72$, 6 df, $P < 0.005$). The relationship, however, was not as clear as at touchdown, but this may be partly a reflection of the caribou's responses to our activities prior to take-off. The O/E ratios for take-offs at <200 m and between 501–1000 m were as follows: O/E = 1.59 and 1.52 for ELIRS, O/E = 0.88 and 0.84 for MLIRS and O/E = 0.62 and 0.76 for MAIRS. The O/E indices suggested that caribou were less responsive during take-offs between 201–500 m distant as MLIRS and MAIRS occurred with greater than expected frequency (O/E = 1.12 and 1.24) and ELIRS occurred less frequently than expected (O/E = 0.56). We speculate that the Peary caribou at >501 m were more responsive during take-offs than caribou that were between 201–500 m because mostly the former had already responded to the helicopter, and the observers during earlier phases of the landing, by moving away, and were thus perhaps at a lower threshold of responsiveness.

We encountered problems in attempting to standardize the procedures for our landings. Weather conditions, especially cloud ceiling, and terrain caused us to vary the altitudes (m agl) of the helicopter approaches. In addition, wind conditions and topography frequently determined the location of a landing relative to the caribou. Rolling terrain such as beach ridges often caused us to lose sight of the caribou during or after the landing. Finally, wind and terrain frequently determined our immediate flight path after take-off and on occasion we were forced to fly towards the caribou, but we were always able to avoid flying within about 100 m of them. We attempted to record the resultant variations during phases of the landings, but it is probable that small sample sizes will preclude analyses of the effects of such variations.

Another problem with interpretation of the IRS is the bias introduced by the few observations of animals that moved out of sight and so their responses during later phases of the landings could not be observed. The observations of the later phases of landings may have been of Peary caribou that had apparently, in a limited sense, "accepted" the presence of the helicopter.

7.1. Peary caribou, simulated amateur photography parties

We designated 39 landings near Peary caribou as simulations of amateur photography when the Peary caribou remained in the immediate vicinity of the helicopter after it had touched down. We walked slowly toward the caribou and attempted to remain about 50–200 m away from them. Of the 975 IRS recorded between 2 and 24 min after touchdown, 59.1% were recorded when the observers were within 200 m of the caribou, compared to 24.9% of the IRS within 200 m of the observers during the simulated work parties.

We generally returned to the helicopter after 8 min but we also continued to record caribou behaviour for up to 24 min after shutdown. At 2 min after shutdown, we recorded 198 IRS, but at 8 min after shutdown only 156 IRS were observed because some of the Peary caribou moved out of sight. We recorded 76.2% (743/975) of the IRS from 2 to 8 min after shutdown and the remaining 23.8% (232) from 10 to 24 min. Based on the total IRS observed from 2 to 24 min after shutdown, 18.8% (183/975) were ELIRS, 35.2% (343) were MLIRS and 46.0% (449) were MAIRS. The relative distributions of response levels at 2 min and 8 min after shutdown were significantly different ($\chi^2 = 21.42$, 1 df, $P < 0.005$). At 2 min after shutdown, which was the first 2 min of our activity on the ground, ELIRS occurred at a lower frequency than expected (O/E = 0.53) compared to the slightly greater than expected frequencies of MLIRS and MAIRS (O/E = 1.04 and 1.07, respectively). Response levels increased during the subsequent 6 min of ground activity and ELIRS were observed more often than expected (O/E = 1.62) 8 min after shutdown, whereas, both MLIRS and MAIRS were observed less frequently than expected (O/E = 0.83 and 0.91, respectively).

There was a direct relationship between time elapsed (between 2 and 18 min after shutdown) and the distance between the observers and the Peary caribou. The percentage of IRS in the distance class <200 m increased with 2-min intervals from 48.0% (95/198) at 2 min after shutdown to

100% (24) at 14 min after shutdown. At 20 min after shutdown 57.0% (8/14) of the IRS were at <200 m and at 22 and 24 min after shutdown 50.0% (6/12) and 100% (6/6) respectively of the IRS were at >200 m.

We found a significant difference between response levels when the observers were < and >200 m from the Peary caribou between 2 and 18 min after shutdown (χ^2 = 25.98, 2 df, $P<0.005$). ELIRS for < and >200 m distance classes occurred at slightly greater and lesser frequencies than expected (O/E = 1.04 and 0.97, respectively). MLIRS occurred more frequently than expected when the observers were within 200 m of the caribou (O/E = 1.18) whereas MAIRS (O/E = 0.87) were observed less often than expected at this distance. At >200 m MLIRS were observed less frequently than expected (O/E = 0.75) and MAIRS were observed more often than expected (O/E = 1.18).

It seems probable, therefore, that the increase in response levels during the simulations of amateur photography were, at least in part, related to the distances between observers and animals. During 22 of the 39 landings, we walked directly toward the Peary caribou, though if they trotted or galloped away, we did not follow. Our activity was probably the cause of the direct relationship between time, distance and response levels.

7.2. Peary caribou, simulated work parties

The simulation of work parties was distinguished from other types of landings by our remaining within 50 m of the helicopter and not directly approaching the Peary caribou. We made 55 such simulations and have included the landing and take-off phases in section 7. We generally returned to the helicopter 8 min after the helicopter had shutdown but we continued to observe the Peary caribou for up to 18 min.

We recorded 284 IRS at 2 min after shutdown and and 174 IRS at 8 min as some Peary caribou moved out of sight. At 2-min intervals between 10 and 18 min after shutdown, we recorded a total of 996 IRS. Of the total IRS for all 2-min intervals from 2 to 18 min after shutdown 22.2% (221/996) were ELIRS, 35.9% (358) were MLIRS and 41.9% (417) were MAIRS.

The distributions of response levels at 2 min and 8 min after shutdown were significantly different (χ^2 = 143.01, 1 df, $P<0.005$). After 2 min of our activity, (two or three observers walking and talking) around the helicopter, both ELIRS and MLIRS occurred at greater than expected rates (O/E = 1.49 and 1.25 respectively) and MAIRS were observed at less than expected rates (O/E = 0.45). Response levels of the Peary caribou that remained in the vicinity of the helicopter had decreased at 8 min after landing. Fewer ELIRS and MLIRS than expected were observed (O/E = 0.19 and 0.59) and more MAIRS than expected (O/E = 1.89).

During the period of simulated work party activity, 35 IRS involved the Peary caribou approaching the ground observers and helicopter. We differentiated between Peary caribou that moved around the helicopter to take our wind from the 35 Peary caribou that approached within 50–100 m of us. Those 35 IRS were dominated by sub-adults (5 bulls and 9 cows, compared to 3 juveniles, 9 yearlings and 9 calves) and the approach appeared to be investigative behaviour.

7.3. Peary caribou, observer pick-ups

The difficulties our observers experienced in maintaining contact with Peary caribou are reflected in the relatively small number (22) of observations during pick-up landings. The 78 IRS were divided between the 201–500 m distance class (47.4%) and >501 m class (52.6%).

A total of 78 IRS were observed between 2 and 6 min after touchdown of the helicopter. As the landings involved only the return of ground observers to the helicopter, most of the IRS (62) occurred at 2 min and only 8 IRS were recorded at both 4 and 6 min after touchdown.

The response levels were dominated by 76.9% MAIRS. There were no ELIRS and 23.1% of the IRS were MLIRS. The sample sizes were too small to compare response levels by distance or time.

8. Muskoxen, helicopter landings

In 1976, we made two landings near solitary muskox bulls, two landings near single sex groups of bulls and 10 landings near mixed sex groups (Miller and Gunn 1977a). Our impressions were that the responses of muskoxen to overflights increased during a subsequent landing, especially if the landing was visible to the muskoxen. Landing without a preceding flight and out of sight of the animals elicited the least response. The only landing without a preceding flight and within sight of the animals caused an extreme response. Our activities on the ground increased the levels of response and usually caused animals that had taken group defence formations to gallop or walk away. We also had the impression that there was consistency in the levels of response by the same group exposed to more than one landing under similar conditions.

We made 69 landings near muskoxen in 1977 that we classified into three types depending on our activity between the actual landing (touchdown) and the take-off. As the approaches, landings and take-offs were similar for the three types of landings we have not separated the analyses of those phases.

The 69 landings near muskoxen involved a varying number of IRS for each phase (initially seen, maximum approach, touchdown, shutdown) as muskoxen were sometimes moving in and out of our sight depending on the terrain (Table 53). The sample size was largest (1238) when the muskoxen initially came into view and decreased to 1228 during the maximum approach phase, 1192 at touchdown and 725 at shutdown. During the three departure phases the sample size had decreased as muskoxen had moved out of our sight. During the power-on phase, we recorded 569 that increased to 625 during the take-off phase and 590 when we last saw the animals.

There was a significant difference in the frequency of response levels relative to the phase of the landing preceding and including shutdown (χ^2 = 1514.55, 6 df, $P<0.005$). As there was a high percentage of muskoxen that were not responding when initially observed (91.8%), the differences among the other three phases may have been masked. When we exclude the IRS of the initial phase, the test of independence remained significant (χ^2 = 346.95, 4 df, $P<0.005$).

During the initial phase only 5.2% of the muskoxen were already responding at the extreme level and 3.1% at the moderate level. Extreme responses were observed more often than expected during the approach phase (O/E = 1.71) but less often than expected during touchdown and shutdown phases (O/E = 0.64 and 0.38, respectively). Moderate level responses were observed less frequently than expected during the approach phase (O/E = 0.63) but there were more MLIRS than expected during touchdown and shutdown (O/E = 1.13 and 1.41, respectively). The frequencies of MAIRS did not vary as much from the expected frequencies during the three phases; more MAIRS than

Table 53
Distribution of individual response samples by landing phases during helicopter landings and take-offs near muskoxen during the helicopter harassment study, Prince of Wales Island, NWT, 1977

	Level of response		
Landing phases	Maint.	Mod.	Ext.
First seen	1136	38	64
Approach	486	339	403
Touchdown	460	585	147
Shutdown	225	447	53
Power-on	242	164	163
Take-off	201	319	105
Last seen	224	341	25

expected were observed during maximum approach (O/E = 1.06) and touchdown (O/E = 1.03) and fewer MAIRS than expected were observed during shutdown (O/E = 0.83). The O/E indices indicate that more extreme responses by muskoxen occurred during the approach of the helicopter than during the other phases. Once the helicopter had touched down, more muskoxen responded at the moderate level and fewer muskoxen foraged or bedded.

After our ground activity, we returned to the helicopter and the engine was restarted, or the power was increased if it had been idling. After 1 to 2 min, we took off and flew away from the muskoxen, if wind conditions permitted. The differences between response levels relative to these three phases (power-on, take-off and last seen) were significant (χ^2 = 173.02, 4 df, $P<0.005$). The greatest contribution by ELIRS was during the power-on phase (O/E = 1.74). ELIRS were observed slightly more often than expected during take-off (O/E = 1.02) and less often than expected when the animals were last within sight (O/E = 0.25). The contributions of MLIRS increased during the three departure phases from fewer than expected during power-on (O/E = 0.62) to more than expected during take-off (O/E = 1.11) and when the animals were last observed (O/E = 1.25). Observations of maintenance activities were more common than expected during power-on (O/E = 1.14) and when the animals were last observed (O/E = 1.02) but less common than expected during take-off (O/E = 0.86). These indices suggest that the muskoxen responded most frequently at the extreme level when the helicopter power was increased or switched on, but muskoxen also responded more extremely than expected during take-off.

Sample distributions limit comparison of responses at touchdown to only two distance classes, < and >500 m. We found a significant difference between response levels and the distance that the helicopter landed from the muskoxen (χ^2 = 116.52, 2 df, $P<0.005$). Both ELIRS and MLIRS were observed more often than expected during touchdowns within 500 m of the muskoxen (O/E = 1.27 and 1.16, respectively) and less often than expected during more distant touchdowns (O/E = 0.29 and 0.59, respectively). Maintenance activities were observed less frequently than expected (O/E = 0.71) during touchdowns within 500 m of the muskoxen and more often than expected (O/E = 1.75) during more distant landings.

Although we found a direct relation between response and the distance of the helicopter from the muskoxen during touchdowns, there was no significant relationship during take-offs (χ^2 = 5.75, 2 df, $P>0.05$) and the trend suggested by O/E indices was the reverse of that found during touchdowns. The distributions by ELIRS suggest that muskoxen responded more to take-offs >500 m from them (O/E = 1.27) than to take-offs <500 m away (O/E = 0.88). Moderate level responses were observed as often as expected (at <500 m, O/E = 1.00; at >500 m, O/E = 1.01). Muskoxen were observed foraging or bedded more often during take-offs within 500 m (O/E = 1.07) than during take-offs further away (O/E = 0.84). We speculate that muskoxen responded more at the extreme level during take-offs relatively far away (>500 m) from them, because they had already responded to activities preceding the take-off by moving away. Muskoxen that were closer to the helicopter (<500 m) had not responded by moving away during preceding activities and were possibly at a lower level of responsiveness before the take-off. We have already described in section 7 of the Results the bias introduced by the differences between animals that did or did not move away during the early phases of the helicopter landing and its effect on the interpretation of responses to later phases of take-offs.

8.1. Muskoxen, simulated amateur photography parties

We designated 14 landings as simulations of amateur photography. We only made these simulations when the muskoxen remained in the immediate vicinity of the helicopter after it had touched down. Of the 1982 IRS recorded between 2 and 30 min after touchdown of the simulations of amateur photography, 72.5% were recorded when the muskoxen were 201–500 m from the observers.

Although we usually returned to the helicopter after 8 min, we continued to record muskox behaviour for up to 30 min after shutdown. At 2 min after shutdown, we recorded 249 IRS compared to 246 IRS after 8 min and 42 IRS after 30 min. Of the total IRS observed from 2–30 min after shutdown, 17.2% (340/1982) were extreme responses, 32.7% (649) were moderate responses and 50.1% (993) were maintenance activities.

The distributions of response levels at 2 min and 8 min after shutdown were significantly different (χ^2 = 50.06, 2 df, $P<0.005$). The O/E indices indicate a decrease in responses during our activity on the ground, since extreme responses were observed more often than expected (O/E = 1.12) at 2 min after shutdown and less often than expected (O/E = 0.88) at 8 min after shutdown. Moderate level responses followed the same trend with O/E = 1.27 and 0.72 for 2 and 8 min after shutdown, respectively. Maintenance activities were less frequent than expected (O/E = 0.58) at 2 min after shutdown and more frequent than expected (O/E = 1.43) at 8 min after shutdown.

Although there was a trend toward a decrease in response with time, there was no direct relationship between time and distance. Of the IRS obtained at 2 min after shutdown, 16.1% (40/249) were in the 51–200 m class, 83.1% (207) were in the 201–500 m class and 0.8% (2) were in the 501–1000 m class of distance between muskoxen and observers. At 8 min after shutdown 19.1% (47/246) of the IRS were in the 51–200 m class, 75.2% (185) were in the 201–500 m class, and 5.7% (14) were in the 501–1000 m class. Thus it does not seem that the decrease in responsiveness during our ground activities was related to changes in the distance between observers and animals.

8.2. Muskoxen, simulated work parties

We designated 12 landings as simulations of work parties. We only made these simulations when the muskoxen remained in the immediate vicinity of the helicopter after it had landed. Of the total 646 IRS recorded between 2 and 30 min after touchdown of simulations of work parties, 26.3% were recorded when the muskoxen were 201–500 m from the observers and 51.1% were recorded when the animals were between 501–1000 m from the observers.

We recorded a similar number of IRS at 2 min (121) and at 8 min (120) after shutdown. At 16 min after shutdown,

we observed 25 IRS and after 30 min, only seven IRS were observed. Of the 646 IRS observed between 2 and 30 min after shutdown, 3.4% (22/646) were ELIRS, 43.8% (283) were MLIRS and 52.8% (341) were MAIRS.

The distributions of response levels at 2 min and 8 min after shutdown were not significantly different ($\chi^2 = 3.19$, 1 df, $P > 0.05$). Extreme responses were observed too infrequently to allow a separate analysis and they have been combined with moderate responses. The O/E indices suggest that response levels decreased with time following shutdown. ELIRS and MLIRS were together observed more often than expected (O/E = 1.14) 2 min after shutdown and less often than expected (O/E = 0.86) 8 min after shutdown.

As we were not walking toward the muskoxen and only one of 23 muskoxen walked away from us, there was no relationship between time and the distance between muskoxen and observers. Thus the trend toward decreasing response levels was not a reflection of increasing distance with time.

8.3. Muskoxen, observer pick-ups

Most of the observer pick-ups were brief and the muskoxen were only observed until the helicopter touched down. During 43 landings to change observers, it was possible to observe the muskoxen after the shutdown from 2 to 16 min. At 2 min after shutdown, we obtained 151 IRS which had decreased to 56 IRS after 8 min and 12 IRS after 16 min.

There was a significant difference in the response levels at 2 and 8 min after shutdown ($\chi^2 = 32.79$, 2 df, $P < 0.005$). The O/E indices indicate an increase in responsiveness with time as ELIRS and MLIRS were observed at greater than expected frequencies at 8 min after shutdown (O/E = 1.85 and 1.57, respectively). It is probable, however, that the clumped distribution of IRS (by herds) distorts the analysis as three of the cells include IRS from only one group.

8.4. Muskox defense formations, helicopter landings

Muskoxen moved together to take up group defense formations and one solitary bull moved to a defense position during 33 landings. Only twice did muskoxen coming together not result in a group defense formation and on both of those occasions only a few of the herd members had moved together. Muskoxen usually took up group defense formations during the approach and touchdown of the helicopter (29 landings) compared to only three occasions during observer activities on the ground and once during a take-off.

Only one herd was already responding by moving together when first observed during the helicopter approach and they subsequently took up a group defense formation. Of the 22 herds that moved together during the maximum approach phase, 17 took up group defense formations during the maximum approach phase, and four herds reached group defense formations during touchdown. One herd that moved together during the maximum approach phase was out of sight during the landing and shutdown phases, but was in a group defense formation when the observers sighted them 2 min after shutdown.

During the touchdown phase we observed 22 group defense formations and one herd moving together that did not reach a defense formation. Of these 22 defense formations, 14 had been formed during the approach phase, four were forming during the approach phase and finally came together during touchdown and four were groups that moved toward each other and formed up during touchdown. As the helicopter touched down, we lost sight of two group defense formations but the two bulls in one herd that had walked together were already separating when they were last sighted.

Of the 10 group defense formations taken up during landings for simulation of amateur photographers only one herd remained grouped in place. Five herds began to forage and move apart between 2 and 8 min after shutdown when the observers were 200–400 m away. Our approach toward two herds resulted in them returning to group defense formations and agonistic behaviour of the herd bull caused a third herd to take up a defense formation. Although foraging, the muskoxen were also walking away from the observers and in addition, four herds cantered and walked away from us. When the helicopter started up, three of the herds that had separated re-assumed defense formations. There were three muskox herds that did not form defense formations during the landing or take-off phases but did so for 2–4 min when approached within 100 m by observers.

We have only three observations of the subsequent behaviour of muskoxen in group defense formations when the observers did not approach the animals during observer activity on the ground (simulated work parties). A herd of 22 muskoxen that had been in a group defense formation during the approach and touchdown walked away from the observers but resumed a group defense formation when the helicopter increased power and took off. A second herd of 14 moskoxen remained grouped during the helicopter landing 600 m away until the helicopter took off, then they broke into a gallop. The third muskox herd started to forage and drift apart 4 min after the helicopter shutdown though agonistic behaviour by the herd bull caused the herd to regroup briefly.

The observations recorded during observer pick-up and placement mainly ended when the observers returned to the helicopter. We recorded the responses to six take-offs after group formation during the landing phases. One defense formation remained in place, individuals in a second formation broke into a gallop and individuals in two additional formations began foraging. One muskox herd that had not taken up a defense formation during the landing phases did so during the take-off.

In summary, there was considerable variation among herds that took up group defense formations during landings. We believe that some of that variation was a unique attribute of individual herds and not related to the factors of the landing such as the distance between the muskoxen and helicopter. We also noted that relatively few herds remained in place in a group defense formation. The animals either drifted apart and foraged or moved away, usually at a canter punctuated by brief walks. The tendency not to hold a defense formation, unless the observers were within 50 m, may reflect a threshold situation in which the harassing stimuli that initially caused the individuals to form a defense formation have waned to a point that allows them to return to an alerted maintenance routine. Alternatively, the harassing stimuli may cause vascillations between response levels that result in a series of displacements and regroupings when there is sufficient distance (apparently < 50 m) between the harassing agent and the muskoxen. Social tensions inherent in close groupings may at times play a part in stimulating individuals that are still alerted to the harassing stimuli to disperse from the group defense formations and/or displace themselves and regroup.

9. Maximum group response samples

In the light of our limited knowledge of the impact of aerial harassments of Peary caribou and muskoxen, the most extreme response of any individual within a group could be used as a standard measure of the effect of harassment. We term such a measure the maximum group response sample (GRS). When the maximum responses of all members of a group are uniform, the GRS are equivalent to the IRS, but when the maximum responses of individuals within a group are mixed the maximum GRS would be an extreme measure of the group's maximum response to a given level of harassment. The precision of the maximum GRS would depend on the proportion of the group that responded at the maximum level.

Over the long term, all individuals within a group have the potential for realizing the maximum response experienced by any other individual in the group. Therefore, the GRS is probably a valid, although somewhat inflated measure, which could be applied in a stringent evaluation of the maximal impact of aircraft harassment.

Sample distributions of GRS by altitude and variable classes obtained during helicopter harassment overflights are given for Peary caribou in Table 54 and muskoxen in Table 55. Maximum GRS by altitude and variable classes are given for Peary caribou, single and first passes (Table 56) and subsequent passes (Table 57); and for muskoxen, single and first passes (Table 58) and subsequent passes (Table 59).

9.1. Peary caribou, GRS

A comparison of GRS and IRS from Peary caribou implies the following:

a) At least one individual in each group responded at the extreme level (GRS) during 49.5% of the overflights whereas only 35.1% of the IRS were at this level;

b) At least one individual in each group responded at the moderate level during 40.1% of the overflights whereas only 28.9% of the IRS actually responded at this level; and

c) All individuals in each group did not respond during 10.4% of the overflights whereas 36.0% of the IRS remained engaged in maintenance activities.

If the GRS was used as a measure of the impact of helicopter harassment the extreme level GRS (ELGRS) would exceed the corresponding ELIRS by 41.0% (1 to 1.410). If the detrimental effects of helicopter harassment are greater than we could ascertain by the observed overt mixed responses of all individuals (IRS), perhaps the measure given by GRS is a good indicator of the true potential or actual impact to the group as a whole.

A comparison of the three levels of GRS of Peary caribou obtained during 671 helicopter harassment overflights relative to the five altitude classes (Table 60) gave a significant difference ($\chi^2 = 74.03$, 8 df, $P < 0.005$). O/E indices for the above test indicate that at the extreme level of GRS, groups were more responsive than expected during overflights at < 100 m agl, about as responsive as expected during passes at 101–200 m agl and less responsive than expected during passes at > 200 m agl (Table 60). The reverse pattern was obtained for moderate level GRS (Table 60).

A test of independence between maximum uniform group responses, maximum mixed group responses involving > 50.0% of the group members and maximum mixed group responses involving ≤ 50.0% of the group members gave a significant difference ($\chi^2 = 32.39$, 2 df, $P < 0.005$). O/E indices for the above test indicate that (*a*) uniform group responses were more frequent than expected (O/E = 1.21)

Table 54
Sample distribution of Peary caribou group response samples, by altitude class (metres above ground level), obtained for variable classes during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Flight types and variable classes	Altitude classes, m agl				
	1–50	51–100	101–200	201–300	301–400
Single passes and first passes of multi-passes (n = 413)					
Group size					
Solitary	2	21	42	0	0
Cow–calf	2	6	9	1	0
2–5	24	72	112	7	1
6–9	13	22	26	13	0
10–19	1	12	8	12	0
20–27	1	2	2	1	1
Group type					
Bull	15	44	39	5	1
Bull–cow–juv–yr–calf	1	4	2	5	0
Bull–juv–yr	7	12	19	9	0
Juv–yr	3	8	2	1	0
Cow–juv–yr–calf	4	14	15	4	0
Cow–calf	11	26	53	9	1
Cow–juv–yr	2	27	69	1	0
No. calves					
0	27	92	130	16	1
1	9	15	30	2	0
2	6	15	23	2	0
3	0	8	11	3	0
4	0	2	4	6	0
5	0	1	0	2	0
6	0	0	1	1	0
7	0	0	0	1	0
8	1	2	0	0	0
9	0	0	0	1	0
12	0	0	0	0	1
Season					
24 June – 15 July	0	48	141	20	1
16 July – 7 August	41	83	56	4	0
8–24 August	2	4	2	10	1
Wind					
HIW (into)	19	52	74	11	1
HWW (with)	7	36	29	10	0
HGS (> 60°)	17	47	96	13	0
HNW (calm)	0	0	0	0	1
Sun					
SHA (back)	12	41	85	15	1
SAH (front)	9	59	81	14	0
SNV (obscured)	22	35	33	5	1
Terrain					
Flats	25	53	65	6	0
Slopes	16	60	63	20	1
Ridges	0	14	61	8	1
Plateaus	0	2	7	0	0
Barriers	2	6	3	0	0
Passes subsequent to first passes of multi-passes (n = 258)					
Group size					
Solitary	9	14	6	0	0
2–5	12	22	18	24	1
6–9	5	4	3	71	0
10–19	0	3	0	55	0
20–27	0	1	0	5	5
Group type					
Bull	18	31	19	25	1
Bull–cow–juv–yr–calf	0	1	0	27	0
Bull–juv–yr	8	8	4	45	0
Juv–yr	0	0	0	5	0
Cow–juv–yr–calf	0	2	1	20	0
Cow–calf	0	1	2	33	5
Cow–juv–yr	0	1	1	0	0
No. calves					
0	26	40	24	75	1
1	0	0	0	7	0
2	0	0	1	0	0
3	0	1	1	16	0
4	0	0	1	34	0
5	0	2	0	10	0
6	0	0	0	5	0
7	0	0	0	3	0
8	0	1	0	0	0
9	0	0	0	5	0
12	0	0	0	0	5
Season					
24 June – 15 July	15	22	13	91	5
16 July – 7 August	1	6	2	14	0
8–24 August	10	16	12	50	1

Table 54 (cont'd)

Flight types and variable classes	Altitude classes, m agl				
	1–50	51–100	101–200	201–300	301–400
Wind					
HIW (into)	9	12	7	45	0
HWW (with)	9	12	12	52	1
HGS (>60°)	8	20	8	57	0
HNW (calm)	0	0	0	1	5
Sun					
SHA (back)	10	20	6	60	0
SAH (front)	11	13	14	57	1
SNV (obscured)	5	11	7	38	5
Terrain					
Flats	13	22	15	28	0
Slopes	5	10	1	85	5
Ridges	5	12	11	42	1
Plateaus	3	0	0	0	0

Table 55
Sample distribution of muskox group response samples, by altitude class (metres above ground level) and variable classes, during helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77

Flight types and variable classes	Altitude classes, m agl				
	1–50	51–100	101–200	201–300	301–400
Single passes and first passes of multi-passes (n = 97)					
Group size					
Solitary bull	15	10	5	0	1
Bull pair	1	4	1	1	2
Bulls, 3+	3	1	1	0	1
Mixed sex, 2–5	0	1	0	0	0
Mixed sex, 6–9	2	1	1	2	3
Mixed sex, 10–19	0	2	6	15	5
Mixed sex, 20–29	0	0	0	9	3
Mixed sex, 40+	0	0	0	1	0
Group type					
Solitary bull	15	10	5	0	1
Single sex	4	5	2	1	3
Mixed sex	2	4	7	27	11
No. calves					
0	19	15	7	1	4
1	2	2	3	2	2
2	0	0	0	8	5
3	0	0	2	2	1
4	0	1	2	1	0
5	0	1	0	3	0
6	0	0	0	1	0
8	0	0	0	9	3
18	0	0	0	1	0
Season					
1–23 June	0	0	0	9	4
24 June – 15 July	0	2	0	7	1
16 July – 7 August	19	11	11	6	10
8–24 August	2	6	3	6	0
Wind					
HIW (into)	12	6	6	12	4
HWW (with)	3	7	3	8	5
HGS (>60°)	6	6	5	6	6
HNW (calm)	0	0	0	2	0
Sun					
SHA (back)	2	3	4	11	7
SAH (front)	8	6	5	10	4
SNV (obscured)	11	10	5	7	4
Terrain					
Flats	14	16	12	17	10
Slopes	6	1	2	10	4
Ridges	1	0	0	1	1
Plateaus	0	2	0	0	0
Passes subsequent to first passes of multi-passes (n = 218)					
Group size					
Solitary bull	0	1	0	0	5
Bull pair	7	4	6	12	1
Bulls, 3+	0	0	0	5	0
Mixed sex, 2–5	0	2	0	0	0
Mixed sex, 6–9	3	2	4	7	9
Mixed sex, 10–19	0	0	8	52	22
Mixed sex, 20–29	0	0	0	50	13
Mixed sex, 40+	0	0	0	5	0
Group type					
Solitary bull	0	1	0	0	5
Single sex	7	4	6	17	1
Mixed sex	3	4	12	114	44
No. calves					
0	7	5	6	17	6
1	3	4	4	7	8
2	0	0	5	33	19
4	0	0	3	3	0
5	0	0	0	11	4
6	0	0	0	5	0
8	0	0	0	50	13
18	0	0	0	5	0
Season					
1–23 June	0	0	5	44	17
24 June – 15 July	0	2	0	35	5
16 July – 7 August	7	4	9	20	28
8–24 August	3	3	4	32	0
Wind					
HIW (into)	2	2	3	41	20
HWW (with)	2	3	4	44	12
HGS (>60°)	6	4	11	36	18
HNW (calm)	0	0	0	10	0
Sun					
SHA (back)	3	2	6	47	24
SAH (front)	1	3	6	50	21
SNV (obscured)	6	4	6	34	5
Terrain					
Flats	9	7	14	71	38
Slopes	1	0	2	51	8
Ridges	0	0	2	9	4
Plateaus	0	2	0	0	0

Table 56
Distribution of maximum group response samples of Peary caribou, by altitude class (metres above ground level) and variable classes, during single and first passes of multi-pass helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 413)

Variable classes by altitude, m agl	Level of response					
	Maint.		Moderate		Extreme	
	Bed	For.	Alert	Walk	Trot	Gal.
Total sample						
1–50	0	1	6	0	27	9
51–100	0	4	20	22	60	29
101–200	4	11	40	41	78	25
201–300	0	6	10	6	10	2
301–400	0	0	1	1	0	0
Group size						
Solitary caribou						
1–50	0	0	1	0	0	1
51–100	0	2	6	3	7	3
101–200	1	5	16	7	9	4
Cow–calf pair						
1–50	0	0	0	0	0	2
51–100	0	0	1	2	2	1
101–200	0	0	2	2	4	1
201–300	0	1	0	0	0	0
2–5 caribou						
1–50	0	0	5	0	15	4
51–100	0	2	10	14	28	18
101–200	3	6	21	27	42	13
201–300	0	1	1	3	1	1
301–400	0	0	1	0	0	0
6–9 caribou						
1–50	0	1	0	0	10	2
51–100	0	0	2	2	15	0
101–200	0	0	0	3	18	5
201–300	0	1	6	2	3	1
10–19 caribou						
1–50	0	0	0	0	1	0
51–100	0	0	1	1	7	3
101–200	0	0	1	2	3	2
201–300	0	3	3	0	6	0
20–27 caribou						
1–50	0	0	0	0	1	0
51–100	0	0	0	0	1	1
101–200	0	0	0	0	2	0
201–300	0	0	0	1	0	0
301–400	0	0	0	1	0	0
Group type						
Bull						
1–50	0	0	5	0	6	4
51–100	0	3	10	13	9	9
101–200	2	8	13	7	7	2
201–300	0	1	1	3	0	0
301–400	0	0	1	0	0	0
Bull–cow–juv–yr–calf						
1–50	0	0	0	0	1	0
51–100	0	0	0	0	2	2
101–200	0	0	0	0	1	1
201–300	0	2	1	1	1	0
Bull–juv–yr						
1–50	0	1	1	0	3	2
51–100	0	1	2	1	6	2
101–200	2	0	4	2	9	2
201–300	0	2	5	1	1	0
Juv–yr						
1–50	0	0	0	0	3	0
51–100	0	0	1	0	4	3
101–200	0	0	0	0	0	2
201–300	0	0	1	0	0	0
Cow–juv–yr–calf						
1–50	0	0	0	0	4	0
51–100	0	0	1	0	10	3
101–200	0	0	1	0	9	5
201–300	0	0	0	0	4	0
Cow–calf						
1–50	0	0	0	0	8	3
51–100	0	0	1	4	15	6
101–200	0	0	6	11	32	4
201–300	0	1	2	1	4	1
301–400	0	0	0	1	0	0
Cow–juv–yr						
1–50	0	0	0	0	2	0
51–100	0	0	5	4	14	4
101–200	0	3	16	21	20	9
201–300	0	0	0	0	0	1
No. calves						
Zero calves						
1–50	0	1	6	0	14	6
51–100	0	4	18	18	34	18
101–200	4	11	33	30	37	15
201–300	0	3	7	4	1	1
301–400	0	0	1	0	0	0
One calf						
1–50	0	0	0	0	6	3
51–100	0	0	1	2	5	7
101–200	0	0	5	6	16	3
201–300	0	1	1	0	0	0
Two calves						
1–50	0	0	0	0	6	0
51–100	0	0	0	0	14	1
101–200	0	0	1	3	14	5
201–300	0	0	0	0	2	0
Three calves						
51–100	0	0	0	1	6	1
101–200	0	0	1	2	6	2
201–300	0	1	0	0	2	0
Four calves						
51–100	0	0	0	1	0	1
101–200	0	0	0	0	4	0
201–300	0	1	2	1	1	1
Five calves						
51–100	0	0	1	0	0	0
201–300	0	0	0	0	2	0
Six calves						
101–200	0	0	0	0	1	0
201–300	0	0	0	0	1	0
Seven calves						
201–300	0	0	0	0	1	0
Eight calves						
1–50	0	0	0	0	1	0
51–100	0	0	0	0	1	1
Nine calves						
201–300	0	0	0	1	0	0
Twelve calves						
301–400	0	0	0	1	0	0
Season						
24 June – 15 July						
51–100	0	2	6	11	19	10
101–200	3	8	26	30	57	17
201–300	0	3	6	2	8	1
301–400	0	0	0	1	0	0
16 July – 7 August						
1–50	0	1	5	0	26	9
51–100	0	2	14	11	39	17
101–200	1	3	14	10	20	8
201–300	0	2	1	0	0	1
8–24 August						
1–50	0	0	1	0	1	0
51–100	0	0	0	0	2	2
101–200	0	0	0	1	1	0
201–300	0	1	3	4	2	0
301–400	0	0	1	0	0	0
Wind						
HIW (helicopter flying into wind)						
1–50	0	1	2	0	14	2
51–100	0	1	5	8	24	14
101–200	2	4	15	13	28	12
201–300	0	1	2	5	2	1
301–400	0	0	1	0	0	0
HWW (helicopter flying with wind)						
1–50	0	0	0	0	6	1
51–100	0	2	7	6	14	7
101–200	1	0	4	5	19	0
201–300	0	2	3	1	4	0
HGS (helicopter flying at > 60° to wind)						
1–50	0	0	4	0	7	6
51–100	0	1	8	8	22	8
101–200	1	7	21	23	31	13
201–300	0	3	5	0	4	1
HNW (wind calm)						
301–400	0	0	0	1	0	0
Sun						
SHA (sun–helicopter–animals)						
1–50	0	0	1	0	8	3
51–100	0	1	7	3	21	9
101–200	3	6	16	16	32	12
201–300	0	2	5	3	3	2
301–400	0	0	1	0	0	0
SAH (sun–animals–helicopter)						
1–50	0	0	2	0	4	3
51–100	0	3	10	10	25	11
101–200	1	4	15	15	34	12
201–300	0	3	4	1	6	0
SNV (sun obscured)						
1–50	0	1	3	0	15	3
51–100	0	0	3	9	14	9
101–200	0	1	9	10	12	1
201–300	0	1	1	2	1	0
301–400	0	0	0	1	0	0
Terrain						
Lowland flats						
1–50	0	0	4	0	16	5
51–100	0	2	10	7	21	13
101–200	1	4	19	9	25	7
201–300	0	1	1	3	1	0
Intermediate slopes						
1–50	0	1	2	0	10	3
51–100	0	2	10	10	25	13
101–200	2	2	7	16	21	15
201–300	0	4	5	3	6	2
301–400	0	0	0	1	0	0

Table 56 (cont'd)

Variable classes by altitude, m agl	Level of responce					
	Maint.		Moderate		Extreme	
	Bed	For.	Alert	Walk	Trot	Gal.
Ridges						
51–100	0	0	0	3	10	1
101–200	1	4	14	14	25	3
201–300	0	1	4	0	3	0
301–400	0	0	1	0	0	0
Plateaus						
51–100	0	0	0	1	1	0
101–200	0	1	0	2	4	0
Physical barriers (water on one or more sides)						
1–50	0	0	0	0	1	1
51–100	0	0	0	1	3	2
101–200	0	0	0	0	3	0

Table 57
Distribution of maximum group response samples of Peary caribou, by altitude class (metres above ground level) and variable classes, during passes subsequent to first passes of multi-pass helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 258)

Variable classes by altitude, m agl	Level of response					
	Maint.		Moderate		Extreme	
	Bed	For.	Alert	Walk	Trot	Gal.
Total sample						
1–50	0	0	7	0	14	5
51–100	2	2	17	6	14	3
101–200	2	5	6	6	6	2
201–300	2	31	60	17	33	12
301–400	0	0	1	2	1	2
Group size						
Solitary caribou						
1–50	0	0	2	0	6	1
51–100	0	1	8	2	3	0
101–200	0	1	3	1	1	0
2–5 caribou						
1–50	0	0	5	0	4	3
51–100	2	1	9	2	6	2
101–200	2	4	3	4	4	1
201–300	0	5	14	2	2	1
301–400	0	0	1	0	0	0
6–9 caribou						
1–50	0	0	0	0	4	1
51–100	0	0	0	0	4	0
101–200	0	0	0	1	1	1
201–300	1	7	26	11	20	6
10–19 caribou						
51–100	0	0	0	2	1	0
201–300	1	18	19	3	10	4
20–27 caribou						
51–100	0	0	0	0	0	1
201–300	0	1	1	1	1	1
301–400	0	0	0	2	1	2
Group type						
Bull						
1–50	0	0	5	0	9	4
51–100	1	2	13	4	9	2
101–200	0	5	5	5	4	0
201–300	0	8	16	1	0	0
301–400	0	0	1	0	0	0
Bull–cow–juv–yr–calf						
51–100	0	0	0	1	0	0
201–300	0	8	9	3	4	3
Bull–juv–yr						
1–50	0	0	2	0	5	1
51–100	1	0	4	0	3	0
101–200	2	0	1	1	0	0
201–300	1	10	23	5	4	2
Juv–yr						
201–300	0	1	0	1	2	1
Cow–juv–yr–calf						
51–100	0	0	0	1	1	0
101–200	0	0	0	0	1	0
201–300	1	1	5	2	9	2

Variable classes by altitude, m agl	Level of responce					
	Maint.		Moderate		Extreme	
	Bed	For.	Alert	Walk	Trot	Gal.
Cow–calf						
51–100	0	0	0	0	0	1
101–200	0	0	0	0	0	2
201–300	0	3	7	5	14	4
301–400	0	0	0	2	1	2
Cow–juv–yr						
51–100	0	0	0	0	1	0
101–200	0	0	0	0	1	0
No. calves						
Zero calves						
1–50	0	0	7	0	14	5
51–100	2	2	17	4	13	2
101–200	2	5	6	6	5	0
201–300	1	19	39	7	6	3
301–400	0	0	1	0	0	0
One calf						
201–300	0	1	4	0	2	0
Two calves						
101–200	0	0	0	0	0	1
Three calves						
51–100	0	0	0	1	0	0
101–200	0	0	0	0	1	0
201–300	0	7	5	0	4	0
Four calves						
101–200	0	0	0	0	0	1
201–300	0	2	5	7	14	6
Five calves						
51–100	0	0	0	1	1	0
201–300	1	0	3	2	4	0
Six calves						
201–300	0	1	2	0	2	0
Seven calves						
201–300	0	0	1	0	0	2
Eight calves						
51–100	0	0	0	0	0	1
Nine calves						
201–300	0	1	1	1	1	1
Twelve calves						
301–400	0	0	0	2	1	2
Season						
23 June – 15 July						
1–50	0	0	5	0	8	2
51–100	1	1	12	3	5	0
101–200	2	2	4	2	2	1
201–300	2	17	31	11	22	8
301–400	0	0	0	2	1	2
16 July – 7 August						
1–50	0	0	1	0	0	0
51–100	1	1	0	1	2	1
101–200	0	0	0	0	1	1
201–300	0	0	5	5	2	2
8 – 24 August						
1–50	0	0	1	0	6	3
51–100	0	0	5	2	7	2
101–200	0	3	2	4	3	0
201–300	0	14	24	1	9	2
301–400	0	0	1	0	0	0
Wind						
HIW (helicopter flying into wind)						
1–50	0	0	2	0	5	2
51–100	1	0	5	1	4	1
101–200	0	1	1	4	1	0
201–300	0	7	19	7	10	2
HWW (helicopter flying with wind)						
1–50	0	0	4	0	4	1
51–100	1	0	3	2	4	2
101–200	2	2	3	1	3	1
201–300	1	13	19	6	11	2
301–400	0	0	1	0	0	0
HGS (helicopter flying at > 60° to wind)						
1–50	0	0	1	0	5	2
51–100	0	2	9	3	6	0
101–200	0	2	2	1	2	1
201–300	1	11	22	4	12	7
HNW (wind calm)						
201–300	0	0	0	0	0	1
301–400	0	0	0	2	1	2

Variable classes by altitude, m agl	Level of responce					
	Maint.		Moderate		Extreme	
	Bed	For.	Alert	Walk.	Trot	Gal.
Sun						
SHA (sun–helicopter–animals)						
1–50	0	0	2	0	8	0
51–100	1	1	7	3	6	2
101–200	0	1	1	3	1	0
201–300	1	11	25	8	11	4
SAH (sun–animals–helicopter)						
1–50	0	0	4	0	4	3
51–100	1	0	5	2	4	1
101–200	2	2	4	1	4	1
201–300	1	13	18	6	12	7
301–400	0	0	1	0	0	0
SNV (sun obscured)						
1–50	0	0	1	0	2	2
51–100	0	1	5	1	4	0
101–200	0	2	1	2	1	1
201–300	0	7	17	3	10	1
301–400	0	0	0	2	1	2
Terrain						
Lowland flats						
1–50	0	0	5	0	5	3
51–100	2	0	11	3	4	2
101-200	2	2	4	3	3	1
201–300	1	3	17	3	4	0
Intermediate slopes						
1–50	0	0	0	0	4	1
51–100	0	1	0	3	6	0
101–200	0	0	0	1	0	0
201–300	1	22	21	10	21	10
301–400	0	0	0	2	1	2
Ridges						
1–50	0	0	1	0	4	0
51–100	0	1	6	0	4	1
101–200	0	3	2	2	3	1
201–300	0	6	22	4	8	2
301–400	0	0	1	0	0	0
Plateaus						
1–50	0	0	1	0	1	1

Table 58
Distribution of maximum group response samples of muskoxen, by altitude class (metres above ground level) and variable classes, during single and first passes of multi-pass helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 97)

Variable classes by altitude, m agl	Level of response								
	Maint.		Moderate		Extreme				
	Bed	For.	Alert	Walk	Can.	Gal.	Walk tog.	Can. tog.	Gal. tog.
Total sample									
1–50	0	0	0	4	0	2	3	1	11
51–100	0	0	3	4	0	3	2	0	7
101–200	0	2	0	2	0	3	5	1	1
201–300	0	3	8	3	1	1	6	3	3
301–400	0	1	2	2	1	0	4	3	2
Group size									
Solitary bull									
1–50	0	0	0	4	0	2	1	1	7
51–100	0	0	1	3	0	2	1	0	3
101-200	0	0	0	2	0	3	0	0	0
301–400	0	0	0	0	0	0	0	1	0
Bull pair									
1–50	0	0	0	0	0	0	0	0	1
51–100	0	0	2	0	0	0	0	0	2
101–200	0	0	0	0	0	0	1	0	0
201–300	0	0	1	0	0	0	0	0	0
301–400	0	0	0	1	0	0	1	0	0
Single sex, 3+									
1–50	0	0	0	0	0	0	1	0	2
51–100	0	0	0	1	0	0	0	0	0
101–200	0	0	0	0	0	0	0	0	1
301–400	0	0	0	0	1	0	0	0	0
Mixed sex, 2–5									
51–100	0	0	0	0	0	0	0	0	1

Table 58 (cont'd)

Variable classes by altitude, m agl	Level of response								
	Maint.		Moderate		Extreme				
	Bed	For.	Alert	Walk	Can.	Gal.	Walk tog.	Can. tog.	Gal. tog.
Mixed sex, 6–9									
1–50	0	0	0	0	0	0	1	0	1
51–100	0	0	0	0	0	0	0	0	1
101–200	0	1	0	0	0	0	0	0	0
201–300	0	1	0	0	0	0	1	0	0
301–400	0	0	1	1	0	0	0	0	1
Mixed sex, 10–19									
51–100	0	0	0	0	0	1	1	0	0
101–200	0	1	0	0	0	0	4	1	0
201–300	0	2	4	1	0	1	4	1	2
301–400	0	1	0	0	0	0	3	1	0
Mixed sex, 20–29									
201–300	0	0	3	2	1	0	1	2	0
301–400	0	0	1	0	0	0	0	1	1
Mixed sex, 40+									
201–300	0	0	0	0	0	0	0	0	1
Group type									
Solitary bull									
1–50	0	0	0	4	0	2	1	1	7
51–100	0	0	1	3	0	2	1	0	3
101–200	0	0	0	2	0	3	0	0	0
301–400	0	0	0	0	0	0	0	1	0
Single sex									
1–50	0	0	0	0	0	0	1	0	3
51–100	0	0	2	1	0	0	0	0	2
101–200	0	0	0	0	0	0	1	0	1
201–300	0	0	1	0	0	0	0	0	0
301–400	0	0	0	1	1	0	1	0	0
Mixed sex									
1–50	0	0	0	0	0	0	1	0	1
51–100	0	0	0	0	0	1	1	0	2
101–200	0	2	0	0	0	0	4	1	0
201–300	0	3	7	3	1	1	6	3	3
301–400	0	1	2	1	0	0	3	2	2
No. calves									
Zero calves									
1–50	0	0	0	4	0	2	2	1	10
51–100	0	0	3	4	0	2	1	0	5
101–200	0	0	0	2	0	3	1	0	1
201–300	0	0	1	0	0	0	0	0	0
301–400	0	0	0	1	1	0	1	1	0
One calf									
1–50	0	0	0	0	0	0	1	0	1
51–100	0	0	0	0	0	0	0	0	2
101–200	0	1	0	0	0	0	2	0	0
201–300	0	1	0	0	0	0	1	0	0
301–400	0	0	0	0	0	0	1	0	1
Two calves									
201–300	0	1	4	1	0	0	2	0	0
301–400	0	1	1	1	0	0	1	1	0
Three calves									
101–200	0	0	0	0	0	0	2	0	0
201–300	0	1	0	0	0	0	0	0	1
301–400	0	0	0	0	0	0	1	0	0
Four calves									
51–100	0	0	0	0	0	1	0	0	0
101–200	0	1	0	0	0	0	0	1	0
201–300	0	0	0	0	0	1	0	0	0
Five calves									
51–100	0	0	0	0	0	0	1	0	0
201–300	0	0	0	0	0	0	2	1	0
Six calves									
201–300	0	0	0	0	0	0	0	0	1
Eight calves									
201–300	0	0	3	2	1	0	1	2	0
301–400	0	0	1	0	0	0	0	1	1
Eighteen calves									
201–300	0	0	0	0	0	0	0	0	1

Variable classes by altitude, m agl	Level of response								
	Maint.		Moderate		Extreme				
	Bed	For.	Alert	Walk	Can.	Gal.	Walk tog.	Can. tog.	Gal. tog.
Season									
1–23 June									
201–300	0	0	4	0	0	0	1	2	2
301–400	0	1	0	0	1	0	1	0	1
24 June – 15 July									
51–100	0	0	0	0	0	0	0	0	2
201–300	0	1	3	1	0	0	1	1	0
301–400	0	0	0	0	0	0	0	1	0
6 July – 7 August									
1–50	0	0	0	4	0	2	2	1	10
51–100	0	0	2	3	0	1	2	0	3
101–200	0	2	0	1	0	3	3	1	1
201–300	0	1	0	0	0	0	4	0	1
301–400	0	0	2	2	0	0	3	2	1
8–24 August									
1–50	0	0	0	0	0	0	1	0	1
51–100	0	0	1	1	0	2	0	0	2
101–200	0	0	0	1	0	0	2	0	0
201–300	0	1	1	2	1	1	0	0	0
Wind									
HIW (helicopter flying into wind)									
1–50	0	0	0	3	0	2	2	0	5
51–100	0	0	0	0	0	2	1	0	3
101–200	0	2	0	0	0	0	2	1	1
201–300	0	2	4	2	0	1	2	1	0
301–400	0	1	0	0	1	0	2	0	0
HWW (helicopter flying with wind)									
1–50	0	0	0	0	0	0	1	0	2
51–100	0	0	2	3	0	0	0	0	2
101–200	0	0	0	1	0	0	2	0	0
201–300	0	1	2	1	0	0	2	0	2
301–400	0	0	1	1	0	0	1	2	0
HGS (helicopter flying at > 60° to wind)									
1–50	0	0	0	1	0	0	0	1	4
51–100	0	0	1	1	0	1	1	0	2
101–200	0	0	0	1	0	3	1	0	0
201–300	0	0	2	0	0	0	2	2	0
301–400	0	0	1	1	0	0	1	1	2
HNW (wind calm)									
201–300	0	0	0	0	1	0	0	0	1
Sun									
SHA (sun-helicopter-animals)									
1–50	0	0	0	1	0	0	0	0	1
51–100	0	0	0	1	0	1	0	0	1
101–200	0	1	0	0	0	2	1	0	0
201–300	0	2	4	1	0	0	1	1	2
301–400	0	1	0	0	1	0	1	2	2
SAH (sun-animals-helicopter)									
1–50	0	0	0	0	0	0	2	1	5
51–100	0	0	1	2	0	1	0	0	2
101–200	0	1	0	1	0	1	2	0	0
201–300	0	1	3	0	0	1	3	2	0
301–400	0	0	1	1	0	0	1	1	0
SNV (sun obscured)									
1–50	0	0	0	3	0	2	1	0	5
51–100	0	0	2	1	0	1	2	0	4
101–200	0	0	0	1	0	0	2	1	1
201–300	0	0	1	2	1	0	2	0	1
301–400	0	0	1	1	0	0	2	0	0
Terrain									
Lowland flats									
1–50	0	0	0	3	0	2	2	1	6
51–100	0	0	2	4	0	3	2	0	5
101–200	0	2	0	2	0	2	5	0	1
201–300	0	2	5	0	1	0	5	1	3
301–400	0	1	1	1	0	0	3	3	1
Intermediate slopes									
1–50	0	0	0	1	0	0	1	0	4
51–100	0	0	1	0	0	0	0	0	0
101–200	0	0	0	0	0	1	0	1	0
201–300	0	1	3	3	0	1	1	1	0
301–400	0	0	1	0	1	0	1	0	1
Ridges									
1–50	0	0	0	0	0	0	0	0	1
201–300	0	0	0	0	0	0	0	1	0
301–400	0	0	0	1	0	0	0	0	0
Plateaus									
51–100	0	0	0	0	0	0	0	0	2

Table 59
Distribution of maximum group response samples of muskoxen, by altitude class (metres above ground level) and variable classes, during passes subsequent to first passes of multi-pass helicopter harassment overflights, Prince of Wales Island, NWT, 1976–77 (n = 218)

Variable classes by altitude, m agl	Level of response								
	Maint.		Moderate		Extreme				
	Bed	For.	Alert	Walk	Can.	Gal.	Walk tog.	Can. tog.	Gal. tog.
Total sample									
1–50	0	0	0	1	0	3	3	1	2
51–100	0	0	6	2	0	1	0	0	0
101–200	0	3	6	1	0	1	6	0	1
201–300	8	26	44	9	1	6	24	9	4
301–400	4	10	6	3	1	0	11	4	11
Group size									
Solitary bull									
51–100	0	0	1	0	0	0	0	0	0
301–400	0	4	0	0	0	0	0	0	1
Bull pair									
1–50	0	0	0	1	0	3	1	0	2
51–100	0	0	3	1	0	0	0	0	0
101–200	0	0	1	0	0	0	5	0	0
201–300	0	0	6	1	0	0	4	0	1
301–400	0	0	0	0	0	0	1	0	0
Single sex, 3+									
201–300	0	0	4	0	0	0	0	1	0
Mixed sex, 2–5									
51–100	0	0	1	1	0	0	0	0	0
Mixed sex, 6–9									
1–50	0	0	0	0	0	0	2	1	0
51–100	0	0	1	0	0	1	0	0	0
101–200	0	1	3	0	0	0	0	0	0
201–300	0	1	1	1	0	1	2	0	1
301–400	0	0	0	0	0	0	4	1	4
Mixed sex, 10–19									
101–200	0	2	2	1	0	1	1	0	1
201–300	3	12	14	4	1	1	13	2	2
301–400	4	3	3	2	0	0	3	1	6
Mixed sex, 20–29									
201–300	5	12	18	3	0	2	4	6	0
301–400	0	3	3	1	1	0	3	2	0
Mixed sex, 40+									
201–300	0	1	1	0	0	2	1	0	0
Group type									
Solitary bull									
51–100	0	0	1	0	0	0	0	0	0
301–400	0	4	0	0	0	0	0	0	1
Single sex									
1–50	0	0	0	1	0	3	1	0	2
51–100	0	0	3	1	0	0	0	0	0
101–200	0	0	1	0	0	0	5	0	0
201–300	0	0	10	1	0	0	4	1	1
301–400	0	0	0	0	0	0	1	0	0
Mixed sex									
1–50	0	0	0	0	0	0	2	1	0
51–100	0	0	2	1	0	1	0	0	0
101–200	0	3	5	1	0	1	1	0	1
201–300	8	26	34	8	1	6	20	8	3
301–400	4	6	6	3	1	0	10	4	10
No. calves									
Zero calves									
1–50	0	0	0	1	0	0	1	3	2
51–100	0	0	4	1	0	0	0	0	0
101–200	0	0	1	0	0	0	5	0	0
201–300	0	0	10	1	0	1	4	0	1
301–400	0	4	0	0	0	0	1	0	1
One calf									
1–50	0	0	0	0	0	0	2	1	0
51–100	0	0	2	1	0	1	0	0	0
101–200	0	1	3	0	0	0	0	0	0
201–300	0	1	1	1	0	1	2	0	1
301–400	0	0	0	0	0	0	5	1	2
Two calves									
101–200	0	2	2	1	0	0	0	0	0
201–300	3	12	11	1	1	0	4	1	0
301–400	4	3	3	2	0	0	1	0	6
Four calves									
101–200	0	0	0	0	0	1	1	0	1
201–300	0	0	0	0	0	1	0	0	2

Variable classes by altitude, m agl	Level of response								
	Maint.		Moderate		Extreme				
	Bed	For.	Alert	Walk	Can.	Gal	Walk tog.	Can. tog.	Gal. tog.
Five calves									
201–300	0	0	2	0	0	0	8	1	0
301–400	0	0	0	0	0	0	1	1	2
Six calves									
201–300	0	0	1	3	0	0	1	0	0
Eight calves									
201–300	5	12	18	3	0	2	4	6	0
301–400	0	3	3	1	1	0	3	2	0
Eighteen calves									
201–300	0	1	1	0	0	2	1	0	0
Season									
1–23 June									
101–200	0	2	2	1	0	0	0	0	0
201–300	0	6	18	4	0	2	9	5	0
301–400	4	1	3	3	0	0	1	3	2
24 June – 15 July									
51–100	0	0	1	1	0	0	0	0	0
201–300	6	14	11	0	1	0	1	2	0
301–400	0	3	1	0	1	0	0	0	0
16 July – 7 August									
1–50	0	0	0	1	0	3	1	0	2
51–100	0	0	3	1	0	0	0	0	0
101–200	0	1	2	0	0	0	6	0	0
201–300	0	1	4	1	0	1	12	0	1
301–400	0	6	2	0	0	0	10	1	9
8–24 August									
1–50	0	0	0	0	0	0	2	1	0
51–100	0	0	2	0	0	1	0	0	0
101–200	0	0	2	0	0	1	0	0	1
201–300	2	5	11	4	0	3	2	2	3
Wind									
HIW (helicopter flying into wind)									
1–50	0	0	0	0	0	0	2	0	0
51–100	0	0	0	1	0	1	0	0	0
101–200	0	1	1	0	0	1	0	0	0
201–300	4	9	13	2	0	2	10	0	1
301–400	3	4	2	2	0	0	2	1	6
HWW (helicopter flying with wind)									
1–50	0	0	0	0	0	0	1	1	0
51–100	0	0	3	0	0	0	0	0	0
101–200	0	0	2	0	0	0	1	0	1
201–300	4	9	14	3	1	3	5	3	2
301–400	1	3	1	0	0	0	3	0	4
HGS (helicopter flying at > 60° to wind)									
1–50	0	0	0	1	0	3	0	0	2
51–100	0	0	3	1	0	0	0	0	0
101–200	0	2	3	1	0	0	5	0	0
201–300	0	8	12	1	0	0	8	6	1
301–400	0	3	3	1	1	0	6	3	1
HNW (wind calm)									
201–300	0	0	5	3	0	1	1	0	0
Sun									
SHA (sun-helicopter-animals)									
1–50	0	0	0	0	0	0	2	1	0
51–100	0	0	2	0	0	0	0	0	0
101–200	0	1	3	1	0	0	0	0	1
201–300	3	11	14	4	0	2	9	2	2
301–400	2	6	2	1	1	0	6	1	5
SAH (sun-animals-helicopter)									
1–50	0	0	0	0	0	0	1	0	0
51–100	0	0	1	1	0	1	0	0	0
101–200	0	2	2	0	0	1	1	0	0
201–300	3	10	19	1	1	2	8	5	1
301–400	2	4	4	2	0	0	3	3	3
SNV (sun obscured)									
1–50	0	0	0	1	0	3	0	0	2
51–100	0	0	3	1	0	0	0	0	0
101–200	0	0	1	0	0	0	5	0	0
201–300	2	5	11	4	0	2	7	2	1
301–400	0	0	0	0	0	0	2	0	3

Table 59 (cont'd)

Variable classes by altitude, m agl	Level of response: Maint. Bed	Maint. For.	Moderate Alert	Moderate Walk	Extreme Can.	Extreme Gal.	Extreme Walk tog.	Extreme Can. tog.	Extreme Gal. tog.
Terrain									
Lowland flats									
1–50	0	0	0	1	0	3	2	1	2
51–100	0	0	5	1	0	1	0	0	0
101–200	0	3	6	1	0	0	4	0	0
201–300	3	8	24	5	0	5	20	4	2
301–400	4	10	4	2	1	0	7	1	9
Intermediate slopes									
1–50	0	0	0	0	0	0	1	0	0
101–200	0	0	0	0	0	1	0	0	1
201–300	5	18	18	3	1	1	1	2	2
301–400	0	0	2	1	0	0	3	2	0
Ridges									
101–200	0	0	0	0	0	0	2	0	0
201–300	0	0	2	1	0	0	3	3	0
301–400	0	0	0	0	0	0	1	1	2
Plateaus									
51–100	0	0	1	1	0	0	0	0	0

Table 60
Distribution of maximum group response samples of Peary caribou, by levels of response and altitude class, during all pass-type helicopter harassment overflights <400 m above ground level (m agl), Prince of Wales Island, NWT, 1976-77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed GRS				
1–50	1	13	55	69
51–100	8	65	106	179
101–200	22	93	111	226
201–300	39	93	57	189
301–400	0	5	3	8
Total	70	269	332	671
Observed/expected indices				
1–50	0.14	0.46	1.62	
51–100	0.42	0.92	1.19	
101–200	0.96	1.02	0.99	
201–300	1.95	1.22	0.61	
301–400	0.00	1.67	0.75	
Chi-square contributions				
1–50	5.18	8.16	13.07	26.41
51–100	6.39	0.45	3.21	10.05
101–200	0.04	0.04	0.01	0.09
201–300	18.05	3.68	14.15	35.88
301–400	0.00	1.35	0.25	1.60
Total	29.66	13.68	36.69	74.03

during overflights at <200 m agl and occurred less often than expected (O/E = 0.60) during passes at >200 m agl; (*b*) maximum mixed group responses that involved >50.0% of the group members were slightly less frequent than expected (O/E = 0.97) during overflights at <200 m agl and slightly more frequent than expected (O/E = 1.05) during passes at >200 m agl; and (*c*) maximum mixed group responses that involved ≤50.0% of the group members occurred less frequently than expected (O/E = 0.85) during overflights at <200 m agl and more frequently than expected (O/E = 1.30) during passes at >200 m agl.

It appears from the O/E indices for this analysis that uniform group responses occurred most often and maximum mixed group responses involving ≤50.0% of the group members occurred least often when the animals should have received the most intense harassing stimuli. Thus, there seems to be little support from this analysis for the assumption that GRS may reflect the actual unobserved impact to group members, unless the impact is not manifested in overt responses.

GRS could also be tabulated by group size, group type, sex/age, number of calves present, season, wind, sun and terrain. More detailed analyses would allow us to better evaluate the use of GRS as a measure of the true potential or actual effects of helicopter harassment overflights on Peary caribou.

9.2 Muskoxen, GRS

A comparison of GRS and IRS from muskoxen implies that (*a*) at least one individual in each group responded at the extreme level (GRS) during 48.3% of the overflights whereas only 28.6% of the IRS actually responded at this level; (*b*) at least one individual in each group responded at the moderate level during 33.6% of the overflights whereas only 15.0% of the IRS actually responded at this level; and (*c*) all individuals in each group did not respond during 18.1% of the overflights whereas 56.4% of the IRS remained engaged in maintenance activities.

If the GRS was used as a measure of the impact of helicopter harassment the ELGRS would exceed the corresponding ELIRS by 68.9% (1 to 1.689). If the detrimental effects of helicopter harassment are greater than we could ascertain by the observed overt mixed responses of all individuals (IRS), perhaps the measure given by GRS is a good indicator of the true potential or actual impact to the group as a whole.

A comparison of the three levels of GRS of muskoxen obtained during 315 helicopter harassment overflights relative to the five altitude classes (Table 61) gave a significant difference ($\chi^2 = 30.93$, 8 df, $P < 0.005$). O/E indices for the above test indicate that at the extreme level of GRS, groups were more responsive than expected during overflights at <50 m agl, 101–200 m agl, 301–400 m agl and less responsive than expected during passes at 51–100 m agl and 201–300 m agl (Table 61). The reverse pattern was obtained for moderate level GRS (Table 61).

A test of independence between maximum uniform group responses, maximum mixed group responses involving >50.0% of the group members and maximum mixed group responses involving ≤50.0% of the group members did not give a significant difference ($\chi^2 = 5.94$, 2 df, $P > 0.05$). The O/E indices for the above test indicate, however, that

(*a*) uniform group responses were more frequent than expected (O/E = 1.35) during overflights at <200 m agl and occurred less often than expected (O/E = 0.90) during passes at >200 m agl;

(*b*) maximum mixed group responses involving >50.0% of the group members also occurred more frequently than expected (O/E = 1.10) during overflights at <200 m agl and slightly less often than expected (O/E = 0.97) during passes at >200 m agl; and

(*c*) maximum mixed group responses involving ≤50.0% of the group members occurred less frequently than expected (O/E = 0.74) during overflights at <200 m agl and more often than expected (O/E = 1.07) during passes at >200 m agl.

As for Peary caribou, the frequency distribution for maximum uniform and maximum mixed group responses suggest that maximum uniform group responses occurred most often and maximum mixed group responses occurred least often when the animals should have received the most intense harassing stimuli. Again, as for Peary caribou, there seems to be little support from this analysis for the assumption that GRS may reflect the actual unobserved impact to group members, unless the impact is not manifested in overt responses.

GRS for muskox groups that formed group defense formations were observed on 76 occasions (Tables 62 and 63). There was no significant difference between the GRS for gaits used by muskoxen as the group came together to form group defense formations and whether or not the formations took place during approach or departure phases of the helicopter harassment overflights ($\chi^2 = 0.54$, 2 df, $P > 0.9$; Table 62). O/E indices for this comparison indicate, however, that (*a*) groups that walked together did so about as frequently as expected during both approaches and departures (Table 62); (*b*) groups that cantered together did so less frequently than expected during the approaches and more frequently than expected during the departures (Table 62); and (*c*) groups that galloped together did so more frequently than expected during the approaches and less frequently than expected during the departures (Table 62). The analysis indicates that muskoxen were observed galloping together most often during the first phases of exposure to harassing stimuli.

GRS for muskox groups that formed 36 tight and 40 loose group defense formations are given in Table 63. A comparison of tight or loose group defense formations by whether the groups formed during the approach or departure phases of the helicopter harassment overflights was significant ($\chi^2 = 3.93$, 1 df, $P < 0.05$; Table 63). O/E indices for this comparison indicate that tight group defense formations occurred more often than expected during approach phases and less often than expected during the departure phases (Table 63). The reverse was true for loose group defense formations (Table 63). The analysis indicates that tight group defense formations occurred most often during the first phases of exposure to harassing stimuli.

GRS could also be tabulated by group size, group type, sex/age, number of calves present, season, wind, sun and terrain. More detailed analysis would allow us to better evaluate the use of GRS as a measure of the true potential or actual effects of helicopter harassment overflights on muskoxen.

Table 61
Distribution of maximum group response samples of muskoxen, by level of response and altitude class during all pass-type helicopter harassment overflights <400 m above ground level (m agl), Prince of Wales Island, NWT, 1976–77

Altitude class, m agl	Level of response: Maint.	Mod.	Ext.	Totals
Observed GRS				
1–50	0	5	26	31
51–100	0	15	13	28
101–200	5	9	18	32
201–300	37	64	58	159
301–400	15	13	37	65
Total	57	106	152	315
Observed/expected indices				
1–50	0.00	0.50	1.73	
51–100	0.00	1.67	0.93	
101–200	0.83	0.82	1.20	
201–300	1.32	1.19	0.75	
301–400	1.25	0.59	1.19	
Chi-square contributions				
1–50	0.00	2.50	7.99	10.49
51–100	0.00	4.04	0.07	4.11
101–200	0.17	0.36	0.60	1.13
201–300	2.87	1.95	4.81	9.63
301–400	0.75	3.70	1.12	5.57
Total	3.79	12.55	14.59	30.93

Table 62
Comparison of type of gait used by muskox group response samples (GRS) that came together to form group defense formations, during helicopter approaches and departures, Prince of Wales Island, NWT, 1976–77

Gait	Flight stage: Approach	Departure	Totals
Observed GRS			
Walk	28	12	40
Canter	9	6	15
Gallop	16	5	21
Total	53	23	76
Observed/expected indices			
Walk	1.00	1.00	
Canter	0.90	1.20	
Gallop	1.07	0.83	
Chi-square contributions			
Walk	0.00	0.00	0.00
Canter	0.10	0.20	0.30
Gallop	0.07	0.17	0.24
Total	0.17	0.37	0.54

Table 63
Comparison of the type of group defense formation taken up by muskox group response samples (GRS) during helicopter approaches and departures, Prince of Wales Island, NWT, 1976–77

Defense formation type	Flight stage: Approach	Departure	Totals
Observed GRS			
Tight	29	7	36
Loose	24	16	40
Total	53	23	76
Observed/expected indices			
Tight	1.16	0.64	
Loose	0.86	1.33	
Chi-square contributions			
Tight	0.64	1.43	2.07
Loose	0.55	1.31	1.86
Total	1.19	2.74	3.93

10. Analysis of group activities

10.1. The approach

Our inability to consistently distinguish between individual muskoxen or caribou within a particular sex/age category for extended periods of time required that we consider the group as a unit, rather than as individuals in a group. The behaviour of a group at a specific instant is, therefore, the aggregate of the activities of the member individuals. Both muskoxen and caribou spent more time bedded and foraging than any of the other basic activities that we recognized (stand, alert, walk, trot/canter and gallop). Locomotor activities that did not involve foraging were observed infrequently and have been grouped with stand and alert in an "other activity" class to distinguish them from bedding and foraging. For the purposes of this discussion each individual in the group could, therefore, be involved in one of three different activities, but because the behaviour of the individuals comprising the group need not be synchronous, the group could be engaged in any of seven activities: (*a*) synchronous bedded; (*b*) synchronous foraging; (*c*) synchronous other; (*d*) mixed bedded and foraging; (*e*) mixed bedded and other; (*f*) mixed foraging and other; and (*g*) mixed bedded, foraging and other.

Statistical analysis of sequential behavioural events is often compromised because the occurrence of a particular event is partially dependent upon the preceding activity. The effect of this dependence is, however, reduced if individual observations are brief and separated by regular time intervals. Although the activity of caribou and muskox groups was recorded continuously, the instantaneous behaviour of every visible animal in the group was only recorded at 10-min intervals (daily rounds). The data presented in Tables 64–84 are a summary of the temporal distribution of group activities and their relation to helicopter harassment, based on those instantaneous observations (daily rounds).

Group activity was analyzed by two-dimensional contingency tables. *Post hoc* interpretation of the outcome of chi-square tests on those tables employed the O/E index. Whenever more than 20% of the expected frequencies in a contingency table had values less than five, activity classes were combined until only two classes remained. The first of these two classes contained all four of the original classes with information that concerned one of the three basic activities (i.e., class one: synchronous bedded; bedded and foraging; bedded and other; and bedded, foraging and other) and the remaining original classes were grouped into the second class (i.e., class two: synchronous foraging, synchronous other and mixed foraging and other). A thorough examination of the three basic activities required recombination of the original table into three separate tables.

Proportional differences in group activity in relation to helicopter harassment may be an indication of medium term effects of disturbance. Because most harassment observations were conducted during late morning and early afternoon, observations of caribou from 22:00 until 10:00 and of muskoxen from 22:00 until 09:00 were not considered in the analysis of group activity and harassment. Our evaluations of the normal relation of group activity to season and time of day are based upon observation periods that were not interrupted by helicopter harassment and the pre-disturbance portions of harassment observations.

The interactions of group activity, harassment phase and season or time of day were examined by the multivariate methods first introduced in the biological literature by Fienberg (1970). The technique requires the calculation of expected frequencies for a multidimensional contingency table based upon a series of hierarchical models. The most complex model that is germane to the present context assumes that activity by caribou or muskox groups varied between harassment phases and that this relation differed between season or time of day. Less complicated models assume subsets of the interactions expressed in more involved models. Once the expected frequencies have been calculated under a particular model a chi-square test is performed as a measure of the goodness of fit to the observed frequencies. The least complex model that fits the data with 95% probability or less (i.e., $P > 0.05$) is considered a reasonable explanation of the interactions of the variables of interest. Fienberg (1970) contended that small expected frequencies do not affect the accuracy of this technique and three-dimensional tables that included season were not collapsed. Tables that included time of day were so sparse that the chance occurrence of a single activity with one season could greatly affect a goodness of fit test. The seven activities were, therefore, recombined as described above.

We observed the activity of caribou groups on 45 occasions: 16 groups (109 individuals) were not disturbed by helicopter activity; 23 groups (160 individuals) were observed both before and after harassment overflights, landing, or both; and 6 groups (48 individuals) were only observed following a helicopter disturbance. We observed the activity of muskox groups on 56 occasions: 20 groups (152 individuals) were not disturbed by helicopter activity; 29 groups (121 individuals) were observed both before and after harassment overflights, landings or both; and 7 groups (23 individuals) were only observed following a helicopter disturbance. The duration of discrete periods of continuous activity based on sightings at 10-min intervals (daily rounds) was quite variable but generally less than 30 min (Tables 64 and 65). Synchronous bedded, synchronous foraging and mixed bedded–foraging were the most frequently observed group activities and continuous periods of those activities were usually more protracted than periods in which at least one member of the group was engaged in an "other" activity.

Caribou groups were observed from the ground for 10 531 min (175 h 31 min) and muskox herds were observed from the ground for 21 463 min (357 h 43 min). These observation durations do not include periods when the entire herd being observed was out of sight. The observations during passes and landings are included, however.

Table 64
Duration of continuous activity periods based on sightings at 10-min intervals of Peary caribou, Prince of Wales Island, NWT, 1977. Each cell contains the mean duration (min), standard deviation and number of observations

Undisturbed	Preharassment	Postharassment	All observations
Synchronous bedded			
28.8	25.8	21.3	25.9
16.24	15.02	14.08	15.34
24	19	15	58
Synchronous foraging			
44.5	33.5	33.8	37.0
36.77	24.39	23.71	30.47
31	29	40	100
Synchronous other			
12.00	10.0	10.0	11.1
4.47	0.00	0.00	3.33
5	2	2	9
Mixed bedded–foraging			
23.3	26.5	31.1	27.2
18.30	17.23	29.43	23.16
42	31	47	120
Mixed Bedded–other			
10.0	10.0	10.0	10.0
0.00	0.00	0.00	0.00
8	2	2	12
Mixed foraging–other			
14.3	10.0	13.0	12.5
5.35	0.00	6.75	5.32
7	7	10	24
Mixed bedded–foraging–other			
15.3	12.0	12.7	13.9
7.17	4.47	4.67	6.09
17	5	11	33

Table 65
Duration of continuous activity periods based on sightings at 10-min intervals of muskoxen, Prince of Wales Island, NWT, 1977. Each cell contains the mean duration (min), standard deviation and number of observations

Undisturbed	Preharassment	Postharassment	All observations
Synchronous bedded			
48.6	33.1	37.9	39.0
39.23	23.36	28.52	30.33
28	35	57	120
Synchronous foraging			
32.0	21.8	22.5	25.2
29.51	11.90	17.72	21.13
49	50	60	159
Synchronous other			
44.3	12.0	16.1	22.0
73.45	4.47	12.43	36.99
7	5	18	30
Mixed bedded–foraging			
28.3	32.2	29.8	30.1
24.14	24.85	34.22	29.10
64	69	104	237
Mixed bedded–other			
10.0	13.9	11.5	12.2
0.00	6.08	4.89	5.17
7	18	20	45
Mixed foraging–other			
12.6	16.3	16.7	15.3
5.26	14.50	12.42	11.63
27	30	33	90
Mixed bedded–foraging–other			
16.9	14.4	12.4	14.4
11.92	8.78	6.63	9.22
26	32	33	91

10.2. Limitations of the analysis of group activities

This analysis of group activity suffered from several inherent limitations that were in part necessitated by its preliminary nature. By grouping all individual activities other than bedded and foraging into the "other" category, we have ignored any subtle changes in the behaviour of Peary caribou and muskoxen that could be related to season, time of day or harassment phase. In particular, the frequencies of social activities such as rutting behaviour, nursing, care soliciting and play may be responsive to harassment.

Variation in several variables has been left uncontrolled in the analysis and their effect on group activity remains unknown. Group size, group type and the number of calves present are probably important in determining the activity of the group as a unit at any time. The intensity of the harassing stimuli may also influence the medium-term responses of the affected group. Responses to landings have not been examined separately from the responses to overflights, nor have we attempted to control for the effect of the altitude of harassment overflights. Finally, the length of the observation period after the harassment event was variable and the effect of harassment may have been greater than this analysis indicates because of the inclusion of very long post-harassment observations during which the activity of the group returned to pre-harassment levels.

10.3. Peary caribou, undisturbed group activities

The seasonal distribution of group activity by Peary caribou is summarized in Table 66. We observed caribou only once between 1 and 23 June and these instantaneous observations have been omitted. All members of the caribou groups observed were either bedded or foraging for 89.4% (521/583) of the instantaneous observations. At least one member of the herd was bedded for 55.8% (325/583) of the observations and foraging for 76.7% (447/583) of the observations. Non-bedded activities that did not involve feeding were recorded for only 10.6% (62/583) of the interval sightings.

Caribou were observed bedded more often than expected from 24 June to 15 July ($\chi^2 = 13.35$, 2 df, $P < 0.005$) mostly because of the high frequency of mixed bedded–foraging activity (Table 67). Although the relative proportion of synchronous foraging increased through the 2 mon of the observation period, a simultaneous decrease in mixed bedded–foraging (Table 66) resulted in only slight seasonal differences in the combined occurrence of foraging ($\chi^2 = 8.25$, 2 df, $P < 0.025$; Table 66). Other activities were observed more frequently than expected between 16 July

Table 66
Seasonal frequency and percentage occurrence of group activity based on sightings at 10-min intervals of undisturbed Peary caribou, Prince of Wales Island, NWT, 1977

Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
24 June – 15 July						
22	42	2	71	1	4	6
14.86	28.38	1.35	47.97	0.68	2.70	4.05
16 July – 7 August						
82	147	5	74	9	11	22
23.43	42.00	1.43	21.14	2.57	3.14	6.29
8–24 August						
14	46	1	23	0	0	1
16.47	54.12	1.18	27.06	0.00	0.00	1.18

Table 67
The relationship between season and group activity based on sightings at 10-min intervals of undisturbed Peary caribou, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and the observed/expected index

24 Jun. – 15 Jul.	16 Jul. – 7 Aug.	8–24 Aug.
Bedded		
100	187	38
82.50	195.11	47.38
1.21	0.96	0.80
Not bedded		
48	163	47
65.50	154.89	37.62
0.73	1.05	1.25
Foraging		
123	254	70
113.48	268.35	65.17
1.08	0.95	1.07
Not foraging		
25	96	15
34.52	81.65	19.83
0.72	1.18	0.76
Other		
13	47	2
15.74	37.22	9.04
0.83	1.26	0.22
Non-other		
135	303	83
132.26	312.78	75.96
1.02	0.97	1.09

Table 68
Distribution of group activity throughout the day based on sightings at 10-min intervals of undisturbed Peary caribou, Prince of Wales Island, NWT, 1977. Each cell contains the observed frequency and percentage occurrence.

	Bed. only	For. only	Other only	Bed.– for.	Bed.– other	For.– other	Bed.– for.– other
24:00–03:00							
	7	3	0	1	1	0	1
	53.85	23.08	0.00	7.69	7.69	0.00	7.69
06:00–09:00							
	7	7	0	9	0	0	1
	29.17	29.17	0.00	37.50	0.00	0.00	4.17
09:00–10:00							
	10	26	0	20	0	2	1
	16.95	44.07	0.00	33.90	0.00	3.39	1.69
10:00–11:00							
	7	25	1	17	1	1	1
	13.21	47.17	1.89	32.08	1.89	1.89	1.89
11:00–12:00							
	0	22	0	6	0	1	0
	0.00	75.86	0.00	20.69	0.00	3.45	0.00
12:00–13:00							
	11	6	0	9	0	0	2
	39.29	21.43	0.00	32.14	0.00	0.00	7.14
13:00–14:00							
	8	5	0	14	1	0	1
	27.59	17.24	0.00	48.28	3.45	0.00	3.45
14:00–15:00							
	7	31	1	12	1	4	2
	12.07	53.45	1.72	20.69	1.72	6.90	3.45
15:00–16:00							
	5	20	1	21	0	3	10
	8.33	33.33	1.67	35.00	0.00	5.00	16.67
16:00–17:00							
	14	33	2	26	2	1	4
	17.07	40.24	2.44	31.71	2.44	1.22	4.88
17:00–18:00							
	11	20	1	22	0	0	3
	19.30	35.09	1.75	38.60	0.00	0.00	5.26
18:00–19:00							
	8	12	1	9	1	3	3
	21.62	32.43	2.70	24.32	2.70	8.11	8.11
19:00–20:00							
	6	15	0	1	1	1	1
	24.00	60.00	0.00	4.00	4.00	4.00	4.00
20:00–21:00							
	4	2	0	4	0	0	0
	40.00	20.00	0.00	40.00	0.00	0.00	0.00
21:00–24:00							
	13	8	1	9	2	1	2
	36.11	22.22	2.78	25.00	5.56	2.78	5.56

Figure 28
Distribution of observations of Peary caribou throughout the day, Prince of Wales Island, NWT, 1977

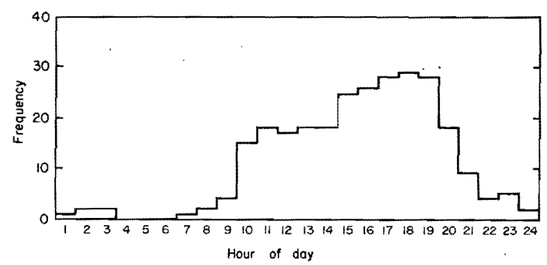


Table 69
Frequency of group activity throughout the day based on sightings at 10-min intervals of undisturbed Peary caribou, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and observed/expected index

	24:00–03:00	06:00–09:00	09:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	20:00–21:00	21:00–24:00
Bedded															
	10	17	31	26	6	22	24	22	36	46	36	21	9	8	26
	7.37	13.60	33.43	30.03	16.43	15.87	16.43	32.87	34.00	46.47	32.30	20.97	14.17	5.67	20.40
	1.36	1.25	0.93	0.87	0.37	1.39	1.46	0.67	1.06	0.99	1.11	1.00	0.64	1.41	1.27
Not bedded															
	3	7	28	27	23	6	5	36	24	36	21	16	16	2	10
	5.63	10.40	25.57	22.97	12.57	12.13	12.57	25.13	26.00	35.53	24.40	18.03	10.83	1.33	15.60
	0.53	0.67	1.10	1.18	1.83	0.49	0.40	1.43	0.92	1.01	0.86	0.89	1.48	1.50	0.64
Foraging															
	5	17	49	44	29	17	20	49	54	64	45	27	18	6	20
	10.05	18.56	45.63	40.99	22.43	21.65	22.43	44.85	46.40	63.41	44.08	28.61	19.33	7.73	27.84
	0.50	0.92	1.07	1.07	1.29	0.79	0.89	1.09	1.16	1.01	1.02	0.94	0.93	0.78	0.72
Not foraging															
	8	7	10	9	0	11	9	9	6	18	12	10	7	4	16
	2.95	5.44	13.37	12.01	6.57	6.35	6.57	13.15	13.60	18.59	12.92	8.39	5.67	2.27	8.16
	2.71	1.29	0.75	0.75	0.00	1.73	1.37	0.68	0.44	0.97	0.93	1.19	1.23	1.76	1.96
Other															
	2	1	3	4	1	2	2	8	14	9	4	8	3	0	6
	1.45	2.68	6.59	5.92	3.24	3.13	3.24	6.48	6.70	9.16	6.36	4.13	2.79	1.12	4.02
	1.38	0.37	0.46	0.68	0.31	0.64	0.62	1.23	2.09	0.98	0.63	1.94	1.08	0.00	1.49
Non-other															
	11	23	56	49	28	26	27	50	46	73	53	29	22	10	30
	11.55	21.32	52.41	47.08	25.76	24.87	25.76	51.52	53.30	72.84	50.63	32.87	22.21	8.88	31.98
	0.95	1.08	1.07	1.04	1.09	1.05	1.05	0.97	0.86	1.00	1.05	0.88	0.99	1.13	0.94

and 7 August and less frequently than expected between 8 and 24 August ($\chi^2 = 9.54$, 2 df, $P < 0.01$; Table 67).

The observed proportions of bedding, foraging and other activities remained relatively constant throughout the day (Tables 68 and 69). We did not attempt to observe caribou through the night and the large contributions to the chi-square test of foraging activity ($\chi^2 = 47.49$, 14 df, $P < 0.05$; Table 69) from our infrequent nocturnal observations (Fig. 28) may be spurious. The level of activity was altered during midday by a decline in bedding from 11:00 to 12:00 ($\chi^2 = 54.26$, 14 df, $P < 0.005$; Table 69) due to an increase in synchronous foraging (Table 68) followed by 2 h of increased bedding. Between 14:00 and 15:00, bedding was again observed less frequently than expected (Table 69) because of an increase in synchronous foraging (Table 68). An increase in other activities (Table 69) particularly mixed bedding–foraging–other (Table 68) from 15:00 to 16:00 ended the afternoon deviation in activities. Other activities were again observed in a greater proportion than expected from 18:00 to 19:00 ($\chi^2 = 23.85$, 14 df, $P < 0.05$; Table 69) primarily because of a concurrent increase in mixed foraging –other and bedded–foraging–other (Table 68).

10.4. Peary caribou, group activities after harassment

All of the seasonal patterns in bedding and foraging behaviour that we have reported for undisturbed caribou groups are also evident for groups that had been subjected to helicopter harassment overflights (Tables 70 and 71). However, we did not observe caribou herds bedded as often as expected following harassment from 16 July to 24 August ($\chi^2 = 35.81$, 2 df, $P < 0.005$). Contrary to our observations of undisturbed groups, other activities were observed among harassed groups more frequently than expected between 24 June and 15 July, but only as often as expected from 16 July to 7 August ($\chi^2 = 9.82$, 2 df, $P < 0.01$). There were no significant differences between seasons in the frequency of foraging ($\chi^2 = 4.06$, 2 df, $P > 0.1$).

Although the overall medium-term effect of helicopter harassment on Peary caribou appears to have been a reduction in synchronous bedding and an increase in mixed bedded–foraging ($\chi^2 = 22.60$, 6 df, $P < 0.005$; Table 72) knowledge of the interaction between harassment phase and activity is not required to explain seasonal differences in activity relative to harassment (Table 73). We sampled caribou groups for different lengths of time both before and after harassment and from one season to the next. Once those variations had been controlled for, variation in activity by caribou groups can be explained by seasonal effects alone. Peary caribou groups were not observed often enough after harassment to enable a determination of the impact of harassment throughout the day (Table 74).

Table 70
Seasonal frequency and percentage occurrence of group activity based on sightings at 10-min intervals of Peary caribou following helicopter harassment overflights, Prince of Wales Island, NWT, 1977

	Bed. only	For. only	Other only	Bed.– for.	Bed.– other	For.– other	Bed.– for.– other
24 June – 15 July							
	20	44	2	106	1	12	10
	10.26	22.56	1.03	54.36	0.51	6.15	5.13
16 July – 7 August							
	6	30	0	5	1	0	3
	13.33	66.67	0.00	11.11	2.22	0.00	6.67
8 – 24 August							
	6	61	0	35	0	1	1
	5.77	58.65	0.00	33.65	0.00	0.96	0.96

Table 71
The relationship between season and group activity based on sightings at 10-min intervals of Peary caribou following helicopter harassment overflights, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and observed/expected index

24 June – 15 July	16 July – 7 August	8–24 August
Bedded		
137	15	42
109.97	25.38	58.65
1.25	0.59	0.72
Not bedded		
58	30	62
85.03	19.62	45.35
0.68	1.53	1.37
Foraging		
172	38	98
174.59	40.29	93.12
0.99	0.94	1.05
Not foraging		
23	7	6
20.41	4.71	10.88
1.13	1.49	0.55
Other		
25	4	2
17.57	4.07	9.37
1.42	0.98	0.21
Non-other		
170	41	102
177.43	40.94	94.63
0.96	1.00	1.08

Table 72
Activity of Peary caribou groups based on sightings at 10-min intervals before and after helicopter harassment overflights, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and observed/expected index

	Bed. only	For. only	Other only	Bed.– for.	Bed.– other	For.– other	Bed.– for.– other
Preharassment							
	81	191	7	141	7	14	27
	65.53	186.16	5.22	166.44	5.22	15.66	23.78
	1.24	1.03	1.34	0.85	1.34	0.89	1.14
Postharassment							
	32	130	2	146	2	13	14
	47.47	134.84	3.78	120.56	3.78	11.34	17.22
	0.67	0.96	0.53	1.21	0.53	1.15	0.81

Table 73
Goodness of fit tests of models that assume various interactions between harassment phase [1], season [2] and activity of Peary caribou groups [3] based on sightings at 10-min intervals, Prince of Wales Island, NWT, 1977. The occurrence of two variables within square brackets in the model description indicates an assumption of dependence between those variables

Model	χ^2	df	P
[1] [2] [3]	340.32	32	<0.005
[12] [3]	135.11	30	<0.005
[13] [2]	283.97	26	<0.005
[23] [1]	190.90	20	<0.005
[12] [13]	110.45	24	<0.005
[12] [23]	17.66	18	>0.01
[13] [23]	170.11	14	<0.005
[12] [13] [23]	11.07	12	>0.5

Table 74
Distribution of group activity throughout the day based on sightings at 10-min intervals of Peary caribou harassed by helicopter overflights, Prince of Wales Island, NWT, 1977. Each cell contains the observed frequency and percentage occurrence

Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
10:00–11:00						
0	7	0	2	0	1	0
0.00	70.00	0.00	20.00	0.00	10.00	0.00
11:00–12:00						
7	3	0	11	0	0	2
30.43	13.04	0.00	47.83	0.00	0.00	8.70
12:00–13:00						
5	13	1	28	1	1	3
9.62	25.00	1.92	53.85	1.92	1.92	5.77
13:00–14:00						
1	14	0	25	1	0	3
2.27	31.82	0.00	56.82	2.27	0.00	6.82
14:00–15:00						
3	6	1	10	0	1	3
12.50	25.00	4.17	41.67	0.00	4.17	12.50
15:00–16:00						
4	16	0	10	0	5	1
11.11	44.44	0.00	27.78	0.00	13.89	2.78
16:00–17:00						
2	20	0	13	0	1	0
5.56	55.56	0.00	36.11	0.00	2.78	0.00
17:00–18:00						
7	19	0	19	0	0	0
15.56	42.22	0.00	42.22	0.00	0.00	0.00
18:00–19:00						
3	19	0	19	0	0	1
7.14	45.24	0.00	45.24	0.00	0.00	2.38
19:00–20:00						
0	7	0	7	0	3	1
0.00	38.89	0.00	38.89	0.00	16.67	5.56
20:00–21:00						
0	6	0	2	0	1	0
0.00	66.67	0.00	22.22	0.00	11.11	0.00

Table 75
Seasonal distribution of group activity based on sightings at 10-min intervals of undisturbed muskoxen, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and observed/expected index

Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
1–23 June						
121	93	7	164	19	31	27
100.11	105.67	14.70	160.09	12.71	32.97	35.75
1.21	0.88	0.48	1.02	1.49	0.94	0.76
24 June – 15 July						
2	19	1	65	0	6	6
21.45	22.64	3.15	34.31	2.72	7.07	7.66
0.09	0.84	0.32	1.89	0.00	0.85	0.78
16 July – 7 August						
50	98	27	120	4	23	29
76.06	80.28	11.17	121.63	9.66	25.05	27.16
0.66	1.22	2.42	0.99	0.41	0.92	1.07
8 – 24 August						
79	56	2	54	9	23	28
54.39	57.41	7.99	86.98	6.91	17.91	19.42
1.45	0.98	0.25	0.62	1.30	1.28	1.44

Table 76
Distribution of group activity throughout the day based on sightings at 10-min intervals of undisturbed muskoxen, Prince of Wales Island, NWT, 1977. Each cell contains the observed frequency and percentage occurrence.

Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
24:00–03:00						
8	0	0	3	0	0	0
72.73	0.00	0.00	27.27	0.00	0.00	0.00
03:00–06:00						
4	6	0	6	0	1	1
22.22	33.33	0.00	33.33	0.00	5.56	5.56
06:00–09:00						
11	3	0	21	1	0	3
28.21	7.69	0.00	53.85	2.56	0.00	7.69
09:00–10:00						
22	23	3	27	3	11	7
22.92	23.96	3.13	28.13	3.13	11.46	7.29
10:00–11:00						
20	16	0	38	3	9	10
20.83	16.67	0.00	39.58	3.13	9.38	10.42
11:00–12:00						
25	12	2	34	4	5	6
28.41	13.64	2.27	38.64	4.55	5.68	6.82
12:00–13:00						
26	22	2	35	0	10	12
24.30	20.56	1.87	32.71	0.00	9.35	11.21
13:00–14:00						
22	26	0	44	10	7	7
18.97	22.41	0.00	37.93	8.62	6.03	6.03
14:00–15:00						
19	30	1	21	2	12	4
21.35	33.71	1.12	23.60	2.25	13.48	4.49
15:00–16:00						
23	27	2	31	2	8	6
23.23	27.27	2.02	31.31	2.02	8.08	6.06
16:00–17:00						
10	27	4	32	1	5	14
10.75	29.03	4.30	34.41	1.08	5.38	15.05
17:00–18:00						
17	17	2	36	2	2	12
18.28	18.28	2.15	38.71	2.15	7.53	12.90
18:00–19:00						
20	23	0	21	2	3	3
27.78	31.94	0.00	29.17	2.78	4.17	4.17
19:00–20:00						
10	1	5	29	0	1	1
21.28	2.13	10.64	61.70	0.00	2.13	2.13
20:00–21:00						
12	0	6	16	1	1	4
30.00	0.00	15.00	40.00	2.50	2.50	10.00
21:00–24:00						
3	33	10	9	1	3	0
5.08	55.93	16.95	15.25	1.69	5.08	0.00

Table 77
Frequency of group activity throughout the day based on sightings at 10-min intervals of undisturbed muskoxen, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and observed/expected index

24:00–03:00	03:00–06:00	06:00–09:00	09:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	20:00–21:00	21:00–24:00
Bedded															
11	11	36	59	71	69	73	83	46	62	57	67	46	40	33	13
7.35	12.03	26.06	64.14	64.14	58.79	71.49	77.50	59.46	66.14	62.13	62.13	48.10	31.40	26.72	39.42
1.50	0.91	1.38	0.92	1.11	1.17	1.02	1.07	0.77	0.94	0.92	1.08	0.96	1.27	1.24	0.33
Not bedded															
0	7	3	37	25	19	34	33	43	37	36	26	26	7	7	46
3.65	5.97	12.94	31.86	31.86	29.21	35.51	38.50	29.54	32.86	30.87	30.87	23.90	15.60	13.28	19.58
0.00	1.17	0.23	1.16	0.78	0.65	0.96	0.86	1.46	1.13	1.17	0.84	1.09	0.45	0.53	2.35
Foraging															
3	14	27	68	73	57	79	84	67	72	78	72	50	32	21	45
7.96	13.03	28.24	69.50	69.50	63.71	77.47	83.98	64.44	71.67	67.33	67.33	52.13	34.03	28.96	42.72
0.38	1.07	0.96	0.98	1.05	0.89	1.02	1.00	1.04	1.00	1.16	1.07	0.96	0.94	0.73	1.05
Not foraging															
8	4	12	28	23	31	28	32	22	27	15	21	22	15	19	14
3.04	4.97	10.76	26.50	26.50	24.29	29.53	32.02	24.56	27.33	25.67	25.67	19.87	12.97	11.04	16.28
2.63	0.80	1.12	1.06	0.87	1.28	0.95	1.00	0.90	0.99	0.58	0.82	1.11	1.16	1.72	0.86
Other															
0	2	4	24	22	17	24	24	19	18	24	23	8	7	12	14
2.29	3.75	8.12	19.98	19.98	18.31	22.26	24.14	18.52	20.60	19.35	19.35	14.98	9.78	8.32	12.28
0.00	0.53	0.49	1.20	1.10	0.93	1.08	0.99	1.03	0.87	1.24	1.19	0.53	0.72	1.44	1.14
Non-other															
11	16	35	72	74	71	83	92	70	81	69	70	64	40	28	45
8.71	14.25	30.88	76.02	76.02	69.69	84.74	91.86	70.48	78.40	73.65	73.65	57.02	37.22	31.68	46.72
1.26	1.12	1.13	0.95	0.97	1.02	0.98	1.00	0.99	1.03	0.94	0.95	1.12	1.07	0.88	0.96

10.5. Muskoxen, undisturbed group activities

We observed muskoxen more frequently than caribou, particularly from 1 June until 15 July (Table 75). Muskoxen were observed either bedded or foraging for 79.2% (921/1162) of the interval sightings. One or more members of the herd were bedded for 66.8% (777/1162) of the observations and foraging for 72.4% (842/1162) of the observations. Muskoxen engaged in activities other than bedding and foraging (20.8%; 242/1162) as did caribou.

Synchronous bedding and mixed bedded–other occurred in greater proportions than expected from 1 to 23 June and synchronous other activities were relatively less frequent than expected ($\chi^2 = 138.72$, 18 df, $P < 0.005$; Table 75). A decline in the proportion of synchronous bedding observations between 24 June and 15 July was associated with a concurrent increase in mixed bedded–foraging. We observed synchronous foraging and other activities more frequently than expected from 16 July to 7 August, while synchronous bedding and mixed bedded–other were observed less frequently than expected. Between 8 and 24 August the proportion of observations of synchronous bedding doubled relative to the period between 16 July and 7 August. Observations of mixed bedded–foraging–other were also more common than expected from 8 to 24 August, whereas synchronous other and mixed bedded–foraging were less common.

Muskoxen did not appear to have a distinct daily activity cycle (Tables 76 and 77). Although we observed muskoxen from 21:00 to 09:00 more often than caribou (Fig. 29) the observations are probably too infrequent to be considered a representative sample of nocturnal activity. Bedding by at least one member of the herd was observed less frequently than expected from 14:00 to 15:00 (Table 77) primarily because of an increase in synchronous foraging and mixed foraging–other (Table 76). The proportion of other activities declined between 18:00 and 19:00 (Table 77) when synchronous bedding and synchronous foraging were observed with greater than average frequency (Table 76). During the following hour, observations of bedding, specifically mixed bedded–foraging were more numerous than expected (Table 77). Synchronous foraging was observed only once from 19:00 to 21:00, but 43.2% of all observations of synchronous other occurred during this 2-h period (Table 76).

Figure 29
Distribution of observations of muskoxen throughout the day, Prince of Wales Island, NWT, 1977

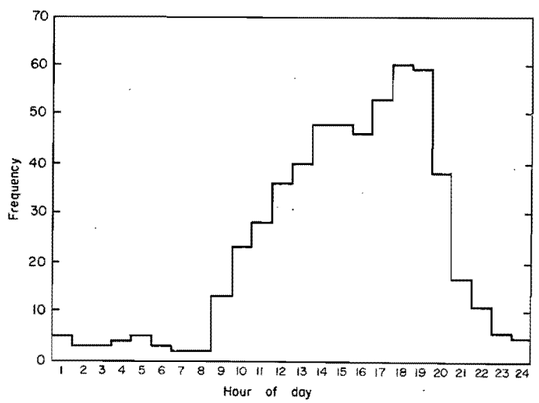


Table 78
Goodness of fit tests of models that assume various interactions between harassment phase [1], season [2] and activity of muskox herds [3] based on sightings at 10-min intervals, Prince of Wales Island, NWT, 1977. The occurrence of two variables within square brackets in the model description indicates an assumption of dependence between those variables

Model	χ^2	df	P
[1] [2] [3]	519.47	45	<0.005
[12] [3]	217.09	42	<0.005
[13] [2]	497.28	39	<0.005
[23] [1]	380.09	27	<0.005
[12] [13]	211.64	36	<0.005
[12] [23]	80.67	24	<0.005
[13] [23]	363.25	21	<0.005
[12] [13] [23]	66.44	18	<0.005

Table 79
Seasonal distribution of group activity based on sightings at 10-min intervals of muskoxen relative to harassment phase, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and O/E index. Expected frequencies and O/E indices were calculated on the assumption of dependence between season and activity, season and harassment phase and harassment phase and activity

	Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
Preharassment							
1–23 June							
	97	76	7	135	18	30	25
	91.95	67.24	7.99	154.68	15.75	27.17	23.22
	1.05	1.13	0.88	0.87	1.14	1.10	1.08
24 June – 15 July							
	2	17	1	61	0	6	6
	11.20	21.45	0.60	51.05	0.82	4.71	3.17
	0.18	0.79	1.67	1.19	0.00	1.27	1.89
16 July – 7 August							
	50	76	17	114	4	20	29
	54.94	82.94	16.08	104.28	4.16	17.53	30.08
	0.91	0.92	1.06	1.09	0.96	1.14	0.96
8–24 August							
	77	55	2	54	8	23	26
	67.92	52.37	2.34	53.99	9.27	29.59	29.53
	1.13	1.05	0.85	1.00	0.86	0.78	0.88
Postharassment							
1–23 June							
	130	52	15	162	16	28	20
	135.05	60.76	14.01	142.32	18.25	30.83	21.78
	0.96	0.86	1.07	1.14	0.88	0.91	0.92
24 June – 15 July							
	47	49	2	98	3	11	4
	37.80	44.55	2.40	107.95	2.18	12.29	6.83
	1.24	1.10	0.83	0.91	1.38	0.90	0.59
16 July – 7 August							
	19	20	4	7	1	1	6
	14.07	13.06	4.92	16.73	0.84	3.47	4.92
	1.35	1.53	0.81	0.42	1.19	0.29	1.22
8–24 August							
	7	5	1	8	3	12	8
	16.09	7.63	0.66	8.01	1.73	5.41	4.47
	0.44	0.66	1.52	1.00	1.73	2.22	1.79

Table 80
Goodness of fit tests of models that assume various interactions between harassment phase [1], activity of muskox herds [2] and time of day [3] based on sightings at 10-min intervals, Prince of Wales Island, NWT, 1977.
The occurrence of two variables within square brackets in the model description indicates an assumption of dependence between those variables

		Bed.		For.		Other	
Model	df	χ^2	P	χ^2	P	χ^2	P
[1] [2] [3]	34	233.79	<0.005	208.33	<0.005	176.11	<0.005
[12] [3]	33	230.98	<0.005	203.09	<0.005	173.42	<0.005
[13] [2]	23	88.24	<0.005	69.97	<0.005	28.26	>0.1
[23] [1]	23	192.20	<0.005	185.54	<0.005	169.64	<0.005
[12] [13]	22	85.20	<0.005	60.43	<0.005	26.12	>0.1
[12] [23]	22	188.83	<0.005	178.22	<0.005	167.84	<0.005
[13] [23]	12	46.35	<0.005	42.86	<0.005	20.13	>0.05
[12] [13] [23]	11	42.46	<0.005	29.64	<0.005	18.51	>0.05

10.6. Muskoxen, disturbed group activity

The activity of muskox herds after harassment showed less correspondence with pre-harassment activity than did caribou activity. None of the possible combinations of two variable interactions between season, harassment phase and group activity of muskoxen provided a satisfactory fit to the observed frequencies (Table 78) which indicates that activity was dependent on harassment phase and that this relation varied between seasons. Observations of mixed bedded–foraging were less common than expected prior to harassment and more common following harassment from 1 to 23 June (Table 79). The very infrequent occurrence of synchronous bedding before harassment between 24 June and 15 July did not continue after harassment. Synchronous foraging; bedded–other and bedded–foraging–other were observed more often than expected after harassment from 16 July to 7 August. Finally, synchronous bedding occurred less frequently than expected following harassment between 8 and 24 August while mixed foraging–other and bedded–foraging–other were observed more frequently than expected.

There were also three-way interactions between harassment phase, time of day from 09:00 to 21:00 and bedding and foraging by muskox herds (Table 80). There was only one 10-min interval, in all the observations of harassed muskox herds between 10:00 and 12:00, in which we observed foraging by at least one animal (Table 81). Synchronous bedding was particularly frequent among harassed herds from 10:00 to 11:00, while bedded–foraging–other was relatively infrequent. These deviations from the expected pattern of activity are responsible for large contributions to the chi-square tests for bedding and foraging (Tables 82 and 83).

Synchronous bedding was also relatively common from 12:00 to 13:00, but uncommon from 14:00 to 15:00. There were also major contributions to the bedding chi-square from the 19:00 to 21:00 period (Table 82). All non-bedded activities occurred slightly more often than normal among harassed herds from 19:00 to 20:00 (Table 81). Synchronous foraging was not observed among undisturbed muskox herds between 20:00 and 21:00, but this activity was observed among harassed herds relatively more frequently during this period than during any other 1-h period (Table 81). There was also a proportionately low occurrence of mixed bedded–foraging among disturbed herds from 20:00 to 21:00 (Table 81). Other activities occurred at an essentially constant rate from 09:00 to 21:00 (Table 84) and that rate was not affected by harassment experiments (Table 80).

Table 81
Distribution of group activity throughout the day based on sightings at 10-min intervals of muskoxen harassed by helicopter overflights, Prince of Wales Island, NWT, 1977. Each cell contains the observed frequency and percentage occurrence

	Bed. only	For. only	Other only	Bed.–for.	Bed.–other	For.–other	Bed.–for.–other
09:00–10:00							
	5	3	1	5	0	1	1
	31.25	18.75	6.25	31.25	0.00	6.25	6.25
10:00–11:00							
	9	0	0	4	3	0	1
	52.94	0.00	0.00	23.53	17.65	0.00	5.88
11:00–12:00							
	17	1	0	19	0	0	2
	43.59	2.56	0.00	48.72	0.00	0.00	5.13
12:00–13:00							
	31	1	3	21	0	5	1
	50.00	1.61	4.84	33.87	0.00	8.06	1.61
13:00–14:00							
	20	11	4	16	0	4	12
	29.85	16.42	5.97	23.88	0.00	5.97	17.91
14:00–15:00							
	4	15	2	19	1	5	2
	8.33	31.25	4.17	39.58	2.08	10.42	4.17
15:00–16:00							
	11	17	3	33	3	3	2
	15.28	23.61	4.17	45.83	4.17	4.17	2.78
16:00–17:00							
	37	17	2	51	4	10	8
	28.68	13.18	1.55	39.53	3.10	7.75	6.20
17:00–18:00							
	23	31	3	50	5	12	1
	18.40	24.80	2.40	40.00	4.00	9.60	0.80
18:00–19:00							
	32	12	0	36	4	10	8
	31.37	11.76	0.00	35.29	3.92	9.80	7.84
19:00–20:00							
	8	8	3	19	3	2	0
	18.60	18.60	6.98	44.19	6.98	4.65	0.00
20:00–21:00							
	6	10	1	2	0	0	0
	31.58	52.63	5.26	10.53	0.00	0.00	0.00

Table 82
Distribution of bedding relative to harassment phase and time of day based on sightings at 10-min intervals of muskox herds, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and O/E index. Expected frequencies and O/E index were calculated on the assumption of dependence between time of day and activity, time of day and harassment phase and harassment phase and activity.

	09:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	20:00–21:00
Preharassment												
Bedded												
	59	71	69	73	83	46	62	57	67	46	40	30
	59.17	74.13	73.22	77.83	80.78	44.71	61.76	62.77	59.13	49.88	35.53	27.09
	1.00	0.96	0.94	0.94	1.03	1.03	1.00	0.91	1.13	0.92	1.13	1.11
Not bedded												
	37	25	19	34	33	43	37	36	26	26	7	7
	36.83	21.87	14.78	29.17	53.22	44.29	37.24	30.23	33.87	22.12	11.47	12.92
	1.00	1.14	1.29	1.17	0.94	0.97	0.99	1.19	0.77	1.18	0.61	0.54
Postharassment												
Bedded												
	11	17	38	53	48	26	49	100	79	80	30	8
	10.83	13.87	33.78	48.17	50.22	27.29	49.24	94.23	86.87	76.12	34.47	13.92
	1.02	1.23	1.12	1.10	0.96	0.95	1.00	1.06	0.91	1.05	0.87	0.57
Not bedded												
	5	0	1	9	19	22	23	29	46	22	13	11
	5.17	3.13	5.22	13.83	16.78	20.71	22.76	34.77	38.13	25.88	8.53	5.09
	0.97	0.00	0.19	0.65	1.13	1.06	1.01	0.83	1.21	0.85	1.52	2.16

Table 83
Distribution of foraging relative to harassment phase and time of day based on sightings at 10-min intervals of muskox herds, Prince of Wales Island, NWT, 1977. Each cell contains the observed and expected frequencies and O/E index. Expected frequencies and O/E index were calculated on the assumption of dependence between time of day and activity, time of day and harassment phase and harassment phase and activity

09:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	20:00–21:00
Preharassment											
Foraging											
68	73	57	79	84	67	72	78	72	50	32	21
68.03	67.51	57.23	71.30	84.04	72.22	76.63	72.65	74.48	51.57	33.75	23.60
1.00	1.08	1.00	1.11	1.00	0.93	0.94	1.07	0.97	0.97	0.95	0.89
Not foraging											
28	23	31	28	32	22	27	15	21	22	15	19
27.97	28.49	30.77	35.70	31.96	16.78	22.37	20.37	18.52	20.44	13.25	16.40
1.00	0.81	1.01	0.78	1.00	1.31	1.21	0.74	1.13	1.08	1.13	1.16
Postharassment											
Foraging											
10	5	22	28	43	41	55	86	94	66	29	12
9.97	10.49	21.77	35.70	42.96	35.77	50.37	91.35	91.52	64.44	27.25	9.40
1.00	0.48	1.01	0.78	1.00	1.15	1.09	0.94	1.03	1.02	1.06	1.28
Not foraging											
6	12	17	34	24	7	17	43	31	36	14	7
6.03	6.51	17.23	26.30	24.04	12.22	21.63	37.65	33.48	37.57	15.75	9.60
1.00	1.84	0.99	1.29	1.00	0.57	0.79	1.14	0.93	0.96	0.89	0.73

Table 84
Frequency and percentage occurrence of other activity based on sightings at 10-min intervals throughout the day of muskox herds following helicopter harassment overflights, Prince of Wales Island, NWT, 1977

09:00–10:00	10:00–11:00	11:00–12:00	12:00–13:00	13:00–14:00	14:00–15:00	15:00–16:00	16:00–17:00	17:00–18:00	18:00–19:00	19:00–20:00	20:00–21:00
Other											
3	4	2	9	20	10	11	24	21	22	8	1
18.75	23.53	5.13	14.52	29.85	20.83	15.28	18.60	16.80	21.57	18.60	5.26
Non-other											
13	13	37	53	47	38	61	105	104	80	35	18
81.25	76.47	94.87	85.48	70.15	79.17	84.72	81.40	83.20	78.43	81.40	94.74

Summary discussion

The background to the status of the Peary caribou population along proposed pipeline routes on the Arctic Islands can be briefly summarized: on the western Queen Elizabeth Islands, Peary caribou suffered a drastic decline (89%) between 1961 and 1974, especially on eastern Melville and Bathurst islands; on Prince of Wales and Somerset islands the decline was considerably less drastic; muskoxen also declined on the western Queen Elizabeth Islands.

Our helicopter harassment study is the first project known to us to be specifically designed to obtain a measure of the responses of large, free-ranging ungulates to aircraft harassment. The design of our study met as many of the points as possible raised by Geist (1975) in his critique of reports of aircraft harassment. We considered the likely types of helicopter activities that could be anticipated during the construction and maintenance of a pipeline and we chose response categories based on behavioural positions or locomotory patterns which did not require subjective decisions by the observers. Our standardized single and multiple flights are repeatable and the response categories are verifiable from Super 8 movie films taken during the flights by both observers in the helicopter and observers on the ground.

Our study was based on recording only the more obvious overt behavioural responses for three reasons. (*a*) Under field conditions, we rarely could be sure that we detected subtle behaviour patterns such as movements of the ears, widening of the eyes, tightening of the back muscles and other indications of induced tensions. In particular for muskoxen, the relatively stocky appearance and long, hairy coat, would have hindered detection of those responses. (*b*) Other potential effects of harassment (Geist 1975:4–9) would only become apparent months or even years after harassment (Table 85). Within the duration of our study, the only pathological conditions resulting from harassment that we could have recognized would have been traumatic injuries caused by panic behaviour. We did not observe any such injuries or circumstances likely to produce them. Although we observed an increase in agonistic behaviour between muskoxen during overhead helicopter harassment flights and landings, we did not see any injuries resulting from the aggression between bulls, although fighting is known to lead to severe injuries and even death (Wilkinson and Shank 1974). (*c*) Caribou physiology has been partially described, but almost nothing is known about muskox physiology and time did not permit us to go through the exercise of transposing our behavioural responses into theoretical physiological terms based on the physiology of other ruminants.

An animal's behaviour is often as much a manifestation of its internal as of its external environment and its behaviour will be reflected in its physiological state. It is, thus, inescapable that behavioural responses to harassment will be accompanied by physiological responses. Physiological responses range from changes in heart or respiration rates to acute pathological conditions such as overstraining disease. We did not expect to observe any such acute conditions during our study as the published accounts suggest that those conditions are associated with extreme harassment including chases by vehicles or aircraft.

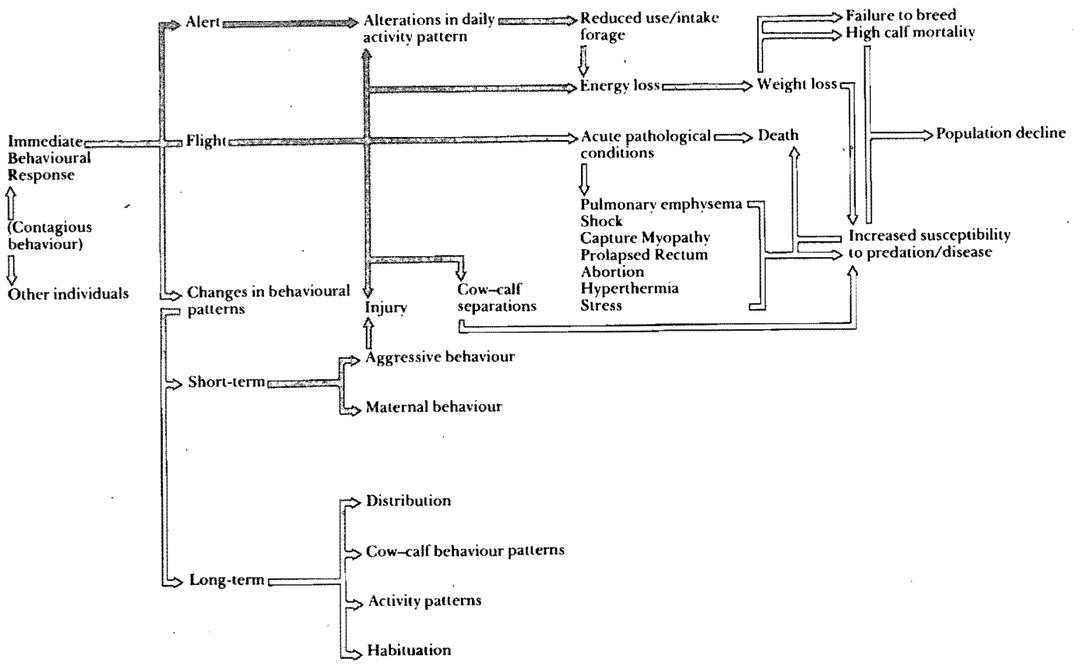
The remote monitoring of physiological responses such as changes in heart rate requires the use of telemetry, but although telemetric techniques are rapidly being refined, a reliable field tested system is not yet available. Besides the perfection of suitable systems, there are other problems with monitoring physiological parameters that would have to be overcome. It is possible that an animal that has been captured, drugged and handled to attach a telemetric package may respond at a different level to a harassing agent, especially if the agent can be associated by the animal with the original capture and handling. In addition, associative learning by the animal could restrict our ability to successfully monitor the telemetric signals unless an extremely remote receiver can be developed.

We concur with those who have called for a physiological approach to harassment, but we would stress that even once the telemetric techniques are available, the questions on the effects of harassment will still not be answered completely. We do not have the baseline data required to interpret changes in physiological parameters, though some likely difficulties in interpretation of changes in heart rate may be deduced from a 15-year study on the monitored heart rate of penned white-tailed deer (Moen pers comm).

Moen and Chevalier (1977) have noted tachycardia and bradycardia, in penned deer, that were not associated with overt behavioural responses to disturbing stimuli such as rustles in the grass and snowmobiles and they have also observed behavioural responses that were not accompanied by changes in heart rate. The results of their studies reinforce the need for behavioural observations to interpret some of the changes in heart rate. Firstly, muscular activity can cause interference with and artifacts in the heartbeat trace (though this depends somewhat on electrode location). Secondly, behavioural observations will be necessary to interpret some changes in heart rate. For example, Moen and Chevalier (1977) found that other deer approaching the subject deer and environmental factors such as rain caused changes in heart rate.

Interpretation of behavioural observations has to be based on sound baseline data if misleading impressions are to be avoided. Calef *et al.* (1976) have used observations of

Table 85
Schema of some potential effects of harassment and their interrelationships for Peary caribou and muskoxen



barren-ground caribou cows standing over their dead offspring and not apparently responding, at least by flight, to nearby landings of helicopters as examples of little or no response to helicopter harassment. We must take exception to their interpretation of those observations, as we do not believe that the examples are meaningful, unless some attempt is made to explain the psychological forces associated with such situations.

The retention and persistence of a one-way mother–young bond after the death of one of the pair members has been reported for chamois (*Rupicapra rupicapra*) by Krammer (1957), black-tailed deer (*Odocoileus hemionus columbianus*) by Miller (1971) and barren-ground caribou by Miller and Broughton (1973). Cows will often stand over their dead offspring for days and in some cases, will keep returning to the death sites for several weeks. The bond apparently will not be broken until the maternal caribou is displaced (or enticed) a given distance (unknown) from the neonate's carcass, by a stimulus such as wolf or human harassment or a large post-calving aggregation passing close by. There is also probably a temporal consideration associated with the displacement and/or a direct relationship to the strength of the stimuli from the displacing agent.

Contrary to the inferred supposition of Calef *et al.* (1976) a maternal cow with a dead offspring is not likely responding in a manner that is comparable with its responses in the company of a live calf. Maternalistic responses vary considerably and there is no reason, known to us, to suppose that all maternal cows accompanied by live calves will respond in a like manner to harassing stimuli. It is more probable that their responses will vary with the individual makeup and motivational state of the maternal cows and their recent past experiences.

Calef (pers. comm) indicated that their discussion of maternal cows with dead calves (Calef *et al.* 1976) was meant to reflect the tenacity of the mother–young bond between maternal cows and live calves. We must disagree, however, with this belief that the responses between maternal cows with dead calves and maternal cows with live calves are comparable. We believe that the critical difference is one of alternatives available to the cows under those conditions.

(*a*) When a maternal cow with her dead offspring is disturbed, she basically has only two choices: i) to remain standing over her dead calf or withdraw briefly for a short distance, or ii) to take flight and abandon the carcass. We believe that because of the ordering of the behavioural repertoire of most maternal cows she has in reality but one choice, that is, to remain at or near her dead neonate. She will do so until sufficiently stimulated to permanently break her bond with the dead calf, as described by Miller and Broughton (1973).

(*b*) When a maternal cow is in the company of a live calf, she can respond to stimuli by flight and the calf will follow suit. Often the calf is first to take flight and the cow responds in kind, often, seemingly, before actually determining the cause. In whatever manner the cow or calf respond to stimuli, the remaining pair member can follow and do likewise if not simultaneously. Each member can and often does take cues from the other and their subsequent responses are most often harmoniously predetermined in kind and usually in degree.

Therefore, we conclude that a maternal cow is more likely to respond by flight from harassing stimuli when in the company of a live calf, that can do likewise, than when "guarding" a dead neonate. In addition, the apparent lack of or low level of response by a maternal cow with a dead calf (or the reverse) to harassing stimuli is more a measure of the strength of retention of the mother–young bond by the surviving member of the pair, than a direct measure of response to harassing stimuli. The responses of maternal cows with dead offspring should not, therefore, be used as a valid measure of the severity of impact of helicopter harassment.

The above discussion would also apply to maternal cows with live calves that could not for one reason or another travel with their mothers. We think the above would be especially true for maternal cows with live calves that were at least several days old that had been immobilized through disease or trauma because the mother–young bond is strengthened by continued care-giving and care-soliciting behaviour by both members of the pair. Therefore, a maternal cow with an older calf that could not respond to her cues for flight would be more likely to remain with the calf during periods of harassment than if the calf was only a few hours old. The caribou calf is a precocial neonate but it is more or less immobile during the first few hours of life. If the lapse of time for bond formation had been only a few hours, bond formation would probably be weak or incomplete. In general, strong bonding should occur more quickly between experienced (multiparous) cows and their offspring than between inexperienced (prima-parous) cows and their newborn calves. Cows bearing young for the first time are often poor mothers and apparently not psychologically well adjusted to the birth event. Therefore, their behaviour is more apt to vary when harassed and they might either stay with or abandon their newborn calves more on an individual basis. Cows that have previously produced young are usually better mothers and most often respond more quickly and appropriately to motherhood. Therefore, their responses to harassment should be relatively more fixed and they should most often remain with their calves, at least, during low levels of harassment.

Our observations of Peary caribou and muskoxen are to date the most detailed available on the responses of free-ranging large ungulates to aircraft harassment. Peary caribou and muskoxen have differences in the dynamics of their social orders, forage preferences and consequently selection of foraging sites and the presence (muskoxen) or absence (Peary caribou) of defense in their repertoires of escape behaviour, and those differences contribute to the variations in their responses to helicopter harassment. In fact, the generalizations that apply to both species are few.

(*a*) There is an inverse relationship between the strength and intensity of their responses and the altitude of the helicopter above the animals.

(*b*) Cows and calves of both species are the most sensitive sex/age class to harassment, but the sensitivity of muskox cows and calves is partly masked by their participation in group defense formations.

(*c*) Some aspects of their annual life history cycles and associated behavioural changes (e.g. calving, postcalving, rutting and migration) affect the level of responses and cause variations to some degree at different seasons of the year.

(*d*) The effect of some physical properties of wind and sun associated with harassing stimuli influence their levels of responses.

(*e*) The psychological security borne of familiarity with terrain (preferred habitat for foraging, resting and escape) influence to some degree their relative responsiveness: Peary caribou being associated more with uplands and muskoxen with lowlands.

The initial responses of ungulates to harassing stimuli are basically similar to the response to a predator. Energetic constraints probably require most animals to minimize the risk (of predation) and at the same time minimize the energy expended to avoid predation when it is not imminent. For example, caribou primarily rely on their speed to avoid predation, but rather than running needlessly as soon as a predator appears, they wait until it is within a threshold (flushing) distance. The behavioural responses to a harassing agent such as a predator can probably be modified by experience. If the caribou or muskoxen are chased and/or surprised by the sudden appearance of a harassing agent to the extent of "panic" behaviour, they may associate the experience with that agent and will probably respond at an extreme level on subsequent occasions. We do not know if such extreme responses are self-reinforcing. There should be less stress with time; as the animals become experienced with the harassing agent they may habituate.

We do not know if some of the variation in response levels to similar intensities of harassment that we observed is the result of previous experience with helicopter overflights. Other factors such as the stability of social order within the herd (especially in muskoxen), recent exposure to other stressful situations (such as a predator attack) and individual variation in behaviour are possible modifiers of the response levels. There were distinct differences among the herds of muskoxen that we had observed on several occasions to the extent that we could label them as (relatively) calm or excitable. Although we believe that we observed a waning of response levels within sets of passes (simulated slinging) this apparent habituation did not hold between different sets of passes. Unfortunately, we do not know the situations that will develop and maintain habituation. Thomson (1972), Espmark (1972) and Calef *et al.* (1976) have all suggested the possibility of habituation of caribou to aircraft but on even less tangible evidence than we have presented.

Muskoxen respond to a predator by assuming a group defense formation, but this behaviour considerably increases their vulnerability to human disturbance. In the past, defense behaviour led to near extinction over most of their range (Hone 1934) because of the ease with which hunters could kill animals in a group defense formation. The grouping and remaining in place tends to attract the attention and curiosity of humans partly because the muskox is a unique and intrinsically interesting mammal, but also, because of the mistaken impression that if the muskoxen are not running away, they are not afraid.

The attraction for photographers or curious people is obvious and is perhaps reflected in the fact that almost every published photograph of muskoxen is of a defense formation. This practice is not without potential hazard to the photographer: we were impressed by the speed and agility with which individual muskoxen briefly charged out of a defense formation at a wolf and the precision with which the closely packed herd then charged and routed the wolf after its abortive attack (Miller and Gunn 1977c).

Use of ground observers considerably expanded our collection of data: as well as data on individual cow–calf pairs and group behavioural patterns before and after harassment, we were also able to record durations of responses and estimate distances covered by the animals. We often had difficulties in keeping the animals in view without inadvertently alarming them, especially in rolling terrain. It was likely that the animals were more often aware of our presence than their recorded behaviour suggested.

The estimates that we made of the distances that animals travelled during their locomotory responses to harassment are a measure of the intensity of their response. Our estimates of the distances moved by Peary caribou during overhead passes suggest they rarely travelled more than 400 m. Bergerud (1963) and Calef and Lortie (1973) suggested

that caribou usually moved less than 500 m when overflown by an aircraft. The distances that muskoxen moved after taking up a group defense formation varied, but were usually less than 200 m: only one group (in 1976) galloped between 200–400 m during passes. Although we do not understand the mechanism of group defense formation (e.g. initiation, focal point, etc.) we believe that the distances between group members (or a solitary bull from a physical feature) partially determined the gait used to take up the defense formation.

Our inability to recognize and maintain contact with individual groups prevented us from estimating straight-line distances travelled by caribou between harassments. We were able to record straight-line distances between locations of muskox groups (Miller and Gunn 1977a: Table 14). Those data are limited as we know little about the daily rates of travel of undisturbed animals. We believe, however, that during the three months in 1977 we observed the Back Bay and Allen Lake herds, we did not cause them to leave their normal ranges in that area of northeastern Prince of Wales. Our impression is that muskoxen are mainly sedentary in summer with a relatively fixed size of range within which they move according to phenology of the vegetation, drainage conditions and possibly the size of the herd. The consensus from the literature is also that muskoxen are relatively sedentary (Hone 1934, Tener 1965, Gray 1973, Wilkinson and Shank 1974). Gauthier (1975) watched apparently undisturbed muskox groups on central Bathurst Island and described mean rates of travel of 1.29 km/h (0.0–3.1 km/h) during periods of 90% snow cover, and 0.29 km/h (0.0–0.52 km/h) during snow-free periods. Wilkinson and Shank (1974: 122–136) describe detailed movements of some muskox herds on Banks Island. Their results show that although muskoxen remained feeding in relatively small areas for days at a time, they would also move several kilometres to new foraging areas. All the movements that we observed are within the ranges of daily movements described by Wilkinson and Shank (1974) and Gauthier (1975). We do not know the degree of influence of terrain, snow cover, phenology of vegetation, weather and reproductive cycle phase on movements. Our observations of the durations of responses, distances travelled, apparent affinity for normal ranges and absence of unusual or unexpected behaviour patterns suggested that our helicopter harassment overflights did not have a detrimental effect on the animals harassed. We must stress, however, that we do not know (*a*) the energy cost of the responses and what that means to the animal and population over an extended period of time; and (*b*) whether there were any undetected behavioural or physiological changes that would become significant over a period of time – for example, change in reproductive potential is a likely sensitive indicator of the well-being of a population.

Comparisons of our results with those of Klein (1973), McCourt and Horstman (1974), McCourt *et al.* (1974), Surrendi and DeBock (1976) and Calef *et al.* (1976) during aerial counts of the Porcupine caribou herd in Alaska and Yukon Territory are restricted for four reasons: (*a*) it is not clear from those other reports exactly how and when their flights were flown; (*b*) we used a helicopter but the other reports refer mainly to fixed-wing aircraft with some helicopter use; (*c*) we used different response categories; and (*d*) our study was in a different area with distinct vegetation and terrain and a different subspecies of caribou (*Rangifer tarandus pearyi* rather than *Rangifer tarandus granti*).

In general, the reported results emphasized altitude as an important determinant of response levels, but group size, sex and age class, season, terrain, previous activity and aircraft type were all considered as contributing to the response levels. There were some differences in the recommended operational ceilings for aircraft to minimize disturbance to caribou. Calef *et al.* (1976: 210) suggested that aircraft operating at above 150 m during spring or fall migration would avoid "most potentially injurious reactions by caribou", but during calving period, the rut and early winter, a minimum altitude of 305 m would be required. McCourt *et al.* (1974) suggested 305 m as a "minimum altitude tolerance level." Although we realize that both caribou and muskoxen have adapted to human presence (and disturbance) in certain situations, we do not understand the processes that lead up to habituation. This knowledge is critical to fostering the compatability of the well-being of caribou and muskox populations with northern development. It is not, however, only the animals that will have to adapt: industry and government will also have to adapt their operation schedules and policies to provide opportunities for the animals to accept the changes in their environments. In particular, we stress that low-level flights overhead, circling or following the animals and landings close-by animals with on-foot approaches are extremely detrimental to animals not only in the short-term, but also in reducing the likelihood of habituation. Based on our findings and the belief that there is a need for a judicious approach to the conservation of wildlife and habitats, especially in the light of our limited knowledge of the true consequences of petroleum development on the arctic ecosystem, we recommend that all possible aircraft flights be kept above 300 m agl at all times and above 600 m agl during calving and post-calving periods (May–August) and rutting periods (August–November).

The setting of minimal height regulations for aircraft is not an imposition for much of the aircraft traffic that would be associated with pipeline construction, as flying at those altitudes or higher makes navigation by landmarks relatively easy and most pilots also prefer the added safety margin afforded by the higher altitudes in the event of mechanical problems. Another justification for setting minimal altitudes on the high side is the abrupt nature of much of the terrain of the Arctic Islands with its vertical rises and drops of several hundred metres. Pilots seldom compensate for the ground elevational changes unless the elevation puts them dangerously low to the ground.

Some flights such as inspection flights will have to be flown considerably lower than the recommended 300–600 m agl. Thus, if approval for pipeline construction is given, aircraft activities will cause some degree of harassment during such low altitude flights. Perhaps, under those conditions, the best we can plan for is that the pilots are made aware of the impact of their activities on the wildlife.

We must have the pilot's cooperation (willingly, if possible) to minimize any unnecessary flying in the vicinities of wildlife for the purposes of photography, or a "better look" at, or an impulse to run the animals encountered. The likelihood of enforcing such height restrictions for aircraft is questionable at best and then only if development companies choose to comply with the rules. Also, weather conditions in the Arctic often force single engine aircraft below 200 m agl to maintain visual contact with the ground, the need for and the wisdom of which cannot be argued against by anyone who has flown under such conditions – especially if they have ever "lost an engine"!

The federal, provincial and territorial agencies charged with the responsibility for conservation of wildlife and their habitats must vigorously press for the constraints necessary to protect their charges in a time of hasty development of unrenewable resources. The "corporate citizen" may preach moral sensibility with some degree of sincerity, but such principles are not revered by subcontractors faced with deadline penalities, narrow profit margins and a transient labour force that often shows a conqueror's indifference to the land that they are manipulating and the native species of that land.

Conclusions

A comparison of our analyses of independence and regressions of individual response samples from Peary caribou and muskoxen indicate the following.

(1) The responses of Peary caribou and muskoxen exhibit an inverse relationship with the altitude of the helicopter harassment overflights: proportionately fewer animals respond at the extreme level with each ascending altitude class.

(2) Peary caribou and muskox cows and calves are usually more responsive than other sex/age classes.

(3) The apparent responsiveness of Peary caribou yearlings and juveniles is usually a reflection of their investigative nature.

(4) Peary caribou bulls are the least responsive sex/age class.

(5) Muskox bulls are least responsive in mixed sex groups of muskoxen.

(6) Peary caribou in larger groups (> 20 animals) tend to be more responsive than individuals in smaller groups, especially if calves are present.

(7) Solitary muskox bulls or bulls in single sex groups tend to be more responsive than individuals in mixed sex groups.

(8) The responses of muskoxen in mixed sex groups appear more as a function of the makeups of individuals within the group than size of the group.

(9) Peary caribou cow–calf pairs are the most responsive caribou group type.

(10) Single sex groups of muskox bulls are the most responsive muskox group type.

(11) Peary caribou are more responsive when calves are present.

(12) The levels of responsiveness of muskoxen in mixed sex groups show no direct relationship between the number of calves present.

(13) Both Peary caribou and muskoxen may respond more (by greater displacements from activity centres) to people than to a helicopter only, based on our observations during ground party activities (simulated amateur photography and work parties).

(14) We need to determine when and where Peary caribou and muskoxen calve. Caribou calving is highly synchronized within a population and most calves are born within a few days of each other. This synchrony implies that if the location and timing of calving were known, it would not be difficult to adapt construction schedules to avoid disturbance to such vulnerable areas. Muskox calving is a more prolonged event and the probable existence of calving areas is unknown, but it is likely that a suitable schedule could be worked out, if the proper research was done.

(15) The presence of humans and their installations, such as work camps and pump stations along pipelines has several implications for the future well being of caribou and muskoxen.

a) It interrupts and/or disrupts restocking of islands or portions of islands that have undergone severe losses of caribou and muskoxen due to environmental stresses (usually caused by snow and ice conditions that reduce forage availability).

b) It interrupts and /or disrupts intra- and inter-island migrations of caribou to traditional seasonal ranges, traditional calving, post-calving and rutting areas.

c) It interrupts and/or disrupts daily feeding activities.

d) It reduces the genetic plasticity and long-term survivability of the population by restricting free movements and thus gene flow.

Current concepts of the roles of leadership and socialization in disseminating experience within a population strongly suggest that the unfavourable contact of even a few dominant caribou or muskoxen of a population with a man-made obstruction could affect the subsequent movements of many caribou and muskoxen. We have only fragmentary observations of Peary caribou and muskox responses to human installations which are not sufficient to permit us to review proposals from the private sector or evaluate Environmental Impact Statements. The only information to date that relates to responses of caribou to human activity and installations is cursory and fragmentary and needs to be considerably expanded if we are to be in a position to protect and wisely use Canada's wildlife resources.

(16) Our observations suggest that some percentages of any helicopter overflights at <400 m agl and greater percentages at <200 m agl will cause harassment to both Peary caribou and muskoxen. The short-term costs to individuals and the long-term impact on populations are not known. Therefore, the matter must be treated with concern if we are to maintain harvestable ungulate populations for the native peoples of Arctic Canada.

Implications and recommendations

1. Pipeline construction and operation

1.1. Aircraft harassment

The route of the proposed Polar Gas pipeline crosses sensitive and critical areas of the ranges of Peary caribou and muskoxen including calving grounds, post-calving areas and rutting areas. In view of the greatly increased air traffic that will be necessary over those areas during construction and maintenance activities, as described by the proponent, we make the following recommendations.

(1) Minimal flying heights of all aircraft types be set at no lower than 300 m agl from December through April.

(2) Both Peary caribou and muskoxen be afforded extra protection during calving and post-calving periods (May–August) by increasing the minimal flying height to 600 m agl to reduce the possibility of man-induced mortality to young of the year.

(3) The 600 m agl minimal flying height be extended from August through November to prevent additional stress to adult breeding animals during their rutting periods and young animals who are building up their body reserves essential for their survival through the winter.

(4) Information be available to pilots and other air crew members to explain the need for the recommended flight altitudes. In particular, the potential consequences to the animals of pilots satisfying their own curiosity, or that of their passengers to "take a look" at the animals should be emphasized.

(5) Although the need for low level inspection flights of the pipeline has been stated by Polar Gas, they should be restricted to the pipeline corridor.

1.2. Ground activity harassment

The locations of staging areas, construction camps and the pipeline corridor itself will be scenes of ground activities by work crews and land vehicles. Those activities have potential to harass Peary caribou and muskoxen particularly in critical calving, post-calving and rutting areas. Therefore, we recommend the following.

(1) Ground crews and vehicles should not approach animals to within 1000 m. The investigative behaviour of young caribou should not be regarded as evidence that the animals will not be subsequently stressed as the result of the encounter with ground crews and vehicles.

(2) Camp dogs should not be used to chase or herd animals or hold muskoxen at bay for any purpose.

(3) During and after construction, materials of any kind should not be left where they could be a hazard to Peary caribou or muskoxen.

2. General

Peary caribou and muskox behaviour have been the subject of relatively few studies, therefore, apart from our harassment data we were able to obtain valuable data on both species. We obtained data on bedding and foraging patterns and specific behaviours including nursing, care soliciting, play and agressive behaviour. We also obtained extensive evidence of Peary caribou crossing on the sea ice between Somerset, Prince of Wales and Russell islands.

3. Personal views and judgements

The successful reproduction and rearing of young is sporadic at best for Peary caribou and muskoxen on the Arctic Islands (Tener 1965, Gray 1973, Miller *et al.* 1977a). In addition, the physical condition of many Peary caribou and muskoxen over 1 year of age is poor and mortality can be high during some years, especially during periods of unfavourable snow and ice conditions (Parker *et al.* 1975, Thomas *et al.* 1976, 1977; Miller *et al.* 1977a).

Our observations from Prince of Wales during this study and observations from the western Queen Elizabeth Islands (Miller *et al.* 1977a) suggest that even in years when reproduction is high, survival of Peary caribou and muskoxen during the first year of life is sometimes low. It is unlikely that annual increments to the population of 10 to 20% are maintained over the long term: this is indeed true for the last decade. Therefore, we suggest that helicopter harassment has the potential for causing additional stress leading to increased mortality under certain conditions. Any additional mortality could hinder or prevent Peary caribou and muskoxen from maintaining their numbers from year to year. The probability of such mortality requires that some constraints be employed to guard against mortality from aircraft harassment. The possibility of additional mortality is particularly important because numbers of Peary caribou on traditional hunting areas are now so low that the Inuit are turning to the harvest of muskoxen.

Need for further study

1. Harassment

The gaps in our knowledge of the effects of harassment on Peary caribou and muskoxen fall into two temporal categories: short and long term. In this section we are not restricting ourselves to helicopter harassment, but all types of man-induced harassment connected with the construction and maintenance of a gas pipeline in the High Arctic.

We do not know the cost of the response to harassment in terms of an individual's energy budget. We do not know whether animals that did not overtly respond were in fact responding at a physiological level and we do not know the cost. Our budget limited our work to June through August, the period when Arctic operations were most economical and most easily carried out. Therefore, we do not know how Peary caribou and muskoxen would respond to harassment from September to June. The late winter period (March to May) is when animals lack, or have their lowest, energy reserves and the effects of harassment may be the most severe at that time.

We do not know the long-term effects of harassment on individuals. Although the energy costs of responses to harassment may appear low, any extra drain of energy over a relatively long period could seriously deplete the reserves essential for successful reproduction and survival. At best, we have only a limited understanding of the role of adversive conditioning or habituation in determining changes in response levels over prolonged exposure to harassing stimuli.

Sufficient accumulation of affected individuals will lead to impacts at the level of the population over the long term. Although we know that high reproductive success over the long term for both species is, at best, sporadic, we do not have a good measure of an additional slight loss of reproductive effort and/or a slight increase in mortality. But we can judge with confidence that such changes would be detrimental and most likely adversely influence sustainment of the population. We do not understand the degree of affinity to traditional ranges and migratory routes by the animals, nor the levels of harassment that might force the animals to abandon ranges and/or routes or the total consequences of such abandonments. We can, however, predict that it is probable that almost any interference with the distributions of the animals by foreign activities that drive them from their preferred ranges or cut-off migratory routes will have a marked effect on the segment of the population concerned. It will be of little or no benefit to Peary caribou and muskox populations to enact regulations that will partially protect individuals from harassment, if development activities interfere with their movements and turn them from their preferred ranges.

Although many of the questions on the effects of harassment could be answered by monitoring heart rate and body temperature by telemetry, to measure the cost of harassment we would still require baseline studies of the physiology of both species to be able to fully interpret the data. Studies of marked animals over several years would be required to detect changes in migratory routes and preferred areas in association with aerial surveys to monitor the reproductive trends in the populations. The collection of animals in association with the traditional hunting by Inuit would provide information on the well-being of the animal populations but climatological studies, especially snow studies, would be necessary to interpret the data.

2. Critical areas and likely areas of intensive interaction

Although any time human activities contact animals there is a potential for harassment, there are areas where the potential is enhanced by an increase in the sensitivity of the animals.

2.1. Winter ranges

Particularly towards late winter (February–May) the declining energy reserves of both Peary caribou and muskoxen and the extreme cold increased their vulnerability to harassment. Other AIPP projects have, however, located and described winter ranges for both species. As the coverage of the islands was not complete, it is possible some sensitive winter ranges have not been mapped.

2.2. Calving and rutting areas

It is a critical gap in our knowledge that we have located no proven calving grounds for Peary caribou. For example, the Inuit of Resolute Bay, Cornwallis Island, have suggested that Aston Bay on Somerset Island may be an important calving area. As Aston Bay is a proposed staging area for pipeline construction, the possibility of interference of construction at one of the most sensitive phases of caribou life-cycle should be further investigated. Eastern Melville Island may also be an area of calving but the exact location is unknown. We know even less about the potential location of rutting areas, except there is potential for interference at another critical period in the life-cycle of caribou. Muskoxen calve and rut in discrete herds and their use of such traditional areas is unknown. Their use of preferred areas during different phases of their annual life-cycle needs more study.

2.3. Migratory routes

The activities associated with the pipeline and the pipeline itself have potential to interfere with or prevent the free movements of animals. Our ability to predict potential problem areas is reduced by our lack of knowledge and we are limited to generalizations. We believe the west-to-east, early summer movement of Peary caribou on eastern Melville (some individuals crossing from Prince Patrick Island, Miller *et al.* 1977b), the south-to-north movement to summer ranges on northern Bathurst and east-to-west movements across Somerset (some individuals crossing Peel Sound to Prince of Wales Island, Miller and Gunn 1978a) are all movements that should be further investigated. In addition, local movements of both species in the area of pipeline activities are vulnerable to interference, the importance of which will vary with the phase of the annual life-cycles and relative availability of forage for each species.

Summary

Our objectives were to determine the response of Peary caribou and muskoxen to helicopter-induced harassment. We simulated likely activities of helicopters involved in inspection flights, cargo slinging and deployment of work parties and personnel involved in amateur photography. We flew about 289 h in a Bell-206B helicopter in July–August, 1976, and June–August, 1977, over northeastern Prince of Wales Island and Russell Island, NWT. In 1976, we used a three-man team for mainly airborne observations during flights mostly <200 m agl. In 1977, we used four, two-man teams as ground observers during mainly high level flights (>200 m agl).

We took the maximum response of one individual during one flight and categorized it as at the extreme level if the animal galloped or trotted (caribou) or galloped, cantered or moved together to take up a group defense formation (muskoxen). If the animals walked or became alerted, but stayed in place, we categorized the response as at the moderate level. If the animals did not aparently respond but remained foraging or bedded, we recorded the response as at the maintenance level. We analyzed the IRS in relation to measured variables by observed/expected indices from Chi-square tests of independence and three stepwise multiple regressions for each species. Our results were as follows.

(1) Of the 3939 IRS obtained for Peary caribou during 671 pass-type harassment overflights, 35.1% were extreme level responses, 28.9% were moderate level responses and 36.0% were maintenance activities.

(2) Of the 4011 IRS obtained for muskoxen during 315 pass-type harassment overflights, 28.6% were extreme level response, 15.0% were moderate level responses and 56.4% were maintenance level activities.

(3) Both Peary caribou and muskoxen showed a decline in response levels within a set of passes (simulated cargo slinging) which may be a form of habituation but such declines did not persist between different sets of passes flown days apart.

(4) The most extreme and intense level of response would have been galloping and/or tight defense formation during approach and departure of helicopter. We only observed this strength and intensity of response in 0.3% of the Peary caribou and in none of the muskox responses.

(5) Peary caribou and muskox response exhibited an inverse relationship with the altitude of the helicopter overflight: the higher the helicopter the smaller the proportion of animals which responded at the extreme level.

(6) Peary caribou cows and calves were the most and bulls the least responsive of the sex/age classes. The apparent responsiveness of caribou juveniles and yearlings was usually a reflection of their investigative behaviour.

(7) Muskox bulls as solitaries or in single sex groups tended to be more responsive than individuals in mixed sex groups. Muskox bulls in mixed sex groups tended, however, to be least responsive.

(8) Peary caribou were more responsive if calves were present and cow–calf pairs were the most responsive group type. Peary caribou were also more responsive in larger groups.

(9) The responsiveness of muskoxen in mixed sex groups appeared to be more a function of the make-ups of individuals within the group rather than group size or the number of calves present.

(10) In 1977, we made 116 and 69 landings within 201–1000 m of Peary caribou and muskoxen, respectively, and the inverse relationship between distance from the harassing agent and extreme responses by animals pertained.

(11) Ground activities by people after the landings seemingly influenced the subsequent responses more than did the presence of the helicopter.

From our findings we have made the recommendation of an altitude ceiling for all aircraft types of 300 m agl from November to April and 600 m agl from May to October, which is the period of calving, post-calving and rutting – three critical periods in the annual life cycle of both species. We also recommend that aircraft land no less than 1000 m away from animals and much further if possible and that the low level inspection flights be restricted to the pipeline corridor. We have recognized the importance of the cooperation of the pilots and have recommended the need for regulations and the reasoning behind them to be fully explained to pilots and others concerned with pipeline construction and maintenance.

Not only pipeline construction but any major exploratory or development activity in the Arctic greatly relies on aircraft support. The effect of the increased aircraft traffic on the Arctic wildlife has been a matter of growing public concern. The impact of the increased aircraft traffic has had to be predicted from a variety of fields and disciplines in the absence of baseline information and appropriate techniques. The predicted impacts include increased energy expenditure leading to lowered reproductive success, increased mortality and eventual population decline, range desertion and acute and/or chronic pathological conditions such as overstraining disease and pulmonary emphysemia.

Our studies do not provide any information on energy expenditures or long-term effects, but only on the immediate behavioural responses to helicopter harassment. It appears that the levels of harassing stimuli used in this study did not induce any acute pathological conditions, calf desertion or group splintering. Our study, the first designed specifically to measure behavioural response to helicopter harassment, has to be regarded as only the beginning of the research necessary to gain an adequate understanding of the subject. This condition is especially true if the Government of Canada is to honour its obligations to maintain the traditional rights of native peoples and to wisely manage renewable resources for all Canadians in a manner that will minimize the impact of northern development. In relation to the pipeline project and other forthcoming projects we urgently require baseline information on the location of traditional areas critical for the survival of both species (including calving, post-calving and rutting areas) and the patterns of movements between those critical areas. We will require physiological studies of harassment and long-term studies to examine the adequacy of our recommendations.

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