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REACTION OF MOOSE (*ALCES ALCES*) TO SNOWMOBILE TRAFFIC IN THE GREYS RIVER VALLEY, WYOMING

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ABSTRACT: Understanding how human activities influence wildlife populations is increasingly important as recreational demands on critical habitat increase. We studied the effects of snowmobile traffic on wintering moose (*Alces alces*) in the Greys River drainage, Wyoming from January through February, 1994. Based on 736 moose-hours of direct observations on large willow flats, moose (6 females, 8 males, and 3 juveniles) were active 41.7% and inactive 58.3% of the observation time. Bedding activity lasted on average 118.7 min (range: 1-444 min) and feeding averaged 32.1 min (range: 1-274 min). Standing, walking, and running occurred only for short periods of time, less than 7 min on average. Moose bedding within 300 m and feeding within 150 m of passing snowmachines altered their behavior in response to the disturbance. This response was more pronounced when moose were within 150 m of the disturbance. The frequency of snowmobile traffic did not seemingly affect the average percent of moose active, or the number of moose present in the study areas. Moose appeared to move away from the active snowmobile trail as the day progressed. Consequently, snowmobile traffic, although it did not appear to alter moose activity significantly, did influence the behavior of moose positioned within 300 m of a trail and did displace moose to less favorable habitats.

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Key words: *Alces alces*, behavior, human disturbance, moose, snowmobile, winter habitat, Wyoming

Animals living in areas of heavy snow fall and low temperatures like moose (*Alces alces*) are morphologically adapted to cope with this harsh environment (Renecker and Hudson 1986). These adaptations are especially evident in moose, with long legs, large hooves and body size, and dense hollow hair (Andersen and Sæther 1992). Moose are the largest North American cervid, and in addition to helping with locomotion through deep snow (Kelsall 1969) and thermoregulation (Renecker and Hudson 1986), their size allows them to reach browse from trees and shrubs above the snow line.

Despite such adaptations, moose can suffer malnutrition in harsh winters (Gasaway and Coady 1974). If the food supply is depleted, if it is an especially cold or snowy winter, or if the animal is diseased or weakened by parasites, an animal's chances of survival decrease (McLaren and Peterson 1994). Predation and/or human-related stresses can also weaken the animal (Van Ballenberghe and Ballard 1994).

In areas without large carnivores, humans are the main threat to moose. In winter, this threat commonly comes in the form of snowmobilers and cross-country skiers traveling through wintering areas. Although moose response to snowmobiles is not well documented, other ungulates utilize areas near snowmobile trails less, hide from the disturbance, or, if the interaction is direct, run from the machine (e.g., Dorrance *et al.* 1975, Eckstein *et al.* 1979, Tyler 1991).

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The incremental energetic costs to an animal of moving from a disturbance can be considerable. For example, a disturbance causing a large animal (e.g., an elk, *Cervus elaphus*, or moose) to stand from a laying position, can consume 25% more energy (Parker *et al.* 1984, Renecker and Hudson 1986). Alternatively, if an animal is forced to lie down to avoid a disturbance the animal is unable to forage and acquire necessary energy. Perhaps the worst scenario is if animals are driven from crucial winter habitat during the most severe parts of the winter (Ferguson and Keith 1982, Cassirer *et al.* 1992).

Ungulates can, however, habituate to human activity in high-use areas, such as National Parks (Schultz and Bailey 1978), or they can be trained for the purposes of research (e.g., Parker *et al.* 1984). Ungulates also exhibit differential responses to stimuli particularly if emitted by a mechanical source (Tyler 1991, Andersen *et al.* 1996) or in winter, when animals are less vigorous (Altmann 1958).

In the mountainous region near Jackson Hole, Wyoming, skiing and snowmobiling occur winter-long in many remote locations. The impact that these human activities have on wintering moose (*A. a. shirasi*) was investigated. Four hypotheses were tested: (1) moose alter their behavior in response to passing snowmobiles; (2) the number of moose in riparian areas varies with the frequency of passing snowmobiles; (3) the percent of moose active in riparian areas varies with the frequency of passing snowmobiles; and (4) snowmobile activity displaces moose to occupy habitats further from snowmobile trails.

STUDY AREA

The Greys River (43°00'N, 110°51'W; elevation ~2000 m), in western Wyoming, flows from south to north through steep mountainous terrain. The narrow flood plain opens into areas of dense willow (*Salix* spp.) habitat 2 - 20 ha in size. We selected 2 large (15 - 20 ha) riparian areas for observations of moose: Kennington Flat, and the Box Y Ranch (Fig. 1). A U.S. Forest Service road runs parallel to the river for its entire length and generally follows the demarcation between the upland forest and riparian landscapes. In winter, the road is groomed for snowmobile use.

In winter, trees and shrubs are visible above the deep snow cover. Both sites are dominated by *Salix boothii*, with *S. exigua* and *S. drummondiana* occurring in lesser quantities (Colescott 1996). The upland vegetation varies with slope and aspect:

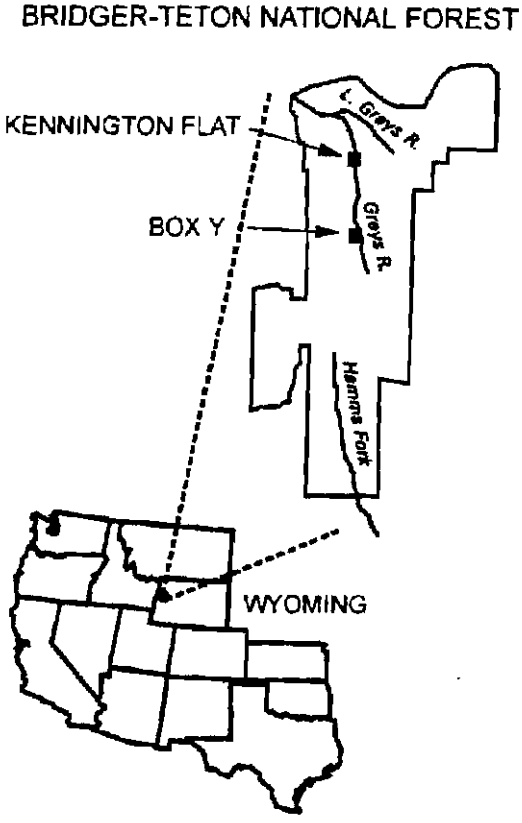

Fig. 1. The location of the Greys River in the Bridger-Teton National Forest, Wyoming. Kennington Flat and the Box Y sites (shaded squares) are 16 km apart and represent 2 large (15-20 ha) willow riparian areas.

quaking aspen (*Populus tremuloides*), subalpine fir (*Abies lasiocarpa*), Colorado blue spruce (*Picea pungens*) and Englemann spruce (*P. engelmannii*) are common on north-facing slopes, whereas on south-facing slopes, sagebrush (*Artemisia* spp.) and grasses are common.

Winters in the study area fluctuate in intensity. Ten-year average temperatures for January and February (1983-1994) range from -12.7 to -1.1°C, and snow depth varies from 12.7 to 149.9 cm. In 1994, January and February temperatures were close to normal with averages of -6.3 and -7.8°C for each month, respectively. Snowfall for the same months was slightly above the previous 10-year average with maximum depths on the ground of 58.4 and 91.4 cm, respectively (Bedford, Wyoming Climatological Station; National Climatic Data Center 1983-94).

METHODS

We observed moose from blinds situated on hillsides above the Kennington Flat and Box Y sites. From each blind the entire riparian area and the snowmobile trail paralleling the site were visible. All moose were observed with binoculars and a spotting scope. We recorded location, the amount of time spent by each moose feeding, walking, bedding and running, and particularly the time at which observed behavior changed. To evaluate whether the distance between a moose and the edge of the riparian area (where the snowmobile trail was located) affected behavioral responses, we divided the riparian areas into 3 strata: <150 m from the road (Strata 1); 150-300 m from the road (Strata 2); and >300 m from the road (Strata 3). We also recorded the time when a snowmobile passed by the riparian area, and noted any change in behavior elicited by the passing machine.

Whenever moose were lying down or bedded, we considered them to be inactive. By contrast, bouts of activity consisted of periods of non-bedding behavior and included standing, walking, feeding, and running behaviors. To estimate active and inactive bout duration, we only used data from complete bouts (bouts for which we had recorded both the beginning and end of the activity). Each behavior was tested for differences between sexes with a 1-way ANOVA (PROC GLM, SAS 1987). We described the diurnal activity budgets for the moose by calculating the mean percent time actively engaged in feeding, walking, standing and running (all active behaviors) or bedding (inactive behavior). We tested age and sex differences with ANOVA following an arcsin transformation (Sokal and Rohlf 1995) as appropriate.

Because animals were unmarked during our study, individual animals were resampled differing (and unknown) numbers of times. To avoid psuedoreplication, we used as our sample sizes for all statistical tests of behavior, the minimum number of unique male, female, and juvenile animals observed throughout the study. While conservative, we took these numbers to be the maximum number of males, females, and juveniles visible at any time during the study.

To determine if moose behavior was affected by passing snowmobiles, we calculated the proportion of moose that altered their behavior when snowmobiles passed. The data were treated as a binomial distribution, that is, animals either displayed the same behavior (e.g., bedding or feeding) immediately before and after the disturbance or altered their behavior in response to the disturbance. These proportions were calculated for all 3 strata, and then compared in pairs (Strata 1 versus Strata 2, etc.) by 1-tailed z-test for proportions (Zar 1984) to determine if the observed responses for each strata differed significantly. We also used z-tests to determine if the observed proportions of animals that did not alter their

behavior from bedding or feeding when a snowmobile passed were significantly different from a $\hat{p}$ of 1.0.

To test if the number of moose in the riparian area varied with the frequency of passing snowmobiles, we examined the possible correlation (Sokal and Rohlf 1995) between the percent change in moose numbers and the number of passing snowmobiles per hour. We calculated the percent change by subtracting the number of moose present at the end of the observation period from those at the beginning and dividing by those at the beginning. To exclude transient moose, we only included moose present in the riparian area for greater than one-third of the observation period in our analyses. The number of snowmobiles per hour was calculated by dividing the total number of machines passing by the duration (number of hours) of the observation period.

We also used correlation analysis to test the relationship between the number of passing snowmobiles per hour and the percent of moose active on a daily basis. The percent of time spent active was expressed as the ratio of the time active divided by the total time an individual moose was observed. For each observation period, we calculated the average percent of time active for all moose in the observation areas.

To examine if moose activity was related to snowmobile events, we used correlation analysis to examine the relationship between the average number of moose active at each half-hour interval of our observations and the average number of snowmobiles passing the riparian area over the same interval. We summarized the behavior data by half-hour intervals for each moose watched. Because a different number of moose was observed each day, we used the weighted mean such that value presented is the average of the daily mean percent active for all observation periods (11 January to 21 February, 1994; n=19 days).

Finally, again using correlation analysis, we examined the relationship between the location of moose within Strata 1 and 2 and the timing of snowmobile events throughout the day. That is, did moose avoid the disturbance without seeking the cover of conifers. We used the location of moose at the beginning and end of each observation period, and every time a snowmobile passed a site (>15 min apart) to calculate the proportion of moose present in each of the 2 strata. The proportion was calculated by dividing the number of moose in each strata by the total number of moose in both strata. The mean proportion was calculated for each 30-min period from all data (both sites and all observation periods). Because the proportion produced inverse results for each strata, we only used the proportion of moose present in Strata 2 in this analysis.

RESULTS

During our observations, from 11 January to 21 February, the number of moose in Kennington Flat varied daily from 3 to 13 individuals (4 female, 7 male, and 2 juvenile moose) and in the Box Y from 1 to 4 (2 female, 1 male, and 1 juvenile moose). A total of 164 man-hours resulted in 736 moose-hours of observation data collected from at least 17 individual animals.

The duration of each behavior did not differ between the sexes or between the sites (all $P > 0.540$, $n = 17$; Fig. 2). The longest period of time was devoted to bedding (118.7 $\pm$ 72.7 min; $\bar{x} \pm$ SD; all animals), then to feeding (32.1 $\pm$ 32.2 min), and only short periods of time were spent walking, standing, and running (all $\bar{x} < 7.0$ min). Similarly, daily activity budgets were mainly devoted to bedding behavior (58.3%), and feeding (35.6%; Fig. 3). The other activities (walking, standing, and running) constituted less than 6.1 % of the activity budgets. On average therefore, moose were generally

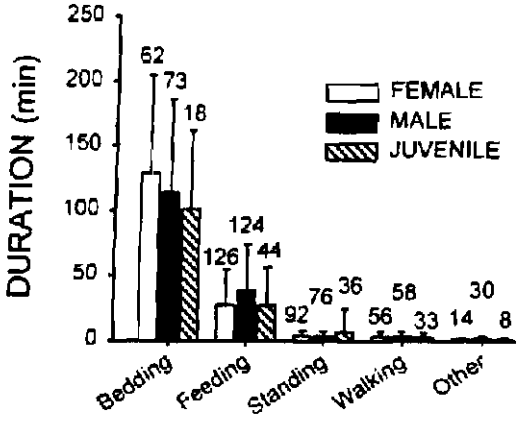

Fig. 2. Duration of time ($\bar{x} \pm$ SD) female ($n = 6$), male ($n = 8$), and juvenile ($n = 3$) moose spent in each activity in the observation areas between 11 January and 21 February, 1994. The number above each bar represents the frequency of each activity observed, not the n used in tests of significance.

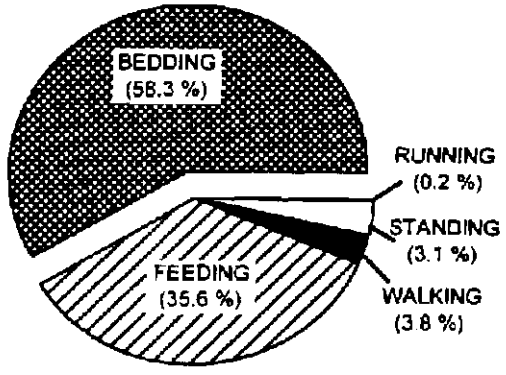

Fig. 3. Diurnal activity budgets of moose in the Greys River drainage, Wyoming. Data are based on 736 moose-hours of direct behavioral observations of at least 17 individual moose from 11 January to 21 February, 1994.

active 41.7% of the time during the observation periods.

The distance between a moose and a passing snowmobile appeared to affect its behavioral response (Table 1). Moose in Strata 1 remained bedded only 76.0% of the time in response to a passing snow machine; in Strata 2, moose remained bedded 85.1% of the time. Both these proportions are significantly different from a $\hat{p}$ of 1.0 (i.e., no change in behavior; Table 1). Similarly, moose only remained feeding 68.6% of the time when snowmachines passed if they were within 150 m of the disturbance (Table 1). When we compare the proportions of moose that altered their behaviors across the strata (1-tailed z-tests) we see that the 75.9% of moose that did not alter their behavior from bedding within 150 m of the road is significantly less than the 97.7% of moose that remained bedded in Strata 3 (>300 m from road; $P = 0.030$). All other

Table 1. The proportion of all observations of moose in which animals did not change their behavior from bedding or feeding in response to the passing snow machines. The denominators for the proportions represent the total number of observations for animals when snow machines passed the observation areas. P values indicate the probability that the observed proportions ($\hat{p}$) are less than 1 (1-tailed z test) using a conservative n of 17 (the minimum number of unique individuals identified in the study areas).

Distance	Response to Disturbance					
	Remained Bedding			Remained Feeding		
from Road	Frequency	$\hat{p}$	P	Frequency	$\hat{p}$	P
0-150	85/112	0.759	0.010	35/51	0.686	0.003
150-300	213/238	0.851	0.042	96/106	0.906	0.092
>300	43/44	0.977	0.264	15/17	0.882	0.066

comparisons were not significant, likely in part due to our very conservative estimate of our sample size.

Moose were more active before 0930 h than later in the day (Fig. 4). There was, however, no relationship between the percent of moose active per half-hour interval (Fig. 4) and the average number of snowmobiles passing over the same time period (Fig. 5; $r = -0.26$; $P = 0.28$). Moose numbers could also not be explained by snowmachine disturbance as there was no relationship between the number of moose remaining in the riparian area ($r = 0.003$; $P = 0.99$) or the average daily percent active moose ($r = -0.116$; $P = 0.26$) when these were compared to the average number of snowmobiles per hour. These analyses suggest that moose are only minimally affected by increasing snowmobile activity.

Human disturbance, however, was related to the distribution of moose within the riparian areas. Snowmobiles normally did not arrive at Kennington Flat or Box Y sites until about 1030 h (Fig. 5). Comparison of the average proportion of moose present in Strata 2 (150 – 300 m from the road) for each 30-min period, indicates that there is no difference in the distribution of moose until 1030 h (Fig. 6). After that time, a larger proportion of moose was found in Strata 2 ($r = 0.35$, $P < 0.05$, $n = 100$ observations).

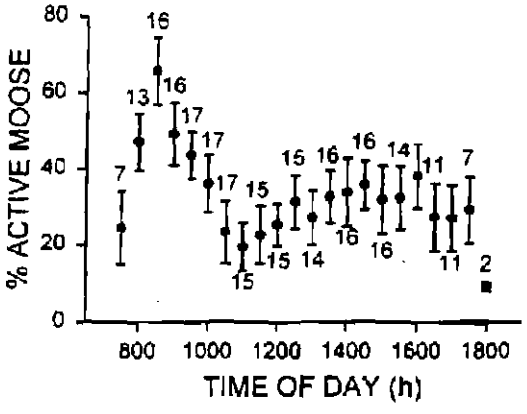

Fig. 4. The percent of moose active (weighted mean ± SE) calculated for each half-hour interval. Data were collected over 19 days (11 January to 21 February, 1994) and combined from both observation sites. Numbers above or below the error bars represent the number of individuals in each sample.

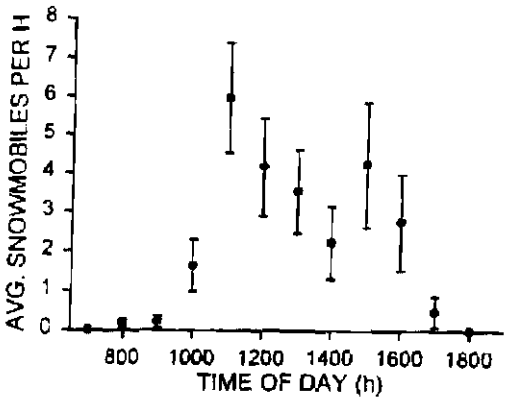

Fig. 5. The mean (± SE) number of snowmobiles passing the Kennington Flat and Box Y study sites per hour. Data were collected over 19 days (11 January to 21 February, 1994).

DISCUSSION

When attempting to study the behavior of free-ranging animals, researchers are

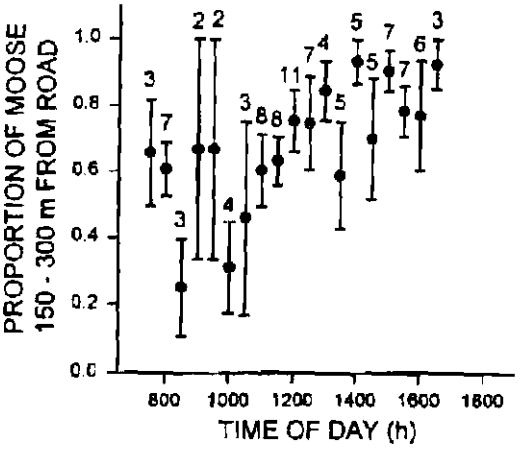

Fig. 6. The proportion ($\bar{x}$ ± SE) of all moose present in the riparian zone that were found 150 to 300 m from the snowmobile trail (Strata 2) as a function of time of day. Data were collected from 11 January to 21 February, 1994. Numbers above the error bars represent the number of individuals in each sample.

frequently faced with the decision of whether or not to attempt to mark individual animals. If all individuals in an observation area are marked, then the observer is aware of the number of individuals in the study and can avoid biasing samples by oversampling some individuals and related issues of pseudoreplication. While marking all individual moose within the Grey's river drainage was not at all practical, capturing or pursuing moose by snowmobile or aircraft would likely have altered moose response to snowmachines throughout the study. For example if a moose originally captured or marked from a snowmobile later fled at the first sound of another machine, we would not be accurately recording the response of previously unharassed moose. The consequence of not marking individuals, however, is that we do not know our exact sample sizes and consequently behavioral observations are likely not all independent.

Throughout the analyses of the behavioral data, we have adopted a very conservative approach to this problem. We have chosen to use the minimum numbers of unique individuals that we observed throughout the study as our *n* for statistical inference when comparing activity budgets and behavioral response to human activity. Because all animals in the study area were not likely observed at the same time, our data are likely based on far more than 17 individual moose. Consequently our statistical tests are quite conservative and events of marginal statistical significance may warrant further investigation. Nonetheless we feel that this approach is better than having disturbed the animals for marking purposes, an action that would have invalidated the rest of the study design.

Our findings indicate that on average, inactive bouts for Greys River moose lasted approximately 2 hours. The average percent active for daylight hours was 41.7% with the largest proportion of animals active in the early morning (0800-0900 h). These results, and the high degree of variation in these data, are consistent with findings of Risenhoover (1986), Cederlund (1989), Renecker and Hudson (1989), and Gillingham and Klein (1992) who similarly reported that moose, in winter, generally rest and ruminate more often than feed, and that their activity is generally crepuscular.

While the number of moose in the riparian area, and the percent of moose active is seemingly not affected by snowmobile activity, behavior of moose within 150 m is altered. A knowledge of the exact number of moose observed (presumably >17 individuals) would likely show that the zone of disturbance extends to at least 300 m for both bedding and feeding animals (Table 1). When snowmobilers arrive, moose gradually move farther from the snowmobile trail. Similarly, Ferguson and Keith (1982) reported that moose and elk occupy an area near cross-country ski trails less frequently than the surrounding habitat. Likewise, deer (*Odocoileus* spp.) and elk avoid roads that are either heavily traveled, or sparsely vegetated (Rost and Bailey 1979).

Avoidance of disturbed areas is incomplete because some of the animals return to the vacated habitat shortly after the disturbance ends (Cassirer *et al.* 1992, Linnell and Andersen 1995, Andersen *et al.* 1996). A study of the effects of logging operations on the movements of roe deer (*Capreolus capreolus*) demonstrated that during active logging the deer remained bedded in the forest adjacent to the active work area. When the logging ceased for the day, the deer moved into the newly cut area to forage (Linnell and Andersen 1995). Similarly, in Norway, moose were partially displaced by military maneuvers, but shortly after the disturbance ended, the moose had returned to their pre-disturbance home range (Andersen *et al.* 1996).

Comparisons of the effects between

mechanized activity and direct human interaction on ungulates suggest that animals demonstrate greater avoidance of people than of their machines. In Norway, for example, human disturbances caused flight responses in moose at a greater distance than did activity of military machinery, and it took longer for the heart-rate of these moose to return to normal after responding to human disturbance (Andersen *et al.* 1996). In Idaho, in a study comparing the impacts of human disturbance and mine operations on movements of elk calves, human-disturbed calves moved farther, ascended more elevation, and generally used more area than calves exposed to mine noise (Kuck *et al.* 1985), presumably due to the more unpredictable nature of human disturbance.

In the Greys River, where the disturbance is predominantly of a mechanized nature (snowmobile), it did not cause moose to permanently leave the large riparian areas. They did however, move farther into the willow habitat. The Kennington Flat and Box Y sites represent 2 of the largest riparian areas (15-20 ha) in the valley. Moose in this part of the Rocky Mountains depend on willow for winter browse (Peek 1974), thus access to willow habitat in winter is crucial. There are other, narrower, willow areas along the river, which are also suitable for winter browse. Moose that utilize these areas are, however, positioned closer to the snowmobile trail. If these moose should respond similarly to moose in the Kennington Flat or Box Y areas, by moving away from the active snowmobile trail, they would likely be displaced to less favorable habitat. Thus, while snowmobile activity may only impact moose in a small way, their effects, particularly in limited riparian areas, may be augmented as animals may be displaced from their preferred habitat.

The time of day when snowmobilers arrive appears important. There is a striking lack of overlap between moose and human activity schedules in this study. The mouth of the Greys River is about 1 hour travel time from Jackson Hole, Wyoming, from which many tourists come to snowmobile. They arrive at Kennington Flat, or at Box Y, about 1000h. It is at this time that moose generally bed down and ruminate and thus, direct interactions are largely avoided. If the area was closer to a major population center, however, or if overnight accommodations were established in the Greys River, snowmobile activity might not only start at an earlier hour but also continue later into the day. Conflicts with foraging moose would likely occur and perhaps become a significant disturbance factor to moose wintering in the area.

Many snowmobiles travel the Greys River (113 on 19 February, 1994), with the number expected to increase (Wyoming Dept. of Tourism, Cheyenne, WY). Based on this study, the effects of snowmobiles on moose behavior would be reduced if snowmobile activities were restricted to 1000 – 1600 h. This coincides with the resting period of moose and would therefore offset the time lost foraging to time spent hiding. In addition, snowmobilers should avoid the willow-riparian areas to avoid conflicts with moose. The response of moose to a passing snowmobile, when >100 m distant on a trail, is not severe, but if the snowmobile is driven through the willows, moose react overtly and in so doing exert energy unnecessarily. Also, if snowmobilers stop to observe moose, they should remain on, or next to, their machines, thereby reducing the negative response of moose typically displayed to a person walking, snowshoeing, or skiing. Whenever possible, snowmobile trails should be constructed in the conifer habitat, or along the transition between the upland and riparian vegetation, to maximize the separation between the disturbance and moose in the riparian vegetation.

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