Bienn. Symp. North. Wild Sheep
and Goat Counc. 14:49-63

EFFECT OF HELICOPTER LOGGING ON MOUNTAIN GOAT BEHAVIOUR IN COASTAL BRITISH COLUMBIA

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Abstract: We examined the effect of helicopter activity associated with industrial forestry on the behaviour of coastal mountain goats (*Oreamnos americanus*) during spring, summer and autumn 2001 and 2002. We collected 959 hours of instantaneous scan data on 2 herds over 95 field days in the upper Powell River watershed in south-western BC. The "sightability" of mountain goats (proportion of scans where at least one goat was observed versus no goat observations when visibility was favourable) was lower in 2002 during disturbance phases associated with helicopter activity than during other phases. The proportion of time adult females and kids spent engaged in different behaviours differed among disturbance phases and year. No obvious pattern was observed in 2001 but both age-sex classes spent less time bedded during phases associated with helicopter activity than during other phases in 2002. Overt changes in behaviour were also observed anecdotally during helicopter yarding activities in both 2001 and 2002.

Our results support the research hypothesis that helicopter logging activity affects mountain goat behaviour and we recommend that helicopter activity <1.5 km from occupied mountain goat habitat be managed to reduce behavioural disruptions.

Key words: Mountain goats, *Oreamnos americanus*, instantaneous scan surveys, behaviour, log-linear analysis, disturbance, helicopter logging

Disturbance of ungulates by helicopters can result in a variety of negative effects, including: habitat abandonment, changes in seasonal habitat use, alarm responses, lowered foraging and resting rates, increased rates of movement and reduced productivity (Pendergast and Bindernagel 1976, MacArthur et al. 1979, Foster and Rahs 1981, Hook 1986, Joslin, 1986, Pedevillano and Wright 1987, Dailey and Hobbs 1989, Côté 1996, Frid 1999, Duchense et al. 2000, Gordon and Reynolds 2000, Phillips and Alldredge 2000, Dyer et al. 2001, Frid 2003, Gordon 2003, Keim 2004). Mountain goats (*Oreamnos americanus*) in coastal British Columbia seasonally occupy habitats associated with high timber values,

and the use of helicopters by the forest industry to access these otherwise inaccessible trees is increasing.

We examined the effect of helicopter activity associated with industrial forestry on the behaviour of mountain goats near Powell River, BC. We tested the following research hypotheses:

1. Helicopter logging activity affects the "sightability" of mountain goats by increasing their tendency to hide, bed, or use forested habitats; and,
2. Helicopter logging activity affects the proportion of time mountain goats spend engaged in different categories of behaviour.

METHODS

The study area was located 60 km north-east of Powell River, BC (Figure 1). The area is dominated by granite rock faces interspersed with stands of Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) at low elevations, and mountain hemlock (*Tsuga mertensiana*) and yellow-cedar (*Chamaecyparis nootkatensis*) at higher elevations. Industrial forestry is the dominant land use.

We conducted instantaneous scans (Hurley and Irwin 1986, Martin and Bateson 1993) of mountain goats using 20-60x spotting scopes at distances of 1-3 km during 5 phases of helicopter logging: pre-falling (no activity), falling (chainsaw, tree-falling and twice-daily helicopter activity), post-falling (no activity), yarding (frequent heavy-lift helicopter activity), and post-yarding (no activity). We also collected observations from a herd located approximately 4 km from the treatment herd. The two herds of mountain goats were subjected to varying degrees of helicopter logging activity during the falling and yarding phases (Table 1). Data were collected 27 April-16 November 2001 and 3 May-13 October 2002 (Figure 2).

Scans were conducted at 5-min intervals (during daylight hours and favourable visibility) and goat behaviours were classified into different categories: 1) not visible (obscured by terrain); 2) bedded (including ruminating, pawing at beds, sleeping); 3) feeding; 4) walking; 5) running; and 6) other (including vigilance, standing, fighting or any activities not captured in the other categories).

Goats were classified by age and sex: adult, adult female, adult male, sub-adult, sub-adult female, sub-adult male, juvenile, kid and unclassified. Adult females and kids were readily identifiable (Chadwick 1973, Smith 1988) but classifying sub-adults and juveniles with certainty was difficult, although these animals could be confidently classified as non-adults.

We used log-linear analysis (Agresti 1996) to infer relationships between logging phases and year and the "sightability" of goats (proportion of scans where at least one goat was observed versus no goat observations when visibility was favourable). We also used log-linear analysis to infer relationships between behaviour categories and disturbance phase, year, and age-sex class. Interactions were included in final models if the omission of the

interaction resulted in a significantly poorer fit, based on differences between log-likelihood χ^2 values. All interactions between design variables were retained in final models.

A conservative alpha of 0.01 was used for all statistical analyses because the sampling unit was considered either an individual scan (for sightability analyses) or an individual goat-observation (for behavioural analyses). Ideally, analyses would have considered an individual goat to be the sampling unit; however, the population was unmarked and individuals could not be consistently identified. As a result, sample sizes were inflated and statistical tests were oversensitive (i.e., the null hypothesis was more likely to be rejected).

RESULTS

We conducted 11,510 scans over 959 hours of observation time. Of the 10,191 scans not obscured due to weather conditions, 5,144 (50.5%) yielded actual goat sightings. The majority of observations consisted of bedding (47.4%) and feeding (35.4%) behaviours.

There was a significant interaction between sightability (i.e., successful versus unsuccessful scans) and disturbance phase (partial association $\chi^2 = 1275$, $df = 4$, $P = 0.000$) and year (partial association $\chi^2 = 331$, $df = 1$, $P = 0.000$) for the treatment herd. Sightability declined with each disturbance phase in 2001, but in 2002 sightability was lowest for disturbance phases associated with falling and yarding activities (Figure 3). Results for the treatment herd in 2001 were consistent with a sightability trend by season for the control herd (Figure 4) in 2002.

Analyses of behavioural observations were restricted to adult females and kids because these classes could be identified most confidently in the field and because sample sizes were sufficient among disturbance phases, years and behaviour categories to perform a log-linear analysis. There was a significant interaction between the frequencies of different behaviours and disturbance phase (partial association $\chi^2 = 63$, $df = 12$, $P = 0.000$), year, (partial association $\chi^2 = 1$, $df = 3$, $P = 0.012$) and among adult females and kids (partial association $\chi^2 = 3$, $df = 3$, $P = 0.004$). There was also a significant higher-order interaction among behaviour classes, disturbance phases and year (partial association $\chi^2 = 112$, $df = 12$, $P = 0.000$).

There was no obvious pattern between behaviour and disturbance phases in 2001 for either adult females or kids (Figure 5, Figure 6), but in 2002 both adult females and kids spent less time bedded and more time engaged in other behaviours during disturbance phases when falling or yarding activities were occurring, compared to other disturbance phases (Figure 5, Figure 6).

DISCUSSION

This is the first observational study of mountain goat behaviour in relation to helicopter logging activity in coastal British Columbia. Studying an unmarked herd in a remote location provided some assurance that the animals had not previously been sensitized, or were habituated to, helicopter activity. The drawback was that animals could not be

identified individually, which complicated data analysis. Also, the instantaneous scan method failed to capture many interesting behaviours. We observed numerous intra-specific interactions, including dominance displays, agonistic encounters and adult female dominance. We also observed inter-specific interactions including predator avoidance, aggression and vigilance postures, consistent with observations elsewhere (DeBock 1970, Chadwick 1973, Foster and Rahs 1981, Foster 1982, Masteller and Bailey 1987, Fournier and Festa-Bianchet 1995, Côté et al. 1997, Dane 2002).

In both years, adult females were observed with new kids in late May and early June, consistent with the highly synchronous birthing in mountain goats noted elsewhere (DeBock 1970, Côté and Festa-Bianchet 2001). Adult female mountain goats have been documented to behave differently than other age/sex classifications (Foster 1982) and are particularly sensitive to disturbance during the parturition and early rearing periods (Penner 1988, Dyer et al. 2001). Adult female goats also show a higher degree of habitat fidelity relative to other age/sex classifications (Chadwick 1973, Fox 1983, Stevens 1983, Gordon 2003).

Few adult male goats were sighted during the course of this study; habitat use patterns observed for the adult male class were consistent with previous research, with usually solitary billies occupying higher elevation habitats compared to nannies (Geist 1964, Rideout 1974, Chadwick 1977, Masteller 1980, Foster 1982, Risenhoover and Bailey 1982, Main et al. 1996, Frid 2003).

Whether mountain goats were even visible to the observers was itself an important aspect of our research. Although no obvious trend was observed in 2001 data, a significantly lower proportion of scans during 2002 resulted in mountain goat observations during disturbance phases that involved helicopter activity than during other phases. In fact, there were no sightings of goats at all during a 5-day period of helicopter yarding in 2002, even though goats had been visible for the previous 4 days. Sightability was lower because animals increased their use of forest or other cover, and/or moved farther from the helicopter disturbance. This was contrary to our expectation that goats would perceive helicopters as a predation risk and would increase their use of precipitous terrain (DeBock 1970, Geist 1971, Chadwick 1983, Fox and Streveler 1986, Côté et al.1997, Shackleton 1999). We opportunistically observed the response of mountain goats to the presence of a black bear (*Ursus americanus*) and watched the goats move immediately to escape terrain. Our observations suggested that mountain goats perceive and respond to helicopters differently than they do to predators, contrary to what has been suggested by some researchers (Foster and Rahs 1981, Joslin 1986, Côté 1996, Frid 1999, Wilson and Shackleton 2001).

Results from 2001 were most consistent with the seasonal trend we observed for the control herd in 2002; mountain goats were generally less visible as the year progressed. There were insufficient data to consider season in our log-linear analyses; however, the observed trend for the treatment herd in 2002 was more consistent with the disturbance hypotheses than with expected seasonal trends in sightability.

The reason we observed a relationship between helicopter activity and sightability in 2002 and not 2001 is unknown; however, it may be that mountain goats were sensitized by the activities in 2001 and increased their response to the disturbance stimuli in 2002 (Penner 1988, Frid 1999, Wilson and Shackleton 2001). Flight initiation distance or vigilance may actually increase with repeated exposure to non-lethal stimulus if the stimulus is sufficiently averse (DeBock 1970, Frid and Dill 2002).

Results from our analysis of mountain goat behaviour showed a similar pattern to that observed for sightability. In 2001, there was no consistent trend between the behaviour of adult females or kids and disturbance phase. In 2002, adult females and kids both showed a high proportion of walking relative to other behaviours in the helicopter-yarding phase and an increase in bedding in the post-yarding phase.

Bedding behaviour is associated with rumination, which is an important activity for the physiological health of ungulates (Chadwick 1973, Frid 1999). The proportion of time spent bedding increased for adult females and kids immediately following disturbance phases that were associated with helicopter activity (Figures 5, 6).

Anecdotal observations of the responses of mountain goats to the presence of helicopters were more dramatic than the instantaneous scan data suggested. Upon initiation of helicopter-yarding activity adjacent to the treatment herd in 2001, we observed alarm responses, including raised tails, vigilance postures, and flight responses. We also observed a herd of 5 goats (a nursery group composed of an adult female, three sub-adult or juveniles and one kid) aggregate and move quickly uphill, gaining approximately 500 m elevation in approximately 1 h. While alpine habitats are often used by mountain goats in the summer (Hebert 1967), the reaction of the treatment herd to the start of the helicopter yarding activity in 2001 suggested habitat displacement resulted from the helicopter-yarding activity. After the first full day of yarding, goats returned to their original location 1.25 h after the end of helicopter activity; however, during subsequent days of helicopter yarding, the herd did not return to lower elevations. Though animals choose habitats that maximize their chances for survival and reproduction (Schoener 1987), disturbance stimuli may cause animals to utilize sub-optimal habitats and increase locomotion costs (Bunnel and Harestad 1989, Bradshaw et al. 1998). We suggest that movements of goats to the top of the mountain coincident with the start of helicopter yarding in 2001 were an avoidance response to disturbance stimuli and not due to habitat selection.

There was no evidence that mountain goats habituated to the disturbance during the course of the study. Habituation to disturbance stimuli is often partial or negligible (Bleich et al. 1994, Steidl and Anthony 2000, Frid 2003), particularly if the disturbance is irregular and unpredictable (Bergerund 1978, Risenhoover and Bailey 1982, Penner 1988). Results of the behaviour analysis suggested, as did the sightability analysis, that goats were sensitized to the helicopter activity, rather than habituated to it.

Behavioural responses to disturbance may not be evident through observations. Researchers involved in physical capture of goats (G. Schultze *pers. comm.*, Keim 2004, S. Taylor *pers. comm.*) have noted that goats often do not exhibit overt reactions to high-stress helicopter net-gun capture and can remain perfectly still during handling. Longer-term behavioural effects may be more important that short-term reactions (Lima and Dill 1989), affecting overall vitality or survival of goats by affecting habitat selection, including displacement from preferred habitats. Physiological responses to disturbance also may not result in observable behavioural responses to disturbance (Macarthur et al. 1982, Stemp 1983, Chabot 1991, Millspaugh et al. 2001, Creel et al. 2002).

Controlled experimental manipulation of exposure to helicopter disturbance is required to better understand the effects of helicopter activity on mountain goat behaviour. Control over helicopter activity is needed to determine threshold distances at which behavioural disturbance effects are evident and to assess the effects of other variables, such as: relative elevation, approach speed, and type of helicopter. Researcher control over the helicopter variable will also increase the robustness of statistical tests and reduce the field time required to collect adequate behavioural data. Further research is also needed to assess the importance of topography in mitigating disturbance effects of helicopter activities on goats and other ungulates.

In combination with instantaneous scans, focal observations of individual animals could allow a more detailed assessment of whether the degree and duration of disturbance effects on behaviour varies according to age/sex classification and group size and also allow for a more detailed assessment of the effects of disturbance on daily activity patterns.

Paired studies are required to enhance scientific understanding of both the behavioural and physiological effects of helicopter activity on mountain goats; opportunities to employ techniques such as examination of faecal glucocorticoid levels, heart-rate telemetry technology paired with behavioural studies should be explored.

MANAGEMENT RECOMMENDATIONS

Helicopter activity should be managed within 1.5 km of areas occupied by nursery herds of adult females and kids between May 15 and June 15, to reduce the possible effects of disturbance on the recruitment potential of local mountain goat populations. Helicopter yarding activity adjacent to occupied mountain goat habitat should occur during the summer period when goats occupy the highest-available portions of their seasonal ranges and thus have greater opportunity to spatially avoid disturbance.

The management of disturbance stimuli should be based on the distance between the stimuli and the mountain goats, the type and duration of disturbance, and the presence of topographic features to ameliorate auditory and visual effects. Monitoring of the effectiveness of management strategies for the maintenance of goat populations and habitat use is essential.

ACKNOWLEDGEMENTS

Funding was provided by the Habitat Conservation Trust Fund, Forest Renewal British Columbia, and the Forest Investment Account. In-kind support was provided by Weyerhaeuser Company Ltd., Stillwater Timberlands, BC Ministry of Water, Land and Air Protection, BC Ministry of Sustainable Resource Management and BC Ministry of Forests. Neil Ives and Greg Straathof assisted with field work. Bill Dushenko, David Shackleton and Alton Harestad provided assistance with study design and Jonah Keim helped with data analysis.

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Table 1. Logging and helicopter activity during yarding phases for two mountain goat herds in the upper Powell River, 2001-2002.

Year	Herd	Helicopter	Helicopter time (h)	Distance to goats (km)
2001	Treatment	Boeing 234	125.6	0.5-1.0
	Treatment	Hughes 500/ Bell 206	71.2	0.5-1.0
	Control	Boeing 234	16.6	>1.0
	Control	Hughes 500/ Bell 206	10.0	>1.0
2002	Treatment	Sikorsky 64	102.0	1.0-1.5
	Treatment	Hughes 500	18.0	1.0-1.5
	Control	No activity		

Figure 1. Study area location map, upper Powell River, Sunshine Coast, British Columbia, Canada.

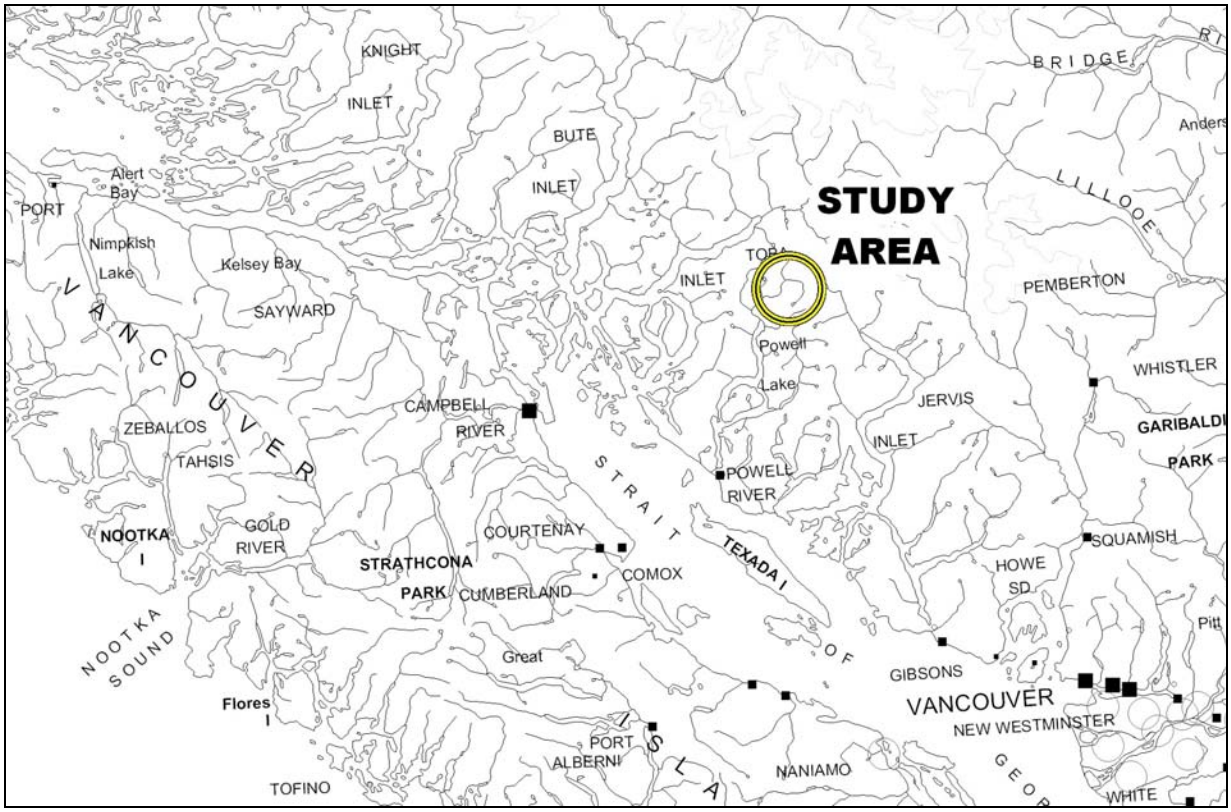


Figure 2. Timing of disturbance phases for 2001 and 2002, showing the number of scans conducted in each phase.

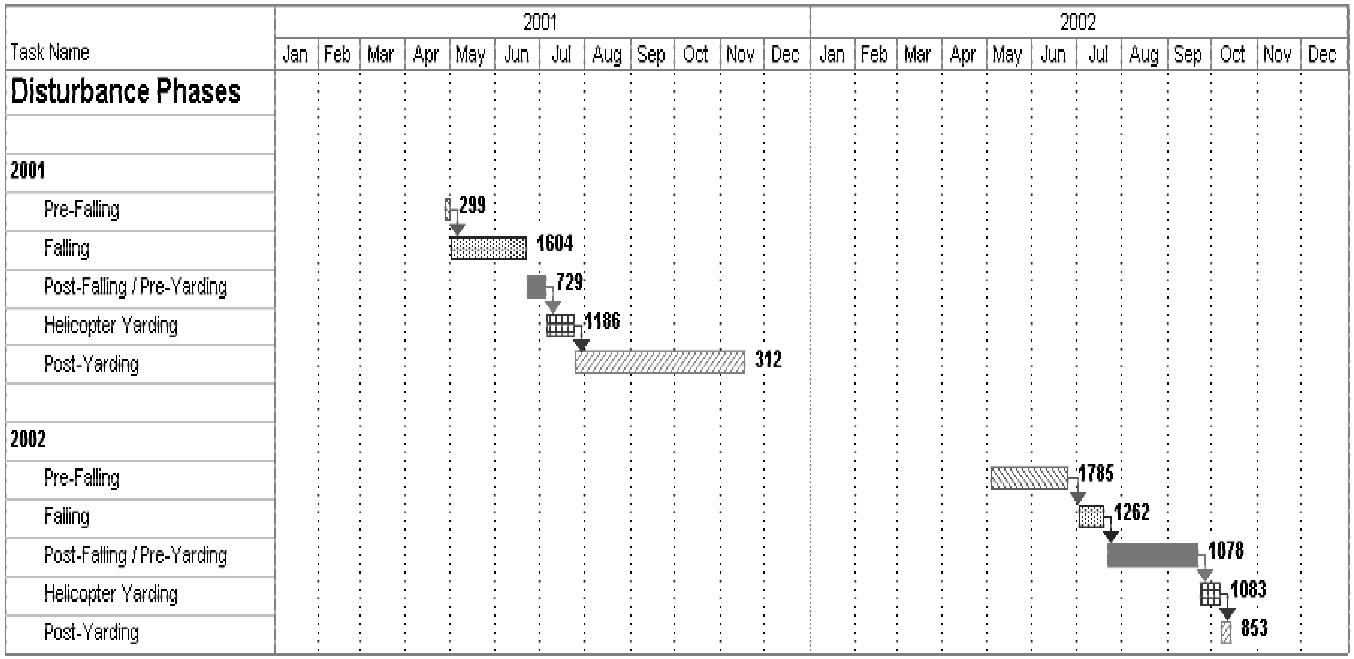
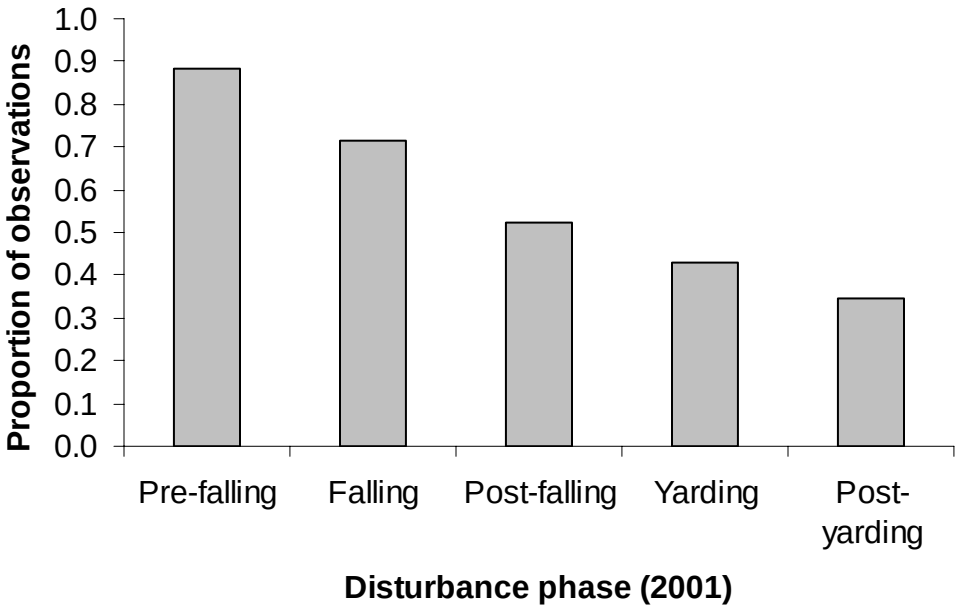


Figure 3. Proportion of scans during which mountain goats were observed, 2001 and 2002, treatment herd.



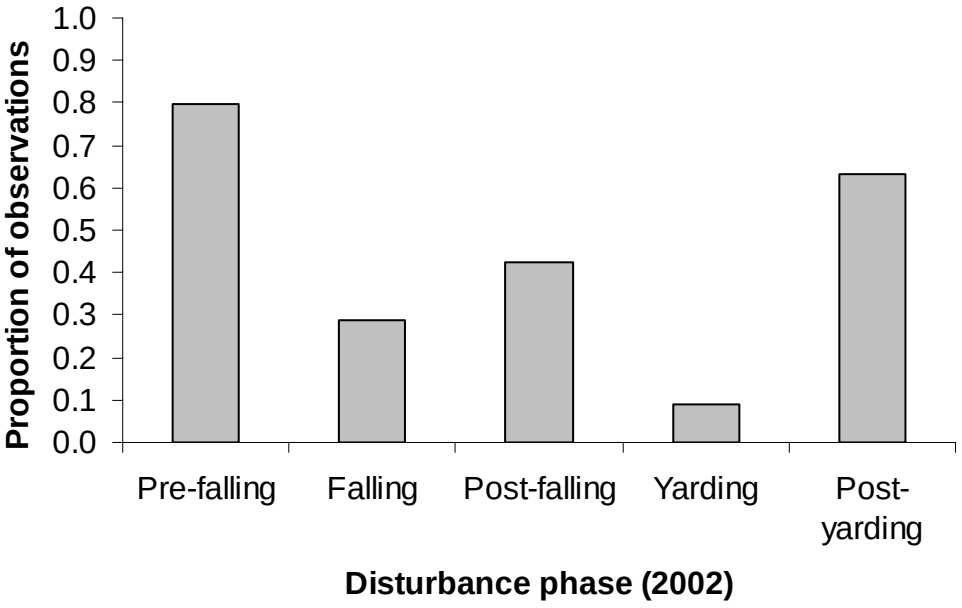


Figure 4. Control herd proportion of instantaneous scans containing mountain goat observations by season, upper Powell River, 2002.

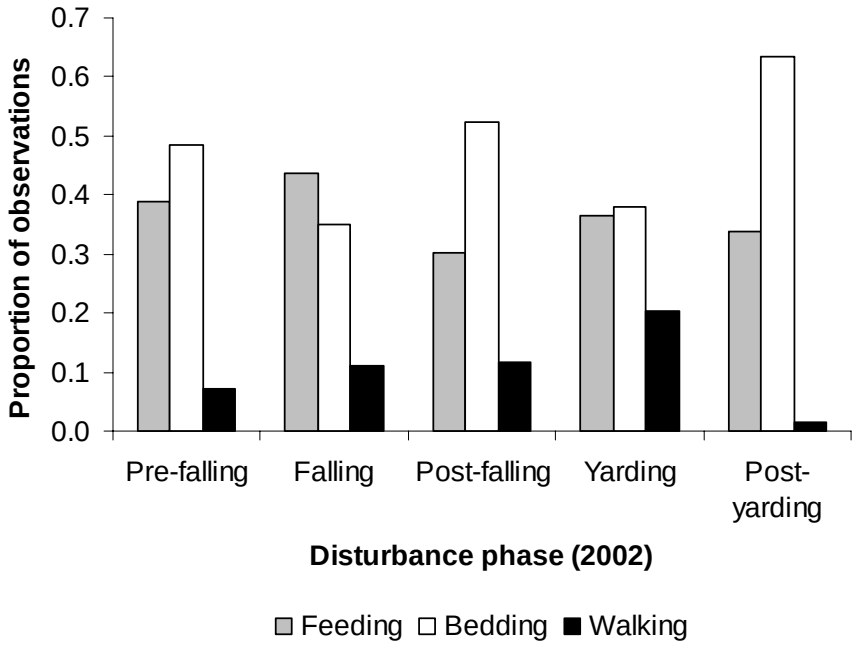


Figure 5. Proportion of observations of adult females in each behaviour category, by disturbance phase (treatment herd).

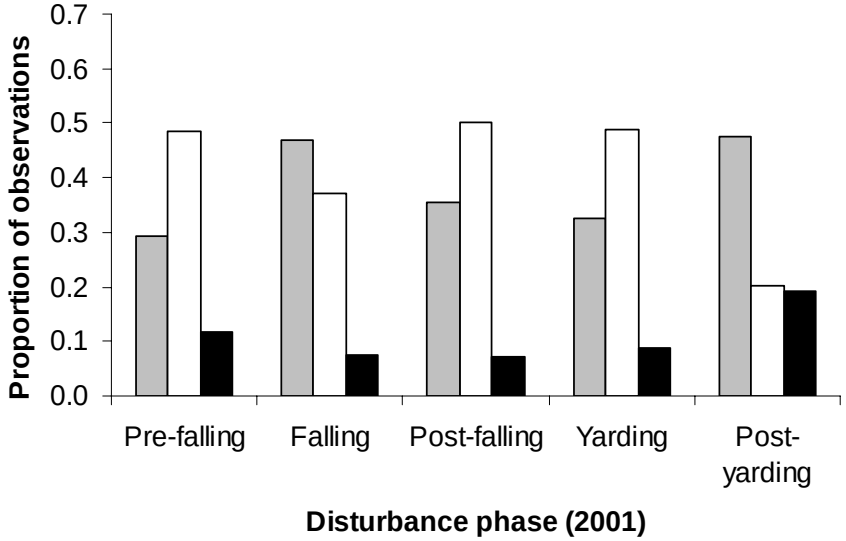


Figure 6. Proportion of observations of kids in each behaviour category, by disturbance phase (treatment herd).