ATTACHMENT 4

Behavioral Responses of North American Elk to Recreational Activity

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ABSTRACT Off-road recreation on public lands in North America has increased dramatically in recent years. Wild ungulates are sensitive to human activities, but the effect of off-road recreation, both motorized and nonmotorized, is poorly understood. We measured responses of elk (*Cervus elaphus*) to recreational disturbance in northeast Oregon, USA, from April to October, 2003 and 2004. We subjected elk to 4 types of recreational disturbance: all-terrain vehicle (ATV) riding, mountain biking, hiking, and horseback riding. Motion sensors inside radiocollars worn by 13 female elk recorded resting, feeding, and travel activities at 5-minute intervals throughout disturbance and control periods. Elk fed and rested during control periods, with little time spent traveling. Travel time increased in response to all 4 disturbances and was highest in mornings. Elk travel time was highest during ATV exposure, followed by exposure to mountain biking, hiking, and horseback riding. Feeding time decreased during ATV exposure and resting decreased when we subjected elk to mountain biking and hiking disturbance in 2003. Our results demonstrated that activities of elk can be substantially affected by off-road recreation. Mitigating these effects may be appropriate where elk are a management priority. Balancing management of species like elk with off-road recreation will become increasingly important as off-road recreational uses continue to increase on public lands in North America. (JOURNAL OF WILDLIFE MANAGEMENT 73(3):328–338; 2009)

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Recreational use of public lands in the United States has increased dramatically since the 1970s, especially off-road recreation such as all-terrain vehicle (ATV) riding (United States Department of Agriculture Forest Service 2004). Other popular types of off-road recreation include mountain biking, horseback riding, and hiking. Off-road recreation, especially ATV riding, can negatively impact wildlife (Knight and Gutzwiller 1995, Havlick 2002), but the topic has received little research attention. Only recently have a few studies examined effects of different types of off-road recreation on wildlife in a comparative manner (Taylor and Knight 2003, Wisdom et al. 2004*a*, Preisler et al. 2006).

Although effects of off-road recreation are not well-known, effect of roads and road use on wildlife has been well-documented (Trombulak and Frissell 2000). Wild ungulates such as North American elk (*Cervus elaphus*) have been shown to consistently avoid roads open to motorized vehicles across a variety of environments (e.g., Perry and Overly 1977, Lyon 1979, Edge and Marcum 1985, Cole et al. 1997, Rowland et al. 2000). Moreover, human disturbances associated with road access increases movements and decreases survival of elk (Cole et al. 1997). Accordingly, we evaluated effects of off-road recreation on elk because of the species' noted sensitivity to human disturbances, combined with its economic, social, and recreational importance. We also selected elk for study because the species may habituate to some road uses and other human disturbances in nonhunted areas such as National Parks (Schultz and Bailey 1978). Elk may also habituate to human disturbances in urban fringe areas, where elk find refuge from hunting pressure (Thompson and Henderson 1998). We designed our study so that we monitored the same individuals before, during, and after disturbance events, thereby making it possible to detect potential habituation to those events.

Our objective was to evaluate effects of off-road recreational activities on elk behavior and to determine if different types of recreation elicited different responses. We were specifically interested in elk responses to 4 recreational activities: ATV riding, mountain biking, hiking, and horseback riding. We developed 4 hypotheses to guide our research: 1) off-road recreation (also called disturbance) produces a change in elk behavior patterns, altering the percentage of time that elk travel, rest, and feed; 2) different types of off-road recreation cause different behavioral responses in elk, with each type of recreation causing a different change in time spent traveling, resting, and feeding; 3) the time required for elk to return to predisturbance behavior patterns of traveling, feeding, and resting varies with each disturbance type; and 4) continued exposure to off-road recreation leads to conditioning of elk to the disturbance, resulting in reduced behavioral responses (i.e., habituation).

STUDY AREA

We conducted our research from April to October 2003 and 2004 at the United States Department of Agriculture Forest Service Starkey Experimental Forest and Range (hereafter,

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Starkey), 35 km southwest of La Grande in northeast Oregon, USA (45°12′N, 118°3′W). In 1987, approximately 10,125 ha (25,000 acres) of elk summer range within the area was enclosed by a 2.4-m-(8-foot)-high elk-proof fence for long-term ungulate research (Thomas 1989, Bryant et al. 1993, Rowland et al. 1997). We conducted our study in the 1,453-ha northeast study area (Northeast) which was further subdivided by an elk-proof fence into 2 pastures, East (842 ha) and West (610 ha; Stewart et al. 2005). Vegetation was a mosaic of forests and grasslands dominated by ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), bluebunch wheatgrass (*Pseudoroegneria spicatum*), and Idaho fescue (*Festuca idahoensis*). The study area and its extensive history of ungulate research are described in detail in Wisdom (2005).

METHODS

Actiwatch Calibration

We used motion-sensitive accelerometers (Actiwatch™; Mini Mitter Company Inc., Sunriver, OR) to record elk behaviors. These sensors were housed in battery packs of Global Positioning System (GPS) collars worn by female elk. We calibrated sensors to detect 3 behaviors—feeding, resting, and traveling—using visual observations of 6 randomly selected, tame female elk (Gates and Hudson 1983, Kie et al. 1991). Sensors collected activity data over 1-minute time periods and calibration followed methods described by Naylor and Kie (2004).

During summer 2003 we observed tame elk equipped with activity sensors for 1,073 minutes over 12 observation periods (Trials), ranging from 25 minutes to 106 minutes each. To ensure that only one behavior was causing the Actiwatch measure, we selected data when we observed only one behavior during a given 1-minute period, providing 868 minutes of observations for analysis. We recorded elk behavior on a hand-held personal digital assistant (Newton MessagePad™; Apple Computer, Inc., Cupertino, CA) running Ethoscribe™ dedicated software (Tima Scientific™, Halifax, NS, Canada). We then identified class intervals for the range of Actiwatch measures associated with each behavior for each 1-minute recording period.

We used Discriminant Function Analysis (DFA) to establish the percentage of correct classifications of Actiwatch measures into each of the 3 behaviors (Naylor and Kie 2004). Sample sizes and frequencies of behaviors were not equal; therefore, prior probabilities in the DFA were proportional to sample sizes. Activity monitors on wild elk recorded activity over 5-minute periods. Consequently, we established class intervals for Actiwatch data associated with traveling, resting, and feeding for the time frame of 5 minutes. Actiwatches recorded the aggregate of motion over the recorded interval, not an average (Mini Mitter 1998). We estimated class intervals for the 5-minute periods for each behavior by ordering the 1-minute data chronologically and summing the recorded measure of each continuous 5-minute period where only one behavior occurred.

Disturbance Method

Field work began each year in April, when we fitted 16 female elk (8 animals/pasture) with GPS radiocollars containing Actiwatch activity monitors set to record at 5-minute intervals. We released these elk as part of a larger herd of approximately 24 and 97 individuals into the West and East pastures. We released the same female elk into the study area each year.

Following the early April release of elk we implemented a 14-day period of no human activity. We then randomly selected and implemented each of the 4 recreation activities, individually, for 5 consecutive days, with no other human activities occurring in the study area during a particular treatment. Each treatment period was followed by 9 days of control, during which no human activity occurred in the study area, thereby providing data on elk activity in the absence of human disturbance.

Elk may return to areas associated with disturbance within a few hours or days after cessation of human activity (Stehn 1973, Wisdom et al. 2004*a*). Consequently, we assumed that the 9-day control period between treatments provided sufficient time to allow animals to return to predisturbance activity patterns. The alternating pattern of 5-day treatments and 9-day controls allowed for us to replicate each of the 4 treatment types 3 times each year (Apr to Oct).

We applied each treatment by establishing approximately 32 km of routes, composed of trails and primitive roads, which encompassed all portions of the study area. We traveled these routes twice a day (once each morning and afternoon) during each 5-day treatment. To allow coverage of the entire study area by each of the 4 recreation activities, one group (1–3 people) of ATV riders covered the 32 km of routes each morning and afternoon, traveling at approximately 5.3–5.7 km/hour. By contrast, to cover the same distance along the routes required 2 groups of mountain bikers (each covering approx. 50% of the 32-km routes), traveling at 2.6–2.9 km/hour, and 3 groups of hikers and horseback riders (each covering approx. 33% of the 32-km routes), traveling at 1.6–1.9 km/hour. This design provided the same coverage of routes among all activities and saturated the study area such that all 4 activities were applied to all portions of East and West pastures (Wisdom et al. 2004*b*). Each treatment followed a tangential experimental approach in which observers did not directly pursue animals but remained along the predetermined routes (Taylor and Knight 2003). Each group of recreationists traveled together under an interrupted movement design, which allowed momentary stops to record observations of elk and take short rest breaks (Wisdom et al. 2004*b*).

During data collection in 2003, one elk activity monitor failed and 2 were not retrieved from the study area; therefore, we used data from 13 elk in our analysis. During 2004, one monitor was not retrieved and 2 monitored elk crossed from the East to the West pasture when a gate was left open at the end of a treatment week. Consequently, we

Table 1. Discriminant Function Analysis results, based on Actiwatch recordings (from 868 1-min record intervals collected over 12 trials) to discriminate among 3 behavior classes of Rocky Mountain elk at Starkey Experimental Forest and Range, La Grande, Oregon, USA, during summer 2003. We set prior probabilities to proportional in the Discriminant Function Analysis.

Observed behavior	Classified behavior (min)				
	Resting	Feeding	Traveling	Total	% correct
Resting	459	11	4	474	96.84
Feeding	20	299	3	322	92.86
Traveling	0	7	65	72	90.28
Total	479	317	72	868	93.32

did not include data from these elk in our analysis, resulting in 13 elk for the analysis.

Data Analysis

We organized data for each replicate into 10-day periods, 5 days for each treatment paired with the last 5 days for its prior control. We calculated the difference in activities for each elk as percentage of time spent in each behavior within the treatment period minus percentage of time spent in each behavior during the paired control period. Consequently, a positive value for the activity difference indicated elk spent more time in that behavior during the treatment compared to the control, and a negative value indicated less time was spent. We then calculated and plotted the mean difference and 95% confidence intervals for each behavior per treatment, replicate, and year. We summarized behavior of female elk hourly and averaged it for each hour across all control periods to describe how animals allocated their activities in the absence of human disturbance.

We used a univariate procedure to check for a normal distribution of the residuals of activity differences between each treatment type and its control. Plots of residuals showed that data were normally distributed. We analyzed the activity difference for each year using a Proc Mixed Repeated Measures model (SAS Institute 2001) to test for differences among treatments, replicates, and treatment $\times$ replicate interaction, with each female elk repeatedly measured throughout the year. We determined covariance structure for each model using the lowest Akaike's Information Criterion score. For 2003, the covariance structure was a first-order ante-dependence (ANTE [1]); for 2004, we used a first-order autoregressive structure (AR [1]). A priori significance level for all statistical tests was 0.05. We adjusted significance level of all pairwise comparisons of least-square means using the Tukey Honestly Significant Difference procedure (Harris 1998).

To test for differences among pastures and time-of-day (morning or afternoon), we analyzed the activity difference for travel, resting, and feeding for each year using a Proc Mixed Repeated Measures model. This model included treatment, replicate, pasture, and time-of-day variables and all interaction terms. We adjusted significance levels of all pairwise comparisons using a Bonferroni critical value (Harris 1998).

RESULTS

Actiwatch Calibration in Lotek GPS collars

Calibration of activity data with tame elk, using DFA based on 1-minute data, correctly classified 96.8% of resting, 92.9% of feeding, and 90.3% of travel activities (Table 1), with an overall correct classification of 93.3%. Ranges of Actiwatch measures for each 5-minute data were estimated as 0–1,896 for resting, 1,900–5,135 for feeding, and $\geq$6,166 for traveling. We could not correctly classify Actiwatch measures that were between these intervals and we discarded them from the wild elk dataset (<2% of data).

Treatment and Replicate Differences

Elk spent little time traveling during all control periods (<5% of each hr); feeding and resting comprised most of their activities (Fig. 1). Resting was highest at approximately 0800 hours (80% of their activity budget) and gradually decreased during daylight hours as feeding increased. Peak feeding activity occurred at dawn and dusk (Fig. 1). Activity budgets were similar for 2003 and 2004 (Naylor 2006).

Results of the mixed-model repeated-measures analysis of travel activity showed a treatment $\times$ replicate interaction in both 2003 and 2004 (2003 $F_{6,72} = 12.28$, $P < 0.001$; 2004 $F_{6,72} = 2.31$, $P = 0.042$; Table 2). Percentage of travel time also was different among treatments for both years (2003: $F_{3,36} = 32.25$, $P < 0.001$; 2004: $F_{3,36} = 7.65$, $P < 0.001$). In addition, there was a treatment $\times$ replicate interaction for resting (2003: $F_{6,72} = 15.11$, $P < 0.0001$; 2004: $F_{6,72} = 8.29$, $P < 0.0001$). We also found differences among treatments in resting time for both years (2003: $F_{3,36} = 10.60$, $P <$ 0.001; 2004: $F_{3,36} = 11.62$, $P < 0.001$; Table 2).

Similarly, time elk spent feeding was different for the treatment $\times$ replicate interaction (2003: $F_{6,72} = 21.45$, $P <$ 0.001; 2004: $F_{6,72} = 7.89$, $P < 0.001$). As with travel and resting, time spent feeding also was different among treatments (2003: $F_{3,36} = 16.41$, $P < 0.001$; 2004: $F_{3,36} =$ 13.35, $P < 0.001$; Table 2).

Elk traveled more during ATV and mountain biking treatments than during controls in all 2003 and 2004 replicates (Fig. 2, Table 3). Elk traveled more than the controls during 5 of 6 hiking replicates and during 3 of 6 horseback riding replicates (Fig. 2, Table 3). Elk spent more time resting during 4 of 6 ATV treatments compared to controls. Elk rested less during mountain biking in contrast to controls during 4 of 6 replicates. Resting time by elk was not different from controls for 3 of 6 hiking replicates and was less than controls during 2 replicates. Elk rested more than controls during 4 of 6 horseback replicates (Fig. 3). Elk spent less time feeding compared to controls during 5 of 6 ATV replicates, 3 mountain biking replicates, 2 hiking replicates, and 4 horseback replicates (Fig. 4).

Mean travel during all ATV replicates in 2003 was higher than the other treatments (Fig. 2, Table 3). For 2004, travel during ATV riding was not different from other treatments except for being higher than horseback riding during replicate 2 (Fig. 2). Travel time by elk was higher during mountain biking compared to horseback riding for replicate 3 of 2003

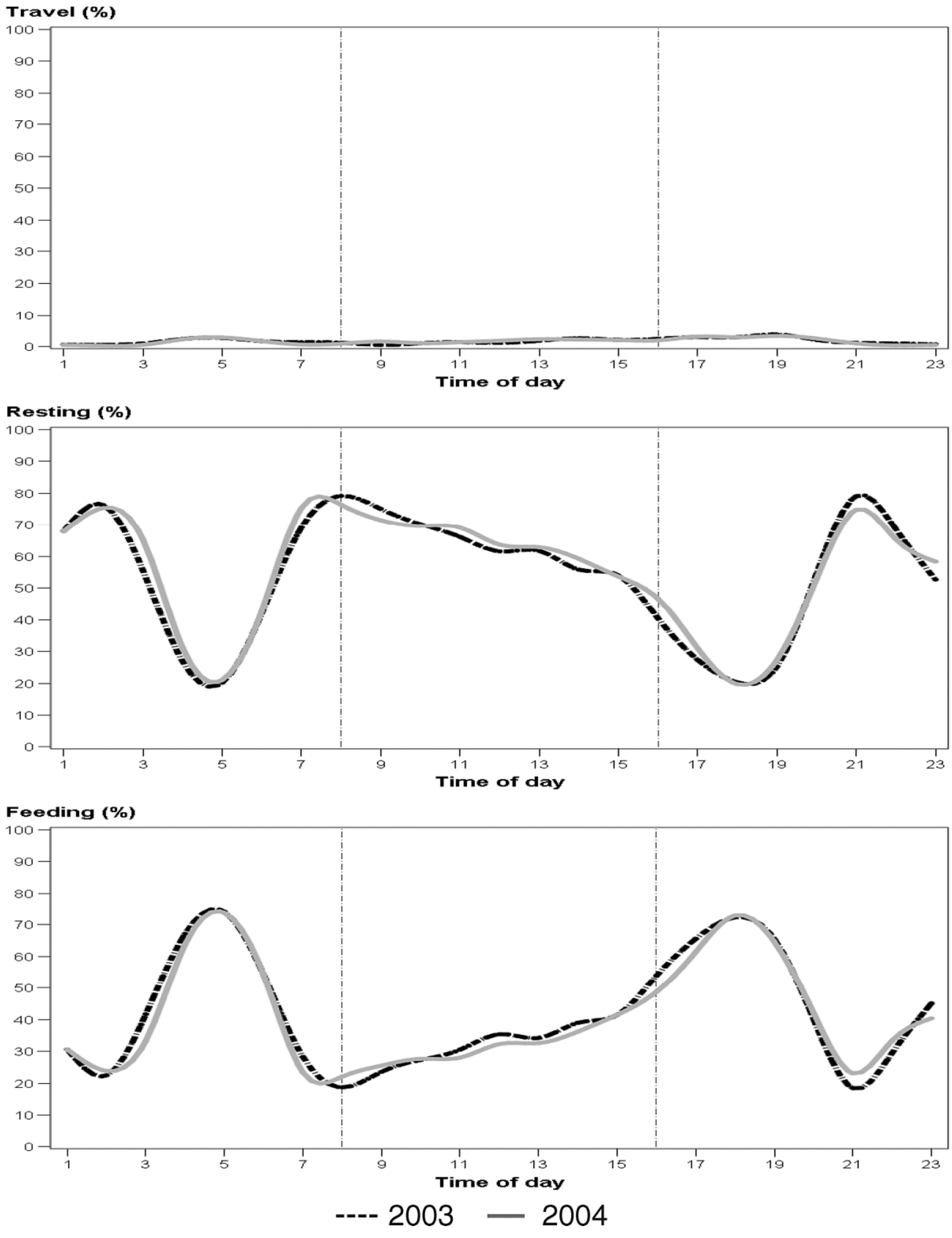

Figure 1. Activity budgets (% time spent traveling, resting, and feeding) of female elk during the first 2-week control periods of 2003 and 2004 at Starkey Experimental Forest and Range, La Grande, Oregon, USA. We averaged data for each hour, over 24-hour periods, expressed in Pacific Daylight Time.

and 2004. Hiking and horseback treatments were similar in the percentage of time that elk traveled during both years. Time elk spent resting was greater during ATV treatments compared to other treatments for 3 of 6 replicates and was greater during the horseback treatment compared to mountain biking and hiking for 4 of 6 replicates. Resting time was similar during both mountain biking and hiking replicates each year (Fig. 3). Elk fed less during ATV riding compared to other treatments in 4 of 6 replicates (Naylor 2006: fig. 4, appendix 1, tables A4, A7). There was no difference in duration of feeding between mountain biking and hiking treatments during 2003 or 2004. Elk fed less during the horseback treatment compared to mountain biking and hiking for 2 of 6 replicates (Naylor 2006: fig. 4, appendix 1, tables A4, A7).

Table 2. Results of a mixed-model repeated-measures analysis of elk activity time. Test was for differences between treatments and replicates of mean activity time by 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004.

Effect	Numerator df	Denominator df	2003		2004	
			F-value	*P*-value	*F*-value	*P*-value
Feeding						
Treatment × replicate	6	72	21.45	<0.001	7.89	<0.001
Treatment	3	36	16.41	<0.001	13.35	<0.001
Replicate	2	24	30.05	<0.001	9.87	<0.001
Resting						
Treatment × replicate	6	72	15.11	<0.001	8.29	<0.001
Treatment	3	36	10.60	<0.001	11.62	<0.001
Replicate	2	24	11.19	0.004	6.36	0.006
Travel						
Treatment × replicate	6	72	12.28	<0.001	2.31	0.042
Treatment	3	36	32.25	<0.001	7.65	0.001
Replicate	2	24	8.50	0.001	1.74	0.196

Differences in elk behavior between treatments and controls were evident only during the periods of each day that treatments occurred. Elk behavior patterns were similar to control periods before treatments commenced each day, showed differences during each treatment activity, and returned to a predisturbance level approximately 1–2 hours after each treatment ended (Fig. 5). Behavior patterns outside the treatment times appeared unaffected by the treatment activity (Naylor 2006: appendix 1, figs. A2–A13).

Travel time by elk was greater than controls for ATV treatments both years, with the greatest response of the 4 treatments being for ATV replicate 1 of 2003. Travel response by elk to ATVs during 2003 declined with each replicate (Fig. 2, Table 3). This decline continued through replicate 1 of 2004. However, travel time then increased for replicates 2 and 3 of 2004 to levels similar to those recorded in 2003 (Fig. 2, Table 3).

Elk also reduced travel time during each horseback riding replicate in 2003, with no difference observed between the treatment and control for replicate 3. During 2004, travel response to horseback riding was less than that of 2003 and was not different from control periods in 2 of 3 replicates (Fig. 2). Overall, horseback riding caused the lowest travel response in elk among treatments. By contrast, elk were consistent in their travel time during all mountain biking treatments, with travel time being higher than controls. Elk travel time during hiking was the most variable among treatment responses, with no evident pattern.

Pasture and Time-of-Day Differences

Differences in travel response between the high elk density (East pasture) versus low elk density (West pasture) areas, considering time-of-day, replicate, and treatment indicated a 4-way interaction of these variables for both years (2003: $F_{6,132} = 21.94$, $P < 0.001$; 2004: $F_{6,132} = 6.40$, $P < 0.001$). All 3-way and most 2-way interactions were significant as were all individual effects. For each treatment, elk travel time in the 2 pastures was similar during mornings. Exceptions to this pattern were ATV, replicate 1 of 2003 and horseback riding, replicate 2 of 2003, when elk traveled more in the east than west pastures. Differences between pastures during the afternoons for 2003 were not significant (Naylor 2006: appendix 1, table A15) with the exception of replicate 1 of the ATV treatment, when travel time was higher in the west pasture ($P < 0.001$).

Elk travel time also differed between pastures during the afternoons in 2004 for ATV replicate 3, mountain bike replicates 2 and 3, and hiking replicate 2 (Naylor 2006: appendix 1, table A16). At these times, elk traveled more in the east pasture during the ATV treatment and more in the west pasture during biking and hiking. Differences in travel time between morning and afternoon in the same pasture showed some significance for 2003, with the morning disturbance causing the greater travel response (Naylor 2006: appendix 1, table A17). There were fewer differences in mean travel activity between mornings and afternoons in 2004 for the same pasture (Naylor 2006: appendix 1, table A18).

DISCUSSION

Activity budgets of elk during control periods were consistent with the literature on elk circadian cycles (Green and Bear 1990, Ager et al. 2003, Kie et al. 2005). Movements of elk (m/min), estimated from telemetry relocation data during the 2002 phase of our study, provided further evidence of elk circadian patterns of movement in the absence of human disturbance (Preisler et al. 2006). Our activity budgets during control periods provided a compelling basis for evaluating changes in activity budgets during each of the recreational activities.

Our results supported hypothesis 1, which postulated that off-road recreation produces a change in elk behavior. Results clearly demonstrated that activity budgets of elk were altered during off-road recreation treatments. Elk increased their travel time during most treatments, which reduced time spent feeding or resting. We recorded an increase in travel throughout the period of disturbance but it was generally greater in mornings than in afternoons. This response was similar to that recorded by Wisdom et al. (2004*b*), where movement rates of elk were higher than that

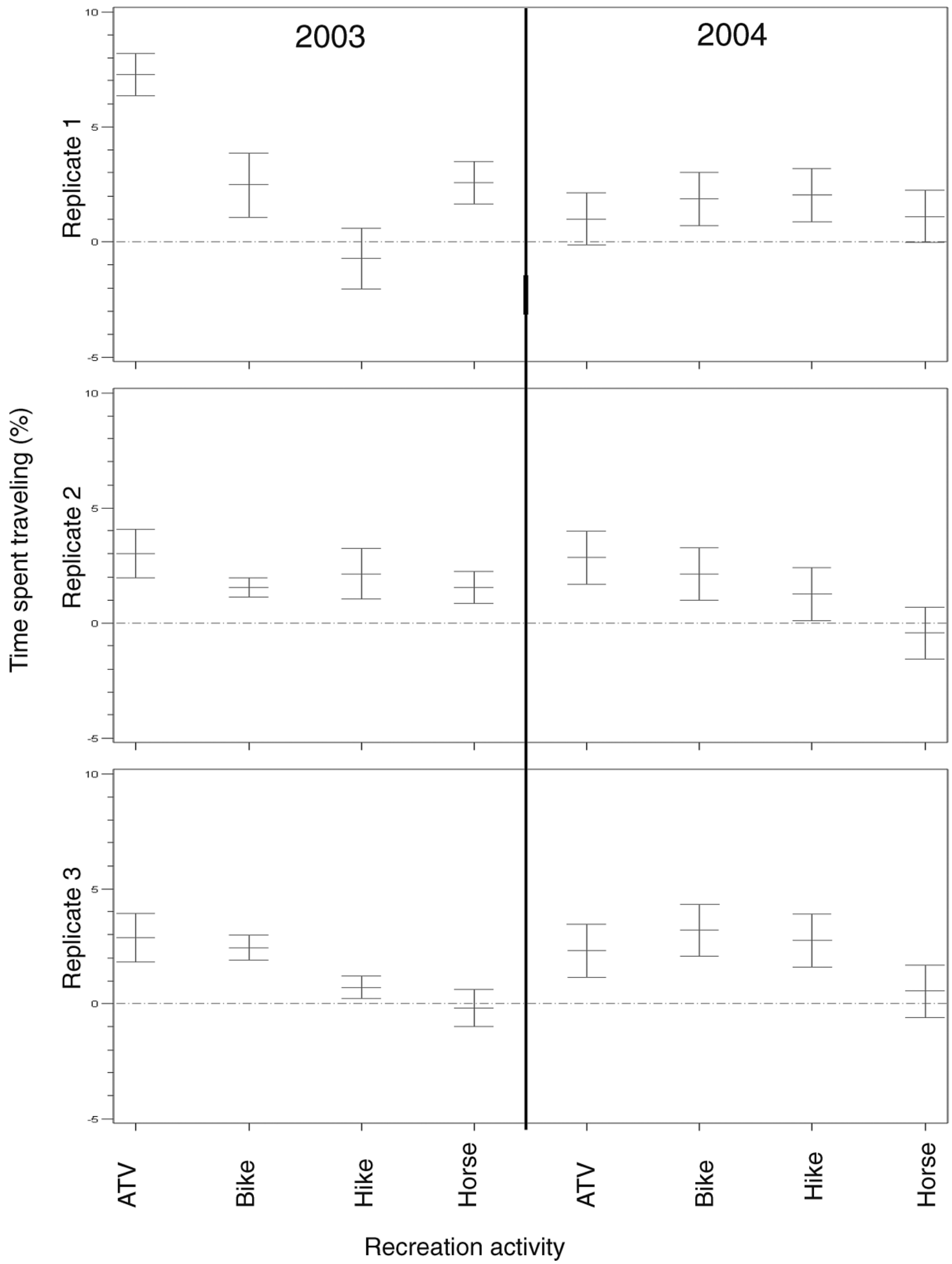

Figure 2. Mean and 95% confidence intervals of the difference in the percent travel time by elk between paired treatments and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent traveling during treatment minus that during control; negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

of controls in the hours immediately after initiation of the disturbance each morning. The reduced response by elk to each treatment in afternoons compared to mornings was likely due to elk moving away from the disturbance routes and avoiding them for the remainder of the day, which reduced the need for more travel and thus conserved energy (M. J. Wisdom, United States Department of Agriculture Forest Service, personal communication).

Table 3. Weekly averages and standard errors of percent time spent traveling above that of paired control periods for 13 female elk at Starkey Experimental Forest, La Grande, Oregon, USA, 2003 and 2004. A positive number indicates elk spent more time traveling during the treatment compared to the control period (no human activity) and a negative number indicates less time was spent traveling. ATV = all-terrain vehicle riding, Bike = moutain biking, Hike = hiking, and Horse = horseback riding.

	ATV		Bike		Hike		Horse	
Replicate	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2003								
1	7.27	0.46	2.47	0.70	−0.70	0.66	2.56	0.45
2	3.00	0.52	1.55	0.20	2.14	0.54	1.54	0.34
3	2.87	0.52	2.44	0.27	0.72	0.24	−0.18	0.40
2004								
1	0.99	0.57	1.86	0.57	2.03	0.57	1.11	0.57
2	2.83	0.57	2.13	0.57	1.26	0.57	−0.43	0.57
3	2.31	0.57	3.20	0.57	2.75	0.57	0.54	0.57

The reduced travel by elk in the afternoons also could be due to the benefits of conserving energy by remaining in a particular habitat. Presumably, more time spent hiding would outweigh the loss of energy caused by fleeing from disturbance. Our study did not include information on elk locations in relation to disturbance routes; therefore, we could not determine any shifts in habitat use during treatments. However, Preisler et al. (2006) demonstrated that elk in our study area moved away from the routes to hiding places near or against fences during 2002.

Hypothesis 2, which postulated that different types of human activity cause different behavioral responses in elk, also was supported by our results. The highest travel response by elk was during ATV exposure and was followed by increased resting time. This type of recreational activity may have forced elk to forgo foraging in favor of hiding until the disturbance ended. In contrast to this any disturbance during the mountain biking and hiking treatments resulted in feeding activity increasing. It is possible that, being quieter than the ATVs, mountain biking and hiking did not disturb elk once they moved away from the routes; elk were, therefore, able to make up any energy lost by resuming foraging activity.

For horseback riding, travel activity during 3 of the 6 replicates was not different from the controls, indicating that elk were not affected as much by this recreational activity. When elk did display an increased travel response to horseback riding, the effects on feeding and resting time were mixed.

Hypothesis 3, which postulated that time required for elk to return to predisturbance behavior varies with disturbance type, was not supported by our results. For all treatments, elk returned to behavior patterns similar to those of the controls once the disturbance ended each day (Naylor 2006: appendix 1, figs. A2–A13). Reduction in foraging time during treatments was not compensated for after the disturbance ended, because elk did not increase feeding intensity or duration beyond that of controls.

Our study design mimicked the daytime pattern of motorized traffic on National Forests (Wisdom 1998), most of which does not occur during peak elk feeding activity at dawn and dusk. Thus, our treatments did not overlap with peak feeding periods of elk. With their main intake of digestible material being unaffected by disturbances, reduced foraging time during treatments may not have had substantial short-term biological consequences for these elk. Elk may have satisfied their immediate nutritional requirements before and after disturbances occurred.

A potential disadvantage to elk is the energy expense of traveling during each disturbance, coupled with a loss in forage intake. A shift away from disturbance routes (as noted by Preisler et al. 2006) to areas of potentially lesser quality forage could have a cumulative effect on long-term body condition. Cook et al. (2004) suggested that if elk body fat was reduced below 9% as the animal enters winter, there is an increased probability of that individual not surviving winter. Comparisons of elk body condition before and after each treatment were beyond the scope of our study. Consequently, we could not conclusively assess long-term physiological effects of repeated disturbance to elk from April to October each year.

Hypothesis 4, which postulated that continued exposure to disturbance leads to conditioning of elk to the disturbance and results in unaltered or reduced behavioral responses (i.e., habituation), was partially supported by our findings.

A complicating factor in our evaluation of potential habituation of elk to recreation treatments is that we did not simultaneously evaluate changes in elk distributions. However, as part of the radiotelemetry monitoring of the same elk we studied, Preisler et al. (2006) found that elk moved away from travel routes during ATV riding with repeated ATV treatments. These movements allowed elk to resume activities similar to those of controls, while avoiding recreation routes. Such avoidance would not be considered habituation, but rather a different type of negative response to recreation.

Travel by elk during 2 horseback replicates was not different from control periods in 2004. Reduction in elk travel during horseback riding in 2004 compared to 2003 suggested that, unlike other treatments, elk may have habituated to horseback riding. Alternatively, elk could have simply avoided areas near horseback routes during 2004, as was done by elk in response to ATV treatments over time (Preisler et al. 2006). Under this possibility, elk could have maintained the same activity patterns as during controls, but farther away from travel routes.

In contrast to horseback riding, elk travel time during mountain bike riding was above that of controls for each year and was consistent among years. Thus, elk showed no evidence of habituation to mountain biking. Similarly, elk travel time in response to hiking was above that of control periods, with the exception of replicate 1 for 2003, suggesting a similar response by elk to each hiking disturbance (i.e., no habituation).

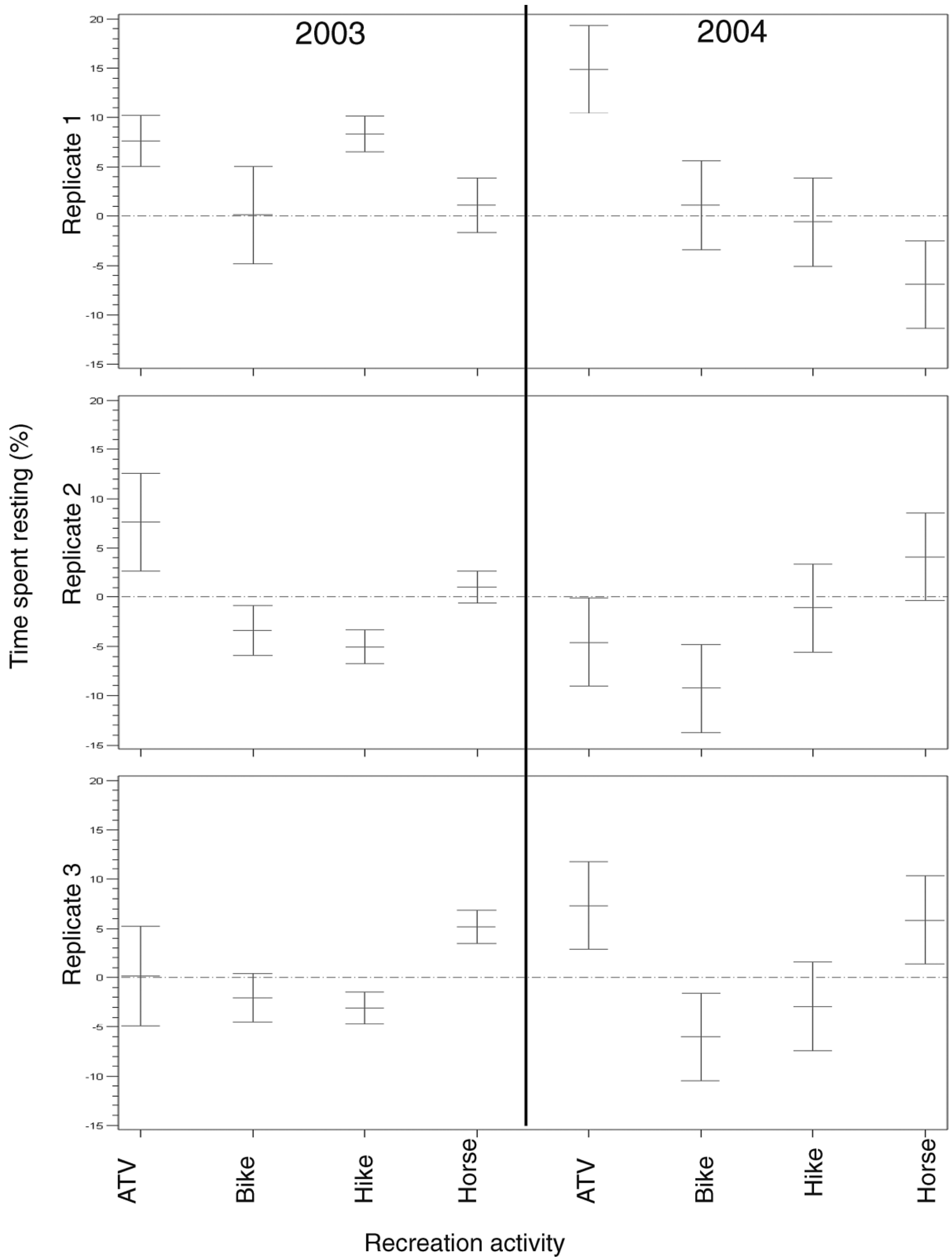

Figure 3. Mean and 95% confidence intervals of the difference in percent resting time by elk between paired treatment and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent resting during treatment minus that during control, so negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

MANAGEMENT IMPLICATIONS

A comprehensive approach for managing human activities to meet elk objectives should include careful management of off-road recreational activities, particularly ATV riding and mountain biking, which caused the largest reductions in feeding time and increases in travel time. Evidence of little or no changes in travel by elk as a response to horseback riding can also be used by managers when planning access to

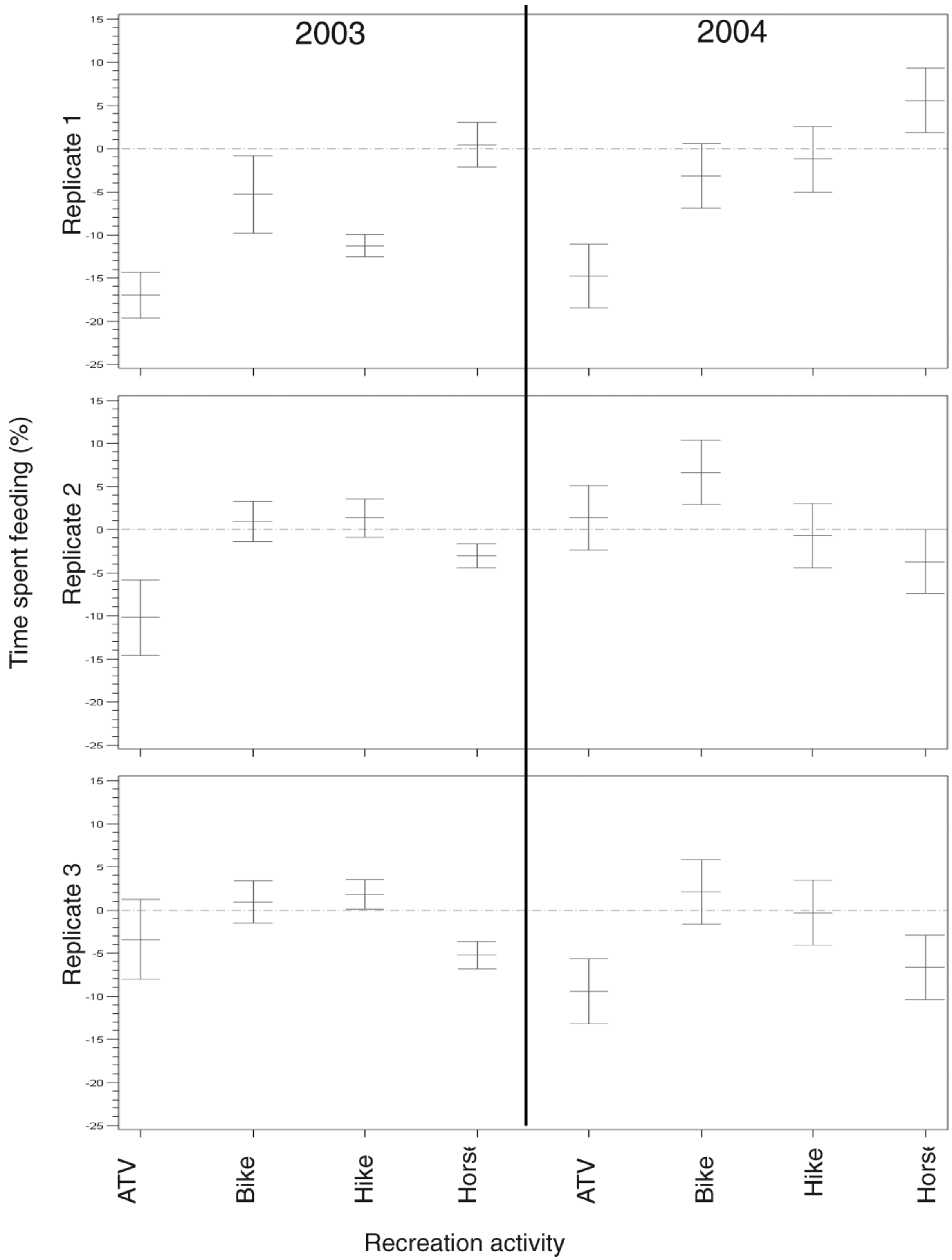

Figure 4. Mean and 95% confidence intervals of difference in the percent feeding time by elk between paired treatment and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent feeding during treatment minus that during control, so negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

areas where disturbance of elk is to be minimized. Such resource allocation trade-offs between management of elk and off-road recreation will become increasingly important as off-road recreation continues to increase on public lands.

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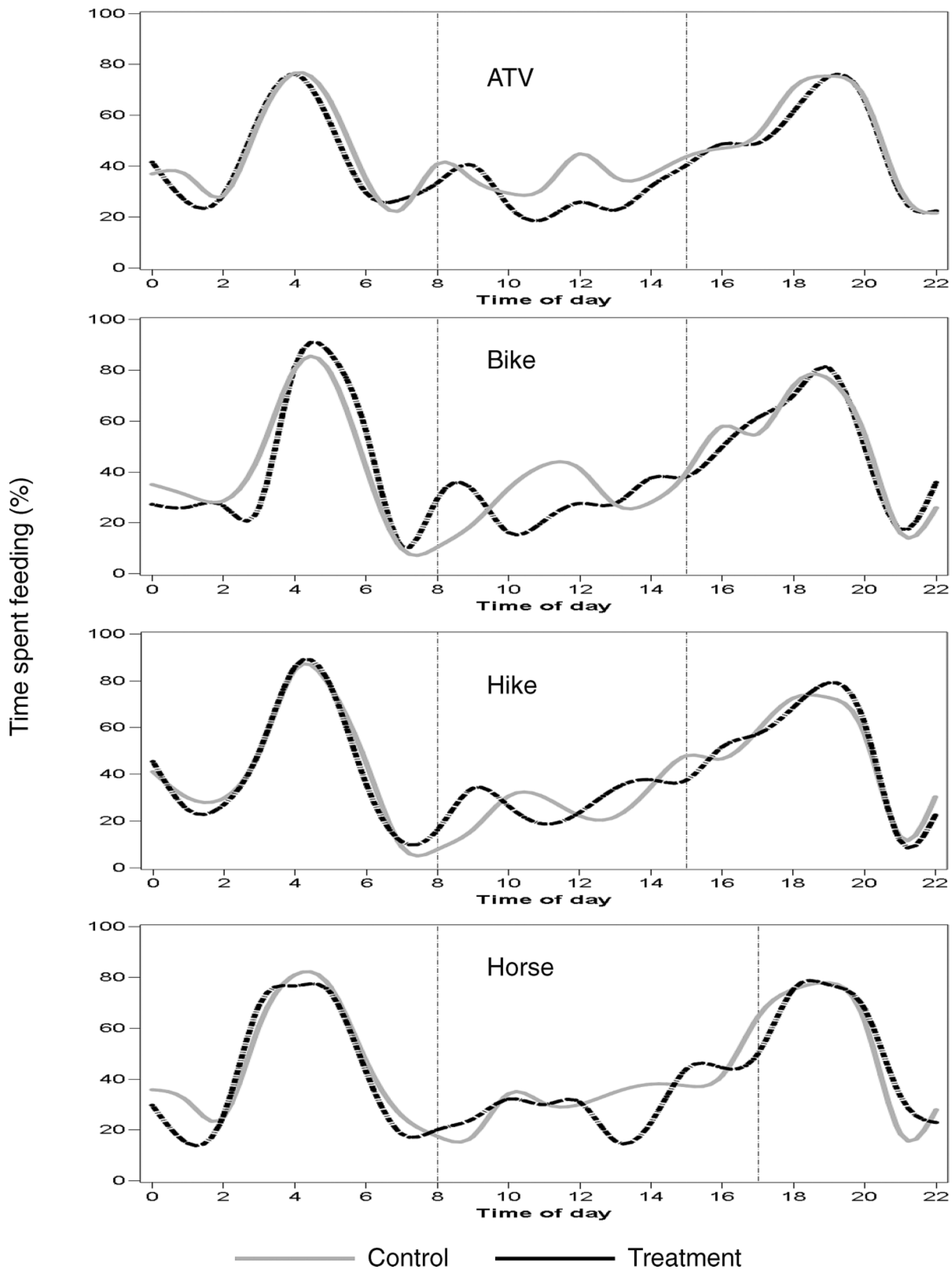

Figure 5. Feeding activity (%) of 13 female elk for replicate 2 of each treatment and its paired control during 2003 at Starkey Experimental Forest and Range, La Grande, Oregon, USA. Area between dotted vertical lines represents times (hr) treatments occurred. Results in this figure typify the pattern of elk activity returning to that like controls each day after a recreation treatment ended.

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