SHORT-TERM RESPONSES BY DALL'S SHEEP TO MULTIPLE HELICOPTER OVERFLIGHTS OCCURRING WITHIN 12-HOUR PERIODS

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INTRODUCTION

In this report I present an assessment of short-term habituation by Dall's sheep to helicopter overflights. Analyses address whether immediate responses to disturbance become milder as the cumulative number of repeated overflights occurring within a 12-hour period becomes greater. While I did expect responses to become milder, I did not expect complete habituation. Thus, my goal also was to assess the behavioural consequences of disturbance that still occur after sheep have been exposed to multiple overflights during the same day.

The analysis does not address whether sheep habituate to helicopters over the course of days, weeks, or longer periods. Thus, any sign of habituation suggested by my results is not necessarily evidence that sheep will respond more mildly to the first overflight of the next day or week than they did to the first overflight of a given day.

While my focus was on the effect of repeated overflights on sheep behaviour, I had to address other independent variables. For example, in previous analyses I found that the sheep's decision to escape (run and/or walk away) during the first overflight of the day depends on the smallest distance between sheep and helicopter during an overflight (least distance), the helicopter's elevation relative to the sheep, and the sheep's distance to security cover (cliffs or scree) and group size (Frid 1998). Thus, I assessed potential artifacts by examining relationships between the above independent variables and the cumulative number of overflights occurring the same day.

My study is preliminary because data beyond the first daily overflight were collected opportunistically, and data are scarce beyond the second daily overflight. I am unaware, however, of other analyses addressing short-term habituation by mountain sheep to helicopter overflights, and such analyses would be useful for wildlife managers. Guidelines prescribing setback distances between helicopters and the sheep range can be used to reduce disturbance of sheep without banning helicopter operations (see Frid 1998). My analysis provides an initial assessment of whether setback distances prescribed for the first overflight of the day can be relaxed for subsequent overflights occurring within the same 12-hour period.

STUDY SITE AND METHODS

Study site and field methods

Field work took place at Hoge Pass during late June to early August 1997. Details of the study site and general field methods can be found in Frid (1998).

Variable definitions and data analyses

I measured responses to disturbance with several dependent variables, but I was unable to record all dependent variables during all overflights. Only the first two overflights of each day had a reasonable sample size for inferential statistics. Dependent and independent variables are defined in Table 1.

I expected data to be temporally autocorrelated because the same sheep groups were exposed to multiple overflights occurring within the same day (see von Ende 1993). For all dependent variables except proportion of sheep unbedding (which had too few samples) and escape (see below), I compared responses between the first and second overflights of the day using non-parametric Wilcoxon paired-sample tests (Zar 1984).

Escape initiation distance might be affected by distance to terrain block (Frid 1998), and least distance (least distance constrains the minimum escape initiation distance that is possible for a given group). Thus, I used box plots to assess potential artifacts caused by these variables in the comparison of escape initiation distance between overflights 1 and 2.

Due to missing values, my analyses of responses to overflights 3-13 were limited to scatterplots. When trends were not obvious and sample sizes reasonable, I used LOWESS smoothing with 0.5 tension to highlight trends (Wilkinson et al. 1996).

Escape is a binomial dependent variable (Table 1) that can be analysed only with logistic regression or other categorical data analyses. I am unaware, however, of a logistic regression analogue to repeated measure analyses, and Chi-square tests assume independence between observations. Thus, I restricted analyses of escape to descriptive scatterplots. I assessed relationships between repeated overflight number and other independent variables that can affect escape with scatterplots and LOWESS smoothing with 0.5 tension (Wilkinson et al. 1996).

Scatterplots included all repeated measures of all groups. This pseudoreplication may introduce biases from groups which contributed a greater number of observations (Machlis et al. 1985), and I have tried to point out potential biases (see Table 2 and results).

RESULTS

Escape vs. not escape

Sheep appeared to become less likely to escape as the number of repeated overflight increased (Fig. 1). When female-young and male groups are pooled (Fig. 1a), sheep escaped during 84 % of observations during the first two overflights, and escape responses differed little between overflights 1 and 2 (11 escapes out of 12 observations during overflight 1; 10 of 13 during overflight 2). Sheep, however, escaped only during 54 % of observations (7 of 13) during overflights 3-5, and during 26 % (5 of 19) of observations during overflights 6-13 (Fig. 1a). Although this descriptive analysis is based on 19 groups, not all groups were exposed to 13 overflights during the same day and all groups had missing values for at least some overflights (Table 2).

A scatterplot (Fig. 1b) that included only the 12 female-young groups (Table 2), and thus is not potentially confounded by effects of group composition, suggests the same trends as the scatterplot containing all observations. Female-young groups escaped in 79 % of observations during the first two overflights (8 escapes out of 9 observations during overflight 1, 7 of 10 during overflight 2), but only in 60 % of observations (6 of 10) during overflights 3-5, and 30 % of observations (3 of 10) during overflights 6-13 (Fig. 1b).

Assessing potentially confounding factors in escape responses

LOWESS smoothing suggested some weak trends on how distance to security cover and group size changed with the repeated overflight number (Fig. 2, which includes all repeated observations of female-young and male groups). Fig. 2a suggested that distance to security cover tended to be higher during the first two overflights than during subsequent overflights, with no substantial change after overflight 3. Fig. 2b suggests that group size tended to decrease after the first and second overflights, and then changed little afterwards. These trends are due to the maximum values for distance to security cover and group size being greatest during overflights 1 and 2 than during subsequent overflights (Figs. 2a,b), partly because groups disturbed during the initial overflights often split up and escaped towards security cover. (Part of the group size decrease occurred because some male groups, which tend to be smaller than female-young groups, were observed only during events 4-13 and contributed no data to earlier events [Table 1].). Figs. 2c and 2d suggested no substantial trends in least distance and relative elevation across repeated overflights.

Escape initiation distance

The median escape initiation distance increased from 1.1 km (range 0.4-2 km) during the first overflight to 1.7 km (range 0.6-2.8 km) during the second overflight (Fig. 3), but not significantly ($N = 8$ groups [5 female-young groups, 3 male groups], $Z = 1.61$, $P = 0.11$). Least distance and distance to terrain block, which potentially may affect escape initiation distance (Frid 1998), changed little between overflights in these samples (Fig. 3).

During overflights 3-13, escape initiation distance was ≥0.9 km during 66 % of observations (8 of 12) ($N = 8$ groups [5 female-young groups, 3 male groups]; two groups contributed two observations each and one group contributed 3 observations). LOWESS smoothing suggested no substantial trends in escape initiation distance across the 13 repeated overflights (Fig. 4).

Distance escaped

Median distance escaped was slightly larger during the first overflight (200 m) than during the second (150 m), but not significantly (Fig. 5; $N = 7$ groups [5 female-young groups, 2 male groups]; $Z = -0.68$, $P = 0.5$). During overflights 3-11, sheep escaped 100-600 m on 4 of 7 observations, but only 10-20 m during the remaining observations ($N = 6$ groups [3 female-young groups, 3 male groups]; one group contributed two observations). Limited data suggested that distance escaped tended to be smaller during overflights 5-11 than during earlier overflights (Fig. 6).

Proportion of group escaping

The proportion of sheep in a group that escaped did not differ between the first two overflights (N = 8 [5 female-young groups, 3 male groups], Z = 0, P = 1), as 100 % of the group escaped in most observations (Fig. 7). During overflights 3-13, 100 % of group members escaped in 75 % of observations (9 of 12) (N = 8 [5 female-young groups, 3 male groups]; including 2 groups with 2 repeated observations and 1 group with 3 repeated observations) (Fig. 8).

Effects on bedded sheep in non-escaping groups

When groups did not escape and at least some animals were bedded, 33-100 % of bedded animals interrupted bedding to stand up vigilant in 36 % of observations (5 of 14) during events 1-13 (N = 6 female-young groups and 2 male groups, with repeated observations for two groups; see Fig. 9). In the remaining observations, 96-100 % of the group remained bedded (Fig. 9). It is noteworthy that 66 % of sheep in one group un-bedded during overflight 5, and 83 % of sheep in a different group un-bedded during overflight 10.

DISCUSSION

Overall, acceptable sample sizes suggested that responses to overflights did not differ substantially between the first two overflights occurring within the same 12-hour period. Smaller sample sizes suggested more tentatively that, except for escape initiation distance, responses became milder after the second overflight due to some level of short-term habituation. Some groups, however, still responded strongly to disturbance during overflights 5-13 overflights.

Results suggest that sheep were very likely to escape during overflights 1 and 2. Sheep, however, seemed to become less likely to escape as the repeated overflight number increased, and to be particularly reluctant to escape after overflight 5. This trend appeared not to be confounded by changes in the helicopter trajectory, as there were no trends in least distance and relative elevation across the number of repeated overflights. Group size and distance to security cover, however, tended to be highest during overflights 1 and 2. According to analyses of the first overflight of the day, for a given least distance groups of smaller size or near security cover have a lower escape probability than other groups (Frid 1998). The decrease in group size and distance to security cover shown in Fig. 2 is large enough to decrease the probability that sheep will escape to the first overflight of the day (Frid 1998). Thus, while the trend in Fig. 1 likely reflects short-term habituation to repeated overflights, it also may be partially due to sheep being in smaller groups and closer to security cover after overflight 2. It is noteworthy, however, that during flights 6-13 sheep still escaped in about a third of observations. Furthermore, most escape responses involved 100 % of the group, although small sample sizes make this conclusion tentative after overflight 3.

Though not significantly, the median escape initiation distance was 1.5 time greater during the second than during the first overflight. This mild increase appeared to not be due to changes in distance to terrain block and least distance (see Frid 1998). Limited data suggested that there were no substantial trends in escape initiation distance across the 13 repeated overflights. It is noteworthy, however, that escape initiation distance was ≥2 km in 2 of 4 observations during overflights 8-13.

The median distance escaped did not differ substantially between the first two overflights, but limited data suggested that distance escaped tended to be smaller during overflights 5-11 than during earlier overflights. It is noteworthy, however, that during overflights 3-11 on 4 of 7 observations sheep were still disturbed enough to escaped 100-600 m.

When groups did not escape, some group members that were bedded stood up to become vigilant. This was the case for ≥60 % of bedded animals on four observations during overflights 3-10. Rumination usually occurs while ungulates are bedded, and bedding interruptions may affect energy assimilation (review in Maier 1996). While sample sizes were too small for generalisations, these data suggest that even if sheep do not escape, for some animals repeated overflights may cause multiple interruptions of rumination and reduce energy assimilation.

Management implications

The management implications derived from this study are as follows:

1) Setback distances prescribed for the first overflight of the day should not be relaxed for the second overflight occurring within the same 12-hour period.

2) While it is possible that future work may determine that setback distances may be relaxed after >2 overflights occurring within the same 12-hour period, data were inadequate to quantitatively determine this with any confidence. Until future work suggests otherwise, setback distance should not be relaxed, regardless of the number of repeated overflights occurring the same day.

Suggestions for future work

To have a quantitative basis to modify setback distances in relation to the number of repeated overflights occurring during the same 12-hour period, the following procedures are required.

1) A repeated-measures study needs to be designed in which field data are collected by systematically exposing the same sheep groups to multiple overflights during the same day. During repeated overflights the helicopter's least distance and relative elevation, as well as the interval between overflights, must remain constant.
2) Except for the dependent variable escape, analyses should consist of Multivariate Analyses of Variance for repeated measures (Von Ende 1993).

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Table 1. Variable definitions.

Variable	Definition
	Dependent variables
Escape	Binomial variable recorded only when sheep were not travelling prior to helicopter overflights. It describes whether ≥ 1 group members (almost always >50 %) interrupted feeding or bedding (occasionally standing inactive) to run and/or walk away ≥ 10 m from a helicopter flying <4 km from them. While 10 m seems like a small escape distance, Côté (1996) considered it a threshold indicating moderate disturbance, and even short escape distances likely reflect increased heart rates (MacArthur et al. 1982), reduced foraging efficiency (Stockwell et al. 1991), and disrupted activity budgets (Maier et al. 1998).
Escape initiation distance	Continuous variable describing the distance (km) from the helicopter at which ≥ 1 group members (almost always >50 %) began to escape. This variable does not apply to groups that did not escape.
Distance escaped	Continuous variable describing the maximum distance (m) ≥1 group members (almost always >50 %) escaped before ≥ 90 % of the group resumed feeding or bedding. This variable does not apply to groups that did not escape.
Proportion of group escaping	Proportion of sheep in a group that escaped during an overflight. This variable does not apply to groups that did not escape.
Proportion of sheep un-bedding	Proportion of bedded animals in a group that stood up and became vigilant during an overflight. This variable excludes lambs (see group size definition for rationale) and considers only groups that did not escape .
	Helicopter-related independent variables (all continuous)
Repeated overflight number	The cumulative number of overflights occurring within the same 12-h period that, at a given point in time, the same sheep group had been exposed to. For example, if the same group is exposed to 13 overflights within 12 hours, overflight 3 and overflight 13 represent, respectively, the third and thirteenth overflight that the sheep experienced that day.
Least distance	Continuous independent variable measuring the smallest distance (km) between sheep and helicopter during an overflight. It is an index of the directness of the helicopter's approach from the perspective of the sheep's location (see Frid 1998 for details).
Relative elevation	The helicopter's elevation minus the sheep's elevation (m). The value is negative when the helicopter is below the sheep.
Distance to terrain block	Distance (km) between sheep and nearest ridge that blocks the line of sight between sheep and helicopter until the latter is past the ridge.
Distance to security cover	The pre-disturbance distance (m) between sheep and steep (>30°) rocky slopes.
Group size	The number of non-lambs in a group. I excluded young of the year from group size values because infant ungulates appear to recognise potential threats less readily than older conspecifics (FitzGibbon & Lazarus 1995), and their responses to risk likely are dependent on the responses of their mothers. I used the same rationale for proportion bedded (see below). Group boundaries were defined as in Frid (1997).

Table 2. Contributions of each group to data on escape decisions (escape vs. not escape) in relation to repeated overflight number. Only groups marked with an asterisk were exposed to the maximum number of repeated overflights (13). Group identifications beginning with an "r" represent male groups.

Group identification	**Event number**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total observations
st16		x												1
1a*	x	x		x	x	x	x	x	x	x	x	x	x	12
1b*	x		x	x	x	x								5
ft1	x	x	x	x										4
ft3		x	x	x			x							4
ft4b	x				x									2
ft5	x	x												2
r2*	x	x	x											3
r3*				x										1
r4*				x		x	x	x	x			x	x	7
r5*										x	x			2
r5b*													x	1
r7	x	x												2
r8	x	x												2
st1	x	x												2
st11	x	x												2
st13		x												1
st30	x	x												2
st4	x	x												2
Total observations	12	13	4	6	3	3	3	2	2	2	2	2	3	57

FIGURE CAPTIONS

Fig. 1. Scatterplots of groups that escaped vs. groups that did not escape in relation to repeated overflight number. Fig. 1a represents groups of female-young (N = 12) and groups of males (N = 7) pooled. Fig 1b includes only the 12 female-young groups. See Table 1 for the number of repeated observations that each group contributed to the data set. Data are jittered so that overlapping data points can be read.

Fig. 2. Relationships between repeated overflight number and other independent variables that might affect whether disturbed sheep escape during overflights (see Frid 1998). Scatterplots include repeated observations of all groups. Smoothing was done with LOWESS at tension = 0.5 (see Wilkinson et al. 1996).

Fig. 3. Paired comparisons of escape initiation distance (eid), distance to terrain block (tb), and least distance (ld) between overflights 1 and 2 (N = 8 groups [5 female young groups, 3 male groups]. Boxes encompass 25 % and 75 % quartiles, the central line within the box represents the median, and the whiskers encompass 90 % of the values (see Wilkinson et al. 1996).

Fig. 4. Relationship between escape initiation distance and repeated overflight number. Data include repeated observations of all groups that escaped. Smoothing was done with LOWESS at tension = 0.5 (see Wilkinson et al. 1996).

Fig. 5. Paired comparisons of distance escaped between overflights 1 and 2 (N = 7 [5 female young groups, 2 male groups]). Boxes encompass 25 % and 75 % quartiles, the central line within the box represents the median, and the whiskers encompass 90 % of the values (see Wilkinson et al. 1996).

Fig. 6. Relationship between distance escaped and repeated overflight number. Data include repeated observations of all groups that escaped.

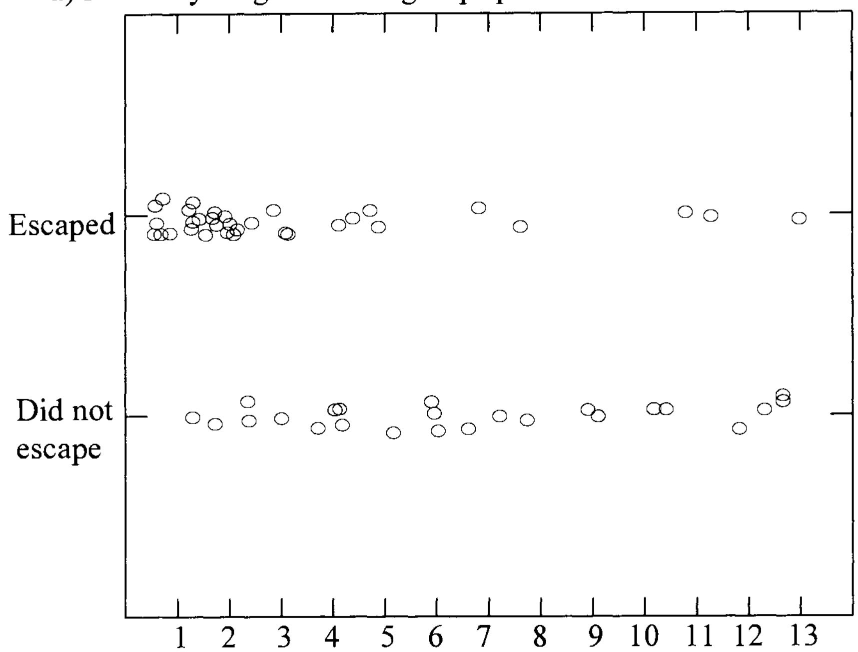
Fig. 7. Paired comparisons of the proportion of sheep in a group that escaped between overflights 1 and 2 (N = 8 groups [5 female young groups, 3 male groups]). Boxes encompass 25 % and 75 % quartiles. For both overflights the median equalled 1 and is located at the top of the box. Whiskers encompass 90 % of the values (see Wilkinson et al. 1996).

Fig. 8. Relationship between proportion of group escaping and repeated overflight number. Data include repeated observations of all groups that escaped. Groups that did not escape were excluded. Data are jittered so that overlapping data points can be read.

Fig. 9. Relationship between repeated overflight number and the proportion of bedded sheep that stood up and became vigilant during an overflight. Each symbol represents a different sheep group (N = 6 female-young groups and 2 male groups, with repeated observations for two groups). Data include only groups in which sheep did not escape.

Fig. 1

a) Female-young and male groups pooled



b) Female-young groups only

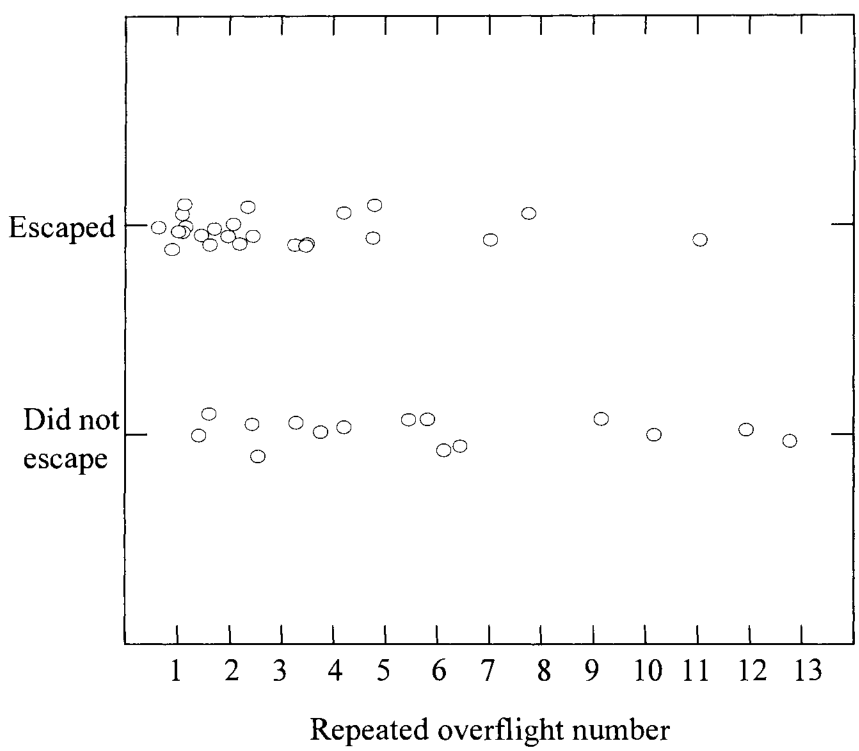


Fig. 2

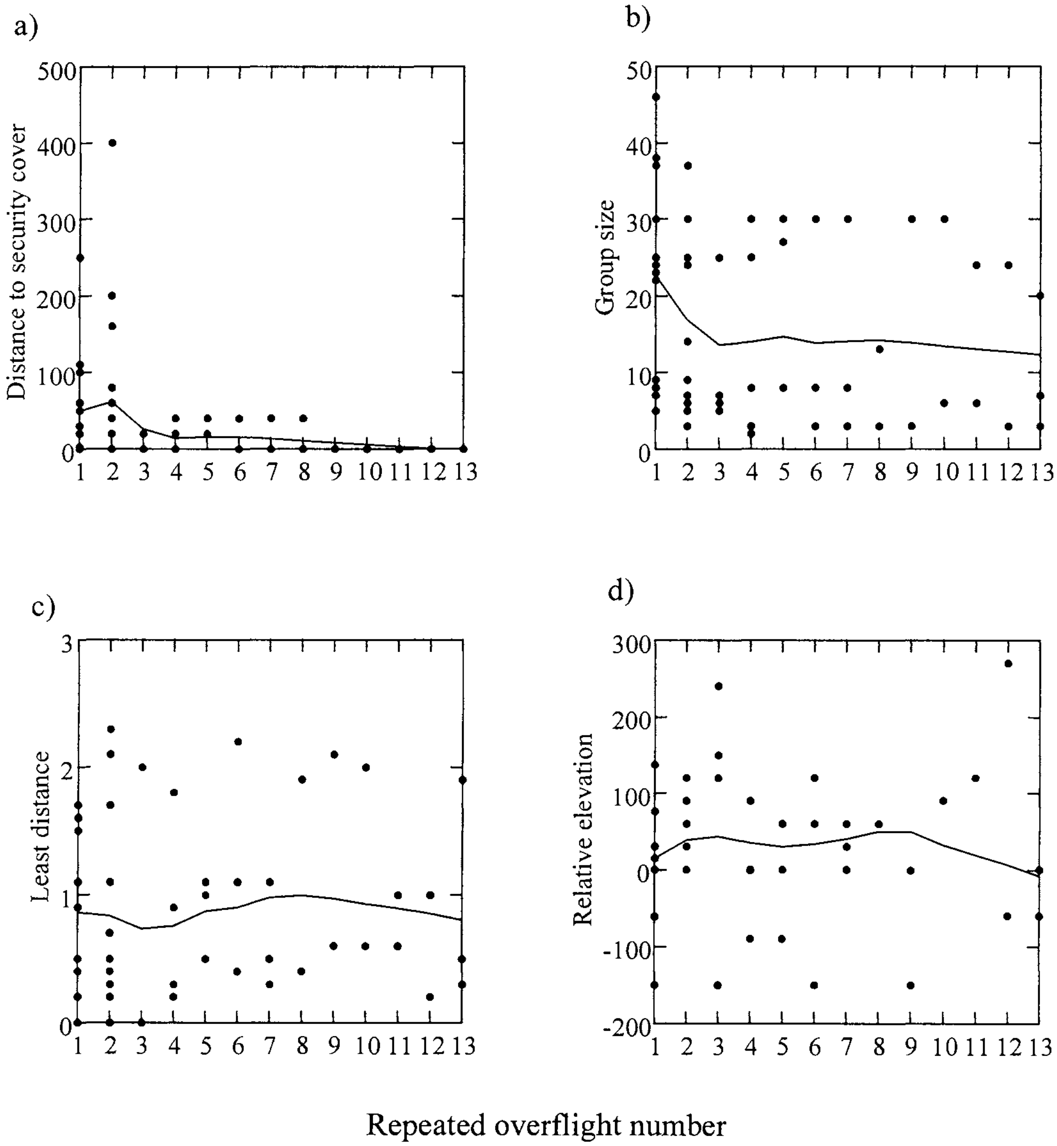
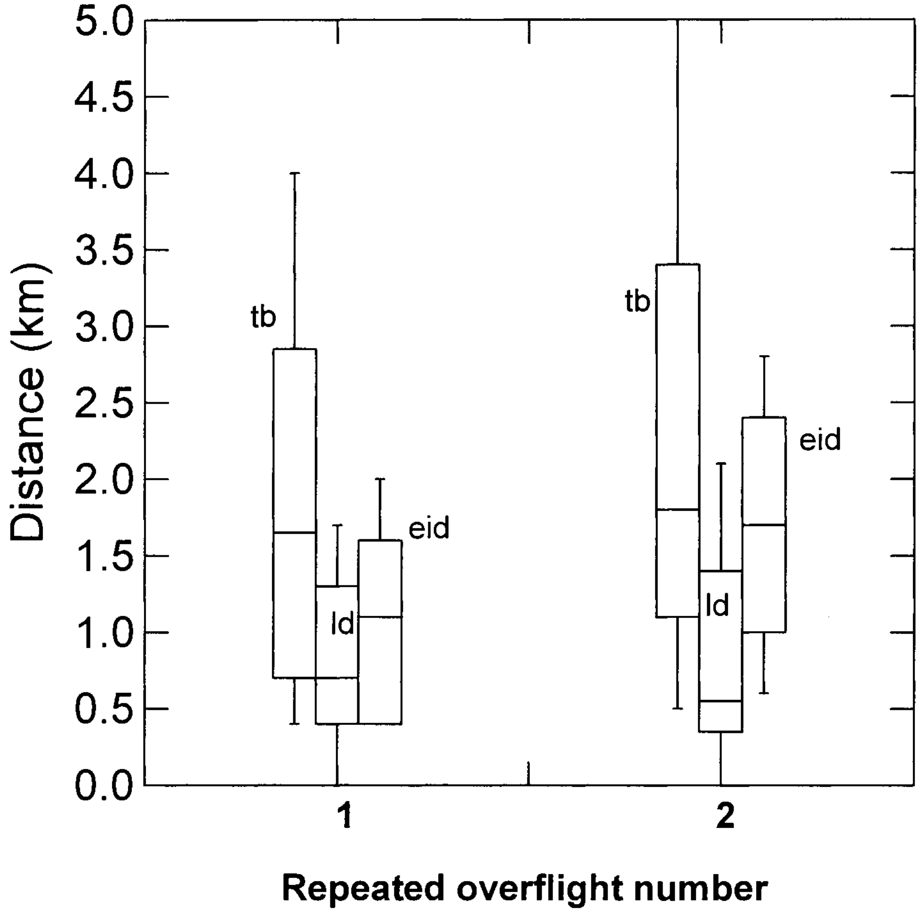

a)
Distance to security cover
0
100
200
300
400
500
b)
Group size
0
10
20
30
40
50
c)
Least distance
0
1
2
3
d)
Relative elevation
-200
-100
0
100
200
300
1 2 3 4 5 6 7 8 9 10 11 12 13
Repeated overflight number

Fig. 3



5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Distance (km)
tb
ld
eid
tb
ld
eid
1
2
Repeated overflight number

Fig 4.

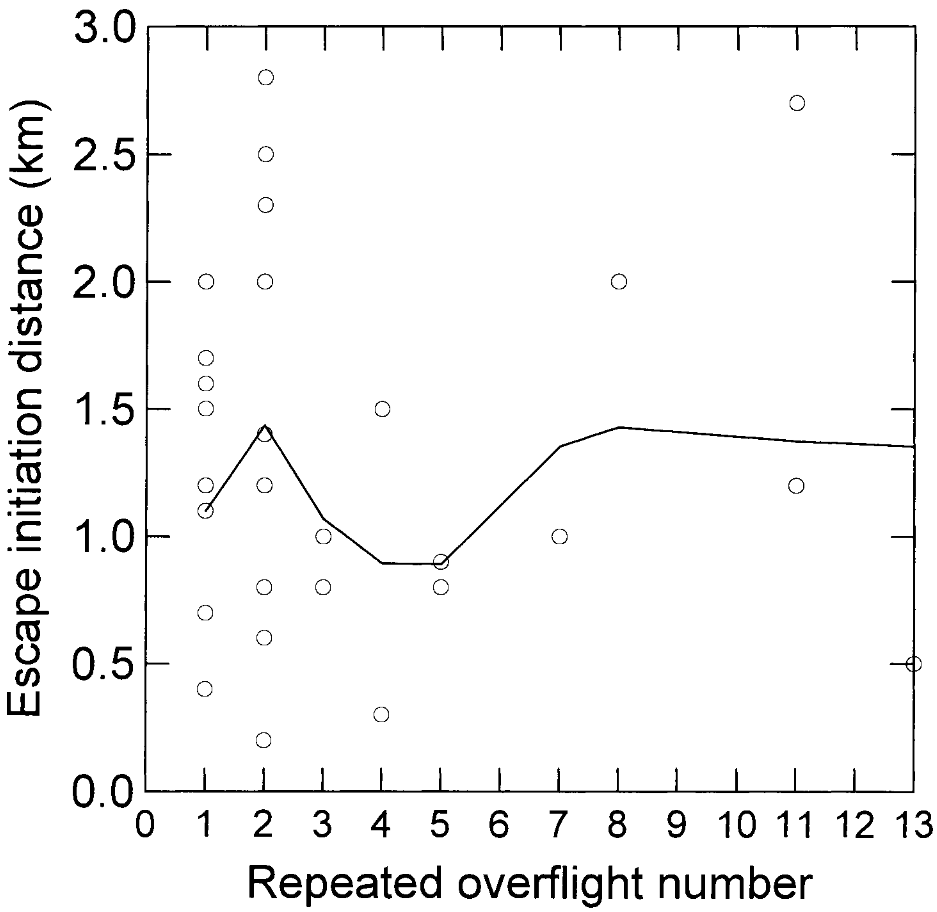
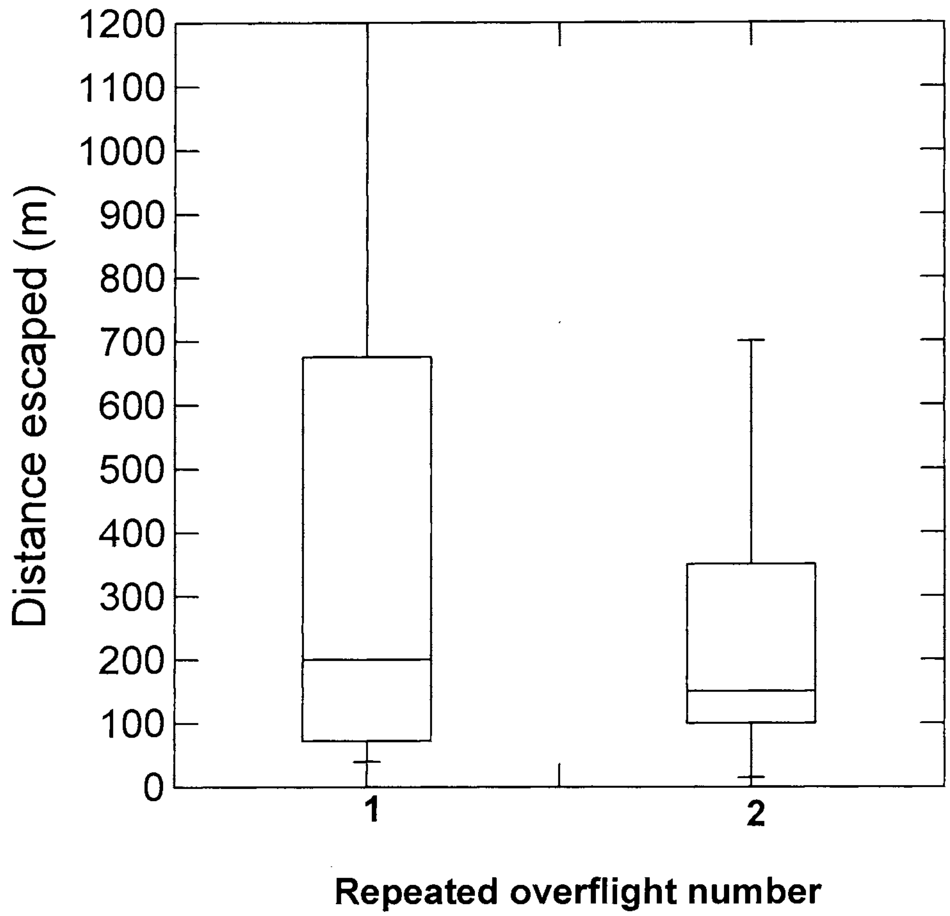
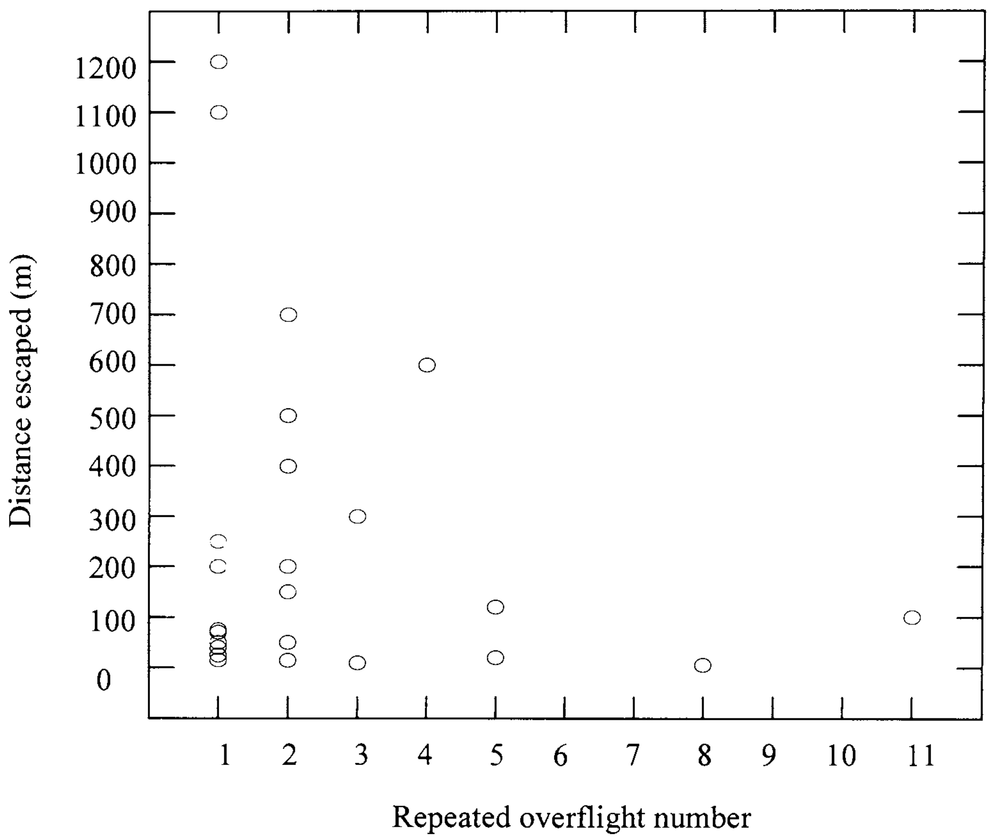

3.0
2.5
2.0
1.5
1.0
0.5
0.0
Escape initiation distance (km)
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Repeated overflight number

Fig. 5



1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Distance escaped (m)
1
2
Repeated overflight number

Fig. 6



Distance escaped (m)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
Repeated overflight number

Fig. 7

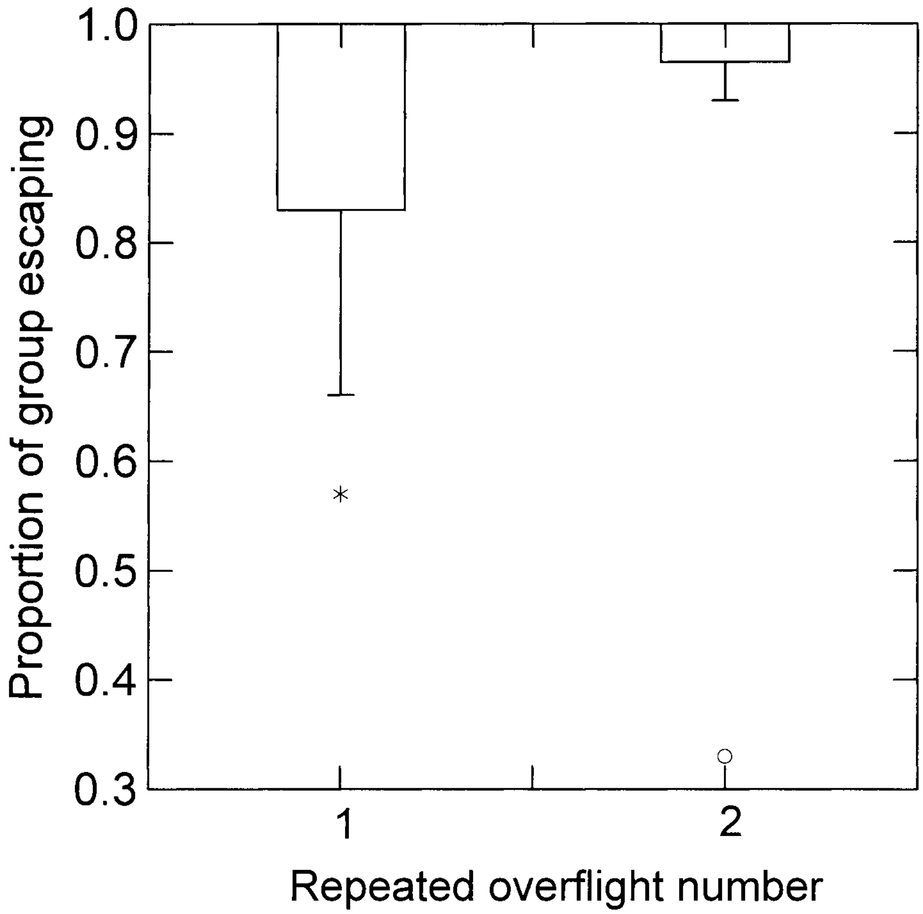

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Proportion of group escaping
1
2
Repeated overflight number

Fig. 8

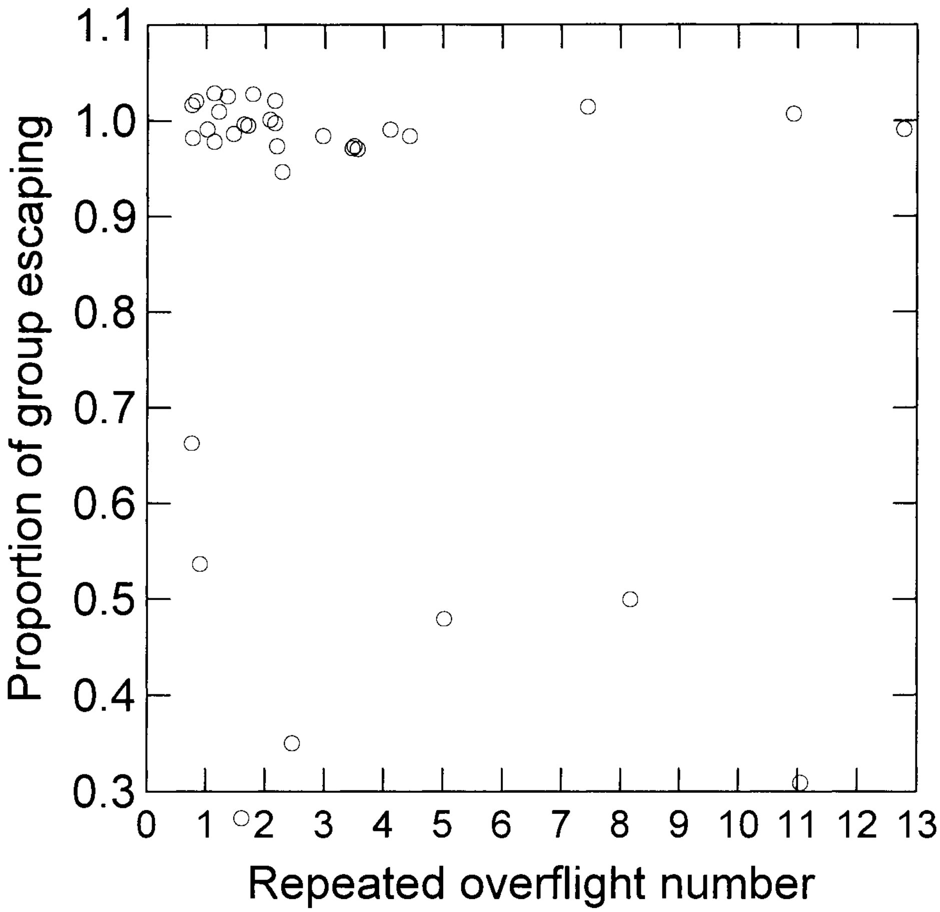
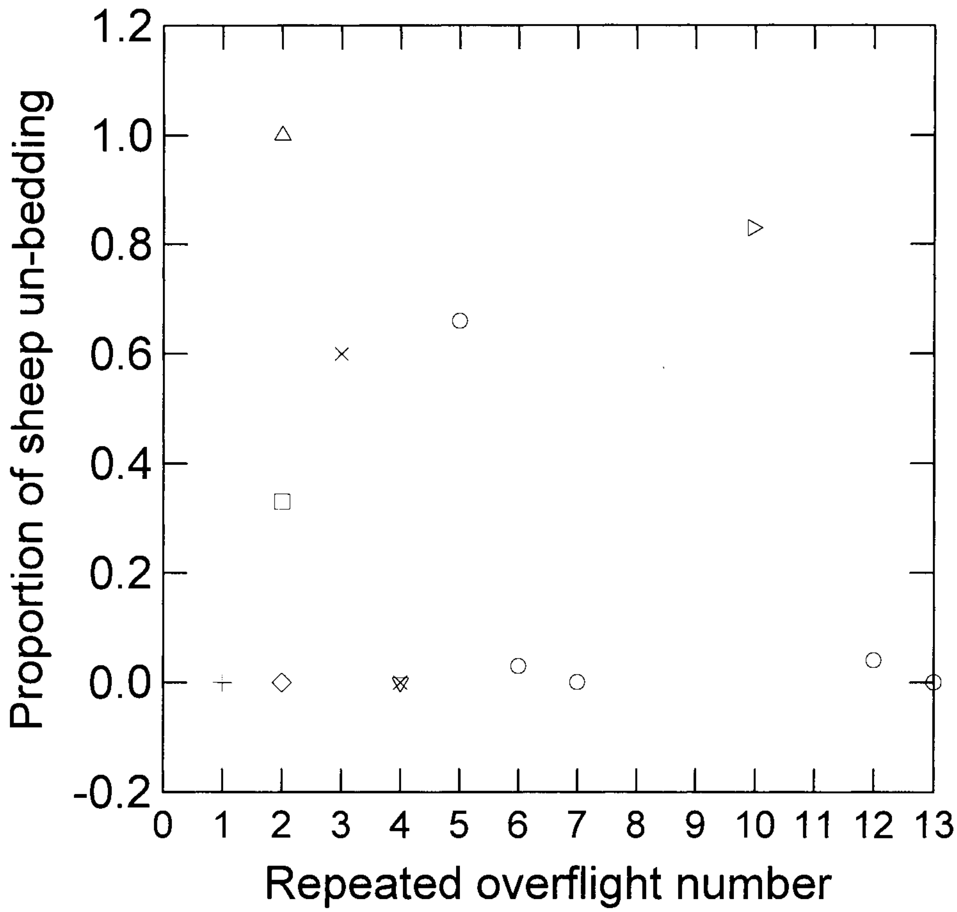

1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Proportion of group escaping
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Repeated overflight number

Fig. 9



1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Proportion of sheep un-bedding
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Repeated overflight number