INVESTIGATING IMPACTS OF HELICOPTER DISTURBANCE ON DALL'S SHEEP: STUDY DESIGN FOR THE 1997 FIELD SEASON

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1.0. INTRODUCTION

In an earlier report I presented hypotheses and preliminary experimental designs for studying the impact of helicopter disturbance on Dall's sheep (Frid 1996). I now follow-up that work by selecting and refining the hypotheses that would be testable within the constraints of a single field season, a single study site, unmarked animals, and a ground-crew of two people. I also present improved experimental designs and further discussion of confounding variables Fieldwork for this project is expected to take place this summer.

The hypotheses I selected provide a starting point for estimating the energetic and foraging costs imposed by disturbance on sheep. Such costs could affect the reproductive success of individuals, and ultimately impact population productivity (review in Frid 1996). Tests of certain predictions are also essential for developing set-back distances and helicopter routes that minimize disturbance on sheep. In the body of the report I develop in more detail the relationship of each hypothesis to conservation.

Hypotheses which I will not test this summer, but which have very strong implications for conservation, deal with reproductive success, habitat shifts, long-term habituation (Frid 1996), and resource utilization (Gill et al. 1996). Testing them is essential for a more complete understanding of how disturbance affects population dynamics of wildlife, but would require commitment for funding research with marked animals on multiple study sites over several years.

In this report I provide almost no background from the literature for the hypotheses. Readers should refer to my previous report (Frid 1996), where such background is developed in detail.

2.0. CONFOUNDING VARIABLES CORRELATED WITH STAGE OF THE FLYING SEASON

The period of concentrated helicopter activity to which the study population will be exposed, which I refer to as the "flying season", will begin in late spring or early summer. As the stage of the flying season advances (as measured by weeks since the first day of disturbance), it is plausible that some correlated factors could cause behavioural responses to disturbance by sheep to become weaker, while other correlated factors could strengthen such responses. These possibilities have to be considered for good experimental designs, and to avoid confounded interpretations.

Responses to disturbance by sheep could become weaker as the weeks of the flying season increase because of habituation (see Mid-term Habituation Hypothesis). Weeks of the flying season, however, are positively correlated with the development of motor skills and independence by lambs. As lambs develop they become less vulnerable to predation, and mothers may reduce their investment in anti-predator behaviour (FitzGibbon & Lazarus 1995), and possibly the strength of their responses to disturbance. The effects of habituation and of lamb development could be separated to some extent by analyzing how the interaction between proportion of lambs in a group (including 0 %) and week of the flying season affects immediate responses to disturbance.

Responses to disturbance by sheep could become stronger as the flying season progresses because of changes in body condition. During late spring and early summer, plant phenology will be advancing, and food quantity and quality will be increasing. Thus, the body condition of all sex-reproductive classes of sheep will be improving, at least up to a peak in mid-summer. Furthermore, the condition of mothers will be improving at a faster rate than that of non-reproductive animals because, as lambs grow and increase their use of solid foods, the physiological demands of lactation will be lowered. Theory predicts that animals in good condition will make a greater investment in antipredator behaviour than animals that are closer to starvation (McNamara & Houston 1987). Thus, at least up to mid-summer, it is plausible that the effects of habituation within the flying season would be diluted by improved body condition of the animals.

In summary, as the flying season advances, habituation and lower vulnerability of lambs could be acting synergistically to reduce the strength of responses to disturbance. Simultaneously, improved body condition (as affected by plant phenology and reduced lactation demands) could be increasing the strength of such responses. These confounding effects are taken into account in the experimental designs described below.

3.0. PREDICTIONS ON SOCIAL AND ENVIRONMENTAL FACTORS AFFECTING IMMEDIATE RESPONSES TO DISTURBANCE

Testing whether responses to disturbance differ between the adult sexes is beyond the scope of the work. All predictions in this study are for groups of adult females and juveniles.

3.1. Predictions on the decision to escape

The probability that sheep will escape from helicopters:

1) Increases with group size.
2) Depends on the proportion of lambs in a group.
3) Depends on distance to cliffs.

Experimental design.

Experimental trials occur semi-daily throughout the flying season and consist of a helicopter directly approaching a focal sheep group during the first flight of the day. Analysis is a multiple logistic regression model (Steinberg & Colla 1991) with escape (see Table 1) as the dependent variable. Independent variables are group size, proportion of lambs in a group, distance to cliffs, and week of the flying season. Unless sample size is limiting, interactions between week of the flying season and remaining factors are also included. (The latter is a control. See section 2.). Backwards stepping procedures are used for reducing model to its most significant form.

Table 1. Variables for quantifying impact of helicopter disturbance on Dall's sheep. The first 10 variables are measures of the strength of the immediate reaction to helicopters. (Reproduced from Frid 1996.)

Variable	Definition
First reaction distance	Distance from helicopter at which sheep first reacted (either vigilance or escape).
Vigilance initiation distance	Distance from helicopter at which sheep first became vigilant. (A sub-component of *first reaction distance.*)
Escape initiation distance	Distance from helicopter at which sheep began escape. (A sub-component of *first reaction distance.*)
Escape	Binomial variable describing whether disturbed sheep moved from their pre-disturbance location to a new area. Usually an initial run is followed by walking; some nervous feeding sometimes occurs during the walk (Frid 1995, 1997a).
Escape distance	Distance sheep escaped before either bedding or feeding without traveling.
Escape run time	The time sheep spent running while escaping from the helicopter
Escape walk time	The time sheep spent walking while escaping from the helicopter
Total escape time	Escape run time plus escape walk time
Response time	Time between first reaction (either vigilance or escape) and resuming bedding or feeding without traveling
Feeding interruption time	For animals feeding prior to disturbance and which did not bed after disturbance, time spent between first reaction and resuming feeding. (A sub-component of *response time.*)
Helicopter time	Time the helicopter was audible to observers (an index of how long the helicopter was in the area).
Least distance	Smallest distance between sheep and the helicopter, which may or may not be smaller than the *first reaction distance*.

3.2. Predictions on strength of immediate responses

First reaction distance, escape initiation distance, escape distance, total escape time, and response time (Table 1):

1) Increase as group size becomes greater.
2) Depend on the proportion of lambs in group.
3) Depend on distance to cliffs.

Experimental design

Experimental trials occur semi-daily throughout the flying season and consist of a helicopter directly approaching a focal sheep group during the first flight of the day. The effects of group size, distance to cliffs, and proportion of lambs on strength of immediate responses is tested with multiple regressions reduced to their most significant form with backwards stepping procedures. Week of the flying season and, if sample size allows, its interactions (see Section 2.) are controlled with additional independent variables in the initial regression model.

3.3. Applying results to conservation

Tests of predictions in sections 2.1 and 2.2 will be applied to sheep conservation in two ways. The first is that results will indicate which group type (possibly large groups with a large proportion of lambs) is most sensitive to helicopter disturbance, and whether distance to cliffs influences this sensitivity. Then, the first reaction distance for the combination of group type and distance from cliffs that is most sensitive can be used to create set-back distances for helicopters. (The lower bound of the confidence interval of the mean first reaction distance would be the most conservative statistic for creating the set-back distance.) By minimizing disturbance for sheep in the most sensitive social and environmental conditions, set-back distances would minimize disturbance for most of the population.

The second conservation application is that analyses of response time, escape distance, and total escape time could help predict how sheep in groups with different combinations of group size, proportion of lambs and distance to cliffs would be affected if set-back distances are lowered or removed. This would be done by analyzing the energetic costs of escaping from helicopters and of missed feeding opportunities, which ultimately could affect population dynamics.

Finally, tests of predictions will help determine which controls are necessary for hypotheses on habituation (Section 3). As explained in the next section, the latter could have strong implications for conservation.

4.0. HYPOTHESES ON HABITUATION IN RELATION TO IMMEDIATE RESPONSES

4.1 Short-term habituation hypothesis

At least in relation to immediate responses, sheep habituate to repeated helicopter disturbance occurring the same day.

Prediction

The strength of immediate responses to helicopters (Table 1) by sheep is greater during the first helicopter flight than during subsequent flights occurring during the same day.

Experimental design

Experimental trials occur semi-daily throughout the flying season and consist of helicopters directly approaching the *same* sheep group several times (≥ 3) in the same day at 1 h intervals between disturbance events. The analyses are repeated measures factorial ANOVA (e. g. Hicks 1982). Dependent variables are immediate responses (Table 1) during each flight. Independent variables include cumulative number of flights in a day, week of the flying season, and the interaction between these two factors. (The latter two variables are a control. See Section 2.) Depending on the results of tests in Section 3, group size, proportion of lambs, distance to cliffs, and pre-disturbance activity may also have to be controlled for statistically or by stratifying analyses. If logistics preclude having consistent intervals between disturbance events, interval length and its interactions should be included as additional independent variables in the ANOVA.

4.2 Mid-term habituation hypothesis

At least in relation to immediate responses, sheep habituate to repeated helicopter disturbance occurring during the flying season.

Prediction

Immediate responses to helicopters by sheep (Table 1) are strongest early in the flying season, but such responses weaken as the cumulative number of days with helicopter flights increase.

Experimental design

During late spring and early summer, plant phenology, body condition and lamb development would be correlated with cumulative number of weeks with disturbance, which would confound and/or dilute the effects of habituation on immediate responses to helicopters (see Section 2.0). Thus, the Mid-Term Habituation Hypothesis can be tested rigorously only with observations of groups of adult females without lambs, from a population in which disturbance *begins* after plant phenology has peaked. However, data on adult females without lambs prior to the peak of phenology could be used for an assessment of the hypothesis.

Experimental trials occur semi-daily throughout the flying season and consist of helicopters directly approaching sheep during the first flight of the day, and occur daily throughout the flying season. Although there is potential for some pseudoreplication (the same sheep group may be observed more than once), each trial is assumed to be independent. Analyses consist of regressions, with dependent variables being immediate responses (Table 1) during each trial. The independent variable is cumulative number of weeks with helicopter flights. Depending on the results of tests in Section 3, group size and distance to cliffs may have to be controlled.

4.3 Applying results to conservation

Testing hypotheses on habituation is important for deciding whether set-back distances can be decreased and other guidelines adjusted for sheep populations with specific disturbance histories. More relaxed guidelines, no doubt, would be desirable for commercial operations using helicopters. The hypotheses in this section are only a starting point. Developing general principals for relaxing guidelines as sheep habituate will be possible only after tests of hypotheses are replicated in time and space, and long-term habituation (Frid 1996) is considered. (Tests of long-term habituation will not be addressed next summer because of logistical constraints.)

Understanding habituation is also important for adjusting predictions on the energetic and foraging costs of disturbance, which ultimately relate to reproductive success and population productivity. In fact, habituation at different time scales (within a day, a flying season, or over multiple years) would be an independent variable in predictive models.

5.0. HYPOTHESIS ON FORAGING EFFICIENCY

The hypothesis is that, similar to predation risk, helicopter disturbance affects foraging efficiency by increasing vigilance.

5.1. Predictions

1) The proportion of vigilant postures in a foraging group is lower prior to disturbance than during the initial part of the first foraging bout following disturbance.
2) During the post-disturbance foraging bout, the proportion of vigilant postures decreases with time until reaching its pre-disturbance level.
3) The above relationships may be correlated with the response time (Table 1) between disturbance and resumption of feeding. (This prediction is to determine whether response time needs to be controlled.)
4) Weeks of the flying season may affect these relationships. (This prediction is both to determine controls and to assess hypotheses on disturbance history effects on foraging, as described in Frid 1996.)

5.2. Experimental design

Experimental trials occur semi-daily throughout the flying season. Prior to disturbance, the proportion of vigilant postures in the foraging group is recorded with instantaneous scan samples. The group is then disturbed by the direct approach of a helicopter during the first flight of the day. Immediate response are recorded (Table 1). When ≥ 90 % of non-lambs in the group resumes foraging, the proportion of vigilant postures in the group is re-sampled with a instantaneous scan sampling lasting until > 10 % of the group is no longer foraging. Samples are included in analysis only if factors known to affect vigilance (group size, distance to cliffs, etc.) do not change substantially while sampling, and if ≥ 90 % of non-lambs in group do not bed prior to resuming feeding.

Analysis is a repeated measures ANOVA design (e. g. Hicks 1982). The dependent variable is proportion of vigilance postures during each instantaneous scan (see Field Methods). The independent variables are time in relation to the helicopter disturbance event, week of the flying season, and the interaction of these factors.

A correlation matrix is used to asses relationships between response time and the proportion of vigilant postures in a group during different stages (perhaps 15 min periods) of the post-disturbance foraging bout. If correlations are significant, the ANOVA may have to be stratified by response time categories. Other independent variables known to affect vigilance (see Field Methods) are recorded during sampling to have options for additional controls.

5.3 Applying results to conservation

Tests of this hypothesis assess the foraging costs of disturbance. Data on foraging and energetic costs are necessary for models predicting how disturbance may affect reproductive success and population productivity.

6.0. BASELINE DATA AND EXPLORATORY ANALYSES

Starting at least one week before the onset of the flying season, and continuing throughout the study, baseline data will be collected on plant phenology, distribution of predators and their signs, the number and distribution of sheep using the mountain, and the sheep's diurnal activity budgets. These data may help develop new hypotheses and/or controls.

One possibility is to assess sheep distribution during one week before and one week after the onset of the flying season. Sheep distribution during afternoon censuses could also be assessed in relation to the point on the mountain to which helicopters got nearest during experimental disturbance in the morning. The data on activity budgets prior to the flying season will be useful for assessing effects of disturbance on foraging opportunities. Specifically, mean response time and feeding interruption time (Table 1) could be used to estimate the reduction in daily feeding time which is caused by each disturbance event.

7.0. FIELD METHODS

Methods for estimating distances between helicopters and sheep, and for recording immediate responses by sheep to disturbance will be as described in

Frid (1996). Methods for censusing sheep on the ground will be similar to those of Frid (1995). Other methodology is described below.

7.1. Experimental harassment

During experimental trials, the helicopter appears from behind a ridge and directly (not obliquely) flies towards the centre of a focal group of sheep while maintaining the same altitude as the sheep. Once the helicopter reaches a distance of approximately 1.6 km from the focal group, it turns around 180 degrees and leaves the area (goes behind a ridge or lands and turns engine off). (The turn-around distance is the lower bound of the confidence interval of the mean first reaction distance recorded in Table 1 of Frid [1995].)

Although this prediction has yet to be tested, sheep might habituate faster when the interval between disturbance days is shorter (Frid 1996). To avoid confounding effects, an attempt should be made for experimental harassment to occur daily. To allow tests of predictions on foraging, tests of the Short-Term Habituation hypothesis should be carried out only every second day.

7.2. Foraging behaviour

Ideally, foraging behaviour would be examined with focal animal samples of marked individuals. Because individuals are unmarked, my predictions can be tested only with instantaneous scans of foraging groups.

The cost of being vigilant while bedded likely is much lower than that of being vigilant while foraging. Thus, to reduce potential confounding effects from bedded animals, which could be acting as sentinels, a foraging group is defined as having ≥ 90 % of animals involved in a foraging bout (which includes alternating vigilance with food searching and/or handling).

Behaviour of each member of a foraging groups is recorded during instantaneous scans (review in Martin & Bateson 1993) at 1-minute intervals. Intervals between scans may be lengthened after preliminary sampling if sheep are found predominantly in very large groups. Sample initiation is determined by when ≥ 90 % of animals in the group begin to forage. Sample termination is determined by when ≥ 90 % of animals in the group stop foraging, or by a disturbance event. The main behaviour categories are vigilant, food handling, and food searching (as defined in Frid 1997). Group size, distances to cliffs and to obstructive cover from centre of group, and number of central and peripheral individuals are recorded by a second observer with instantaneous scans every 3 minutes.

7.3 Activity budgets

Diurnal activity budgets will be estimated with instantaneous scans every 15 min lasting from sunrise to sunset for the same sheep groups. Activities will be classified as feeding (which includes vigilance), bedded, standing, and social/grooming. Because these data are exploratory and require considerable field effort, they will be collected only opportunistically.

7.4. Plant phenology

Phenological thresholds will be used for comparing phenology between different study sites, and will also give the option for comparing phenology between years for the study site. Tracking measurements will also be used to estimate the rate of increase in green biomass within a study site. Although sampling units will be placed at different elevations and will have within unit replication, time limitations likely will not allow replication of sampling units. Thus, measures will be relative indices, and will not be representative of the whole slope. For this reason, sampling units will be picked in places with similar aspect, slope, and drainage characteristics.

The phenological stages of 4 plants known to be important to sheep at one southwest Yukon site (*Agropyron yukonense*, *Carex filifolia, Calamagrostis purpurascens, Artemisia frigida, Salix* spp: Hoefs 1979), and of other plants will be recorded weekly. Sampling will be done by selecting sampling units at 500 m elevation intervals. At each sampling unit, plants will be selected by using a random number table to determine the number and direction of steps taken by the observer (from a permanent stake), who then picks the nearest plant to the last random step. For each species, there will be 10 replicates, and these plants will be marked.

Phenological thresholds recorded for each plant are as follow:

1) For willow leaves: bud break, expanding leaf, and mature leaf.
2) For willow flowers: bud break, expansion of catkin, first pollen for male or first receptive stigma for female, senescence (male flowers fell, female flowers dispersed their seeds).
3) For graminoid leaves: first green up.
4) For graminoid flowers: bud emergence from sheath, emergence of pollen from stamen or stigma, and senescesence of flower head (tips dry out), fall of seeds (after shaking), senescence of stalk.
5) For Artemisia frigida: timing of first green up.

Tracking measurements that will be recorded are:

1) For graminoids: length of longest green leaf.
2) For Artemisia frigida: Proportion of green percent cover.

8.0. STUDY SITE AND FIELDWORK DATES

Study site and fieldwork dates are contingent on the location and schedules of mining and/or heli-tourism operations. Such information has yet to be available, and study sites have yet to be selected.

9.0. LITERATURE CITED

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