GRIZZLY BEAR USE OF ARMY CUTWORM MOTHS IN THE YELLOWSTONE ECOSYSTEM

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Abstract: The ecology of alpine aggregations of army cutworm moths (*Euxoa auxiliaris*) and the feeding behavior of grizzly bears (*Ursus arctos horribilis*) at these areas were studied in the Yellowstone ecosystem from 1988 to 1991. Army cutworm moths migrate to mountain regions each summer to feed at night on the nectar of alpine and subalpine flowers, and during the day they seek shelter under various rock formations. Grizzly bears were observed feeding almost exclusively on moths up to 3 months each summer at the 10 moth-aggregation areas we identified. Fifty-one different grizzly bears were observed feeding at 4 of these areas during a single day in August 1991. Army cutworm moths are a preferred source of nutrition for many grizzly bears in the Yellowstone ecosystem and represent a high quality food that is available during hyperphagia.

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In 1986 the Interagency Grizzly Bear Study Team (IGBST) first observed radio-instrumented grizzly bears excavating and presumably feeding in alpine talus fields located in the southeast portion of the Yellowstone ecosystem. Subsequent visits to these sites in 1987 revealed that bears were feeding on aggregations of army cutworm moths (Mattson et al. 1991). In 1988 we began a long-term project to investigate the ecological relationships between grizzly bears and army cutworm moths in the Yellowstone ecosystem. This paper covers some of the results of the first 4 years of this project.

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STUDY AREA

The grizzly bear Recovery Zone in the Yellowstone ecosystem is approximately 2,460,500 ha and encompasses Yellowstone National Park and adjacent portions of Idaho, Montana, and Wyoming (Fig. 1). A high plateau occupies the central portion and is surrounded by mountains within 5 different national forests. Climate, physiography, and vegetative characteristics of this area were described by Knight and Eberhardt (1985).

The primary study area was in the Absaroka Mountains located in the southeast portion of the grizzly bear Recovery Zone for the Yellowstone ecosystem. Additional survey work occurred adjacent to the primary study area, in the Gallatin National Forest to the northwest, in the northwest corner of Yellowstone National Park, and in the northern mountains of Grand Teton National Park to the southwest (Fig. 1).

The Absaroka Mountain Range originated from volcanic activity during the Late Eocene and Oligocene and varies in elevation from about 2,000 to 4,000 m. The range is generally forested with deep valley bottoms and numerous mountain peaks above timberline.

The alpine terrain has been shaped by distinct glacial erosion since the Pleistocene. Periglacial mesas are distributed throughout this region and are subjected to strong winds, short growing seasons, inclement weather, young soils, and wide temperature gradients, which limit the extent of plant communities. Extreme topographic relief occurs at the interface between mesa landforms and parent rock, such as glacial cirque headwalls, cols, aretes, horns, and isolated rock precipices. This terrain is characterized by andesite and andesitic tuff rock formations exposed chiefly by glaciation, mass wasting, and wind and stream erosion.

Talus fields located directly below parent rock formations contain angular rocks of various size, beginning with fine debris at the uppermost reaches of the steeper slopes and generally increasing in size farther downslope to large boulders on the more gradual slopes near the bottom of the talus fields. Some talus is bare (<10% plant cover) due to the active process of mass wasting, which precludes substantial soil and plant development, and contain small mudflow channels and streams of glacial and snow meltwaters.

Partially vegetated talus (10-50% plant cover) also occurs on moderate slopes that undergo less seasonal

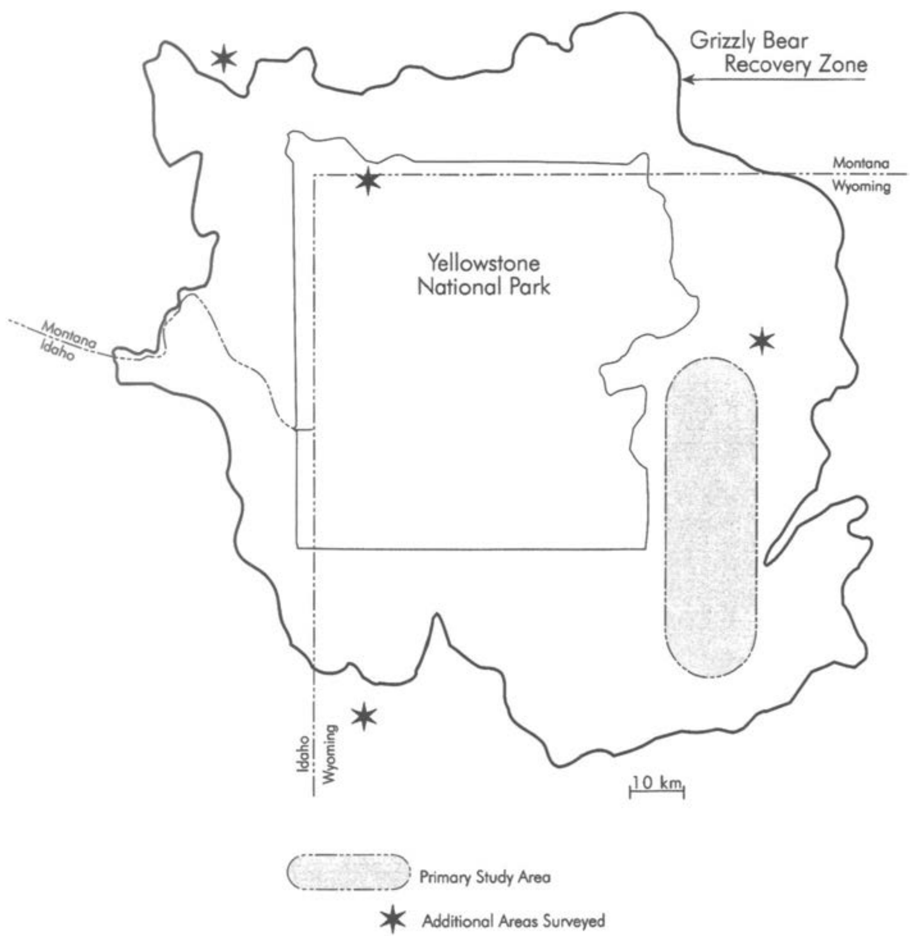

Fig. 1. Study area in the Yellowstone ecosystem.

movement providing greater stability for soil and vegetation development. Vegetative talus (>50% plant cover) occurs within the areas of the least seasonal movement below parent rock, which allows for the greatest soil development.

Alpine meadows containing thickly vegetated areas of gentle to moderate slope are common below the various talus formations. Moist and developed inseptisol soils, protection from strong winds, and relatively longer growing seasons (due to early retreat of annual snowpack) typically yield taller and more diversified communities of vascular plants in alpine meadows compared to that found on periglacial mesas and partially vegetated and vegetated talus.

Krummholz occurs at the lower margins of alpine meadows just above treeline. This zone contains stunted arborescent vascular plants that generally do not exceed 2-3 m in height. Closed forest begins just below this zone and extends to the valley bottoms below.

METHODS

Bear Ecology

Data were collected from ground and aerial observations of bears feeding at alpine moth-aggregation areas from June to November, 1988-91. Time, date, and location were recorded for each observation along with species, age and sex class, and family group composition. Aerial observations were made from fixed-wing aircraft as part of ongoing interagency observation flights and relocation flights for radio-instrumented bears. The location of each bear observation was plotted on U.S. Geological Survey (USGS) 7.5 minute topographic maps. Bear feces were collected from these areas for content analysis each fall after the bears had left.

Observations were made nonintrusively from distant vantage points using binoculars and spotting scopes. A 16 mm motion picture camera and a telephoto lens were used to film some bears for further behavioral analysis. Some bears were identified as individuals by their distinctive physical features.

Subadults were distinguished by their smaller size and shorter body length compared to adult females with offspring observed in the same area. Adult males were identified by genitalia and were also easily distinguished by their larger size relative to adult females with young. In some cases, subadult males were identified by genitalia.

Seasonal use, daily activity patterns, activity budgets, and feeding behavior of bears feeding on moths were studied at 2 areas during 1991. A 15-minute sampling period was used to determine the activity budgets of all age and sex classes of grizzly bears observed while feeding on aggregations of army cutworm moths. A 10-second scan interval was used to record the category of activity throughout the sampling period. Activity categories included digging for moths, walking between excavation sites, looking for moths, and eating moths.

Moth Ecology

Moth activity was determined by direct observations made during the day and at night. Some moths were captured and manually killed for species identification and biochemical analysis. The physical characteristics of moth-aggregation sites were recorded such as geological formation, rock type, size and depth, slope, aspect, elevation, temperature gradient, and proximity to sources of water and vegetation.

Moth samples were oven dried at 100°C for 24 hours prior to nutritive analysis. Crude protein was measured by the macro-Kjeldahl technique, crude fat was determined using chloroform-methanol extraction in a Gold fisch apparatus, and gross energy was determined in an adiabatic bomb calorimeter.

Moth distributions within talus fields were determined by establishing 10 m × 10 m plots with a 2-m grid within each plot. The talus was excavated approximately the width of a hand at each grid point until soil or ice were encountered and each moth was collected and counted. Thermal gradients were determined by measuring air temperatures taken at various depths in the talus. To avoid disturbing bears, these collections and measurements were only made when no bears were observed on or adjacent to the talus fields examined.

RESULTS

Moth Ecology

Behavior.—All moths collected at the various alpine aggregation sites were identified as the army cutworm moth (*Euxoa auxiliaris*). Their arrival each year corresponded to the onset of the flowering season for the alpine flower communities near the end of June and the first part of July. They fed at night on the nectar of several flowers, including green bluebells (*Mertensia lanceolata*), thick-leaved groundsel (*Senecio crassulus*), mules-ears (*Wyethia amplexicaulis* Nutt.), and elephant's head (*Pedicularis groenlandica*). Moths were rarely observed flying or feeding on windy or rainy nights.

During the day, moths aggregated under the various rock formations, presumably to seek shelter from the heat and frequent rain and/or hailstorms while metabolizing nectar. They were located in relatively large clusters distributed nonuniformly throughout the talus and boulder fields. Moth-aggregation sites were altered on a daily basis from extensive bear excavations. Some sites were abandoned by moths when the runoff from meltwaters ceased but other sites became available when large perennial snowfields receded.

Moths were generally inactive while aggregated under rocks although some appeared to be drinking from glacial or snow meltwaters, and copulation was occasionally observed. This sexual behavior was first observed in mid-July and continued until mid-September, and was also observed at night while moths fed.

Moth samples collected in late August were found to contain approximately 72% fat, 28% protein, and less than 1% carbohydrate. The high fat content produced a relatively high gross energy (7.9 Kcal/gm) for moths in late summer compared to other available bear foods (Table 1).

By mid to late September each year, we rarely observed moths feeding at night and by the first of October we no longer found moths at the aggregation sites in the talus slopes. The disappearance of moths from the alpine regions each fall corresponded to the desiccation of alpine flowers or the onset of the first substantial snowfall.

Site Characteristics.—Sixty-eight moth-aggregation sites were identified in the alpine regions of the study area, 38 by aerial observation, 14 by ground observation, and 16 by a combination of both methods. We examined 25 of these sites from 1988 to 1991 and

Table 1. Gross energy of army cutworm moths compared with other bear foods as reported by Pritchard and Robbins (1990).

Food item	Kcal/gm
Blueberries	4.47
White clover	4.83
Ground squirrels	5.28
Cutthroat trout	5.71
Pinyon pine nuts	6.48
Deer	7.32
Army cutworm moths	7.91

recorded their physical characteristics. The total size of each site varied from approximately 1 to 16 ha as estimated from topographic maps. Site elevations varied from 2,768 to 3,645 m ($\bar{x}$ = 3,313 m), while the slope ranged from 10 to 56° ($\bar{x}$ = 39). Ten sites were on NE aspects, 7 on SE aspects, 4 on NW aspects, and 4 on SW aspects.

Aggregation sites examined by ground were located in bare talus fields immediately below parent rock, such as glacier cirques (12), cols (6), or aretes (4). The 3 remaining sites were located at the lower portions of talus within boulder fields. Two-thirds of the sites were considered to be active with ongoing annual rock deposition from above, while the remainder were within partially vegetative talus. Most of these sites contained uniform angular rock varying from 6 to 12 cm in diameter, but some sites had larger, nonuniform rock that varied in size from 82 to 200 cm.

Water was common to all moth-aggregation sites. Ten sites were immediately adjacent to perennial snowfields and 5 were in bare talus on top of glaciers. The 10 remaining sites were moistened by streams or rivulets of glacial or snow meltwaters. Moth sites below small perennial snowfields were abandoned by late summer after the snow had melted and the underlying soils had dried.

A temperature gradient was found within each moth-aggregation site examined. On sunny days the air temperature occasionally exceeded 40°C at the rock surface, but generally dropped to 20°C at soil surface typically within 20-30 cm, or dropped as low as freezing at sites overlying ice fields.

Temperature gradient affected the moths' ability to escape when they were exposed during excavations. Moths exposed near the rock surface had to flap their wings several seconds before flying away, but those exposed farther down where it was cooler had to spend more time warming up before flight, and as a consequence, usually fled by crawling deeper into the rock interstices. This mode of escape concentrated moths at the bottom of the excavations when they were prevented from going down farther by soil or ice.

Bear Ecology

Bears were observed feeding on moths at 64 different aggregation sites. These sites were distributed in clusters of 2-9 sites, each located around a common mountain peak or massif. We commonly observed bears feeding from one site to another within a cluster and also noted that radio-instrumented bears used multiple sites within a single cluster during the year. We therefore defined each discrete cluster of feed sites as a single moth-feeding area. Based upon this definition, we identified 10 moth-feeding areas within the primary study area. The mean elevation of the 10 mountain peaks that contained these areas was 3,378 m (SD ± 191 m). The distance between each moth feeding area averaged about 17 km and varied from 10 to 30 km.

Grizzly and black bears were observed 507 times feeding at the 10 moth-aggregation areas. Grizzly bears constituted 92% (290) of the 314 ground observations and 97% (188) of the 193 aerial observations. There were only 12 observations of radio-instrumented moth-eating grizzly bears during this study, 11 by air of 4 different bears, and once by ground of an unidentified bear with an inactive radio collar.

We developed a model to predict the locations of other moth-aggregation areas based upon the examination of the known moth-aggregation areas used by bears. This model included isolated mountain massifs containing parent rock that created both bare and partially vegetated talus fields below. Parent rock formations include glacial cirque headwalls, cols, aretes, horns, and isolated rock precipices. Talus fields were either adjacent to perennial snowfields or on top of glaciers, and were located near alpine meadows containing a variety of flowering vascular plants.

We tested this model by surveying 4 additional areas that were not known to have either moth-aggregations or bear-feeding activity. We found moth-aggregations at all 4 areas and evidence of bear feeding activity at 3. One was adjacent to the primary study area but the others were more than 100 km away in the northwest and southwest portions of the Yellowstone ecosystem (Fig. 1).

Feeding Behavior.—Bear use of army cutworm moths occurred during a 2-3 month period each year during this study. During the first 3 years this was determined by aerial observations of bears feeding at all 10 known areas throughout July and August, continuing into the first part of September. Based upon ground observations at 2 areas in 1991, the duration of this feeding behavior was slightly longer, beginning in late June and continuing until late September, with a peak of activity observed in August (Fig. 2).

The duration of this feeding behavior by individual bears was determined by monitoring the location and feeding activities of 4 moth-feeding grizzly bears who were radio-instrumented during this study. During 1990 a radio-instrumented adult female grizzly bear was located at a single moth-aggregation area 9 times during an 80-day period, 8 by radio telemetry and once by aerial observation.

In 1991, 3 radio-instrumented subadult male grizzly bears were monitored at 3 separate moth-aggregation areas. The first was located at a moth-aggregation area 8 times during a 38-day period, twice by radio-telemetry flights and 6 by aerial observation. The second was located at another moth-aggregation area on 4 occasions during a 34-day period, once by aerial observation and 3 by radio-telemetry flights.

The third subadult male monitored during 1991 was located at yet another moth-aggregation area 4 times during a 23-day period, 2 by radio-telemetry flights and 2 by aerial observation. He moved approximately 15 km to the valley below but returned to the same moth-aggregation area about 3 weeks later where he was located an additional 3 times during a 15-day period, once by aerial observation and twice by radio-telemetry flights. Therefore, he was located and observed feeding at this moth-aggregation area for a total span of 38 days.

Bears fed on moths in a crepuscular pattern and individual bears generally fed twice each day. This feeding pattern was observed in 38 of 41 individual bears at 1 moth-aggregation area during the months of July and August in 1991. During the daytime they rested in daybeds generally located nearby.

They began their morning feeding sessions sometime in the early morning hours because they were already

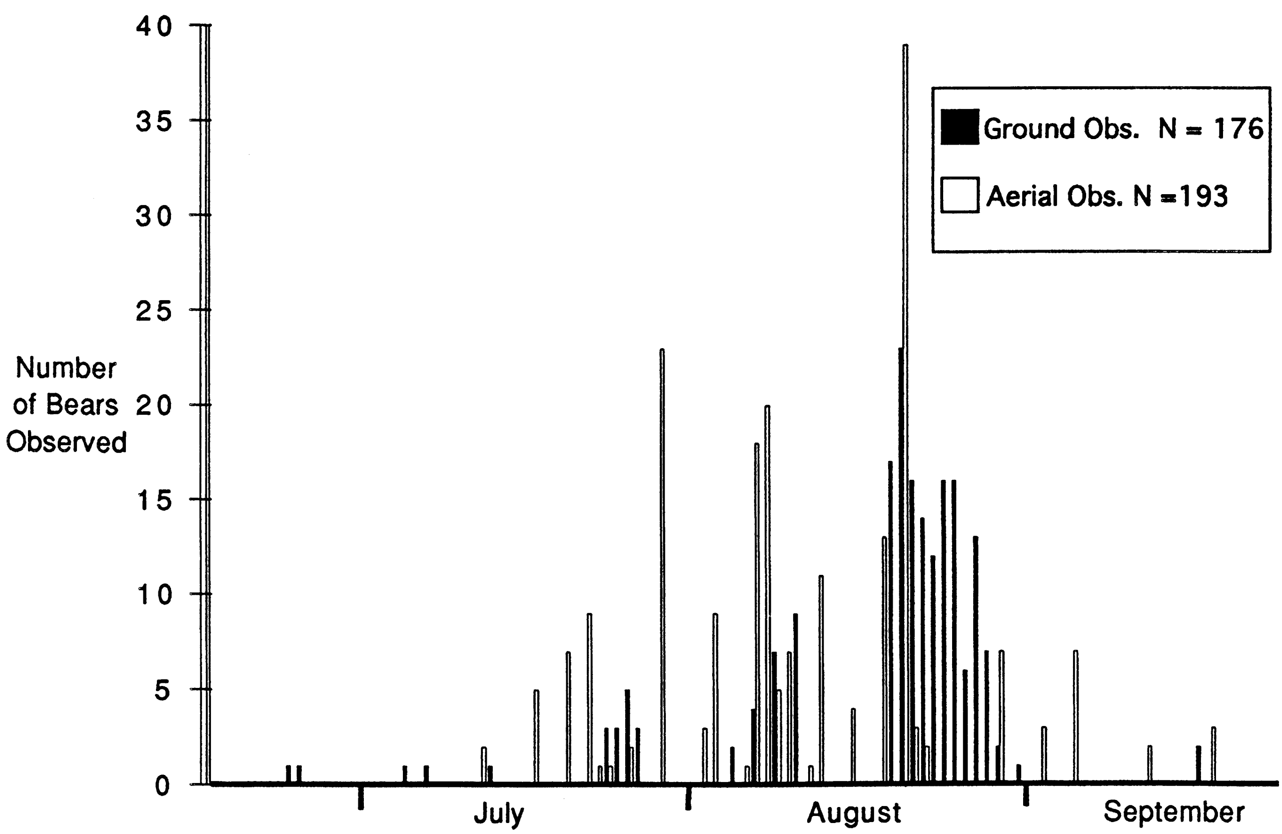

Fig. 2. Seasonal use of alpine aggregations of army cutworm moths by grizzly bears based upon ground and aerial observations during 1991.

on the talus slopes feeding at first light each day. They continued to feed until they started bedding for the day between 0900 and 1100 hours.

We observed 103 instances of bedding by moth-eating bears and examined 73 daybeds. Eighteen were located above the talus slopes on rocky ledges or in caves, 16 were below the talus slopes within the krummholz or edge of the treeline, 13 were within the talus fields, 9 were at the base of large boulders, 9 were on the adjacent mesas or alpine meadows, and 8 were on top of snowfields. Many of these beds were used by different bears during the course of a season and from year to year.

Bears resumed feeding again between 1600 and 1900 hours each day and continued to feed until we left the observation area each evening at dusk around 2030 hours. We observed bears continue to feed on moths until 2300 hours on a moonlit night in August 1991, but observations beyond this time were precluded by cloud cover.

We recorded the feeding behavior of 61 unmarked grizzly bears for a total of 146 hours and found that 95% of their time was directed towards moths. Grazing accounted for 5% of their feeding activities and appeared to be directed, whereas feeding on small mammals, such as picas (*Ochotona princeps*), golden-mantled ground squirrels (*Spermophilus lateralis*), 13-lined ground squirrels (*Spermophilus tridecemlineatus*), and marmots (*Marmota flaviventris*), appeared to be incidental, and accounted for less than 1% of feeding activities. We found no significant differences in this feeding pattern between the various age and sex classes.

We analyzed 284 bear scats collected from these same areas after the bears left in the fall. Moths were present in 84% of scats and composed 34% of the scat volume, whereas graminoids appeared in 85% of the scat and composed 51% of the scat volume (Table 2).

Table 2. Content of grizzly bear scats collected at one moth-aggregation area in 1991, *N* = 284.

	% Frequency	% Volume
Insects	83.80	34.5
Euxoa	79.23	34.12
Ant	6.69	0.19
Bot fly larvae	2.11	0.05
Graminoids	85.21	50.77
Carex	61.97	21.75
Poa	52.46	18.04
Deschampsia	8.45	2.79
Juncus	7.04	2.70
Grass	3.17	0.99
Grass-sedge	2.11	1.68
Melica	1.76	0.70
Bromus	1.06	0.02
Forbs	16.20	4.06
Trifolium	10.92	2.23
Epilobium	2.11	0.50
Taraxacum	1.76	0.27
Lomatium	1.06	0.42
Forb	1.06	0.27
Mammals	7.04	0.35
Ursus sp.	5.98	0.06
Marmot	0.70	0.26
Pika	0.35	0.02
Debris	70.07	9.83
Dirt	69.72	6.03
Rocks	37.32	3.59
Wood	0.35	0.15
Needles	0.70	0.06
Birds (Unidentified)	0.35	0.00
Pine nuts (*Pinus albicaulis*)	0.70	0.54
Shrubs (*Vaccinium* sp.)	0.70	0.08
Sporophytes (*Lycopodium*)	0.70	0.02

The results of the activity budgets measured for 26 individual grizzly bears while feeding on moths indicated that moths were concentrated and easily obtained. Bears meandered back and forth on the talus fields and appeared to locate moth clusters by scent. They spent several minutes excavating and eating before moving on to search for another moth cluster. Approximately 65% of their time was spent eating and only 22% excavating. Review of film records revealed that bears commonly continued to feed on moths while excavating. Therefore, somewhere between 65% and 87% of their total activity was spent eating during their pursuit of moths.

Ground Versus Aerial Observations.—Although aerial-observation techniques were more efficient in surveying for the presence of bear-feeding activity at the remote and widely distributed moth-aggregation areas, they did not appear to be as accurate as ground observations for counting the total number of moth-eating bears at a particular area. On 4 occasions, concurrent aerial and ground observations occurred and only 59% (27 of 46) of the bears observed from the ground were observed from the air.

We also recorded a significant difference in the age and sex structure of the bears observed feeding at one of the moth-aggregation areas during ground observations compared to aerial observations. Families: subadults: lone adults ratios were 16:45:39 during ground observations compared to 28:7:64 from the air. The 62 ground observations were based upon 57 field-observation days between 22 June 1991 and 15 September 1991 and the 14 aerial observations were based upon 5 flights made between 22 July 1991 and 19 September 1991.

Number of Bears Feeding on Moths.—It appeared that a significant number of grizzly bears fed on moths for at least part of each summer during this study. As an example, we observed 51 different grizzly bears feeding at 4 of the 10 moth-feeding areas on a single morning in August 1991. However, we did not estimate the total number of bears feeding on moths because the moth-aggregation areas were not surveyed simultaneously during this study and most of the moth-eating bears observed and monitored were not instrumented.

Social Dynamics.—It was common for several grizzly bears to feed on moths at the same time in close proximity. The largest congregation of bears we observed at one area was 23. On several occasions we observed as many as 9 bears feeding within an area of approximately 50-m diameter. During feeding periods, they traversed an area from side to side and up and down, resulting in a continuous intermingling among all age and sex classes.

Despite the relatively large number of bears that routinely fed in close proximity, very little social tension was apparent. Although agonistic behavior was generally rare, females with cubs appeared to be the most aggressive of all cohorts. They occasionally displaced subadults from specific excavation sites by either walking rapidly or running towards the site. The displaced subadult generally began searching for new excavation sites within 20 m. Only twice did we observed a female with cubs chase a subadult for more than 50 m from an excavation site.

Females with cubs routinely fed in the presence of adult males. Cubs-of-the-year fed independently and occasionally ventured more than 50 m away from their mother. On several occasions, we observed other bears come between a female and her cubs with no apparent reaction from the bears involved. However, twice we observed females charge adult males who came between her and her cubs. Although no physical contact was made in either case, the females remained next to the males with an aggressive posture, ears back, teeth showing, and roaring, until the males moved away, at which time the females resumed feeding.

Adult males were not aggressive towards adult females or their cubs and on several occasions they appeared to avoid interacting with females with cubs by feeding around them or moving out of their way. Adult males were also nonaggressive towards subadults, although subadults generally moved around an approaching adult male thereby avoiding overt aggressive encounters.

There were only 4 aggressive encounters observed between adult males. In each case an adult male displaced another adult to claim a specific excavation site, using a similar method to that adapted by females with cubs to displace subadults.

We recognized several individual bears at 2 of the ground observation areas and were able to follow their daily activities during most of the season in 1991. We occasionally observed other bears, including all age and sex classes, that were unfamiliar to us. We classified these bears as transients because they only remained at an area for a day or 2 before disappearing.

Transient bears, especially subadults and females with young, generally fed near the edge of the talus fields thus avoiding close contact with the resident bears. They also spent a larger amount of time looking at other bears whereas the resident bears spent most of their time looking for pockets of moths, excavating, or feeding, and rarely looked at each other. The reaction of transient adult males to the residents were mixed. Some intermingled with the residents whereas others were more cautious and remained near the edges.

We made 12 observations of moth-eating black bears from the ground at one of the moth-aggregation areas and 7 aerial observations of black bears at 3 other areas. Black bears also fed crepuscularly but all age and sex classes appeared cautious and fed on the edges of the talus fields when grizzlies were present. Grizzly bears were not aggressive towards black bears on the talus fields, although black bears avoided overt aggressive interaction by retreating when a grizzly approached.

Other Activities

Bears spent the majority of their active periods at the moth-aggregation areas feeding (>85%), but play was a significant behavioral component for both subadults (10%) and family groups (6%). Snowfields appeared to stimulate play in both groups, and even adult males on rare occasions (<1%).

Snowfields were also used for a variety of other purposes. Bears appeared to prefer them as travel lanes compared to adjacent rock. They also ate snow, commonly laid on snow for brief rest periods during their feeding sessions, and occasionally dug daybeds in snow and rested during the middle of the day. Several adult males were also observed to lie down upon a snowfield and thrust their pelvis repeatedly into the snow.

Steep snowfields extending to the upper regions of the talus fields were used to gain access to the rocky ledges and caves that were used for daybeds. Bears were cautious when they descended extremely steep sections of snow and backed down while keeping at least 1 paw firmly anchored into the snow. When the snowfield became less steep, they commonly turned and descended head first, sometimes sliding or running, but when they began going too fast or neared the bottom they spun around backwards and stopped by forcing their front claws deep into the snow.

Throughout each summer, individual bears in all age and sex classes were observed feeding at several sites within each of our study areas, sometimes within the same day. Steep ridges and rock walls separating several of these feed sites were negotiated with little difficulty and bears had well established travel routes they used when going from one site to another within an area.

Hazards.—Because of the extreme topographical relief and high elevations characteristic of the moth feeding areas, bears were exposed to significant environmental and physical hazards. Lightning storms were common to the study area throughout the summers and bears were exposed to nearby ground strikes. However, they continued feeding throughout the most severe weather conditions, including lightning, hail, and snow, and were never observed to stop feeding and leave the slopes to seek shelter during such conditions.

Rocks dislodged from natural erosion, from mountain sheep (*Ovis canadensis*), and from bears represented a significant risk of injury for moth-eating bears. They were usually aware of the frequent rockfalls above and most of the time were able to jump clear of danger. However, we occasionally saw bears who were struck, sometimes by rock from above and sometimes by the rocks that they dislodged. Most of these injuries were minor but we observed an adult female black bear who was crushed to death when the large boulder she was digging underneath became dislodged and fell on top of her.

DISCUSSION

Army cutworm moths have 1 generation per year (Pruess 1967). Each fall adult females lay their eggs in the soil at lower elevations throughout the Great Plains. Larvae undergo several instars during winter hibernation and emerge in early spring as the army cutworm. The cutworm feeds on leafy plants, including commercial crops such as wheat, barley, oats, sugarbeets, and alfalfa, and are sprayed with pesticides to reduce crop damage (Morrill and Borchers 1986).

After feeding for several weeks, the cutworm larvae form cells underground where they enter the pupal stage and emerge as adult moths around the first part of summer. Shortly thereafter, they migrate in massive numbers to distant alpine habitats where they stay during the summer (Pepper 1932, Koerwitz and Pruess 1964, Kendall 1981). They have been reported to travel as far as 470 km (300 miles) from the Plains each summer (Pruess 1967). The exact distances they travel from the plains may be even greater. As an example, a marking experiment with the oriental army cutworm moth (*Pseudaletia separata*) of China revealed they migrated at least 1,400 km (870 miles) each summer to the mountains, and traveled at a rate of about 150 to 200 km (95 to 125 miles) each day during migration (Baker 1991).

Earlier researchers believed that army cutworm moths aestivated during their summer stay in the alpine regions (Cook 1927, Pepper 1932, Chapman et al. 1955) but subsequent studies found evidence to suggest they remained active (Pruess 1967, Kendall 1981). Metabolic studies provide strong evidence that army cutworm moths are active during the summer in the alpine. Kendall (1981) reported that the abdominal fat content of army cutworm moths was about 30% when they first arrive in the mountains of Colorado in the spring and increased linearly throughout the summer to about 70% by the time they left the mountains in September.

The army cutworm moths we observed during this study were obviously active during their alpine stay and also appeared to play an important role in alpine ecology. They fed on and pollinated a variety of flowers. Based upon these observations combined with Kendall's metabolic studies, we believe army cutworm moths convert ingested flower nectar to body fat. Army cutworm moths were also observed being preyed upon by black and grizzly bears, coyotes (*Canis latrans*), ravens (*Corvus corax*), American pipits (*Anthus spinoletta*), mountain bluebirds (*Sialia curricoides*), owls (species not identified), and bats (probably *Myotis lucifugus*).

Both sexes of army cutworm moths return to the Plains in the fall where the adult females lay their eggs

(Pruess 1967). Only rare observations of copulation have been reported by moths in the mountains (Kendall 1981) but Pruess (1967) found that females returning to the Plains in the fall had mature eggs and concluded they mated sometime prior to their arrival. Based upon our observations of moths copulating both at nectar feeding sites and at daytime aggregation sites, we believe that a significant amount of reproductive behavior occurs during their alpine stay. The rise in fat content (Kendall 1981) not only provides energetic substrate needed for fall migration, but may also be important for sexual maturation and thus stimulate reproductive behavior.

The army cutworm moth is probably a native species in the temperate zones in North America. Although taxonomic classifications of moths have changed during the past 100 years, the Northern Army Worm Moth is at least an ecological equivalent if not the same species as the army cutworm moth described by Holland in 1903 (1968). This moth has been reported in North America for a least 200 years and was distributed from the Atlantic to the Rocky Mountains and from Canada to Texas. It was first noted to cause major crop damage in great numbers as early as 1743 in the New England area, and in 1861 caused massive crop damages in southern Illinois and Missouri (Holland 1968).

The army cutworm moth was well documented in the general area of the Yellowstone ecosystem prior to the establishment of large-scale agriculture development and human settlement. Previously classified as *Chorizagrotis auxiliaris*, this moth was present in significant numbers in several western regions in the first part of this century, including Montana (Cooley 1908), Colorado (Gillette 1904), and Canada (Strickland 1916).

Humans currently play a major role in the ecology of the army cutworm moth but the net effect this has on the availability of alpine aggregations of army cutworm moths for bears is not known. Extensive agriculture development of the Great Plains during the past 100 years has dramatically altered the native vegetation and thus the army cutworms' lowland habitat. And current pest control measures directed toward the larvae may influence the numbers of adults that migrate to the alpine regions each summer.

Grizzly bear use of alpine aggregations of army cutworm moths is not confined to the Yellowstone ecosystem, but the magnitude of this feeding behavior is greater than reported in other places, in terms of the total number of moth-aggregation areas and the number of moth-eating bears. However, other areas have not been studied as extensively so a direct comparison is difficult.

Grizzly bears have been reported to feed on army cutworm moths in talus slopes below a single peak in the Mission Mountains (Chapman et al. 1955; Servheen 1983; Klaver et al. 1986) but less than 10 bears have been observed feeding at this site each year during the past decade (James Claar, biologist, U.S. Dep. of Agric. [USDA] Forest Service, pers. commun.). Katherine Kendall (biologist, U.S. Dep. of Inter. Nat. Park Serv., pers. commun.) has observed grizzly bears excavating for extended periods in several talus slopes in Glacier National Park and believes they are feeding on moths. And moths identified only as "belonging to the Family Noctuidae" were reportedly fed on by bears in higher elevation rock slides in the Scapegoat Wilderness, although it was unclear how this feeding behavior was documented (Craighead et al. 1982).

There are insufficient historical records to determine how long grizzly bears in the Yellowstone ecosystem have fed on alpine aggregations of army cutworm moths. Although the first scientific documentation of this feeding behavior in this ecosystem occurred in 1987, locations of radio-instrumented bears and incidental aerial observations of unmarked bears in rocky alpine regions suggest that some bears may have been feeding on moths since at least 1981 (Mattson et al. 1991).

There is some evidence that bears may have fed on moths in the Yellowstone ecosystem long before it became apparent to the scientific community. Local outfitters we interviewed recalled seeing bears feeding in the alpine talus on "moths," "bugs," and "insects" since at least the early 1950s. Some reported they killed several bears at these sites prior to the cessation of legal sport hunting in the Yellowstone ecosystem in 1975. However, legal hunting of grizzly bears may have suppressed this feeding behavior by reducing the concentration of bears living near the known current moth-feeding areas and opportunistically killing moth-feeding bears who were vulnerable to hunters when they fed on the open talus slopes.

We are unable to determine if grizzly bear use of army cutworm moths in the Yellowstone ecosystem has increased during the past few years. The effort to observe this feeding behavior has obviously increased in recent years, both from the ground and from the air. Observation flights made prior to this study did not take into consideration the daily feeding patterns. As an example, in 1991 more than 50% of the aerial observations of bears at the moth-aggregation areas occurred between the hours of 0900 and 1100, the period when most bears became inactive. Therefore it is not possible to accurately calculate and compare observation success rates from previous years to quantify any change in the observation of this feeding behavior.

Aerial monitoring of this feeding behavior is definitely more efficient than ground observations although aerial observers who pass over a slope within a few minutes are not as accurate as ground observers who spend several hours scanning the slopes with spotting scopes. Aerial monitoring is possibly the best way to monitor adult female use of army cutworm moths especially since monitoring appears biased towards the observation of family groups.

Moth aggregations appear to be important for all age and sex classes of bears. Klaver et al. (1986) speculated that moth-aggregation areas in the Mission Mountains were used primarily by subordinate bears, such as females with young and subadults, to avoid adult males during the summer months. Mattson et al. (1991) speculated that subadults were underrepresented at the moth-aggregation areas in the Absaroka Mountains based upon aerial observations. However, we demonstrated that aerial observations were inadequate to accurately differentiate between single adult and single subadult bears. Therefore, our study did not support either of these hypotheses.

It was interesting to note the discrepancy between the observed feeding activity and the scat content. Ninety-five percent of the observed feeding activity was directed towards moths, and although moths were found in 84% of the collected scat, they composed a disproportionately low 34% of the scat volume. In contrast only 5% of the observed feeding activity was directed towards grazing, but graminoids were found in 85% of the scats and represented 51% of the scat volume.

There are several possible explanations for the discrepancy between observed feeding activity and scat content. Observations of feeding activity were precluded at night when bears may have moved off the rocky slopes to feed on grasses. Bears may have also fed more on grasses when they left the alpine regions out of our sight but defecated when they returned. Moth scats may have been more likely to become buried within the extensive excavations that occurred in the talus fields. However, we believe the major explanation of this discrepancy lies within the differences between the digestibility and caloric concentration of the 2 foods. Moths are a more concentrated form of energy and are probably more digestible than grasses and therefore contribute more ingested calories per unit weight and volume than grasses.

This study clearly demonstrates that alpine aggregations of army cutworm moths are an important food for many grizzly bears in the Yellowstone ecosystem. They also appear especially important to adult females since each moth-feeding area contained from 1 to 3 distinctive family groups throughout each moth feeding season during this study. Moths are also valuable to bears because they are high in energy, abundant, concentrated, easily obtained, and are available in relatively remote locations that serve to reduce potential human-bear conflicts during the peak tourist season. And finally, moths are important because they are available during hyperphagia, a metabolic stage that begins in mid-July when grizzly bears increase their feeding activity to accumulate fat reserves required for winter hibernation (Nelson et al. 1980).

RECOMMENDATIONS

Moth Ecology

Further study is needed to determine where army cutworm moths originate prior to migration and how the agricultural practices in these areas affect annual moth populations. Of particular concern is the potential that adult moths may harbor pesticide residues that may be contaminating the alpine ecosystems and watersheds and may also bioconcentrate in individual grizzly bears who consume large numbers of moths each summer.

It is also important to develop a method to monitor the long-term availability of army cutworm moths in the Yellowstone ecosystem and determine how climate affects the annual abundance and thus availability of moths to bears. Moth traps located in adjacent alpine and subalpine flower communities appears to be the most practical and reliable method. A grid system of traps could be placed in selected areas to ensure adequate sampling since the period of nectar production varies among plant species and is determined in part by slope, aspect, elevation, canopy, and moisture. Moth collections should also be made at regular intervals each year to determine an index of seasonal and annual abundance. This method could also be used to survey other potential areas to determine the presence of moths.

Bear Ecology

A trapping and monitoring project is needed to evaluate the population and social dynamics of moth-feeding grizzly bears, and to determine their movements, distribution, and habitat use to further define the significance of this feeding behavior.

A survey is needed to locate other moth-aggregation areas in this ecosystem that may be used by bears. Until this survey is completed, we feel that any area that meets the criteria of our predictive model should be excluded from developments or other activities that may preclude bear use until it has been fully evaluated.

Observation flights are useful to monitor the level of bear use at known moth-aggregation areas. However, based upon the crepuscular feeding pattern of bears, we recommend that observation flights be made at first light before bears become inactive and less visible during the day to increase aerial observation efficiency. Since transient bears, especially adult males, may use more than 1 moth feeding area, we further recommend that observation flights be made over all known areas on the same day to preclude duplicate counts. This would allow a more accurate determination of the total use of these areas by the Yellowstone grizzly bear population.

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