

# Grizzly bear feeding activity at alpine army cutworm moth aggregation sites in northwest Montana

Don White, Jr., Katherine C. Kendall, and Harold D. Picton

**Abstract:** Grizzly bears (*Ursus arctos horribilis*) consume army cutworm moths (*Euxoa auxiliaris*) from late June through mid-September at alpine moth aggregation sites in Glacier National Park, Montana. To better understand the importance of army cutworm moths to grizzly bears, we determined the sex and age classes and minimum numbers of grizzly bears foraging at known alpine moth aggregation sites, and documented the timing and use patterns of grizzly bears foraging in these areas. A minimum of 36 grizzly bears were observed 106 times feeding at 6 of 9 known moth aggregation sites from late June through mid-September in 1992–1995; no bears were observed on moth sites in 1993. Bears fed on moth aggregations disproportionately more at elevations >2561 m, on slopes between 31° and 45°, and on southwest-facing aspects. Lone adult grizzly bears appeared to be underrepresented and subadults overrepresented at moth sites. Moths are highly digestible; all parts are digested except for the exoskeleton. We propose that army cutworm moths are an important, high-quality, preferred summer and early-fall food for grizzly bears in Glacier National Park. We do not present any data that demonstrate an increase in the importance of moths when other foods fail.

**Résumé :** Les Grizzlis (*Ursus arctos horribilis*) consomment des Légionnaires grises (*Euxoa auxiliaris*) de la fin de juin au milieu de septembre aux sites de rassemblement de ces insectes dans la zone alpine du parc national Glacier, Montana. Pour mieux comprendre l'importance de cet insecte dans l'alimentation du Grizzli, nous avons déterminé le sexe, l'âge et les nombres minimaux d'ours présents à des sites connus de rassemblement de légionnaires et avons noté le moment de leur présence et leur activité à ces sites. Un minimum de 36 ours ont été observés 106 fois en train de se nourrir à 6 des 9 sites connus entre la fin de juin et la mi-septembre, de 1992 à 1995. Aucun ours n'a été vu aux sites de rassemblement des légionnaires en 1993. Les ours se nourrissaient beaucoup plus aux altitudes >2561 m, sur les pentes de 31–45°, et sur les versants sud-ouest. Les ours adultes solitaires étaient sous-représentés et les sub-adultes étaient sur-représentés aux sites des légionnaires. Les papillons sont très digestibles et toutes leurs structures, à l'exception de l'exosquelette, sont digérées. La Légionnaire grise semble constituer un élément important, de haute qualité, du régime alimentaire du Grizzli dans le parc national Glacier, et il est l'aliment préféré des ours en été et au début de l'automne. Nous ne présentons aucune donnée ou discussion propres à démontrer l'importance accrue des légionnaires en l'absence d'autre nourriture.

[Traduit par la Rédaction]

## Introduction

Grizzly bears (*Ursus arctos horribilis*) feeding on insect aggregations excavated from alpine talus slopes have been documented in several areas in the northern Rocky Mountains: the Mission Mountains (Chapman 1954; Chapman et al. 1955; Servheen 1983; Klaver et al. 1986), Scapegoat Wilderness (Sumner and Craighead 1973; Craighead et al. 1982), and mountains of the Rocky Mountain East Front (Aune and Kasworm 1989) in Montana, and the Absaroka Mountains in Wyoming (Mattson et al. 1991; French et al. 1994; O'Brien and Lindzey 1994). Grizzly bears have been observed to consume both army cutworm moths (*Euxoa auxiliaris*) (Lepidoptera:

Noctuidae) and ladybird beetles (*Coccinella* spp. and *Hippodamia* spp.) (Coleoptera: Coccinellidae) in the Mission Mountains and army cutworm moths in the Scapegoat Wilderness, Rocky Mountain East Front, and Absaroka Mountains.

From 1989 to 1991, 5 radio-tracked grizzly bears spent several weeks each year feeding on army cutworm moths at 2100–2800 m elevation on mountains along the east side of Glacier National Park (GNP), located in northwestern Montana adjacent to British Columbia and Alberta. These bears initiated feeding on moths as early as the third week of June and continued until mid to late August or early September (D. Carney, U.S. Fish and Wildlife Service, Browning, Montana, personal observation). In this paper, we summarize data concerning grizzly bear use of moth aggregation sites in alpine areas of GNP.

## Life history of the army cutworm moth

Army cutworm moths are holometabolous. They lay eggs in the soil of the Great Plains in autumn and develop to the first or second larval instar before hibernation (Johnson 1905; Cooley 1916; Strickland 1916; Burton et al. 1980; Kendall 1981). In spring, the larvae begin feeding on a variety of plants such as alfalfa and small grains (Burton et al. 1980; Morrill 1991). After a total of 6 or 7 instars from egg to last molt,

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pupation occurs in underground cells (Snow 1925; Seamans 1927; Burton et al. 1980). In late May or early June the newly emerged adult moths enter a migratory phase and fly west into the Rocky Mountains, presumably to avoid the high temperatures of summer at lower elevations (Pepper 1932; Walkden 1950; Chapman et al. 1955; Pruess 1967; Hardwick and Lefkovitch 1971; Burton et al. 1980). Army cutworm moths inhabit the interstices of alpine talus slopes diurnally throughout the summer. It is from these sites that they are excavated and consumed by grizzly bears.

Army cutworm moths do not become reproductively active until they migrate back to the Great Plains in late August or early September. On the Plains the females enter a settling phase and oviposit 1000–3000 eggs per individual into the soil (Walkden 1950; Burton et al. 1980). After oviposition the adult moths die (Cooley 1916; Seamans 1927; Burton et al. 1980; Kendall et al. 1981).

## Study area

This study was conducted in GNP, which supports both grizzly bear and black bear (*Ursus americanus*) populations, with an abundance of naturally occurring bear foods. Approximately one-third of GNP's 4100-km<sup>2</sup> area occurs above timberline. Much of the remainder of the park is forested, with scattered meadows. Relief is precipitous. Deep glaciated valleys and basins divide large, rugged mountain massifs. Many valleys are 1800 m below their surrounding summits (Carrara and McGimsey 1981). Elevations in the park range from 950 m at the Middle Fork–North Fork Flathead River confluence to 3190 m atop Mount Cleveland (Finklin 1986).

The mountains of GNP presumably originated with the uplift and folding of sedimentary rocks of the Precambrian Belt Supergroup during the late Mesozoic. These strata are mostly reddish brown and greenish gray argillites with some quartzites (Carrara and McGimsey 1981). Glaciers shaped the terrain to its present appearance during the Pleistocene (Alden 1953; Dyson 1966; Alt and Hyndman 1991).

The climate is Continental with Pacific Maritime modifications, particularly on the west side of the park (Dightman 1967; Carrara and McGimsey 1981). The alpine climate is characterized by frequent strong (>66 km/h) winds, typically westerly in winter (December–February) and southwesterly in summer (July–August) (Finklin 1986). Precipitation generally increases with elevation, but decreases rapidly with horizontal distance east of the Continental Divide (Finklin 1986). Mean July temperatures range from 15 to 17°C in the lower valleys (Finklin 1986). Summer afternoon temperatures usually decrease with increasing elevation, at an average lapse rate of 7.5–8°C per 1000 m (Finklin 1986).

## Methods

### Moth site characteristics

We visited 7 alpine moth aggregation sites in GNP before, during, and after seasonal bear use, which occurred from late June to mid-September in 1992–1995. Data collected at moth aggregation sites included measurements and descriptions of site characteristics (e.g., elevation, slope, aspect) and bear sign (e.g., dig dimensions and dig-site features, bed dimensions and locations).

To quantify the thermal environment of a talus slope, we placed automatic temperature loggers (HOBO TEMP, Onset Computer Corp., Pocasset, Mass.), programmed to measure temperature every 30 min for 36 days, at the surface and at three depths, 10, 20, and 30 cm, within a 2300-m southwest-facing talus slope. The thermometers were placed on 3 August 1995 and removed on 10 September 1995.

### Bear-observation techniques

We observed bear foraging activity at alpine moth aggregation sites using variable-power spotting scopes and telescopes at distances from 250 m to 2 km. Moth aggregation sites were chosen for observability and accessibility, intensity of bear use, minimal bear disturbance by researchers, and researcher safety. Bears were identified to species and sex and age class using established guidelines for field identification of bears (Egbert and Stokes 1976). Subadults were distinguished by size and relative body proportions.

Repeated observations of the same bears on a talus slope allowed us to identify many bears individually with a high degree of confidence. We used the following as distinguishing factors: pelage color and shedding patterns, size, conformation, deformities, sex, age, family grouping, and behavior traits. The locations of each bear observed foraging on moths were recorded on U.S. Geological Survey topographic maps using Universal Transverse Mercator (UTM) coordinates.

### Bear activity budgets

We calculated activity budgets during moth feeding episodes using behavior scans during direct observations and by reviewing 16 mm film records. Grizzly bear behavior was recorded at 10-s intervals for 15 min of each hour during which bears were observed feeding on moths (Altmann 1974). Behaviors were classified as follows: foraging on moths, foraging on vegetation, moving, sleeping, loafing–awake, nursing, and defense (i.e., head down and swaying back and forth, ears laid back on the sides of the head, charges, etc.). Other data collected included the number of bears present, temporal use patterns, and behavior during intraspecific interactions.

### Scat analysis

Bear feces (scats) were collected during visits to moth aggregation sites and were analyzed to identify contents and determine excreted and ingested volumes of items consumed. The ingested volume was estimated by correcting for differential digestibility of items (Hewitt 1989).

### Statistical analysis

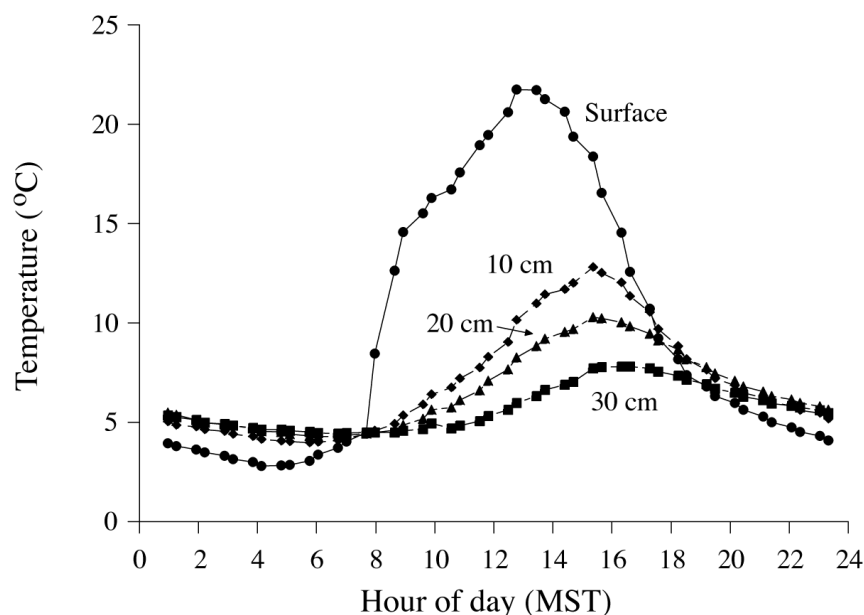
We used the log-likelihood ratio ( $G$ ) to test goodness of fit between observed and expected frequencies (Zar 1984) of bear sightings among bear sex and age classes and elevation, aspect, and slope classes. When a significant difference in overall frequency distributions was found, Bonferroni confidence intervals were used to determine which classes were responsible for the difference (Byers et al. 1984). The expected distribution of sightings among grizzly bear classes was derived from bear-sighting reports by GNP employees, accumulated between January 1967 and December 1994. Lone adults, subadults, females with cubs of the year, and females with yearling or 2.5-year-old cubs constituted 60.5, 13.4, 14.4, and 11.7%, respectively, of 4576 bear observations made during this time period. Employees' observations of bears of unknown species or age and sex classes were not used in our analyses. Expected distributions of observations for elevation, aspect, and slope classes were derived for 20 000 random points using GNP's Geographical Information System (GRASS 3.0, Digital Elevation Model). Random points were restricted to areas above 2141 m, the minimum elevation of documented sites of bears feeding on moths. In all analyses performed, we accepted  $\alpha = 0.05$  as significant.

## Results

### Moth site characteristics

We identified a total of 9 sites in GNP used by bears to feed on army cutworm moth aggregations. We visited 7 of these sites a total of 38 times from 1992 to 1995. Seven sites were located in glacial cirques on talus slopes immediately below steeper

**Fig. 1.** Temperatures on the surface and at 10-, 20-, and 30-cm depths within a southwest-facing talus slope (2300 m) in Glacier National Park, Montana, 3 August – 10 September 1995 (MST is Mountain Standard Time).



**Table 1.** Minimum numbers of different grizzly bears observed on alpine moth aggregation sites in Glacier National Park, Montana, in 1992 and 1994–1995.

Moth site	<i>n</i>	RF	C	Y1	Y2	SA	LA
Twin Peaks	16	4	3	3	1	0	5
Two Medicine	4	1	1	1	0	0	1
Northern Exposure	4	1	3	0	0	0	0
Pinchot Creek	6	1	1	0	0	0	4
Medicine Grizzly	3	1	0	1	0	0	1
Triple Divide	3	0	0	0	0	3	0
	36	8	8	5	1	3	11

**Note:** RF, reproductive females (i.e., females accompanied by cubs); C, cubs of the year; Y1, 1.5-year-old cubs; Y2, 2.5-year-old cubs; SA, subadults; LA, lone adults.

headwalls and 2 sites were at or near the summit of their respective massifs. The talus slopes at the sites were active, and deposition and movement of rock debris commonly occurred during our visits, particularly in the early morning hours (04:00–06:00). The angular rocks of the talus slopes ranged in size from 2 to  $\geq 100$  cm. Elevations at the 9 sites averaged 2621 m and the mean slope was  $37^\circ$ . Five of the sites were on southern aspects and 4 were on western aspects.

Talus slopes used for feeding by bears were essentially devoid of vegetation except for strings of vegetation associated with water-seepage areas; even the lichen cover on rocks was sparse. As the moth sites were located at or near the summit of their associated massifs, few alpine tundra-covered benches occurred above the moth sites. Below the moth sites, however, plateaus and benches occurred and were dominated by forbs, most commonly *Erythronium grandiflorum*, *Polygonum bistortoides*, and *Dryas hookeriana*. Graminoids, including *Poa* spp. and *Carex* spp., were also common on these moister, lower elevation benches.

Daily temperature profiles of talus slopes varied widely with the depth of the talus. Mean surface temperatures of a

2300-m southwest-facing talus slope between 3 August and 10 September 1995 fluctuated widely during the day (e.g.,  $3\text{--}22^\circ\text{C}$ ), with the highest temperatures recorded in early afternoon (Fig. 1). At a depth of 30 cm in the talus, however, temperature fluctuations were dampened, ranging through only a few degrees and averaging about  $5^\circ\text{C}$  over a 24-h period (Fig. 1).

#### Bear use of moth sites

Cutworm moths predominated in the diet of bears occupying talus slopes. We observed a minimum of 36 different grizzly bears feeding at 6 of 9 known moth aggregation sites in GNP from late June through mid-September in 1992–1995 (Table 1). No bears were observed on moth sites in 1993 and only 5 bears (two family groups) were observed in 1994 and 1995. Subadults, lone adults, adult females with cubs of the year, and adult females with yearling cubs were observed. Among a total of 106 bear observations (family groups were counted as a single observation), no black bears were observed.

More subadult and fewer lone adult grizzly bears were found feeding on moths in talus slopes than was expected from GNP employees' observations ( $G = 19.80$ ,  $df = 3$ ,  $P < 0.05$ ) (Table 2). This difference was attributable to overrepresentation of subadults and underrepresentation of lone adults. Frequencies of the numbers of different observed and expected grizzly bear classes did not differ ( $G = 0.0007$ ,  $df = 3$ ,  $P = 0.05$ ), however (Table 2). The frequency of observations among bear classes did not differ ( $G = 0.17$ ,  $df = 2$ ,  $P = 0.92$ ) among the time periods analyzed (15 June – 15 July, 16 July – 15 August, 16 August – 15 September) (Table 3).

Based upon examination of 280 bear scats collected from moth aggregation sites in 1992, 1994, and 1995, bears ate mainly army cutworm moths when in these areas (Table 4). Moths appeared to be highly digestible; essentially all moth parts were digested except for the exoskeleton. Graminoids

**Table 2.** Observed and expected numbers of grizzly bear observations, by sex and age classes, at alpine moth aggregation sites in Glacier National Park, Montana, in 1992–1995.

	Total no. of bears observed	No. of different bears observed	Population expected
Subadults	31 <sub>a</sub>	3 <sub>b</sub>	13 <sub>b</sub>
Lone adults	34 <sub>a</sub>	11 <sub>b</sub>	65 <sub>b</sub>
Females with cub(s) of the year	24 <sub>a</sub>	4 <sub>a</sub>	15 <sub>a</sub>
Females with yearling(s)	17 <sub>a</sub>	3 <sub>a</sub>	13 <sub>a</sub>

**Note:** Values in rows followed by a different letter are significantly different ( $P < 0.05$ ).

**Table 3.** Numbers of grizzly bear observations and proportionate representation of bear classes at alpine moth aggregation sites in Glacier National Park, Montana, in 1992–1995.

	No. of bear observations	Bear class proportion		
		Subadults	Lone adults	Females with young
15 June – 15 July	18	0.33*	0.33*	0.33*
16 July – 15 August	48	0.33	0.35	0.31
16 August – 15 September	40	0.30	0.35	0.35

**Note:** Values are proportions of total bear observations by time period.

\* $n < 24$ .

**Table 4.** Average contents of bear scats ( $n = 280$ ) collected at alpine moth aggregation sites in Glacier National Park, Montana, in 1992–1994.

	Percent frequency	Percent volume	Percent ingested volume <sup>a</sup>
Moths	78.3	67.2	95.2
Debris (mostly rocks)	58.4	16.3	—
Grass/sedge	23.1	15.3	3.8
Ants (Formicidae)	5.8	0.9	0.9
<i>Vaccinium globulare</i>	6.5	0.3	0.1

<sup>a</sup>Ingested volume was estimated by applying the correction factors of Hewitt (1989), excluding debris.

were also eaten, particularly *Poa* spp. and *Carex* spp., but little grazing was observed when bears visited adjacent mesic areas.

Bear excavations were oval and typically 0.2–0.5 m deep (range 0.1–0.8 m). The mean total volume of talus debris excavated for 30 pits was 0.22 m<sup>3</sup>. When 2 or more bears or family groups fed at a moth site at the same time, they maintained a distance of 50–100 m between them; paired subadults occasionally fed side by side. Bear use at each site was concentrated within areas of about 200 × 200 m. We found up to 100+ scats in these areas; others were undoubtedly covered as bears dug. Bears observed digging for moths ( $n = 106$ ) were not distributed randomly with respect to elevation, slope, or aspect (Fig. 2).

Fifteen bedding sites were found at 3 moth sites. These beds were excavated in the open talus feeding sites ( $n = 5$ ) or adjacent to large boulders ( $n = 10$ ). These beds were typically shallow depressions (0.05–0.1 m) shaped from scree or snow. Few scats were found around the beds.

### Bear activity patterns

We determined the timing and type of activity engaged in by 18 adult grizzly bears during 104 fifteen-minute intervals

while the bears were on moth sites. Bears foraged heavily on moths from 06:00 to 12:00, commonly sleeping on site between 13:00 and 18:00, then foraging for moths again in the early evening (Fig. 3). While foraging for moths, a bear typically stayed in one location for up to 10 min before moving to a new location, which was usually within 1–2 m of the previous excavation. A mean of 67% of each day was spent foraging for moths. Moving on, off, or within the site tended to be more common after 12:00. Little movement of the bears occurred before 12:00. Defensive behaviors were observed only during the early morning hours (Fig. 3).

The amount of time devoted to foraging for moths during the summer varied widely among bears. We observed 1 female with a yearling cub use a moth aggregation site for a minimum of 32 days. Five lone adults were observed foraging for moths on 3 different alpine moth aggregation sites for at least 28, 25, 22, 21, and 20 days each. Two females with cubs of the year were observed for only 3 days each. Because it was not possible to observe every alpine moth aggregation site every day (i.e., the most accessible sites were the most studied), these numbers should be considered conservative estimates of the length of time grizzly bears utilize moth sites in GNP.

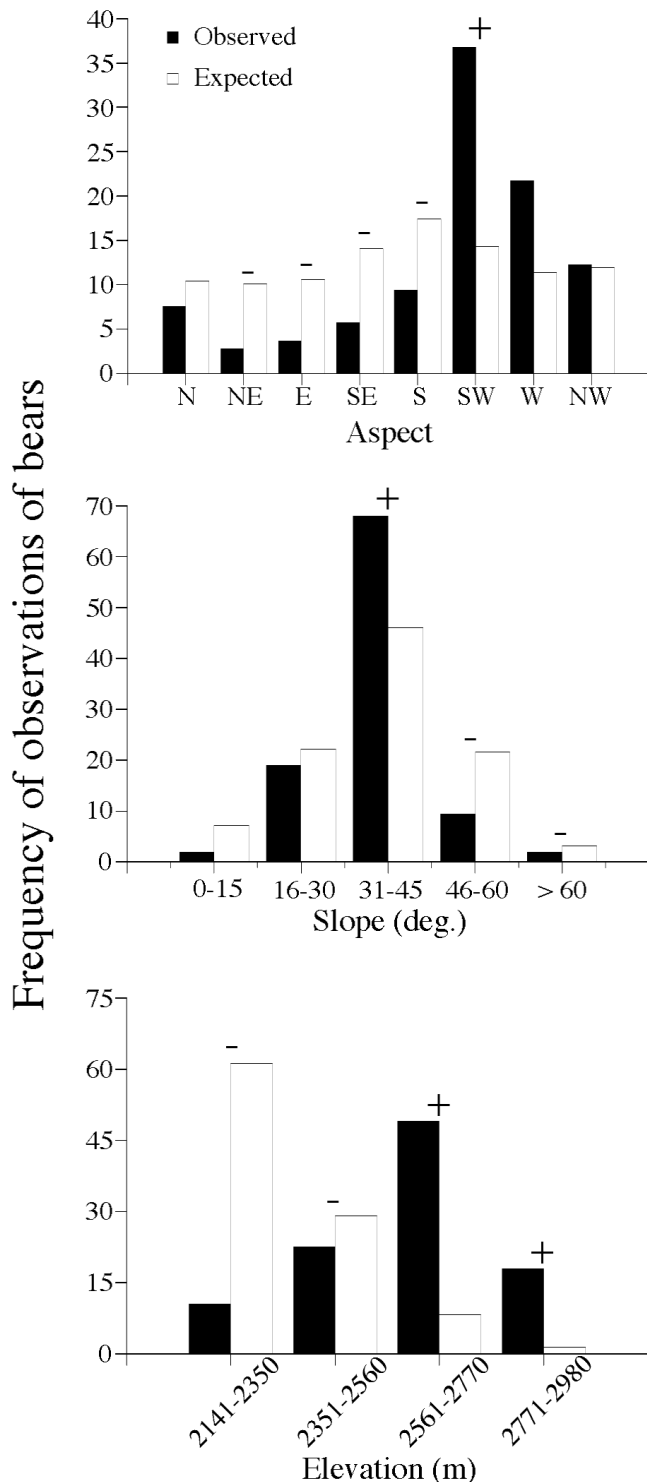
## Discussion

### Bear use of army cutworm moths

Over the past decade, a growing number of studies have documented extensive use of army cutworm moths by grizzly bears in the Rocky Mountain region of Montana. Klaver et al. (1986) observed 29 grizzly bears feeding on army cutworm moths between July and September on McDonald Peak in the Mission Mountains, Montana. Eighteen of these bears were adult females with cubs. The Interagency Grizzly Bear Study Team first documented bears using alpine moth aggregation sites in the Absaroka Mountains east of Yellowstone National Park, Wyoming, in August 1986. Since then, 14 moth site complexes



**Fig. 2.** Observed and expected frequencies of individual grizzly bears or family groups excavating for army cutworm moths in Glacier National Park, Montana, by elevation, slope, and aspect. A plus or a minus sign denotes observed frequencies significantly greater or less than expected, respectively ( $P < 0.05$ ).



containing 27 moth sites have been found (O'Brien and Lindzey 1994). In 1991 and 1992, 45 and 43%, respectively, of all known bears in the Greater Yellowstone Ecosystem

( $n = 236$ ) used moth sites (O'Brien and Lindzey 1994). Bears fed at these alpine moth aggregation sites between 15 June and 15 September, with peak use in mid-August (Mattson et al. 1991; French et al. 1994; O'Brien and Lindzey 1994). Of grizzly bears observed at 2 moth complexes in 1991 and 1992 in the Absaroka Mountains, females with cubs constituted 69% of the observations, with lone adults (16.9%) and subadults (14.1%) making up the remainder (O'Brien and Lindzey 1994).

The proportions of grizzly bear age and sex classes observed in GNP were significantly different from those observed by Mattson et al. (1991) in the Absaroka Mountains ( $G = 11.17$ ,  $df = 2$ ,  $P = 0.004$ ). The difference was due to proportionately more observations of lone adults and fewer subadults in the Absaroka Mountains. Our bear class frequencies were marginally different ( $G = 6.01$ ,  $df = 2$ ,  $P = 0.056$ ) from those obtained by Klaver et al. (1986) in the Mission Mountains, where fewer lone adults and more females with cubs were seen.

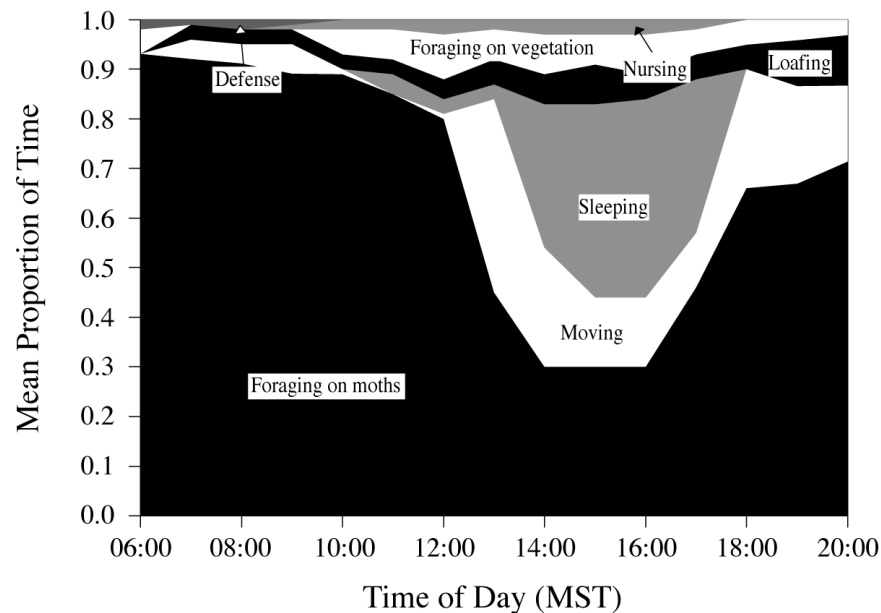
Mattson et al. (1991) found significant differences between the frequencies of bear classes represented at moth sites in the Absaroka and Mission mountains. They attributed these differences to proportionately more observations of lone adults and fewer of subadults in the Absaroka Mountains. They hypothesized, as Klaver et al. (1986) did, that the more security-conscious or subordinate bears disproportionally used alpine moth aggregation sites in the Mission Mountains, and that these sites afforded refuge from lone adults.

Stonorov and Stokes (1972) found similar diurnal foraging/behavioral activities at McNeil River Falls, Alaska. Dominant bears, usually male, controlled the limited number of fishing sites, to the exclusion of all other bear cohorts. Each bear or family group waited its turn to fish. Once the choice fishing sites were relinquished, subordinate bears would then occupy them in order of social position. Bunnell and Tait (1981) suggested that in the Ursidae, aggression by adult males is directed toward subadult males, resulting in the eviction of the latter or their voluntary evacuation from prime feeding areas. The social status of an animal may therefore affect its frequency of visiting alpine moth aggregation sites.

Mattson et al. (1991) believed that habitat differences between the Absaroka and Mission mountains explained the differences in proportions of lone adult and subadult grizzly bears using alpine moth aggregation sites in the two areas. They contend that because the Mission Mountains have an abundance of fleshy fruits in August and September, which they presumed were of greater or at least comparable nutritional quality relative to cutworm moths, fleshy fruits are likely exploited much more heavily by dominant lone adult bears than by subadult bears. In the Absaroka Mountains, fleshy fruits are scarce; those bears are therefore afforded fewer foraging options than bears in the Mission Mountains. Lone adult bears therefore appear to rely more heavily on alpine moth aggregations in the Absaroka Mountains than in the Mission Mountains.

Similarly, compared with the Absaroka Mountains, we found proportionately fewer lone adults and more subadults in GNP, where five species of huckleberries (*Vaccinium* spp.) and a variety of other fruiting shrubs occur. However, we found that cutworm moths collected from alpine moth aggregation sites in GNP represented a high-quality food source for bears in August and early September (D. White, Jr., K. Kendall, and

**Fig. 3.** Diurnal activity patterns of 18 adult grizzly bears relative to time of day on alpine moth aggregation sites in Glacier National Park, Montana, in 1992 and 1994–1995 (MST is Mountain Standard Time).



H.D. Picton, in preparation). The gross energy content of moths collected in late August averaged 7.0 kcal/g dry matter (1 kcal = 4.1855 kJ), which exceeds the energy content of most other high-quality bear foods. For comparison, the gross energy content in kilocalories per gram of dry matter for blueberries (*Vaccinium corymbosum*) fed whole is 4.47, Columbian ground squirrels (*Spermophilus columbianus*) fed whole is 5.28, cutthroat trout (*Salmo clarkii*) fed whole is 5.71, and pine nuts (*Pinus edulis*) fed whole is 6.48 (Pritchard and Robbins 1990). Only mule deer (*Odocoileus hemionus*), composed of 97.6% skeletal muscle and adhering fat and 2.4% skin and hair, was higher at 7.32 kcal/g dry matter (Pritchard and Robbins 1990). If food quality alone were driving habitat selection by lone adults, we would expect disproportionally more lone adults than subadults to utilize army cutworm moths in GNP than we actually observed.

The bears we observed digging for moths were not distributed randomly with respect to elevation, slope, or aspect (Fig. 2). Because our analyses are based on bear observations from only 6 moth sites, we recognize that such a small sample possibly violates the assumption of independence for the *G* test. The importance of these data for both human and bear safety relative to human climbing routes, however, makes detailed presentation of the data essential.

#### Bear activity patterns

Grizzly bears principally spent their active time at a moth site foraging on moths. According to 104 h of observations of 18 adult grizzly bears foraging at 6 moth aggregation sites in 1992, grizzly bears foraged for moths in a bimodal pattern (Fig. 3). From activity studies in which black bears were found to be crepuscular, this pattern was attributed to their avoiding midday heat (Garshelis 1978) while still using daylight for foraging (Eubanks 1976). Activity levels of black bears in Great Smoky Mountains National Park, Tennessee, were found to decline when temperatures exceeded 20°C (Quigley

et al. 1979). If bears observed in this study were responding strictly to temperature, we would expect to observe increased or prolonged activity on cooler days. We detected no such relationship, based on temperatures taken at 30-min intervals for 36 days at a moth site in August and early September 1995.

Foraging constraints imposed by the thermal characteristics of a talus slope may explain the timing of moth feeding by grizzly bears. When we excavated moths in the cool of the morning, they were located within 10 cm of the surface of the talus, but by the afternoon, when temperatures on the surface were high, they were located more than 20 cm deep within the rock debris, where it was cooler. Grizzly bears fed on moths during the cooler parts of the day, morning and evening. Bears were usually already feeding on moths when we arrived at our observation posts at 06:00. They fed until about noon, then were relatively inactive at the sites until about 16:00. At this time they resumed feeding and continued until they left the area later in the evening, usually by 21:00. Grizzly bears possibly foraged on moths in the morning and evening hours because the moths were near the surface of the talus and easily captured. At times when moths were less available to bears, such as during the heat of the day, the energy costs associated with digging for moths deep in the talus may have exceeded the energy yield.

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#### References

Alden, W.C. 1953. Physiography and glacial geology of western

- Montana and adjacent areas. U.S. Geological Survey Professional Paper No. 231.
- Alt, D., and Hyndman, D.W. 1991. Roadside geology of Montana. Mountain Press Publishers, Missoula.
- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour*, **49**: 227–267.
- Aune, K., and Kasworm, W. 1989. Final report: East Front grizzly studies. Montana. Department of Fish, Wildlife and Parks, Helena.
- Bunnell, F.L., and Tait, D.E.N. 1981. Population dynamics of bears—implications. In *Dynamics of large mammal populations. Edited by C.W. Fowler and T.D. Smith*. John Wiley and Sons, New York, pp. 75–98.
- Burton, R.L., Starks, K.J., and Peters, D.C. 1980. The army cutworm. Bull. No. B749, Agriculture Experiment Station, Division of Agriculture, Oklahoma State University, Stillwater.
- Byers, C.R., Steinhorst, R.K., and Krausman, P.R. 1984. Clarification of a technique for analysis of utilization–availability data. *J. Wildl. Manage.* **48**: 1050–1053.
- Carrara, P.E., and McGimsey, R.G. 1981. The late-neoglacial histories of the Agassiz and Jackson Glaciers, Glacier National Park, Montana. *Arct. Alp. Res.* **13**: 183–196.
- Chapman, J.A. 1954. Studies on summit frequenting insects in western Montana. *Ecology*, **35**: 41–49.
- Chapman, J.A., Romer, J.I., and Stark, J. 1955. Ladybird beetle and army cutworm adults as food for grizzly bears in Montana. *Ecology*, **36**: 156–158.
- Cooley, R.A. 1916. Observations on the life history of the army cutworm, *Chorizagrotis auxiliaris*. *J. Agric. Res.* **6**: 871–881.
- Craighead, J.J., Sumner, J.S., and Scaggs, G.B. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Monogr. No. 1, Wildlife–Wildlands Institute, University of Montana Foundation, Missoula.
- Dightman, R.A. 1967. Climate of Glacier National Park. Bull. No. 7, Glacier Natural History Association, West Glacier, Mont.
- Dyson, J.L. 1966. Glaciers and glaciation in Glacier National Park. Bull. No. 3, Glacier Natural History Association, West Glacier, Mont.
- Egbert, A.L., and Stokes, A.W. 1976. The social behavior of brown bears on an Alaskan salmon stream. In *Bears—Their Biology and Management: Proceedings of the Third International Conference on Bear Research and Management*, Binghamton, New York, 31 May – 1 June 1974, and Moscow USSR, 11 June 1974. Edited by M.R. Pelton, J.W. Lentfer, and G.E. Folk, Jr. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland (IUCN Publ. n.s. No. 40). pp. 41–56.
- Eubanks, A.L. 1976. Movements and activity of the black bear in the Great Smoky Mountains National Park. M.S. thesis, University of Tennessee, Knoxville.
- Finklin, A.I. 1986. A climate handbook for Glacier National Park, with data for Waterton Lakes National Park. U.S. For. Serv. Gen. Tech. Rep. INT–204.
- French, S.P., French, M.G., and Knight, R.R. 1994. Grizzly bear use of army cutworm moths in the Yellowstone ecosystem. In *Bears—Their Biology and Management: Proceedings of the Ninth International Conference on Bear Research and Management*, Missoula, Mont., February 1992. Edited by J. Claar and P. Schullery. Bear Biology Association, University of Tennessee, Knoxville. pp. 389–399.
- Garshelis, D.L. 1978. Movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park. M.S. thesis, University of Tennessee, Knoxville.
- Hardwick, D.F., and Lefkovitch, L.P. 1971. Physical and biotic factors affecting *Euxoa* species abundance in western North America: a regression analysis. *Can. Entomol.* **103**: 1217–1235.
- Hewitt, D.G. 1989. Correcting grizzly bear fecal analysis to actual food habits. M.S. thesis, Washington State University, Pullman.
- Johnson, S.A. 1905. Cutworms. *Colo. Agric. Exp. Stn. No. 98*. pp. 17–22.
- Kendall, D.M. 1981. Bionomics of *Euxoa auxiliaris* Grote (Lepidoptera: Noctuidae) in the Rocky Mountains and comparison with two resident species of alpine moths. M.S. thesis, Colorado State University, Fort Collins.
- Kendall, D.M., Kevan, P.G., and Lafontaine, D.L. 1981. Nocturnal flight activity of moths (Lepidoptera) in the alpine tundra. *Can. Entomol.* **113**: 607–614.
- Klaver, R.W., Claar, J.J., Rockwell, D.B., Mays, H.R., and Acevedo, C.F. 1986. Grizzly bears, insects, and people: bear management in the McDonald Peak region, Montana. U.S. For. Serv. Gen. Tech. Rep. INT–207. pp. 205–211.
- Mattson, D.J., Gillin, C.M., Benson, S.A., and Knight, R.R. 1991. Bear feeding activity at alpine insect aggregation sites in the Yellowstone ecosystem. *Can. J. Zool.* **69**: 2430–2435.
- Morrill, W. 1991. Montana small grain insects: armyworms and cutworms. Montana Agriculture Experiment Station, Montana State University, Bozeman, Capsule Information Ser. No. 34, October 1991.
- O'Brien, S.L., and Lindzey, F.L. 1994. Grizzly bear use of alpine insect aggregation sites, Absaroka Mountains, Wyoming. Wyoming Cooperative Fish and Wildlife Research Unit Annual Report, Laramie.
- Pepper, J.H. 1932. Observations on a unidirectional flight of army cutworm moths and their possible bearing on aestivation. *Can. Entomol.* **64**: 241–242.
- Pritchard, G.T., and Robbins, C.T. 1990. Digestive and metabolic efficiencies of grizzly and black bears. *Can. J. Zool.* **68**: 1645–1651.
- Pruess, K.P. 1967. Migration of the army cutworm, *Chorizagrotis auxiliaris* (Lepidoptera: Noctuidae). I. Evidence for migration. *Ann. Entomol. Soc. Am.* **60**: 910–921.
- Quigley, H.B., Garshelis, D.L., Pelton, M.R., Taylor, C.I., and Villarubia, C.R. 1979. Use of activity monitors in telemetry studies. In *Proceedings of the International Conference on Biotelemetry*. Vol. 2. pp. 48–56.
- Seamans, H.L. 1927. Forecasting outbreaks of the army cutworm, *Chorizagrotis auxiliaris* Grote. Rep. No. 58, Entomological Society of Ontario. pp. 76–85.
- Servheen, C.W. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. *J. Wildl. Manage.* **47**: 1026–1035.
- Snow, S.J. 1925. Observations on the cutworm, *Euxoa auxiliaris* Grote and its principal parasites. *J. Econ. Entomol.* **18**: 602–609.
- Stonorov, D., and Stokes, A.W. 1972. Social behavior of the Alaskan brown bear. In *Bears—Their Biology and Management: Proceedings of the Second International Conference on Bear Research and Management*, Calgary, Alberta, 6–9 November 1970. Edited by S. Herrero. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland (IUCN Publ. n.s. No. 23). pp. 232–242.
- Strickland, E.H. 1916. The army cutworm *Euxoa auxiliaris* Grote. Bull. No. 13, Entomology Branch, Canadian Department of Agriculture, Ottawa. p. 31.
- Sumner, J., and Craighead, J.J. 1973. Grizzly bear habitat survey in the Scapegoat Wilderness, Montana. Montana Cooperative Wildlife Research Unit, Missoula.
- Walkden, H.H. 1950. Cutworms, armyworms, and related species attacking cereal and forage crops in the central Great Plains. U.S. Dep. Agric. Circ. No. 849.
- Zar, J.H. 1984. Biostatistical analysis. Prentice Hall, Englewood Cliffs, N.J.