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Elk and Mule Deer Responses to Variation in Hunting Pressure

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Introduction

Hunting can exert a variety of effects on both targeted and nontargeted ungulates, and animals either run or hide in response to hunting pressure. If animals successfully elude hunters by running, the energetic cost may deplete fat reserves needed for survival during winter in temperate regions. If animals successfully elude hunters by hiding, there may be an energetic cost from lost foraging opportunities.

Most studies of ungulate responses to hunting have focused on changes in habitat selection. Ungulates typically respond to hunting by seeking areas of security (Irwin and Peek 1979, Knight 1980, Edge and Marcum 1985, Naugle et al. 1997, Millspaugh et al. 2000), by altering activity patterns (Naugle et al. 1997), by adjusting home ranges (Kufield et al. 1988, Root et al. 1988) or by moving long distances (Conner et al. 2001, Vieira et al. 2003). However, the difficulty of monitoring hunter density and elk and deer populations on large landscapes has prevented the collection of sufficient data to develop models of energetic costs associated with hunting or with other recreational activities. Variation in weather, hunter density, herd dynamics and seasonal conditions can likely bring about changes in the interactions between hunters and animals, making generalizations tenuous at best. Quantitative relationships between levels of hunting pressure and energy expenditure can be used to evaluate potential secondary effects of activities on nutritional condition of ungulates. For instance, frequent human disturbance that results in high energy expenditure by ungulates could adversely affect animal weight dynamics in winter, when forage is scarce, or in summer, when energy requirements are high for lactation and rebuilding body mass following winter (Cook et al. 2004).

In this study, we examined the effects of hunter density and associated motorized traffic on movement and habitat use by elk and mule deer over 10 years during 21 rifle and 2 archery hunting seasons at the Starkey Experimental Forest and Range (Starkey). Our goal was to quantify the relationship between levels of hunting pressure, as measured by hunter density, traffic counts, changes in movement and changes in habitat use patterns. These relationships were then used to estimate effects from variation in hunting pressure and type of hunt on daily and seasonal energy budgets of elk and mule deer.

Study Area

Starkey covers 40 square miles (101 km^2) on the Wallowa Whitman National Forest, 21 miles (35 km) southwest of La Grande, Oregon (45°15'N, 118°37'W). Our study was conducted in the Main Study Area (30 square miles [77.6 km^2]), which was enclosed with 7.9-feet (2.4-m) tall woven-wire fence (Bryant et al. 1993) and has been used for studies on Rocky Mountain elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*) and cattle since 1989 (Rowland et al. 1997). Starkey contained habitat for elk and mule deer that was typical of summer range conditions in the Blue Mountains. A network of drainages in the project area created a complex and varied topography. Vegetation at Starkey was a mosaic of coniferous forests, shrublands, wet meadows, riparian areas and grasslands.

Approximately 37 percent of the study area had forest canopy of more than 40 percent, and about 4 percent had forest canopy greater than 70 percent.

Traffic levels, recreational activities (including hunting), cattle grazing and timber management were representative of adjacent public land. About 500 cow-calf pairs of domestic cattle grazed the Main Study Area on a deferred rotation system through four pastures within the study area between June 15 and October 15 (Coe et al. 2001). Our study area at Starkey was three to four times larger than typical summer home ranges of elk in the Blue Mountains (7.7 to 11.2 square miles [20–29 km^2], Leckenby 1984), providing study animals with large-scale habitat choices commensurate with free-ranging herds. Details of the study area and facilities are available elsewhere (Wisdom et al. 1993, Noyes et al. 1996, Rowland et al. 1997).

Materials and Methods

Hunt Sample

We analyzed 13 rifle elk hunts, 8 rifle mule deer hunts and 2 archery elk hunts conducted between 1991 and 2000 (Table 1). Elk rifle hunts were 5 to 9 days long with 75 to 175 tags issued to hunters, and deer rifle hunts were 7 to 12 days long with 25 tags issued. Archery hunts were 30 days long with 85 tags issued. We staffed a hunter check station starting the day before the opening of each hunt through the end of the hunt; this was done for all elk rifle hunts, through the first three days of deer hunts and intermittently during the rest of the deer seasons. We staffed the archery check station during most days with project personnel or volunteers. For each hunter, we recorded number of days hunted and success. Prior to any hunts, the yearling and adult elk populations were estimated between 313 and 443 females and between 78 to 153 males (Noyes et al. 1996, 2002), and the mule deer population was estimated between 262 and 342 total males and females (Rowland et al. 1997). Densities of adult elk and deer in the study area were similar to those on adjacent public land (Johnson et al. 2000).

Animal Locations

We determined animal locations with an automated telemetry system that uses retransmitted long-range aid to navigating signals (LORAN-C) (Findholt et al. 1996, Rowland et al. 1997). Each radiocollared elk was used an average of 1.6 years, while each mule deer was used about 1.9 years. We monitored between 25 and 60 elk and 12 and 33 deer during the hunts. Locations

Table 1. Summary of elk (E) hunts and deer (D) hunts included in the study held in Main Study Area (30 square miles [77 km²]) at the Starkey Experimental Forest and Range. H = habitat; V = velocity; T = traffic; Hu = hunter.

Hunt label	Date	Days of elk velocity data	Days of deer velocity data	Days of elk habitat data	Days of deer habitat data	Number of hunters	Traffic counts/ day	Elk locations	Deer locations	Available dependent variables for elk telemetry	Available dependent variables for deer telemetry	Available independent variables for both deer and elk
E3[1]	Aug. 15–23, 1992	6	Na[6]	8	Na	19–168	65–245	904	0	HV		HuT
E4[2]	Dec. 5–12, 1992	3	Na	4	Na	24–73	59–103	753	0	HV		HuT
E5[1]	Aug. 14–22, 1993	3	5	6	6	50–117	74–164	1,855	771	HV		HuT
E6[3]	Aug. 27–Sep. 25, 1994	30	20	30	30	2–53	26–66	6,368	4,146	HV	HV	HuT
E7[1]	Oct. 26–30, 1994	5	5	5	5	74–113	87–116	1,552	1,122	HV	HV	HuT
E8[4]	Nov. 5–13, 1994	9	9	9	9	25–130	42–168	3,407	2,054	HV	HV	HuT
E9[5]	Nov. 19–27, 1994	7	7	7	7	7–63	25–106	2,264	1,588	HV	HV	HuT
E10[1]	Aug. 18–25, 1996	9	1	9	4	15–134	Na	2,632	318	HV		Hu
E13[2]	Nov. 29–De. 5, 1997	5	5	5	5	12–69	Na	3,972	2,106	HV	HV	Hu
E15[2]	Dec. 5–11, 1998	4	5	4	5	13–46	2–25	1,496	723	HV	HV	HuT
E18[1]	Aug. 1–5, 2000	3	4	4	4	33–122	Na	859	712	HV	HV	Hu
E19[3]	Aug. 25–Sep. 24, 2000	29	28	30	30	12–52	1–33	9,709	5,993	HV	HV	HuT
E21[2]	Dec. 3–9, 1994	3	3	3	3	51–82	76–105	890	634	HV	H	HuT
D1[7]	Sep. 28–Oct. 4, 1991	5	Na	7	Na	Na	48–85	842	0	HV		T
D2[7]	Oct. 3–9, 1992	4	Na	4	Na	Na	58–145	1,042	0	HV		T
D3[7]	Oct. 2–8, 1993	7	4	7	6	2–16	33–71	2,272	878	HV	HV	HuT
D4[7]	Oct. 1–12, 1994	10	4	10	10	Na	14–54	2,040	1,322	HV	HV	T
D7[7]	Sep. 30–Oct. 11, 1997	8	7	8	7	3–12	Na	4,294	2,079	HV	HV	Hu
D8[7]	Oct. 3–14, 1998	12	7	12	12	0–24	10–100	4,225	1,615	HV	HV	HuT
D9[7]	Oct. 2–13, 1999	11	Na	12	12	Na	11–43	3,515	1,412	HV	HV	T
D10[7]	Sep. 30–Oct. 11, 2000	Na	10	12	12	Na	55–158	4,363	2,410	H	HV	T

[1] Rifle Spike-only elk hunt
[2] Rifle Antlerless elk hunt
[3] Archery any elk hunt
[4] Rifle any elk hunt
[5] Rifle antlered elk hunt
[6] Data not available due to sample size restrictions of 10 animals each with 10 locations, missing traffic counts, or missing hunter numbers
[7] Rifle antlered deer hunt.

were assigned to Universal Transverse Mercator coordinates of associated 98.4 by 98.4-feet (30 by 30-m) pixels containing habitat information stored in a geographic information system (GIS). Locations had a mean error of 175 feet ± 19 feet (53 m ± 5.9 SE, Findholt et al. 1996).

Vehicular Traffic

We measured traffic throughout the year from a network of 71 traffic counters (Rowland et al. 1997, 2000). Preliminary analysis of traffic counter data showed that data collected at the counter located 0.15 miles (0.24 km) inside the main gate were highly correlated with data obtained at the other counters located throughout the study area. For this analysis, we used the daily counts of vehicles that passed over the Starkey main entrance counter as an index to total traffic activity. In addition, by using a single counter, the application of our results to areas with limited traffic data is made more feasible.

Habitat Variables

We selected 10 variables that were significant in resource selection models for elk or mule deer in previous studies at Starkey (Johnson et al. 2000, Table 1). However, we used distance to open roads rather than distance to roads of various traffic rates because, during hunting seasons, daily use of open roads was greater than the minimum value associated with roads with high traffic rates (more than 4 vehicles per 12 hours). These variables were significant in resource selection models for elk or mule deer in previous studies at Starkey. Additional details can be found in Johnson et al. (2000) and Rowland et al. (1998).

Data Analysis

We used day as our sampling unit and required a minimum of 10 locations from each of at least 10 animals of a species per day. Choice of minimum sample sizes was based on previous analyses (Ager et al. 2003). We calculated velocity between successive locations by dividing the horizontal distance moved by the elapsed time. We deleted velocity for any location if elapsed time to the previous location was fewer than 5 minutes or more than 240 minutes. Shorter elapsed times (fewer than 5 minutes) yielded velocities that were positively biased because of the random location error in the telemetry system. Velocities determined at longer elapsed times were negatively biased as a result of undetected movements between observations and home range effects (Ager et al. 2003). For habitat analysis, average sample size for elk during elk hunts was 254 observations per day on a total of 23 animals. Deer sample size during elk hunts was 171 observations per day on 15 animals. Sample sizes for velocity calculations were reduced approximately 15 percent as a result of the time filter placed on data.

Response Variables

We compared responses of elk and deer during elk and deer hunts to seven-day prehunt periods that started 2 weeks before the start of the hunting season. We calculated daily average velocity of elk and mule deer as dependent variables and used daily traffic counts and hunter density as independent variables in a regression analysis. We used the daily averages for the prehunt periods to set the intercept.

We calculated hourly velocities and habitats used for the prehunt and hunt periods and examined how normal daily patterns changed in relation to variation in hunter density. We pooled data across all animals and hunts to maximize the number of hunting days in the analysis. Although hunt-to-hunt variability was of interest, our goal was to obtain an overall estimate of animal response over a wide range of hunting conditions. Variation among hunts was high and number of hunts had one or more of the following conditions: (1) limited data for prehunt conditions, (2) limited variability in the hunter density and traffic counts, and (3) differences in the range of traffic and hunter density. Thus, using a single linear model containing a term for individual hunts would have reduced the possibility of obtaining useful information from several of the hunts, but the effects among the hunts would not have been comparable in many cases. We did not pool animals used in multiple years but rather considered them independent samples in each hunt because day was the sampling unit. We did not test for serial correlation in the data from successive days within a hunt after observing that elk and deer response to hunters at Starkey is dynamic and rapid in terms of changes in distribution and velocity.

Energetic Calculations

We estimated energy consumption as a function of velocity from equations provided by Robbins et al. (1979:449) and Parker et al. (1984:478). Robbins et al. (1979) estimated the cost of locomotion in kilocalories per kilogram per hour where Parker et al. (1984) estimated cost of locomotion in kilocalories per kilogram per minute. Robbins et al. (1979) estimated cost of location on slopes for uphill and downhill, but we did not factor energy consumption for slope because we could not accurately estimate animal paths and their respective slopes. The differential energy expenditure for uphill versus downhill travel results in an underestimation of energy expenditure. Average slope at Starkey was 17 percent.

Results

Daily density of hunters per square mile averaged 2.4 (0.91 hunters/km^2, range 0.03–1.66/km^2) for elk hunts, 0.1 (0.04 hunters/km^2, 0–0.31/km^2) for deer hunts, and 0.7 hunters per square mile (0.26 hunters/km^2, 0–0.67/km^2) for archery hunts. Daily traffic counts averaged 78 (6–272 range) for elk hunts, 56 (10–158 range) for deer hunts, and 55 (17–133 range) for archery hunts. During the prehunt periods, vehicles per day averaged 46 (18–86 range) before archery, 45 (1–165 range) before elk rifle, and 27 (1–65 range) before deer hunts. All deer hunts were excluded from further analysis because there was no measurable response of elk or mule deer during deer hunts, most likely because of the low hunter density and traffic rates.

Velocity

Velocity of elk movements increased during rifle and archery hunts (Figure 1A). During nonhunt periods, elk displayed daily patterns of velocity characterized by crepuscular peaks of about 11.5 feet per second (3.5 m/min) at 0600 to 0800 and 1700 to 1800 hours, and lower midday velocity of around 6.6 feet per second (2 m/min) during nonhunt periods. Elk velocity was greater in the early morning during rifle hunts than during archery hunts, but this pattern reversed during the afternoon (Figure 1A). Differences in timing of peaks during prehunt periods for archery and rifle hunts probably reflects differences in sunrise and sunset times for September versus December hunts.

During elk rifle hunts, the daily patterns of velocity were strongly affected by hunter density (Figure 2). At the lower density values (fewer than 0.8 hunters per square mile, [0.3 hunters/km^2]) the crepuscular peaks were broader and increased by around 3.3 feet per minute (1 m/min), and the midday velocity returned to prehunt levels. At high hunter density, more than 3.2 hunters per square mile (1.25 hunters/km^2), the daily pattern consisted of large velocity

Figure 1. Mean hourly velocities of elk (A) and mule deer (B) during and before elk rifle and archery hunts at Starkey.

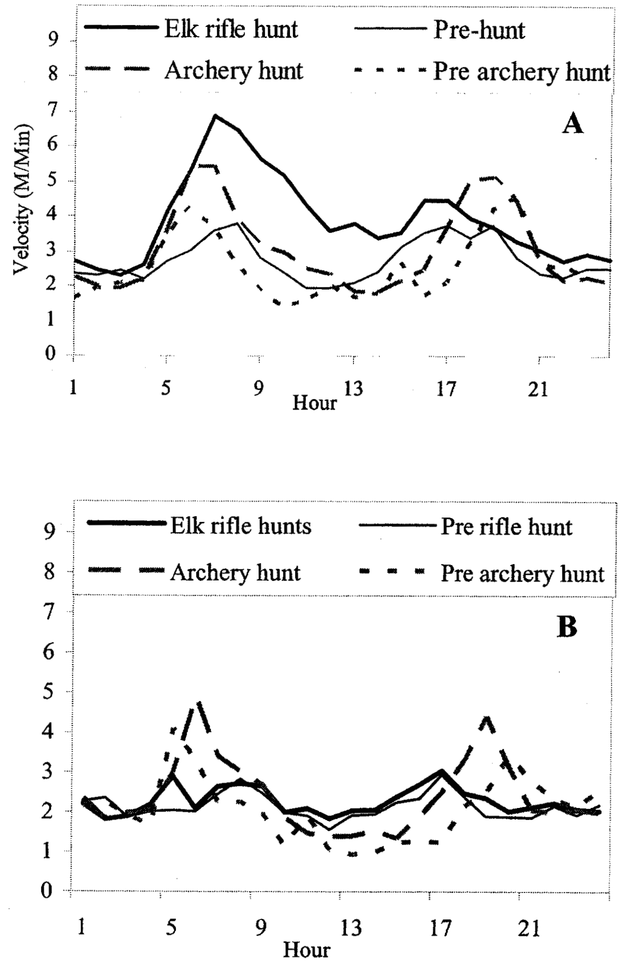
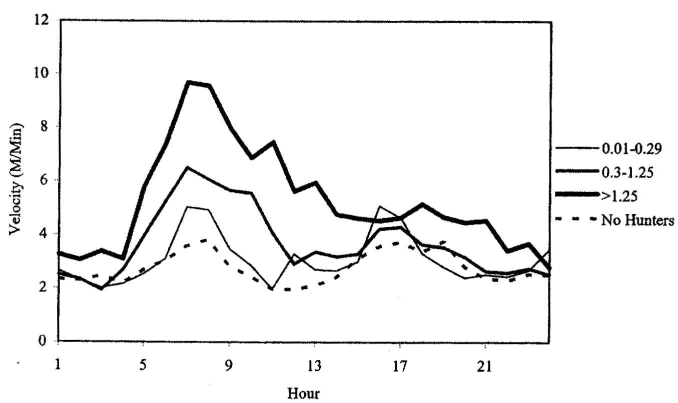


Figure 2. Hourly velocities of elk at four hunter densities (hunters/km²)for elk rifle hunts at Starkey.



increases throughout the day, with a peak at 0800 hours that was about 20 feet per minute (6 m/min) above the prehunt velocities (Figure 2). Only between 0000 to 0400 hours did the velocity at high hunter density return to values close to prehunt conditions.

Daily mean velocity of elk to rifle hunter density showed a linear relationship (Figure 3, $R^2 = 0.46$, $P < 0.001$), the velocity increasing 1.4 meters per min per hunter per square kilometer. The regression predicts that at the highest daily rifle hunter densities during the Starkey hunts, estimated mean velocity would increase from 6.9 feet per minute (2.7 m/min) during the prehunt period to around 16.5 feet per minute (5 m/min). Effects of archery hunters on elk appeared to be greater than that of rifle hunters, as velocity increased 2.2 meters per minute per hunter per square kilometer ($P < 0.001$) (Figure 4).

Figure 3. Daily mean elk and mule deer velocities versus hunter density for elk rifle hunts at Starkey.

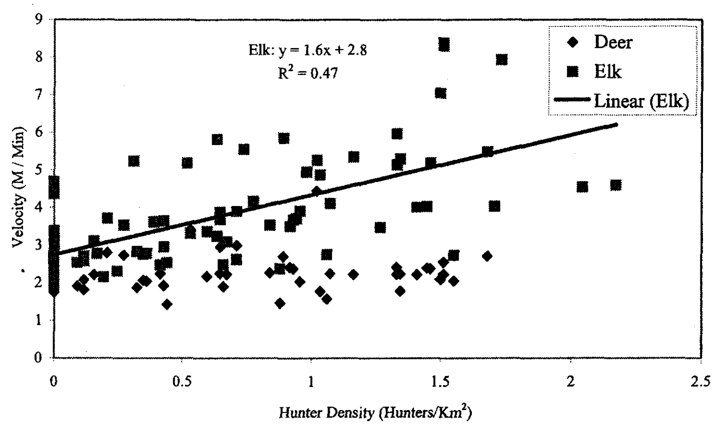
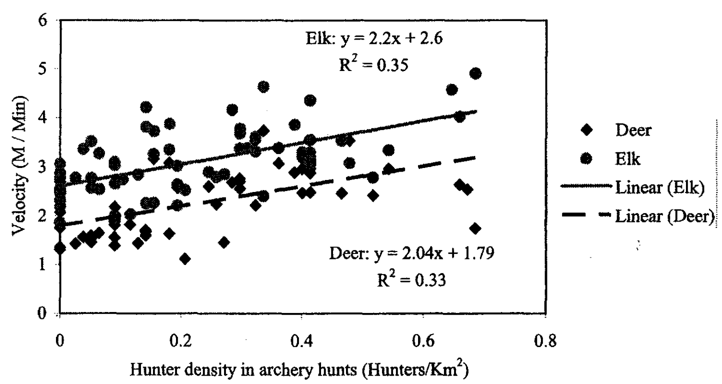


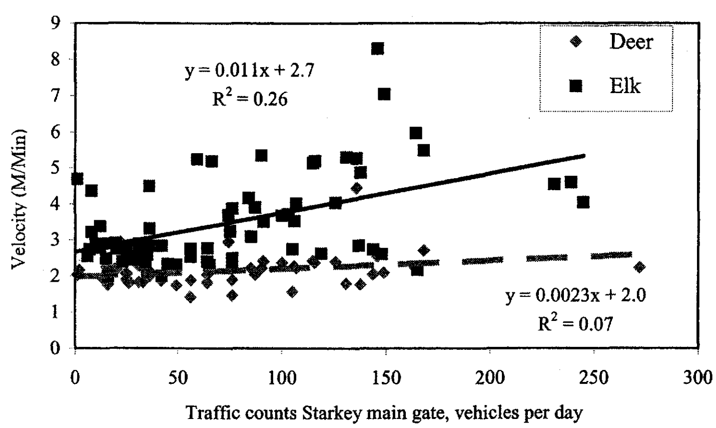
Figure 4. Daily mean elk and mule deer velocities versus hunter density for elk archery hunts at Starkey.



Mule deer showed little increase in hourly velocities during elk rifle hunting seasons (Figure 1B), except for a small increase in velocity around 0500 hours, but there was no significant increase in velocity as rifle hunter density increased (Figure 3). Mule deer velocity increased as archery hunter density increased (Figure 4, P <0.001), and the hourly velocities during archery season increased at sunrise and sunset (Figure 1B).

There was a positive relationship between traffic counts during elk rifle seasons and daily mean velocity of elk (Figure 5, $R^2 = 0.28$); although, this relationship was considerably weaker than that between hunter density and velocity. Also in contrast to rifle hunts, no relationship was observed between traffic counts and elk velocity during the archery hunts, likely due to the lower traffic levels. Deer showed a very low response to increased levels of traffic (Figure 5).

Figure 5. Elk and mule deer velocities versus traffic counts before and during elk rifle hunts at Starkey.



Habitat Variables

Distance of elk to open roads increased as both elk rifle hunter density ($y = 83x + 751$, $r^2 = 0.12$, where x = hunter/km^2) and traffic counts increased ($y = 0.8x + 740$, $r^2 = 0.11$, where x = daily traffic count and y is distance in m). During archery seasons, as hunter density increased, elk use of canopy cover decreased ($y = -7.3x + 38.5$, $r^2 = 0.18$, where x = hunter/km^2 and y = percent canopy cover). There were no other significant relations in traffic or hunter density during the archery seasons and any other habitat variables. Hourly habitat use at different levels of hunter density showed that prehunt daily patterns of habitat use for distance to open road (Figure 6) and all other habitat variables (not shown) were increasingly disrupted as hunter density increased. In addition to disruption, distance of elk to open roads increased especially in the nighttime hours, when elk did not move closer to roads, compared to prehunt distributions.

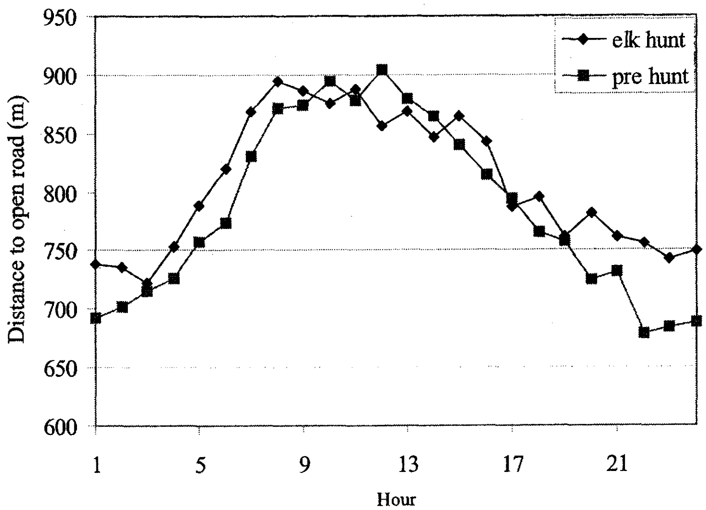


Figure 6. Hourly average distance of elk from an open road during rifle elk hunts at Starkey Experimental Forest and Range.

Energetic Cost of Hunting for Elk

At the average hunter density observed in this study, 2.3 hunters per square mile (0.91 hunters/km^2), velocity increased 4.3 feet per minute (1.3 m/min) over the background velocity for the nonhunt periods. Based on the relationship provided by Robbins et al. (1979) and Parker et al. (1984), this velocity increase translates to a 4-percent (Parker et al. 1984) to 10-percent (Robbins et al. 1979) increase in the normal daily energy budget. This estimate was slightly conservative because travel was assumed to be on level ground.

Discussion

This study represents our first attempt to measure the effects of variation in hunting pressure on elk and deer over a wide range of hunter densities, hunting conditions, traffic rates and rifle versus archery hunting. We found that elk responded by fleeing disturbance; whereas, deer eluded hunters by hiding. Our data indicate that both traffic count and hunter density have a positive linear relation with elk velocity. Moreover, hunter density appears to be a better indicator of animal disturbance than traffic counts, especially for archery hunts. We found differences between the archery and the rifle hunts in terms of animal responses; although, the study only included two archery hunts. Archery hunts appeared to affect animal movements for a longer portion of the day, suggesting that archers are actively pursuing elk throughout the day and evening.

In contrast to other previous studies (Irwin and Peek 1979, Edge and Marcum 1985, Millspaugh et al. 2000), we did not find major shifts in habitat use by elk or mule deer during the elk rifle hunting seasons. However, the daily patterns of habitat use were disrupted. We also did not observe any effects on elk or deer from the deer rifle hunts, most likely due to the low hunter densities associated with these hunts.

The results of this study suggest that energetic costs to elk from hunting may be significant in the context of both hunter density and the number of days over which hunting occurs; however, the energetic costs to deer may not be as great. In northeastern Oregon, many of the wildlife management units have 30 days of archery hunting, followed by 12 days of mule deer rifle hunting, then 14 days of rifle elk hunting and, finally, up to 9 days of antlerless elk hunting, totaling 56 to 65 days of hunting. In 1999, Oregon Department of Fish and Wildlife (2000) estimated that there were 61,804 and 49,063 recreational days for elk and mule deer hunting in the Starkey and Ukiah Wildlife Management Units (WMUs), respectively. There were 726 square miles (1,859 km^2) and 568 square miles (1,453 km^2) of deer and elk range in the Starkey and Ukiah WMUs, respectively (Oregon Department of Fish and Wildlife 1986) for a hunter density of 1.35 hunters per day per square mile (0.53 hunters/day/km^2).

Based on our estimate of increased velocity associated with rifle hunter density, and the energetic relationships identified in Parker et al (1984), this equated to an additional energy expenditure of 310 kilocalories per day for an adult cow elk assumed to weigh 510 pounds (232 kg). Assuming this additional energy comes from stored fat reserves and there are 9 kilocalories per gram of fat, this results in 1.2 ounces (35 g) of fat consumed per day or 4.4 pounds (2 kg) for the entire 63 days of hunting due to disturbance from hunters. Assuming the ingesta-free body mass of a lactating cow elk is 440 pounds (200 kg) and has 10-percent body fat, these 4.4 pounds (2 kg) of body fat represents about a 10-percent reduction in body fat. Cook et al. (2004) suggest that elk reproduction may be affected when body fat falls below 9 percent and is marginally affected at levels between 9 and 13 percent, conditions that occur in lactating cow elk in late autumn. Because most of the hunting disturbance occurs after the rut, the reduced fat levels may be more important during harsh winters and may carry over through the next year as cows rebuild tissues catabolized during winter.

Elk and mule deer at Starkey were closed populations; thus, animals were unable to escape from human harassment by moving to private land or other reserves. Without hunting, the movement rates we observed at Starkey were similar to those reported by Craighead et al. (1973). In northeastern Oregon, private land, wilderness, and roadless or road management areas provide areas where hunter density is lower. Thus, our estimates of energy expenditure for elk in our example may be high for those animals that are able to move to secluded areas where hunter density is low. However, animals that respond to hunting pressure by moving long distances from that pressure also would exert substantial energy that our study does not address.

Our energy calculations do not account for disruption of foraging cycles where foraging patterns are shortened or where animals move to more secluded areas with poorer forage resources. If those situations occur, then the effects of hunter density may be much more pronounced than we estimated. These potential effects deserve attention in future studies. Estimating absolute levels of energy loss will take more accurate measures of activity patterns, distributions and forage quality of ungulates in relation to variation in hunting pressure. For our analysis, we did not distinguish between flight movements and foraging which require more precise monitoring of elk to quantify the disruption of foraging patterns.

Our results may have implications for design and management of access and hunting seasons for mule deer and elk. First, the energetic costs of eluding hunters may be substantial under the combination of high hunter densities and long hunting seasons. The added energetic costs may have the potential to increase mortality of animals beyond those harvested in areas with severe winter conditions. Second, the motorized access provided to hunters, in combination with hunter density and season length, may affect the degree to which nonharvested animals are negatively affected by hunting. For example, it may be possible to reduce or to restrict human access, particularly motorized access, as part of hunting seasons but still accommodate higher hunter density without negative energetic costs on nonharvested animals. Alternatively, if motorized access is relatively unrestricted and landscape conditions facilitate ease of human movement (e. g., flat terrain and open environments), then managers may consider modifications in hunter densities and season lengths to meet population objectives for elk and mule deer. Such trade-offs deserve careful consideration in the integrated planning of human access with design of hunting seasons for management of elk and mule deer.

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