

---

## HABITAT PROBLEMS AND HUMAN DISTURBANCE

CHAIR: JIM BAILEY, NEW MEXICO DEPARTMENT OF GAME AND FISH

---

### GUY WAGNER - ACTIVITY PATTERNS OF ROCKY MOUNTAIN BIGHORN EWES IN CENTRAL IDAHO

---

Guy D. Wagner, Dept. Fish and Wildlife Resources, University of Idaho, Moscow, ID 83843  
Dr. James M. Peek, Dept. Fish and Wildlife Resources, University of Idaho, Moscow, ID 83843

**Abstract:** Changes in Rocky Mountain bighorn ewe activity patterns were observed in response to season, forage quality, and weather in the Big Creek drainage of central Idaho. The study population was relatively undisturbed by modern development or agriculture, and thus the activity data provides a baseline for similar studies of bighorn populations inhabiting areas with greater human disturbance. Ewes were equipped with motion-sensitive collars and monitored by automated remote telemetry and direct observation from 1994-1997. Bighorn ewes reduced activity during winter when forage resources were of low quality, and increased activity during spring and early summer. Ewes were most active during daylight hours, but during mid- and late-winter nocturnal activity increased. Within days, activity patterns were strongly bimodal during mid-winter, but exhibited several activity peaks during seasons with greater day-length. Ewes moved an average distance of 3.6 km/day during mid-winter, and 4.6 km/day throughout the remainder of the year. Ewes increased activity levels during the third trimester of gestation and while lactating. During this period of nutritional stress, they moved frequently while seeking high quality grasses and forbs. Managers should minimize disturbance of bighorn bands during winter, and ensure that human disturbance does not limit access to habitat providing important sources of nutrients during late gestation and lactation.

---

Activity patterns may reveal how animals deal with changing environmental influences and nutrient sources. Furthermore, estimation of energy requirements necessitates a knowledge of activity patterns. Such knowledge may explain foraging strategies and trophic dynamics. Knowledge of activity patterns may also help managers plan aerial surveys to coincide with time periods when animals are most active and visible, and delineate seasons and daily time periods when animals are most vulnerable to human disturbance.

Bighorn sheep (*Ovis canadensis canadensis*) activity patterns have been studied by Mills (1937), Davis (1938), Blood (1963), Woolf et al. (1970), Geist (1971), Van Dyke (1978), Eccles (1978, 1983), Stemp (1983), Belovsky and Slade (1986), Goodson et al. (1991), and Sayre and Seabloom (1994). Most authors reported from 2-4

daily activity peaks. Geist (1971) noted activity peaks were closer to mid-day in winter months compared to summer, presumably, in response to higher temperatures. Smith (1954) observed the daily activities of bighorn sheep on our study area. He found bighorns generally lacked a strict routine, but usually bedded following morning and mid-day feeding bouts. Weather nor season influenced activity patterns, except during periods of deep snow, when bighorns spent more time feeding, because they were forced to paw through snow to obtain adequate forage.

We collected activity data on adult ewes at lower elevations throughout the year, and constructed seasonal time budgets. We used these data to examine the hypotheses that bighorn ewes altered time budgets to adapt to changes in season, forage, day-length, and environmental variables. In addi-

tion, activity-time budgets were used to construct models of energy expenditure and intake (Wagner 1999).

Due to its isolation in the heart of the largest wilderness in the lower 48 states, the study population is relatively undisturbed by modern development or agriculture. Only the older male segment of the population is hunted (6 permits/year). Therefore, the activity data provides a useful baseline for studies of other bighorn populations in areas more impacted by human developments and habitat changes.

**STUDY AREA:** Big Creek flowed predominantly west to east through the Frank Church River of No Return Wilderness, and drained into the Middle Fork of the Salmon River. Elevations within the drainage ranged from 3500 feet to 9500 feet, and contained some of the greatest relief in Idaho. Southern exposures comprised most of the terrain on the north side of Big Creek. This area served as important winter range to bighorn sheep, mule deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*). Snow depths were generally low and southern aspects usually remained snow-free for much of the winter. Bighorn sheep occupied mainly the lower 12 miles of this range.

Topography at lower elevations was characterized by steep V-shaped canyons. Abrupt changes in aspect resulted in markedly different plant associations. Southern exposures at lower elevations, where soil development was adequate, were dominated by grasslands. Soils were formed from granitic Idaho batholith parent material (Claar 1973), and were generally shallow and rocky. Numerous rock outcrops, cliffs, and talus slopes were present.

Bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), junegrass (*Koeleria cristata*), needle and thread grass (*Stipa comata*), Sandberg's bluegrass (*Poa sandbergii*), and cheat grass (*Bromus tectorum*) comprised the majority of graminoid biomass. Big sagebrush (*Artemesia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and bitterbrush

(*Purshia tridentata*) were important shrub species associated with grasslands. Curl-leaf mountain mahogany (*Cercocarpus ledifolius*) formed extensive stands on steep rocky outcrops. Arrowleaf balsamorhiza (*Balsamorhiza sagittata*), Western yarrow (*Achillea millefolium*), and lupine (*Lupinus* spp.) were important forbs. Douglas-fir forests (*Pseudotsuga menziesii*) were encountered on north aspects and ridgetops. Small stands and individual Douglas-fir were also scattered throughout the grasslands.

Summers were typically hot and dry with maximum July temperatures averaging 35°C. The majority of precipitation fell from late fall through spring in the form of snow. However the lower elevations of the winter range received periodic rain even in mid-winter. Annual precipitation averaged 38.1 cm.

**METHODS: Remote Telemetry.** Automated remote telemetry systems were used to study the activity patterns of red deer (*Cervus elaphus* L.) in Germany (Georgii 1981), moose (*Alces alces*) in Alaska (Risenhoover 1986; Miquelle 1990, Miquelle et al. 1992; MacCracken 1992), mule deer (*Odocoileus hemionus*) in California (Kie et al. 1991), black-tailed deer (*O. hemionus columbianus*) in British Columbia (Gillingham and Bunnell 1985), and white-tailed deer in Michigan (Beier and McCullough 1988). Automated remote telemetry systems enabled researchers to continuously monitor several animals, and record nocturnal behavior.

**System Description:** Nine ewes were captured using a dart gun and collared with Telonics radio-transmitters containing motion-sensitive tip switches. Signals were received from radio-collared animals by a Telonics TR-2 receiver using a Telonics RA-10 Omni-directional antenna, relayed to a Telonics TDP-2 digital processor, and recorded on a Gulton Rustrak (Manchester, New Hampshire) dual-channel strip-chart recorder. Three systems were placed in separate 30 gallon plastic coolers for protection. Chart speed was set at 12.7 cm/hr (5 inches/hour).

**Chart Interpretation:** During operation, 2 lines were recorded: for signal strength and for motion/behavior changes. Motion/behavior lines reflected changes in pulse rate determined by the animal's head position. A lowered head position produced a faster pulse rate than a raised position. Different behaviors recorded different patterns. Experience in chart interpretation was obtained by simultaneously observing the behavior of transmitting ewes and watching data being recorded. Variations in signal strength aided interpretation of the pulse rate line. Both beginning and ending times were marked on the chart paper, and intermediate times were also marked whenever a unit was checked. Upon retrieving a chart, the interpreter placed tick marks at changes in behavior and, then measured the time between changes. Focal animals were monitored continuously up to 6 days, the time between battery and chart paper changes. If possible, monitored animals were selected randomly, but selection was frequently determined by signal strength.

The validity of activity data collected by remote means was questioned by Gillingham and Bunnell (1985). However, other authors have rated their system accuracy at > 90% (Van Ballenberghe and Miquelle 1990). Our system accuracy was dependent upon the degree of behavioral detail selected for sampling. The finer the behavioral detail desired the less certain the estimates. We distinguished active from inactive behavior, and within the inactive category, separated bedded (lying with head up) from sleeping (lying with head down). Other behaviors were measured by direct observation. The accuracy of remote telemetry data interpretation was checked by comparing strip-chart data to information recorded independently in field notes. Eighty-one individual observations from the strip-chart were randomly selected and the interpreted behavior verified from direct observations. Accuracy was expressed as the percentage of correct classifications.

**Direct Observations:** Within active and inactive bouts randomly selected focal animals were observed with 16 x 80 binoculars from 100 to 500 m distance, and their behaviors recorded for 15 min

using a cassette recorder. Later the cassette was replayed and behaviors timed using a stopwatch. Total time spent in each behavioral category was converted to a percentage of the 15 minute observation. Categories included feeding, pawing through snow or gravel, moving, chewing cropped vegetation with head erect, standing alert and/or alarmed, and interacting socially. Feeding was defined as actually biting vegetation. During an observation, individual movements and total distance moved were estimated in meters. During inactive bouts, times spent ruminating and sleeping were estimated by similar observations, except 3 ewes were monitored simultaneously.

**Environmental Variables:** Hourly weather data was collected by an automated meteorological station located at the base of the winter range. Each hour the station's Campbell Scientific CR10 datalogger (Campbell Scientific; Logan, Ut.) recorded maximum wind speed, wind vector, average wind speed, temperature, humidity, solar energy, precipitation, and barometric pressure.

**Data Analysis:** Based upon the annual reproductive cycle of bighorn ewes and plant phenology a year was divided into 5 periods. Summer or period 1 (1 June to 16 August) corresponded to peak lamb drop and lactation, and availability of early summer forage. Late-summer-fall or period 2 (17 August to 15 November) corresponded to decreased lactation, gradual senescence of most herbaceous forage, possible fall resprouting of some grass species, and beginning of fall weather. Winter or period 3 (16 November to February 15) corresponded to mid-winter conditions of frequent snowfall, relatively low temperatures, senescent forage, and mating. Late-winter or period 4 (February 16 to 31 March) corresponded to approximately the second trimester of gestation, and earliest green-up of some grasses. Spring green-up or period 5 (1 April to 31 May) corresponded to the third trimester of gestation, green-up of all forages, and eventually movement to lambing ranges.

For remote telemetry data a sample unit was defined as 24 hr of continuous data collection on

a radio-collared ewe. Due to migrations, deaths, and an irregular capture schedule, it was impossible to use a balanced factorial design that included all animals to test for differences among animals and years. Therefore, these differences were examined with separate t-tests or 1-way analysis of variance (ANOVA). The null hypothesis that no period differences existed in mean minutes engaged in a behavioral category within a 24 hr day was tested with multivariate analysis of variance (MANOVA). Also, mean minutes active, mean bout-length, and mean number of bouts within daylight, night, dusk, and dawn, were tested with separate MANOVA's with period as the main effect. Dusk and dawn were defined as 1 hr before and after morning and evening civil twilight. Civil twilight was defined by the U.S. Naval Observatory, Astronomical Applications Department as beginning or ending when the center of the sun was geometrically 6 degrees below the horizon. Separate univariate ANOVA's for each behavioral category, mean min active per day-part, bout-length, and number of bouts were conducted with period as the main effect. Means were separated with Duncan's multiple range test. A graphical analysis of the mean number of minutes active during each hour of the day was conducted separately for each period. Direct observation data was analyzed using a G-factor test of homogeneity (Sokal and Rohlf 1981, Ott 1993).

Distance moved each 24 hr was estimated by randomly choosing individual distance movements from the direct observation data. These distances were averaged and multiplied by the average number of movements per minute producing an estimate of meters moved per active minute. This rate was then multiplied by the number of active minutes in a 24 hr period obtained from Rustrak recordings. The null hypothesis that no differences existed between periods in mean distance moved/24 hr was tested by ANOVA, and means were separated using Duncan's multiple range tests.

A second method of estimating distance traveled/24 hr was used as a check. When possible, ewes were directly observed for an entire activity

bout. The average distance moved/bout was then multiplied times the number of bouts determined from Rustrak recordings. The estimates of distance moved during a 24 hr day obtained by the 2 methods were compared within periods using t-tests.

Moonlight's effect on the activity patterns of big-horn ewes was examined by regressing minutes active at night on the fraction of the moon illuminated obtained from tables supplied by the U.S. Naval Observatory. A linear regression was conducted for each period, and for the period July 14 to Oct. 11, 1994. This period was chosen because nights were known to be cloudless.

The effects of environmental variables on big-horn ewe behavior were assessed by developing a multiple regression model with minutes active each hour as the dependent variable and weather data serving as the independent variables. Four model-selection methods were used: forward selection, backward elimination, stepwise selection, and maximum  $R^2$  improvement as defined in the SAS/STAT Guide for Personal Computers (SAS Institute; Cary, NC 1987). Independent variables were examined for multicollinearity, and the dependent variable was examined for autocorrelation using the Durbin-Watson statistic. An additional regressor consisting of the dependent variable from the previous time step was added to the model to address autocorrelation (Myers 1990).

All statistical tests were conducted at the  $\alpha = 0.05$  level of significance, except the significance level for entry into the multiple regression model was set at  $\alpha = 0.15$ .

**RESULTS:** A total of 6,504 hours (271 sample units) of activity data on 9 ewes were collected by remote telemetry from 1994 to 1997. Ewes frequently moved behind rock outcrops or across ridges interrupting signal reception. Fragments of data less than 24 hr were not included in the analysis. System accuracy was estimated to be 84%. Behaviors where sheep held heads erect for relatively long periods, such as stand alert, moving, feeding on shrubs, or feeding uphill on steep

slopes were occasionally misinterpreted as inactive-bedded behavior.

No significant differences in behavior existed among years or animals, except during summer 1994. One adult ewe was more active than other radio-collared ewes, this was also apparent from direct observation. However, by fall 1994, her activity patterns were no longer distinct.

The amount of time bighorn ewes spent in different behaviors (active, inactive, bedded, and sleeping) during a 24 hr day differed among periods (MANOVA, Wilks' lambda  $P = 0.019$ ). Ewes were significantly less active and spent more time bedded and inactive during winter than during other periods (ANOVA,  $P = 0.001$ ). The amount of time ewes slept did not differ between periods (ANOVA,  $P = 0.334$ ) (Table 1).

Ewe activity varied between periods when the 24 hr day was divided into daylight, night, dusk, and dawn (MANOVA,  $P = 0.001$  Wilks' lambda). Ewes spent more time active in daylight hours during summer and spring green-up, than during winter (ANOVA,  $P = 0.001$ ). During dawn hours, ewes were most active during late summer-fall and late winter, and least active during winter and spring green-up (ANOVA,  $P = 0.0145$ ). The amount of time ewes were active at night did not differ significantly between periods (ANOVA,  $P = 0.052$ ), although ewes tended to be more active at night during late winter. At dusk, ewe activity did not differ between periods (ANOVA,  $P = 0.5870$ ) (Table 2).

Average bout length differed between periods (MANOVA, Wilks' lambda = 0.011). Night foraging bouts were longer in winter and late winter than during summer (ANOVA,  $P = 0.025$ ) (Table 3).

Average number of active bouts differed between periods (MANOVA, Wilks' lambda = 0.001). During a 24 hr day, the number of active bouts were significantly lower during winter (ANOVA,  $P = 0.014$ ). Ewes tended to have few night feeding bouts during summer and spring green-up, when

daylight was longest, and also during winter. However, during late winter ewes tended to increase the number of nocturnal feeding bouts (Table 4).

Ewe activity generally followed a bimodal pattern through a 24 hr day (Figures 1 - 5). However, during summer, ewes were more active throughout the day and the bimodal pattern, although present, was not as evident. During late summer-fall and winter, the first peak in activity occurred shortly after dawn, followed by a decline in activity at mid-day; then activity increased to a second peak before dusk. As day-length increased during late winter and spring green-up, ewes had several feeding bouts late in the day interspersed with bedding. During all periods, the majority of activity occurred during daylight hours. Generally, lowest levels of activity occurred immediately preceding the morning feeding bout, and following dusk activity peaks.

Within individual active bouts, frequencies of behaviors based on direct observation did not vary significantly among periods ( $G = 27.807$ , d. f. = 20). On average, ewes spent 53% of time feeding, 12% moving, 14% head-up and chewing, 17% at stand alert, 1% pawing, and 3% socializing. Ewes tended to spend more time moving and alert and less time feeding when lambs were present, and tended to spend a greater portion of an active bout feeding during winter. While inactive, ewes ruminated an average of 65% of the time during all periods.

Bighorn ewes covered an average of 4804, 4494, 3558, 4722, and 4548 m/24 hr day for periods 1,2,3,4, and 5, respectively; and traveled an average of 474 m/active bout. Ewes moved significantly less distance during winter (ANOVA,  $P = 0.001$ ,  $N = 60$ ).

During late summer-fall, winter, late winter, and spring green-up bighorn ewes were not significantly more active at night when a greater portion of the moon was visible. Ewes were apparently influenced by lunar phase during summer ( $P = 0.001$ ,  $R^2 = 0.497$ ) (Fig. 6).

Hourly meteorological station data was matched to 3,355 hours of activity data collected by remote telemetry. Environmental variables generally did not greatly influence the hourly activity patterns of resident bighorn ewes ( $R^2 = 0.1125$ ). Adding number of minutes active the previous hour as an additional independent variable (to address autocorrelation) increased  $R^2$  to 0.3584. Solar energy and average wind speed were positively correlated with minutes active per hour ( $r = 0.29$  and  $r = 0.27$ , respectively). Other environmental variables were not included in the model.

**DISCUSSION:** Reduced bighorn ewe activity during winter was consistent with the well documented seasonal cycle of northern ruminant energy metabolism (Silver et al. 1969, 1971; McEwan and Whitehead 1970; Thompson et al. 1973; Holter et al. 1975; McEwan 1975; Weiner 1977). Captive bighorns have demonstrated seasonal changes in metabolism, with resting metabolic rates (RMR) lowest in February and highest in May (Chappel and Hudson 1978, 1980). California bighorns (*O. c. californiana*) in British Columbia spent fewer daylight minutes feeding during winter than at other seasons (Eccles 1983). Declines in basal metabolism, activity, and body weight, plus voluntary restriction of food intake have been considered adaptations for dealing with winter's period of decreased temperatures, less than optimum forage conditions, and increased snow depth (Parker et al. 1993). Risenhoover (1986) argued that reduced forage quality and patterns of forage distribution, rather than snow conditions or food scarcity, mainly cause ungulates to reduce activity levels. Seasonal changes in ewe activity paralleled trends in the crude protein and energy content of important forage species (Wagner 1999). Winter forage, higher in fiber and less digestible, may have slowed passage rate and required more rumination time to reduce particle size sufficiently to permit passage into the omasum (Van Soest 1982, Robbins 1993). Total amount of time ewes spent bedded increased during winter, consequently, absolute amount of time spent ruminating increased. Moose in Alaska ruminated an average of 67% of time spent bedded in winter (Risenhoover 1986), compared to 65% for ewes in our study. In

winter, ewes evidently maximized the amount of nutrition obtained while active and minimized the proportion of time spent in behaviors that did not acquire food. Movements not associated with acquiring food were uncommon for moose during winter (Risenhoover 1986).

With the onset of spring and improved forage quality, ewes increased activity levels and distance traveled per day reflecting an increase in metabolic rate and nutritional requirements for gestation and lactation. Ewes possibly moved greater distances while searching for the most nutritious forage (Warrick 1985). Predator avoidance may have also contributed to the increased distance traveled each day. Similar increases in activity and metabolic rate have been observed in desert bighorns (Alderman et al. 1989), red deer (Georgii 1981), moose (Risenhoover 1986, Regelin et al. 1985, Van Ballenberghe and Miquelle 1990), and white-tailed deer (Silver et al. 1969, 1971; Thompson et al. 1973; Holter et al. 1975). Bighorn sheep in Montana were active 773 min/24 hr day during summer (Belovsky and Slade 1986) compared to 677 min/24 hr day in our study. In general, ewes did not increase bout length during the day, but increased forage intake by increasing the number of daily feeding bouts. With improved forage digestibility and consequent increased passage rates, ewes may have maintained gut fill by feeding more frequently. Increased foraging during summer and fall may be necessary to prepare northern ruminants for the rigors of winter, making foraging an important activity, even though food may be highly abundant (Van Ballenberghe and Miquelle 1990). In British Columbia, captive bighorns averaged 5 diurnal activity peaks (Eccles 1978), where studies of wild bighorns averaged 2 to 3 daily activity peaks in summer (Davis 1938, Van Dyke 1978, Sayre and Seabloom 1994). Geist (1971) and Hoefs (1974) reported Stone's sheep (*Ovis dalli stonei*) and Dall's sheep (*O. d. dalli*), respectively, averaged 4 activity peaks during summer with fewer activity peaks during mid-winter.

Dividing the 24 hr day into daylight, night, dusk, and dawn showed that following parturition, ewes

tended to be less active at night compared to winter or late winter. Ewes may have reduced nocturnal activity to protect lambs (Alderman et al. 1989). The small amount of nocturnal activity observed in summer could be attributed to the regular repositioning of ewes between beds (Sayre and Seabloom 1994, Woolf 1970). The duration of nocturnal activity bouts during winter and late winter suggested actual feeding bouts occurred. Ruminants may need to feed nocturnally during seasons with shortened daylight, because periodic food intake is necessary to keep the digestive system operating (Balch 1955, Welch 1969). Red deer (Georgii 1981) and moose (Risenhoover 1986) were more active at night during late winter and early spring compared to summer. Similar to ewes in Big Creek, bighorn ewes in North Dakota were more active at dusk than dawn (Sayre and Seabloom 1994).

The reasons lunar phase should influence activity during summer and not other periods were unclear. Small sample sizes during this period may account for an apparent relationship. Elk nocturnal activity patterns in Utah were not affected by lunar phases (Collins et al. 1978).

Sunlight, represented by solar energy in the model, and average wind speed were the 2 environmental variables that were related to bighorn ewe activity patterns. Bighorn sheep rely primarily on vision to detect predators (Geist 1971), and may have minimized the amount of activity during darkness to reduce vulnerability to predators. Graphical analysis of hourly activity averages also showed the majority of activity occurred during daylight. Direct observations of bighorns on windy days indicated a heightened alertness or nervousness. Elk in Utah were more nervous on windy days (Collins et al. 1978), however, Bowyer (1981) reported a lack of correlation between elk activity and wind speed, temperature, or humidity in California.

Other variables, such as temperature, humidity, atmospheric pressure, precipitation, and wind direction, apparently did not greatly influence bighorn ewe activity. Previous studies have re-

ported desert bighorns reduced movement during periods of high temperature (Alderman et al. 1989, Simmons 1969, Welch 1969, McCutchen 1984, and Krausman et al. 1985). Rocky mountain bighorn ewes in North Dakota did not alter activity patterns significantly at temperatures >23 C (Sayre and Seabloom 1994). However, Stemp (1983) demonstrated using heart-rate monitors that bighorn sheep were stressed physiologically by temperatures above or below the seasonal thermoneutral zone. Bighorn ewes in Big Creek responded to high temperatures by seeking shade, similar to ewes in North Dakota (Sayre and Seabloom 1994). The physiological stress of high or low temperatures as indicated by increased heart-rates, panting, shade- and shelter-seeking, and postural adjustments may not be reflected in activity patterns recorded by changes in head position.

The form of precipitation may influence bighorn ewe activity more than the absolute amount. Following deep snowfall events bighorns remained inactive for extended periods of time in British Columbia (Eccles 1978). Snowfall may reduce the availability of certain forages, and even small amounts may negatively affect foraging efficiency and diet quality (Goodson et al. 1991), thus slowing passage rates and altering activity patterns.

Rocky Mountain bighorns may adjust their daily feeding and ruminating cycles to optimally fit seasonal forage conditions. Possibly, the physiological state and reproductive condition of bighorn ewes, as well as social interactions, may produce greater influences on activity patterns, and obscure the effects of environmental variables on an hourly scale.

**MANAGEMENT IMPLICATIONS:** Activity patterns of bighorn ewes can be interpreted on annual and daily temporal scales. Annually ewes adapt to the stress of winter by reducing activity levels. Consequently, human disturbances that force ewes to increase their activity levels during midwinter may increase energy requirements at a time when ewes may be operating at a negative energy balance. Likewise, following parturition

nursing ewes are faced with the energetic demands of lactation, possibly before they have completely recovered from winter. They appear to search out the most nutritious grasses and forbs. Human disturbance should also be limited at this time of year to avoid stressing lactating ewes and preventing access to important nutritional sources.

Ewes were the least active shortly before daylight, and after the morning and evening feeding bouts. Since ewes typically bed in or near escape terrain, human disturbances may have less impact during these hours. Mid-day, when ewes bed following the morning feeding bout, would be the most appropriate time to allow human disturbance. Aerial censuses scheduled opposite bedded periods may observe ewes while they are usually foraging in more open areas.

If bighorns adopt feeding-ruminating cycles that optimally fit seasonal forage conditions, then disturbances may disrupt these patterns. Bighorn ewes must have evolved to deal with occasional disruptions. However, if frequent disturbances prevent ewes from following adaptive feeding-ruminating cycles, then ewes may decline in body condition over time. Repeated disturbances may lower survival and fecundity, even though the tangible effects may be delayed to future seasons or years. Managers should allow bighorns a chance to recover from periods of repeated disturbance.

**ACKNOWLEDGMENTS:** Funding for this project was provided by Wildlife Forever, Foundation for North American Wild Sheep, Pope and Young Club, The Charles DeVlieg Foundation, Idaho Dept. of Fish and Game, and Univ. of Idaho McIntire-Stennis Grant 970. We thank Aaron Foster, Scott Schrieber, Gary McCalister, and Teri Wagner for assistance in data collection and interpretation.

#### LITERATURE CITED

Alderman, J.A., P.R. Krausman, B.D. Leopold. 1989. Diel activity of female desert bighorn sheep in western Arizona. *J. Wildl. Manage.* 53:264-271.

Balch, C.C. 1955. Sleep in ruminants. *Nature* 175:940-941.

Belovsky, G.E., and J.B. Slade. 1986. Time budgets of grassland herbivores: body size similarities. *Oecologia* 70:53-62.

Bier, P., and D.R. McCullough. 1988. Motion-sensitive radio collars for estimating white-tailed deer activity. *J. Wildl. Manage.* 52:1-13.

Blood, D.A. 1963. Some aspects of behavior of a bighorn herd. *Can. Field-Natur.* 77(2):77-94.

Bowyer, R.T. 1981. Activity, movement, and distribution of Roosevelt elk during the rut. *J. Mamm.* 62(3):574-582.

Chappel, R.W., and R.J. Hudson. 1978. Winter bioenergetics of Rocky Mountain bighorn sheep. *Can. J. Zool.* 56:2388-2393.

\_\_\_\_\_, and \_\_\_\_\_. 1980. Prediction of energy expenditures by Rocky Mountain bighorn sheep. *Can. J. Zool.* 58:1908-1912.

Clair, J.J. 1973. Correlation of ungulate food habits and winter range conditions in the Idaho Primitive Area. M.S. Thesis. Univ. of Idaho, Moscow, ID. 85 pp.

Collins, W.B., P.J. Urness, and D.D. Austin. 1978. Elk diets and activities on different lodgepole pine habitat segments. *J. Wildl. Manage.* 42:799-810.

Davis, W.B. 1938. Summer activity of mountain sheep in Mt. Washburn, Yellowstone National Park. *J. Mammal.* 19:88-94.

Eccles, T.R. 1978. Activity patterns of captive California bighorn sheep (*Ovis canadensis californiana*) at Penticon, B.C. *Bienn. Symp. North. Wild Sheep and Goat Counc.* 1:274-292.



- \_\_\_\_\_. 1983. Aspects of social organization and diurnal activity patterns of California bighorn sheep. Fish and Wildlife Report ISBN 0701-581X, no.R-8. British Columbia Ministry of Environment. Victoria, B.C. 71 pp.
- Geist, V. 1971. Mountain sheep: A study in behavior and evolution. The Univ. of Chicago Press, Chicago, Il. 383 pp.
- Georgii, B. 1981. Activity patterns of female red deer (*Cervus elaphus L.*) in the Alps. *Oecologia* 49:127-136.
- Gillingham, M.P., and F.L. Bunnell. 1985. Reliability of motion-sensitive collars for estimating activity for black-tailed deer. *J. Wildl. Manage.* 49:951-958.
- Goodson, N.J., D.R. Stevens, and J.A. Bailey. 1991. Effects of snow on foraging ecology and nutrition of bighorn sheep. *J. Wildl. Manage.* 55:214-222.
- Hoefs, M. 1974. Food selection by Dall's sheep (*Ovis dalli dalli* Nelson) IUCN Pub. 24 2:759-786.
- Holter, J.B., W.E. Urban, H.H. Hayes, H. Silver, and H.R. Skutt. 1975. Ambient temperature effects of physiological traits of white-tailed deer. *Can. J. Zool.* 53:679-685.
- Kie, J.G., C.J. Evans, E.R. Loft, and J.W. Menke. 1991. Foraging behavior by mule deer: the influence of cattle grazing. *J. Wildl. Manage.* 55:665-674.
- Krausman, P.R., S. Torres, L.L. Ordway, J.J. Hervert, and M. Brown. 1985. Diel activity of ewes in the Little Harquahala Mountains, Arizona. *Desert Bighorn Counc. Trans.* 29:24-26.
- MacCracken, J.G. 1992. Ecology of moose in the Copper River Delta, Alaska. Ph.D. Diss., Univ. of Idaho, Moscow, ID. 386 pp.
- McCutchen, H.E. 1984. Summer activity patterns of free-ranging desert bighorns, Zion National Park, Utah. *Desert Bighorn Counc. Trans.* 28:9-11.
- McEwan, E.H., and P.E. Whitehead. 1970. Seasonal changes in the energy and nitrogen intake in reindeer and caribou. *Can. J. Zool.* 48:905-913.
- \_\_\_\_\_. 1975. The adaptive significance of the growth patterns in cervid compared with other ungulate species. *Zool. Zh.* 54:1221-1232.
- Mills, H.B. 1937. A preliminary study of the bighorn of Yellowstone National Park. *J. Mammal.* 18(2):205-212.
- Miquelle, D.G. 1990. Behavioral ecology of moose in Denali National Park and Preserve, Alaska. Ph.D. Diss., Univ. of Idaho, Moscow, ID. 141 pp.
- \_\_\_\_\_, J.M. Peek, and V. Van Ballenberghe 1992. Sexual segregation in Alaskan moose. *Wildl. Monogr.* 122:1-57.
- Myers, R.H. 1990. Classical and modern regression with applications. Second ed. PWS-KENT Publ. Co. Boston, MA.
- Ott, R.L. 1993. An introduction to statistical methods and data analysis. Fourth ed. Duxbury Press, Belmont, CA. 1051 pp.
- Parker, K.L., M.P. Gillingham, T.A. Hanley, and C.T. Robbins. 1993. Seasonal patterns in body mass, body composition, and water transfer rates of free-ranging and captive black-tailed deer (*Odocoileus hemionus sitkensis*) in Alaska. *Can. J. Zool.* 71:1397-1404.
- Regelin, W.L., C.C. Schwartz, and A.W. Franzmann. 1985. Seasonal energy metabolism of adult moose. *J. Wildl. Manage.* 49:388-393.
- Robbins, C.T. 1993. Wildlife feeding and nutrition. Second ed. Academic Press, New York, NY. 352 pp.

- Risenhoover, K.L. 1986. Winter-activity patterns of moose in interior Alaska. *J. Wildl. Manage.* 50:727-734.
- Sayre, R.W., and R.W. Seabloom. 1994. Summer activity patterns of bighorn ewes in the northern Great Plains. *Bien. Symp. North. Wild Sheep and Goat Counc.* 9:104-109.
- Silver, H.H., J.B. Holter, N.F. Colovos, and H.H. Hayes. 1969. Fasting metabolism of white-tailed deer. *J. Wildl. Manage.* 33:490-498.
- \_\_\_\_\_. 1971. Effect of falling temperature on heat production in fasting white-tailed deer. *J. Wildl. Manage.* 35:37-46.
- Simmons, N.M. 1969. Heat stress and bighorn behavior in the Cabeza Prieta Game Range, Arizona Desert Bighorn Counc. *Trans.* 13:55-63.
- Smith, D.R. 1954. The bighorn sheep in Idaho, its status, life history and management. *Idaho Fish and Game Dept. Wildl. Bull.* 1. 154 pp.
- Sokal, R.R., and F.J. Rohlf. 1981. *Biometry*. Second ed. W.H. Freeman and Co., New York, NY. 859 pp.
- Stemp, R. 1983. Heart-rate responses of bighorn sheep to environmental factors and harassment. M.S. Thesis. Univ. of Calgary, AB. 313 pp.
- Thompson, G.B., J.B. Holter, H.H. Hayes, H. Silver, and W.E. Urban. 1973. Nutrition of white-tailed deer I. Energy requirements of fawns. *J. Wildl. Manage.* 37:301-311.
- Van Ballenberghe, V., and D.G. Miquelle. 1990. Activity of moose during summer in interior Alaska. *J. Wildl. Manage.* 54:391-396.
- Van Dyke, W.A. 1978. Population characteristics and habitat utilization of bighorn sheep, Steens Mountain, Oregon. M.S. Thesis. Oregon State University. Corvallis, OR. 87 pp.
- Van Soest, P.J. 1982. *Nutritional ecology of the ruminant*. O&B Books Inc., Corvallis, OR. 374 pp.
- Wagner, G.D. 1999 (In press). Diet selection, activity patterns, and bioenergetics of bighorn ewes in central Idaho. Ph.D. Thesis, Univ. of Idaho, Moscow, ID.
- Warrick, G.D. 1985. Mountain sheep foraging behavior. M.S. Thesis, Univ. of Arizona, Tucson, AZ. 28 pp.
- Weiner, J. 1977. Energy metabolism of the roe deer. *Acta. Theriol.* 22:3-24.
- Welch, R.D. 1969. Behavioral patterns of desert bighorn sheep in south-central New Mexico. *Desert Bighorn Counc. Trans.* 13:114-129.
- Woolf, A., T. O'Shea, and D.L. Gilbert. 1970. Movements and behavior of bighorn sheep on summer ranges in Yellowstone Park. *J. Wildl. Manage.* 34:446-450.

Table 1 Average minutes/24 hour day bighorn ewes engaged in active, inactive, bedded, and sleeping behaviors from 1994-1997 at Big Creek, Idaho.

Period <sup>a</sup>	Active	SE	Inactive	SE	Bedded	SE	Sleeping	SE
1	677.50A <sup>b</sup>	41.82	762.50A	41.82	732.65A	42.43	23.45A	3.83
2	633.75A	38.06	806.25A	38.06	790.40A	37.01	21.45A	7.22
3	501.75B	25.13	938.25B	25.13	918.10B	27.42	15.10A	4.94
4	665.90A	25.07	774.10A	25.07	744.00A	22.96	26.00A	6.81
5	641.45A	26.34	798.55A	26.34	733.75A	26.65	17.35A	4.41

<sup>a</sup>Period 1 = 1 June to 15 Aug., period 2 = 16 Aug. to 15 Nov., period 3 = 16 Nov. to 15 Feb., period 4 = 16 Feb. to 31 March, period 5 = April 1 to May 31.

<sup>b</sup>Means with the same letters are not different (ANOVA,  $\alpha = 0.05$ ).

Table 2 Average minutes bighorn ewes were active during daylight, night, dusk, and dawn at Big Creek, Idaho 1994-1997.

Period <sup>a</sup>	Daylight	SE	Night	SE	Dusk	SE	Dawn	SE
1	528.55A <sup>b</sup>	27.89	47.70A	10.44	61.85A	9.54	39.40A	7.78
2	416.80B	31.57	85.60A	19.57	60.20A	8.90	54.95AB	7.18
3	333.55C	15.29	93.30A	17.63	64.75A	8.87	22.25AC	5.24
4	434.15B	24.36	121.95A	23.74	60.00A	9.26	49.60ABD	9.38
5	481.55AB	23.23	54.45A	11.08	78.05A	8.20	29.70ACD	7.22

<sup>a</sup>Period 1 = 1 June to 15 Aug., period 2 = 16 Aug. to 15 Nov., period 3 = 16 Nov. to 15 Feb., period 4 = 16 Feb. to 31 March, period 5 = April 1 to May 31.

<sup>b</sup>Means with the same letters are not different (ANOVA,  $\alpha = 0.05$ ).

Table 3 Average activity bout length (min) of bighorn ewes from Big Creek, Idaho 1994-1997.

Period <sup>a</sup>	Full Day	SE	Daylight	SE	Night	SE	Dusk	SE	Dawn	SE
1	87.82A <sup>b</sup>	10.91	94.99A	9.05	15.49A	3.99	58.67A	9.84	35.93A	7.83
2	77.09A	7.41	101.09A	12.53	23.65AC	6.23	52.96A	9.42	52.30A	7.31
3	91.13A	8.63	93.91A	9.87	52.22BC	11.82	61.68A	8.94	22.60A	5.16
4	91.60A	11.38	129.12A	9.89	32.48BC	4.78	47.14A	8.81	42.81A	9.18
5	112.49A	14.01	108.27A	11.55	26.12AC	5.34	71.58A	8.49	26.78A	6.40

<sup>a</sup>Period 1 = 1 June to 15 Aug., period 2 = 16 Aug. to 15 Nov., period 3 = 16 Nov. to 15 Feb., period 4 = 16 Feb. to 31 March, period 5 = April 1 to May 31.

<sup>b</sup>Means with the same letters are not different (ANOVA,  $\alpha = 0.05$ ).

Table 4 Average number of activity bouts for bighorn ewes in Big Creek, Idaho 1994-1997.

Period <sup>a</sup>	Full day	SE	Daylight	SE	Night	SE	Dusk	SE	Dawn	SE
1	9.80A <sup>b</sup>	1.11	6.30A	0.47	2.75ABC	0.58	0.95A	0.15	1.00A	0.16
2	9.00A	1.11	4.65B	0.31	3.35ABC	0.49	1.30A	0.16	1.00A	0.10
3	6.20B	0.52	4.15B	0.34	1.75AC	0.25	0.90A	0.12	0.65A	0.11
4	9.20A	1.00	4.35B	0.41	3.65ABC	0.46	1.30A	0.21	1.30A	0.18
5	7.20A	0.74	5.15A	0.40	2.20AB	0.38	1.10A	0.10	0.75A	0.14

<sup>a</sup>Period 1 = 1 June to 15 Aug., period 2 = 16 Aug. to 15 Nov., period 3 = 16 Nov. to 15 Feb., period 4 = 16 Feb. to 31 March, period 5 = April 1 to May 31.

<sup>b</sup>Means with the same letters are not different (ANOVA,  $\alpha = 0.05$ ).

Figure 1: Period 1 (June 1- Aug. 15) average minutes active each hour for bighorn ewes from Big Creek, Idaho (1994-1997)

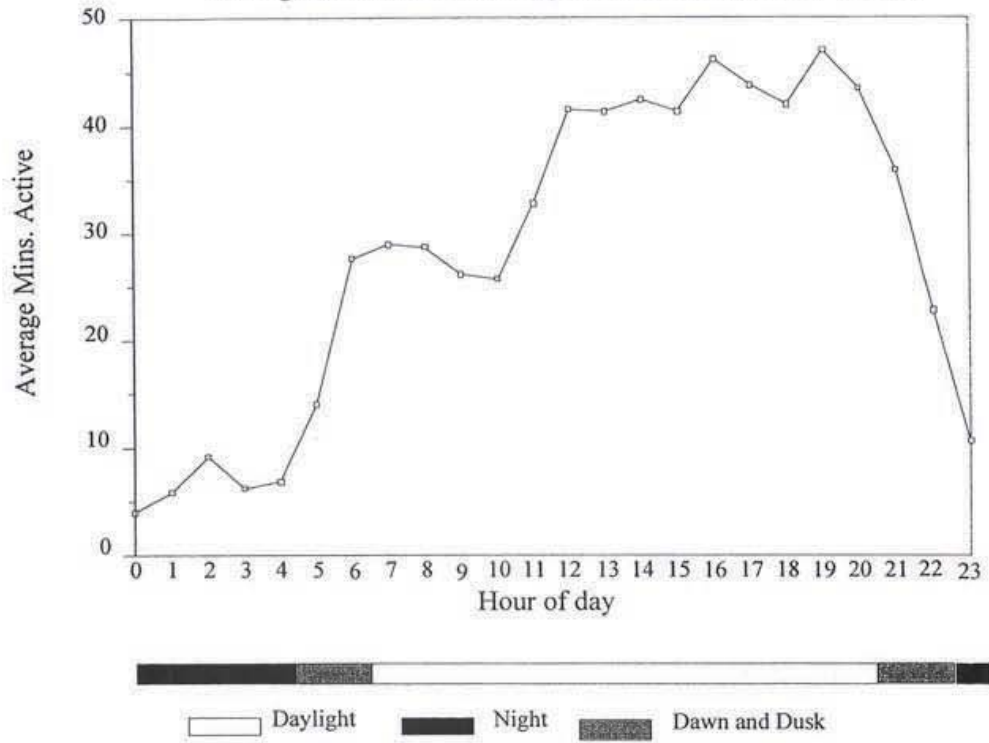


Figure 2: Period 2 (Aug. 16 - Nov. 30) average minutes active each hour for bighorn ewes from Big Creek, Idaho (1994-1997)

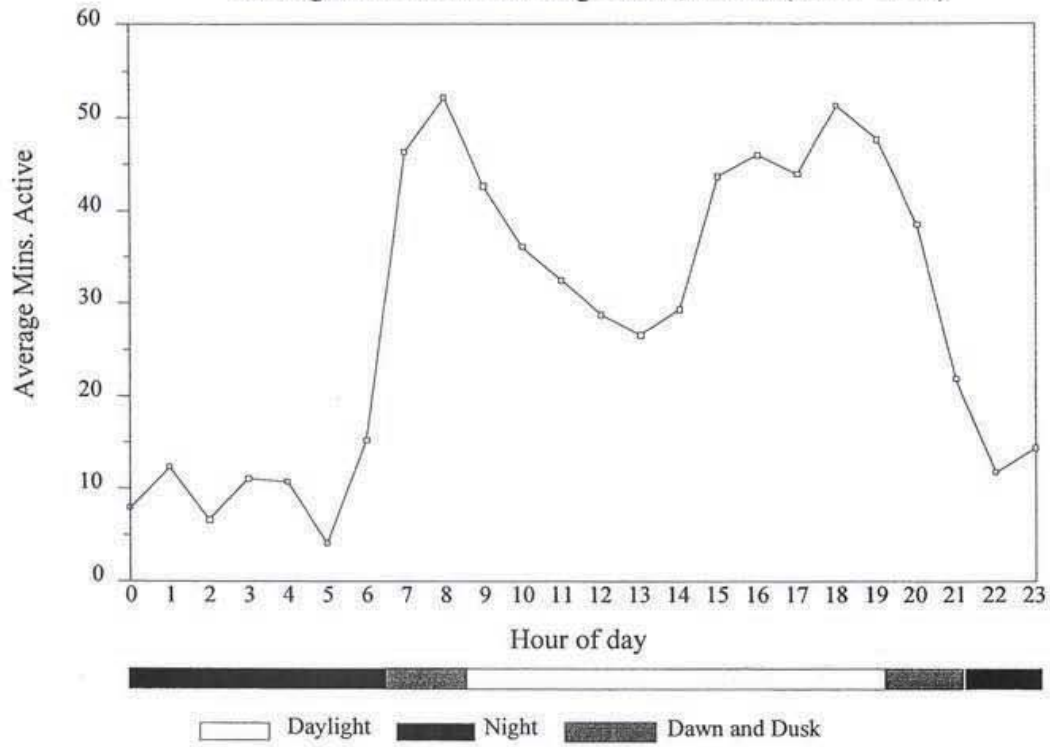


Figure 3: Period 3 (Dec. 1 - Feb. 15) average minutes active each hour for bighorn ewes from Big Creek, Idaho (1994-1997)

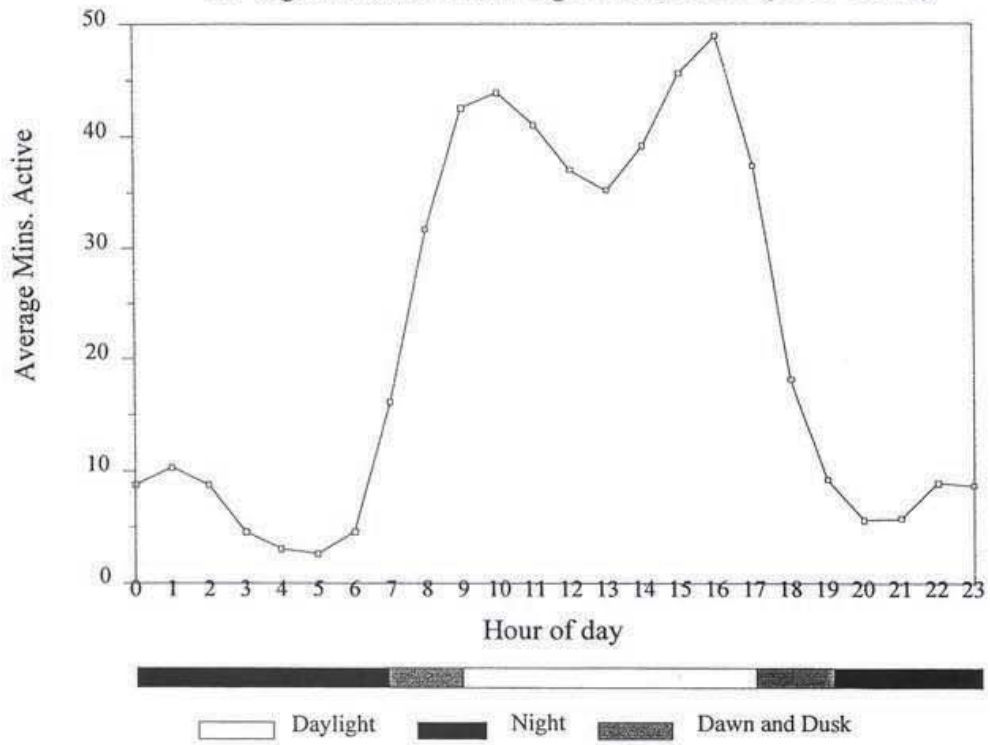


Figure 4: Period 4 (Feb. 16 - March 31) average minutes active each hour for bighorn ewes from Big Creek, Idaho (1994-1997)

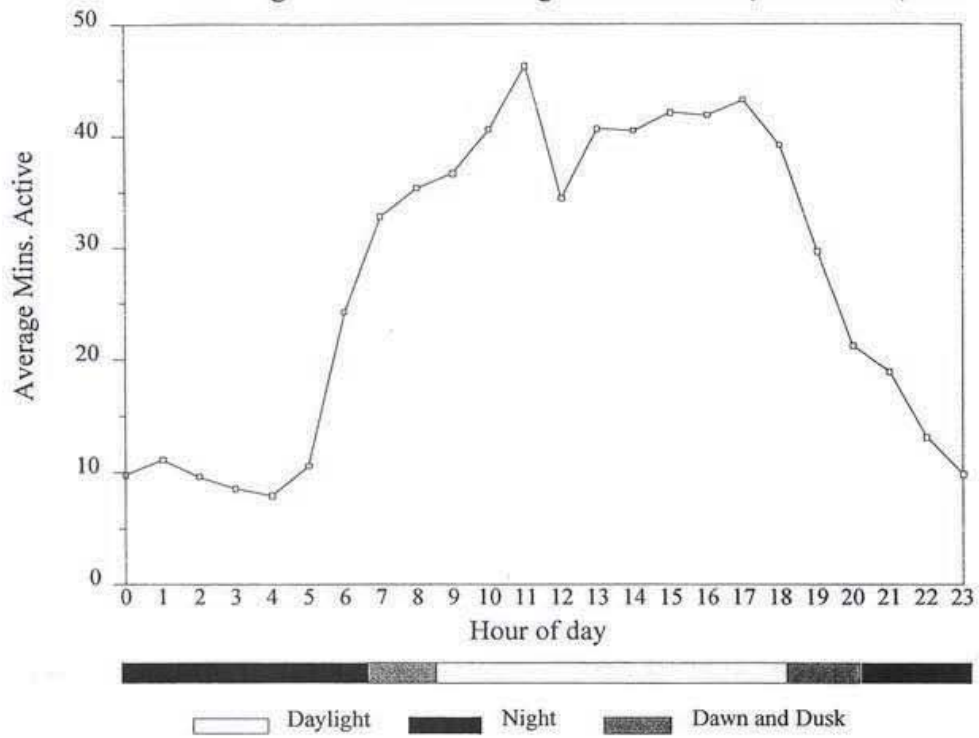




Figure 5: Period 5 (April 1 - May 31) average minutes active each hour for bighorn ewes from Big Creek, Idaho (1994-1997)

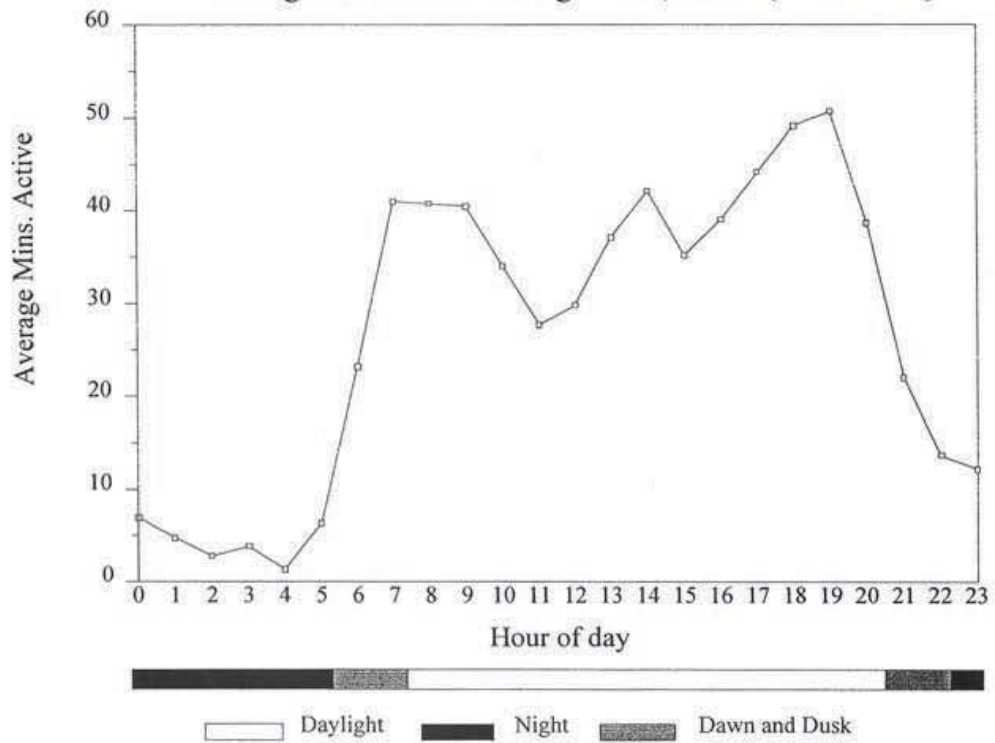
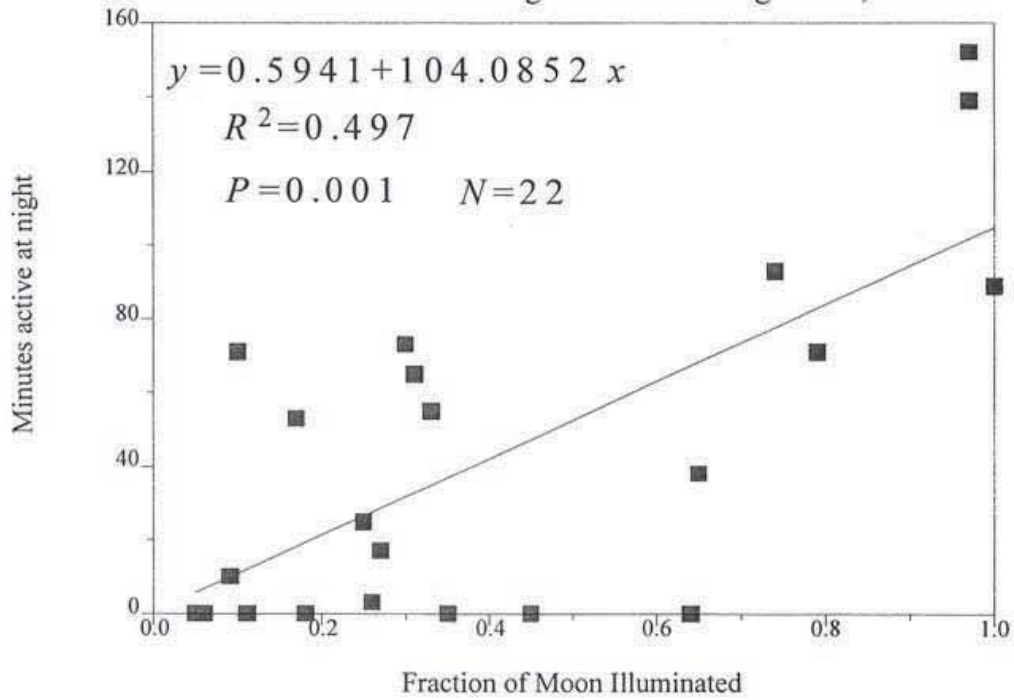


Figure 6: Period 1 (June 1 to Aug. 15) minutes active at night predicted by fraction of Moon illuminated for bighorn ewes in Big Creek, Idaho 1994-97



---

## QUESTIONS, ANSWERS AND COMMENTS - GUY WAGNER PRESENTATION

---

**DALE TOWEILL, IDAHO:** I noticed in your activity diagram you showed increased pawing behavior in late summer and early fall. Would that selection be for thermal relief bedding sites with the ewes pawing down to wet soil or do they select for shade?

**GUY WAGNER:** They always kind of paw out a place to bed. But most of the diagramed pawing behavior was pawing for tubers and roots. At that time of year, certain favorite forages would cure out, including the thistles. The leaves would cure out and the ewes would dig for the roots, also biscuitroot, *Lomatium dissectum*. They would dig whenever they could for biscuitroot, especially in mid-winter if the ground wasn't frozen too hard. Ewes would get on the gravel beds where the talus wasn't quite so large in diameter and spend a lot of time pawing up the tubers.

**TOWEILL:** The pawing should be attributed to the feeding behavior rather than the bedding behavior?

**WAGNER:** Correct.