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Case Study

Grizzly bears and humans at alpine moth sites in Wyoming, USA

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Abstract: Army cutworm moths (*Euxoa auxiliaris*; moths) are an important seasonal higher elevational food source for grizzly bears (*Ursus arctos horribilis*; bears) in the Greater Yellowstone Ecosystem (Wyoming, Montana, and Idaho, USA). Increased human interaction with bears at moth sites is an important management issue because of the potential for displacing bears and the concern for human safety. Managers will need better information regarding human–bear interactions at high-density moth sites that are also accessible to humans to mitigate potential conflicts. In the summers of 2017 and 2018, we studied human–bear interactions at 2 of the most human accessible moth sites in the Shoshone National Forest, Wyoming. We completed 293 bear surveys and documented 266 bear observations. We also recorded human-use levels at the 2 study sites (north site: 3 groups/year; south site: 35 groups/year). We documented 43 interactions (at the south site only) and obtained location data for 29 interactions. During human–bear interactions, bears strongly avoided humans 80% of the time and had no apparent reaction 20% of the time. Our results indicated that human safety and bear displacement are valid management concerns at the south site. Human safety concerns were most apparent in mountain climbing groups with small group sizes (<4 people, n = 64/70) that were unprepared for encounters with bears. Management concerns for human safety and bear displacement are much lower at the north site. We recommend placing information kiosks at trailheads to inform hikers of dangers associated with grizzly bear concentrations on moth sites.

Key words: army cutworm moths, *Euxoa auxiliaris*, Greater Yellowstone Ecosystem, grizzly bears, human–bear interactions, safety, *Ursus arctos horribilis*, wildlife conflicts, Wyoming

Army cutworm moths (*Euxoa auxiliaris*; moths) are an important food source for grizzly bears (*Ursus arctos horribilis*; bears) in the Greater Yellowstone Ecosystem (GYE), Wyoming, Montana, and Idaho, USA (Mattson et al. 1991, French et al. 1994, O'Brien and Lindzey 1994). Every summer, millions of moths migrate to high elevation talus slopes throughout the Rocky Mountains from low elevation agricultural areas (Burton et al. 1980). Migration occurs because the moths cannot withstand the high summertime temperatures at lower elevations (Pruess 1967, Burton et al. 1980). While in the alpine region, this nocturnal species feeds on flower nectar at night and aggregates within the interstitial spaces of talus during the day (Kendall and Kevan 1981, White et al. 1998*b*).

Bears travel to the talus slopes to forage on the aggregated moths from July to September (Chapman et al. 1955, Klaver et al. 1985, Mattson et al. 1991, French et al. 1994, O'Brien and Lindzey 1994; Figure 1). Not only are moths abundant at this time, but they have the highest gross energy of all food sources available to GYE bears (French et al. 1994, Gunther et al. 2014). Furthermore, the moths are available during early onset of fall hyperphagia, an important feeding period in preparation for winter hibernation (Schwartz et al. 2003, White et al. 2017). Vegetation has been documented as an additional food source at these sites, possibly when moths are less abundant or unavailable (e.g., before seasonal arrival or when dispersed at night foraging nectar; French et al. 1994,

Figure 1. Grizzly bear (*Ursus arctos horribilis*) family group foraging army cutworm moths (*Euxoa auxiliaris*) at the south site peak in the Shoshone National Forest, Wyoming, USA, 2017 (*photo courtesy of F. Thomas*).

O'Brien and Lindzey 1994). However, the roots and tubers of several high-elevation plants are likely important food resources. Availability of multiple high-calorie food resources reinforces the importance of these sites to GYE grizzly bears (Lozano 2022).

Grizzly bears foraging at moth sites were first documented in the GYE in 1986 during aerial telemetry flights conducted by the Interagency Grizzly Bear Study Team (IGBST; Mattson et al. 1991). Management agencies have since documented 34 moth sites with confirmed bear use in the GYE. All are within the Absaroka Mountains, Wyoming, spanning 2 national forests (Shoshone, Bridger-Teton), 3 wilderness areas (Washakie, North Absaroka, Teton), Yellowstone National Park, and the Wind River Indian Reservation (IGBST 2018, Bjornlie and Haroldson 2020).

Routine observation flights have documented an increase in bear use at these sites since initial discovery (Bjornlie and Haroldson 2020). O'Brien and Lindzey (1994) estimated that up to 44% of the GYE grizzly population utilized these moth sites, including around half of observed sow and cub groups. However, grizzly bears have high sightability at moth sites compared to other habitats, likely inflating that estimate (O'Brien and Lindzey 1998,Robison 2009,Bjornlie and Haroldson 2020). In comparison, the IGBST has recorded 1,334 unique females with cubs since 1986, 384 (28.8%) of which have occurred at or near moth sites (Bjornlie and Haroldson 2020). The current proportion of the GYE grizzly bear population using moth sites is not known, but it is clear that these locations provide foraging opportunities for a significant number of grizzly bears.

Moth sites not only concentrate bears, but they can attract humans as well (Klaver et al. 1985). The phenomenon of bears foraging on moths has been recognized for its bear viewing potential, an increasingly popular recreational activity in North America (Herrero et al. 2005, Fortin et al. 2016, and Penteriani et al. 2017). In the GYE, there has been a documented increase in human interest associated with moth sites. Since 2007, Shoshone National Forest (SNF) staff recorded increased interest in special use filming permits and permitted outfitting that recognizes the unique business potential provided by bear viewing. Evidence from 1 mountain peak log associated with a moth site indicates increased human use as well; entries amounted to <1 entry per year prior to 2003 compared to 60 entries in 2016.

Overlapping human and grizzly bear use at moth sites generates several potential management concerns. Two studies from outside the GYE in northwestern Montana specifically identified this issue at moth sites (Klaver et al. 1985, White et al. 1999). Both studies identified unaware mountain climbing groups, not bear viewers, traveling through moth sites to reach a summit. These 2 studies highlighted site-specific differences in human use while identifying fundamentally similar management concerns: bear disturbance, human safety, and bear habituation to human presence. As a result of these 2 studies, human access was seasonally restricted at 1 site while access remains unrestricted at the other (Klaver et al. 1985, White et al. 1999).

Currently, there are no specific management plans for moth sites within the GYE. Managers have recognized the potential vulnerabilities of foraging grizzly bears at these exposed alpine sites, particularly regarding human use of the same areas. There is limited literature to help guide management decisions. Only 6 studies have been conducted at GYE moth sites, and none have specifically focused on human use (Mattson et al. 1991, French et al. 1994, O'Brien and Lindzey 1994, Robison 2009, Dittemore 2022, Lozano 2022).

As a result, managers in the GYE have recognized that a better understanding of human

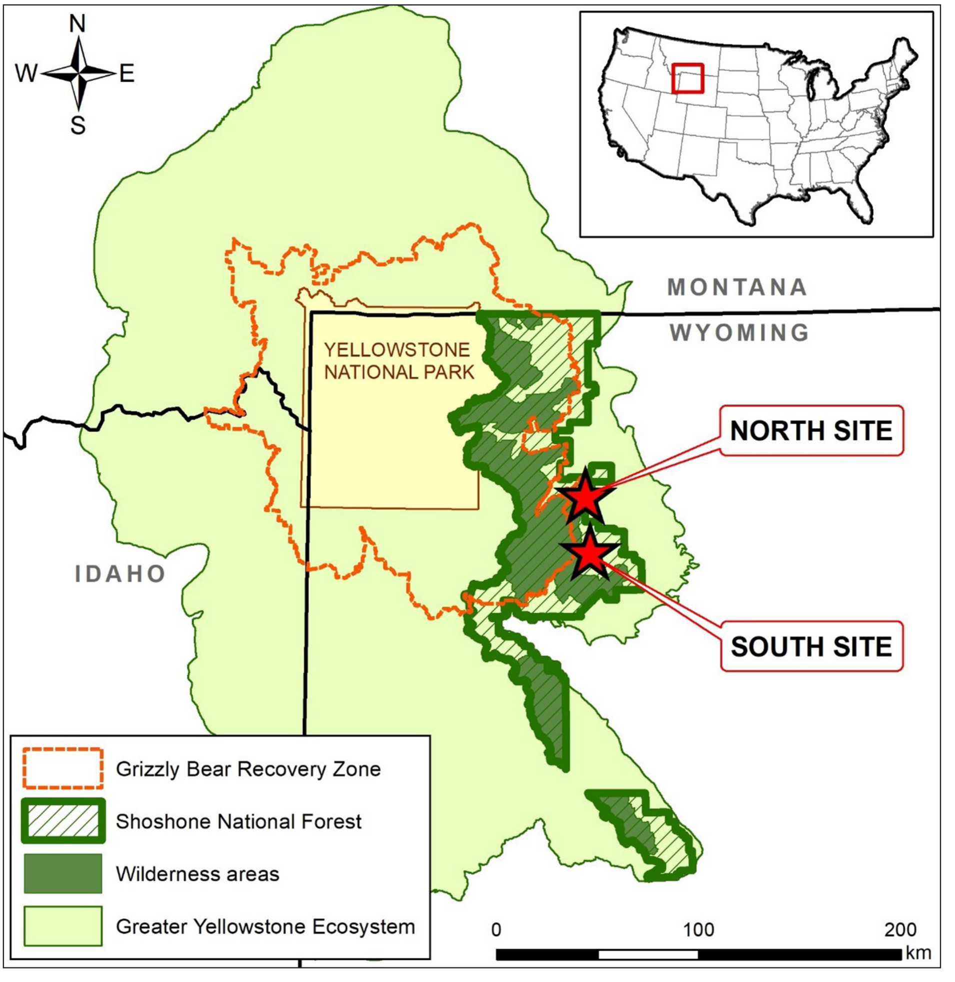

Figure 2. Location of north and south army cutworm moth (*Euxoa auxiliaris*) aggregation sites used to study human–grizzly bear (*Ursus arctos horribilis*) interactions in the Shoshone National Forest, Wyoming, USA.

and bear use dynamics at moth sites is required to inform management of these ecologically important grizzly bear foraging sites. The revised Land Management Plan for the SNF directed the U.S. Forest Service (USFS) to work with other agencies and institutions to gain knowledge of human and grizzly bear interactions at moth sites, as well as other aspects of moth site ecology needed to facilitate management (TES-GOAL-04; USFS 2015). Furthermore, it was identified in 2010 as 1 of 3 top research priorities by the IGBST and USFS related to land management activities in the GYE. Subsequently, staff from the USFS, U.S. Geological Service Northern Rockies Science Center, and Montana State University (MSU) jointly developed research objectives to improve our understanding of moth ecology, the ecology of grizzly bear use of moth sites, and the effects of human activities on foraging grizzly bears. This same staff is interpreting the findings of these studies for agency managers and the public.

Understanding the effects of human activities at moth sites was identified as the highest priority among these objectives. The specific objectives of this project were to quantify and map: (1) bear use at the most human-accessible moth sites, (2) human use at the most human-accessible moth sites, and (3) human–bear interactions at the most human-accessible moth sites.

The results from this project will help inform proactive management decisions regarding moth sites in the GYE. This information will also inform the public who use these sites of the safety risks.

Study area

Our study focused on 2 of the most human-accessible moth sites in the GYE, identified from a modeling approach described by Nunlist (2020). The 2 moth sites were in the Absaroka Mountains, Wyoming, on the SNF (Figure 2). Management concerns associated with human and bear use at these sites require that they remained unnamed; thus, we will refer to them as the "north site" and "south site."

Volcanic activity initially formed the Absaroka Mountains and glacial erosion shaped the range (Sundell 1993, French et al. 1994, O'Brien and Lindzey 1994). The combination of these geologic processes has produced ample talus formation and ideal areas for the large aggregations of moths. Moth aggregations are often found on moderately steep slopes (30–40°) beneath headwalls or rocky outcrops that contribute to continual talus formation. Talus size and depth varies across moth sites but generally consists of medium-sized (8–40 cm in diameter), angular to rounded, volcanic or sedimentary rock varying in depth from 10 cm to >100 cm (Mattson et al. 1991, French et al. 1994, O'Brien and Lindzey 1994, Robison 2009).

Snow cover limits access by vehicle to the Absaroka Mountains most of the year (National Aeronautics and Space Administration 2020, Natural Resources Conservation Service 2020), and we found that our sites were only consistently accessible for 2.5 months each summer (July 1 to September 15). Moderate to strong southwest winds (10–30 kph) were typical, often resulting in mid-afternoon thunderstorms sometimes accompanied by severe lightning and bursts of heavy rain or hail (O'Brien and Lindzey 1994). Elevation at our sites ranged between 2,809 and 3,504 m with treeline typically around 3,110 m (O'Brien and Lindzey 1994, Robison 2009, USGS 2017). Mean July air temperature was 11°C, ranging between 2.8°C and 18°C, 2017 and 2018 (PRISM Climate Group 2020). Wind direction, topography, and snow accumulation influence the distribution and composition of plant communities observed in our study sites (O'Brien and Lindzey 1994, Nagy and Grabherr 2009). Although the talus slopes are mostly void of vegetation, the adjacent plateaus, leeward slopes, and protected saddles support abundant, low-growing herbaceous plant communities (O'Brien and Lindzey 1994).

Methods

Bear observations

We conducted surveys throughout our study sites to obtain bear location data. To define our survey extents, we used a polygon layer of moth sites provided by the IGBST that was derived from spatial data of moth sites from the last 30 years (IGBST 2018, Bjornlie and Haroldson 2020). Logistics and safety precluded randomized surveys across the moth sites. Instead, a view shed analysis in ArcMap (ESRI 2018) was used to identify observation points and survey extents to maximize the total area within the moth sites surveyed (Nunlist 2020). Observation points and survey extents were refined during initial survey visits based on actual visibility and access safety. Final observation points and survey extents were revisited as many times as possible (3–5 times) each season for repeated surveys.

Each survey was conducted by 2 observers simultaneously and independently to validate bear location data. Prior to each survey, observers recorded date, start and end times, observer location, and any applicable notes. Surveys were conducted with 10x42 binoculars and 20–60x spotting scopes for 20 minutes, although more time was taken, if necessary, to complete the survey and enter all bear data. Observers had post-survey discussions to identify data inconsistencies and validate bear locations. We altered start times and travel routes each visit so that surveys were not conducted at the same time every visit. Field efforts were focused during morning hours (0400–1300 hours) for safety and logistical reasons.

Field computer tablets displaying survey viewsheds layered over an aerial photograph of the area and a custom program written in ArcPad 10.2.4 (ESRI 2016) allowed observers to record bear observations. Bear observations were defined as an independent individual or group of bears (i.e., a lone bear and family group were each considered 1 bear). We recorded bear locations observed within the survey extent during the survey period. We also recorded cohort, number of cubs, cub age, predominant activity (i.e., foraging moths, foraging vegetation, moving, sleeping, defense, playing, nursing), and time for all bear observations.

We opportunistically documented all bear sightings outside of the surveys using the field computers, as described above. We only recorded opportunistic observations for bears that we were confident had not already been documented that day based on unique identifying traits, location, and activity. If there was any uncertainty, the sighting was not recorded opportunistically to reduce potential count bias and data inaccuracies.

Distinguishing sex and age class in lone bears can be difficult; if there was any uncertainty about sex in our observations, the bear was classified as "unknown sex." Sex was only confirmed if we saw urination, genitalia, or mating behavior. Subadults can also be difficult to distinguish from adults; we classified subadults primarily on behavior (i.e., family group association, yet clearly independent) and size.

Human observations

Trailhead monitoring efforts were focused on Thursdays through Sundays when we anticipated the most human use at our study sites. Crew members arrived at the trailheads at least 30 minutes before sunrise and remained until 1400 hours, a time after which we assumed few or no new hiking groups would start. Crew members documented time spent at trailheads, all vehicle traffic, human hiking groups, and any other notes of interest during trailhead monitoring efforts. Additionally, verbal and/or written surveys of hiking groups were given to collect data on reason for trip, group size, and how they heard about the area. The MSU Institutional Review Board granted an exemption (2020) for the required human subject protocols since all the data were kept anonymous and could not be attributed to any particular person.

Peak logs (a notebook in a waterproof vessel) are often established at prominent high points so visitors can record their presence. We assumed peak logs would be used by most climbers, providing us with a useful data source to compare to our trailhead efforts and capture use we might not have otherwise. Because both of our study sites are associated with a peak or high point, we took advantage of existing peak logs (south site) or established a new peak log (north site) to document human use at high points. Peak logs were checked every 2 weeks to document human access. We added surveys to the peak log containers as well to gather additional information about users we may not have documented during our trailhead monitoring efforts. The surveys asked users to provide the following information: date, time, reason for trip, trailhead, group size, and general route to peak/high point.

Any human use at the moth sites observed outside the methods listed above were also recorded. These observations included people seen with binoculars or spotting scopes too far away to talk to, blog entries on peak climbing websites (http://www.summitpost.org, http://www.peakbagger.com), and human groups on game cameras intended to capture grizzly bear use.

Global Positioning System (GPS) tracking units were passed out to hiking groups to collect route data. The GPS tracking units were small, keychain-sized units programmed to log location data every minute for up to 12 hours (Qstarz 2013). To get the GPS units back from users, we installed drop boxes at each trailhead for people to leave the GPS units after their trip if we were no longer present. To further maximize our chances of getting the units back, we gave GPS carriers a prelabeled and posted envelope for return via post if they forgot to leave the GPS in the drop box.

Human–bear interactions

Human–bear interactions were defined as any perceived reaction by bears to human presence. Human–bear interaction data were collected through paper and/or verbal surveys during trailhead monitoring efforts and with a survey established with the peak log. Surveys gathered information from groups on number of bears observed, number of interactions, character of interactions, and location of interactions.

The crew also documented any interactions with bears experienced during field work. Crew members did as much as possible to reduce the likelihood of interactions and traveled in groups to increase safety. Location of crew and bear(s), date, time, bear activity prior to interaction, and bear response were recorded for all crew interactions.

Results

Bear observations

Fieldwork was conducted from July to September with 4 crew members for 2 summers. We spent 20 and 39 days conducting surveys from July 1 to September 15 in 2017 and 2018, respectively. We were able to survey 83% of the south site study area extent and 39% of the north site. Areas surveyed were limited by terrain features that affected access, crew safety, and potential for bear disturbance. We conducted 293 bear surveys (south site: n = 233; north site: n = 60) and observed grizzly bears in 76 surveys. We recorded 266 bears (south site: n = 227; north site: n = 39; Table 1) during surveys and an additional 220 bears opportunistically (south site: n = 200; north site: n = 20). Daily observations ranged from 0–20 bears (0–37 bears considering individual cubs) across both seasons. Bears were observed throughout both years, with most observations in July and August (Figure 3).

Across all bear locations, the most common activity observed was moth foraging (57%) followed by vegetation foraging (23%), moving/traveling (14%), sleeping (3%), defense (<1%), nursing (<1%), and playing (<1%). Bear activity across all observations appeared to vary as the season progressed. We documented proportionally more bears foraging on vegetation early in the season until mid-July when moth foraging became the primary activity (Figure 4). This pattern reflects the relative availability of food resources throughout the summer season with newly emerged and palatable vegetation in June and July until the peak moth occurrence in late July through mid-August, varying by year (Servheen 1983, French et al. 1994, White et al. 1998*b*).

We observed the highest concentrations of bears associated with moth foraging at the south site on warmer (S-SW aspects), moderately angled (20–30°), talus slopes with terrain features that contributed to talus accumulation and moisture retention. At the north site, we did not observe similar concentrations of bears, which we believe was largely due to sampling bias. Reports from SNF personnel indicate that bear use is much different, and often greater, in areas that we were not able to survey at the north site.

Human observations

Crew members cumulatively spent 21 and 85 crew-days monitoring trailheads in 2017 and 2018, respectively (Table 2). We documented 34 and 36 hiking groups (79, 93 people) at the south site in 2017 and 2018, respectively. At the north site, we documented 3 hiking groups in 2017 and 3 hiking groups in 2018. Average group size was 2–3 people, ranging from 1–12 people. We documented an average of 3.2 hiking groups per week (range 0–7 groups/week), with the most concentrated use in August during both years (Figure 5).

We recorded 2 post-trip surveys at the north site and 38 post-trip surveys at the south site across both years. We documented relatively high levels of human use along 1 route to the south site peak from the northern trailhead. All other routes across both sites saw little use.

Reasons for visitation at both sites are provided (Table 3); visitation was often dual purpose (i.e., climbing and bear viewing). We recorded 54 groups (77% of all observed hiking use) accessing the south site across both summers. Of these, 38 groups (54% of all documented hiking use) accessed the peak area. We documented no groups accessing the moth site area or peak at the northern site.

We documented both local and non-local groups utilizing the peak. Sources of information for groups visiting these sites often included word of mouth for local groups but also online climbing websites such as http://www.summitpost.org and http://www.peakbagger.com for many non-local groups.

Human–bear interactions

We recorded 43 interactions between visitors and bears at the south site and no interactions at the north site. We were able to collect approximate human location data for 29 of the interactions. Most interactions occurred around the summit (14/29) or along the primary route to the peak from the northern trailhead (12/29). No interactions resulted in physical harm to humans or bears.

Our surveys indicated that 80% of the interactions resulted in grizzly bears running or walking away from humans and the other 20% resulted in bears obviously noticing humans but returning to prior activity. Bear activity prior to disturbance was captured in half of the surveys in which bears foraging moths were most frequently involved (9/43), followed by bears moving (4/43) and foraging vegetation (3/43). Across all interactions, 44% (19/43) involved sows with cubs, 21% (9/43) involved lone adults, 19% (8/43) involved subadults, and bear cohort was unknown in 16% (7/43) of the

Table 1. Grizzly bear (*Ursus arctos horribilis*)observations from north and south army cutworm moth (*Euxoa auxiliaris*) sites in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

	Number of days conducting surveys		Number of bears observed	
	2017	2018	2017	2018
North site	7	11	15	24
South site	21	24	69	158

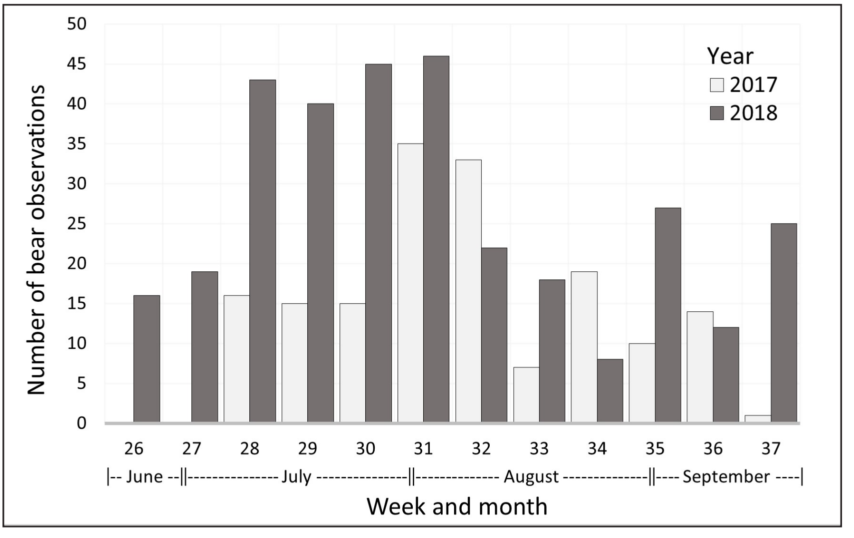

Figure 3. Total combined number of grizzly bear (*Ursus arctos horribilis*) observations from north and south army cutworm moth (*Euxoa auxiliaris*) aggregation sites by week and month in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

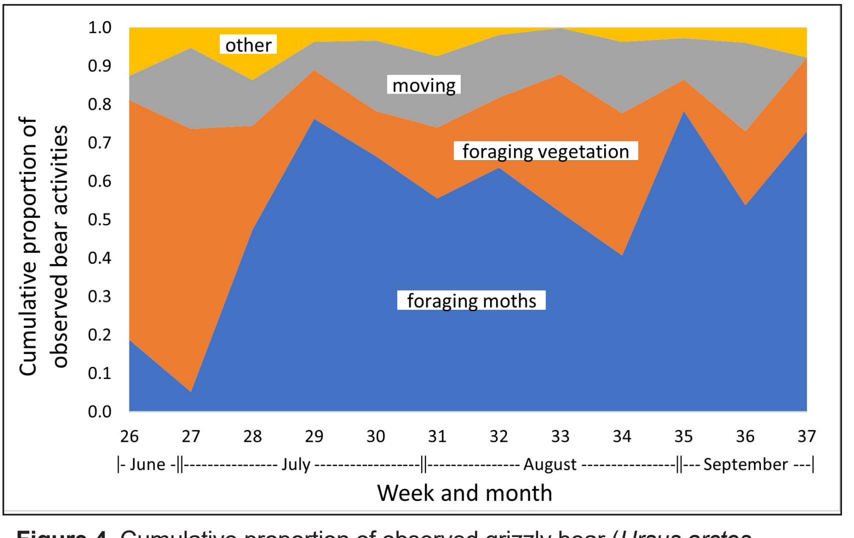

Figure 4. Cumulative proportion of observed grizzly bear (*Ursus arctos horribilis*) activity from north and south army cutworm moth (*Euxoa auxiliaris*) aggregation sites by week and month in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

Table 2. Trailhead monitoring of human activity from north and south sites associated with Army cutworm moth (*Euxoa auxiliaris*) sites in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

	Number of days trailhead monitoring		Hiking groups documented	
	2017	2018	2017	2018
North site	0	21	3	3
South site	20	65	34	36

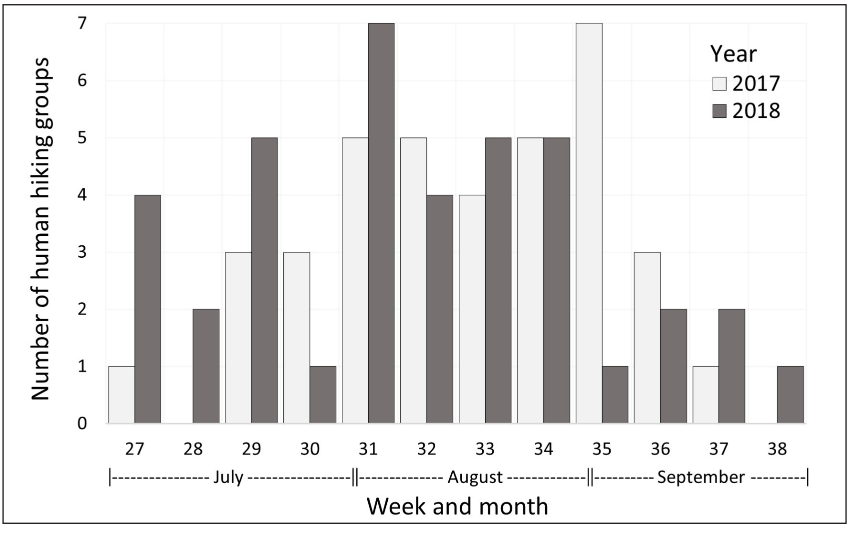

Figure 5. Total combined human use from north and south army cutworm moth (*Euxoa auxiliaris*) aggregation sites by week and month in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

Table 3. Primary reason(s) for visitation for hiking groups at the north and south army cutworm moth (*Euxoa auxiliaris*) sites in 2017 and 2018 in the Shoshone National Forest, Wyoming, USA.

Reason for visitation	North site (*n* = 6)	South site (*n* = 70)
Peak climbing	0%	59%
Bear viewing	0%	34%
Photography and film	0%	24%
Hunting	83%	29%
Day hiking	0%	12%
Other or unknown	17%	5%

interactions. Interactions were reported to occur at an average distance of 171 m but ranged from 9–1,000 m.

Although avoiding bear disturbance and maximizing crew safety were paramount, interactions were unavoidable while working in such an exposed environment with high grizzly bear density. The crew experienced 25 interactions with bears during 2017 and 2018. Interactions occurred at an average distance of 269 m but ranged from 40 to >1,000 m. Bears typically ran as soon as they sensed us, but some walked away unconcerned. Bears most often reacted to our presence after seeing us, but we documented 3 cases where bears scented our tracks or urine and rapidly left the area without ever seeing us.

Crew interactions were more dispersed than what we documented in public hiking groups. Since we knew the interaction hotspots near the south site peak, we were able to avoid many of the interactions with bear family groups. Instead, our interactions with bears tended to be on the periphery of the moth sites, in less predictable areas, with individuals foraging on vegetation (11/25) or traveling (11/25) to or from the moth site. Despite fewer interactions than visitors, we saw a slightly higher percentage (92%; 23/25) of bear displacement in our interactions. Of the 25 interactions, most (60%; 15/25) were with lone adults followed by family groups (20%; 5/25) and subadults (20%; 5/25).

Discussion

We observed bears at 2 moth sites from late June through mid-September in 2017 and 2018. We observed the most bear use from the second week of July through the second week of August both seasons. Peak bear use was similar to timing of peak moth captures in O'Brien and Lindzey (1994), which was reported to be between July 26 and August 6 in 1991 and 1992 in the GYE.

Because we did not conduct surveys throughout the day, bear activities reported here are only reflective of the dawn to early afternoon time period (0400–1300 hours). For this time period, bears foraging on moths was the most common activity, similar to what has been reported in previous studies (French et al. 1994, O'Brien and Lindzey 1994, White et al. 1998*a*). If we had been able to conduct surveys throughout the day and at night, we expect that we would have seen a shift in daily patterns following the availability and cost-efficiency of foraging for moths. For example, previous studies have reported that moth-related foraging activity almost completely subsides by mid-afternoon, reflective of moths becoming harder and less efficient to capture because moths crawl deeper into the talus in response to warmer mid-day temperatures or, if they are near the surface, they are more mobile and can take flight quickly (White et al. 1998*a*).

Anecdotally, we also observed this shift when trying to capture moths out of the talus after 1100 hours. Past that time, collection became notably less efficient. Previous studies have also reported a second moth foraging period during early-to-late evening when moths are near the surface staging for nocturnal activity; this is reportedly a less active bear foraging period and, again, probably reflective of the moths being less available due to their mobility (French et al. 1994, O'Brien and Lindzey 1994, White et al. 1998*a*).

To our knowledge, no one has quantified bear activities at night associated with moth sites. Unlike during the day when the moths are aggregated, they disperse at night to forage across large alpine meadows, making them largely unavailable to bears. O'Brien and Lindzey (1994) speculated that there could be increased vegetation foraging in response to moth unavailability based on the number of bears they observed on or returning from adjacent vegetation areas at dawn. We observed this pattern as well, particularly on the plateau south of the south site peak. Bear visits to camera traps we set up in vegetation areas adjacent to the moth sites occurred mostly from late afternoon (1600 hours) through early morning (0400 hours).

Although both of our study sites had similar human accessibility, we saw different levels of human use between sites (south site: 35 groups/year; north site: 3 groups/year). At the south site, this level of use translated to 3.2 groups a week, with up to 7 groups per week on 2 occasions, or a group every other day. We suspect this is a conservative estimate of human use because we likely missed some despite methodology to capture use on the days we were not at trailheads (e.g., peak logs). For example, we documented that at least 8 (of 38) groups that made it to the peak did not sign the peak log. Human-use levels reported here will likely under-represent future levels based on apparent increasing human-use trends at the south site and the increasing popularity of outdoor recreation overall (Fortin et al. 2016, Penteriani et al. 2017). The level of use observed at the south site may initially seem low, but their effects are likely amplified considering the open terrain of these sites (O'Brien and Lindzey 1994, White et al. 1999). This was readily apparent from some of our interaction data where we recorded bear displacement from far distances (~1 km), displacement from human scent (urine or tracks from hours prior), and strong avoidance reactions (bears running across drainages for >1 km until out of sight).

Differences in observed human-use levels between sites were largely due to reasons for visitation. At the north site, the only documented reason for visitation was bighorn sheep (*Ovis* *canadensis*) hunting. In contrast, the south site generated interest for several reasons. Use was primarily associated with peak climbing and/or bear viewing, but also photography, day hiking, and hunting for mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*) and bighorn sheep. Because we saw so much human interest in peak climbing, we found climbing websites (http://www.peakbagger.com, http://www.summitpost.org) to be helpful in providing insight on human use. In particular, http://www.summitpost.org reported the number of views of the peak information webpage and contained comments from visitors, providing a great indicator of public interest. Any future work concerned with human use at moth sites should consider reviewing climbing websites.

There were no maintained routes or trails at either of our study sites. As a result, human-use routes were affected by reason for visitation. At the north site, use was associated with hunting, and people did not access the moth site area. Similarly, human use associated with hunting at the south site was dispersed and typically did not overlap with the moth site area. However, human use associated with peak climbing and/or bear viewing was concentrated on 1 primary ridge route from the northern trailhead.

Although there are several routes to the south site peak, use was concentrated on the ridge route because many groups were obtaining access information from climbing websites (http://www.peakbagger.com, http://www.summitpost.org) where this route is recommended. The ridge route is popular because it is the most scenic, straightforward, and efficient route to the south site peak. However, this route has the highest potential for interactions with bears. The route takes hikers along a relatively narrow ridge where there is a well-defined game trail often peppered with bear scats. There are blind corners around rocky outcrops and hill crests as hikers travel along the ridge's undulations. Furthermore, the entire ridge route requires travel into the prevailing wind direction to access the peak, which reduces the chance of a bear smelling and avoiding hikers. Additionally, we observed that climbing websites provided little warning about the bear density other than the generally applied food storage requirements and traveling in bear country warnings. If climbing websites are a visitor's only information source, they may be unprepared for interactions with grizzly bears.

Human–bear interaction levels differed between our 2 study sites and corresponded to the primary reasons recorded for visiting each site, respectively. When human use was primarily related to peak climbing, human–bear interactions were much more likely. In this study, we documented no human–bear interactions at the north site where human use was solely related to hunting, while 43 interactions were documented at the south site across both seasons where human use was primarily related to peak climbing and/or bear viewing. As we documented no interactions at the north site, further discussion will focus on south site observations.

Management concerns for human safety, bear disturbance, and human habituation by bears were confirmed at the south site. Evidence of human safety concerns was most apparent with climbing groups. They were generally poorly prepared to travel in bear habitat, which may be attributed to the lack of bear information presented in climbing resources. We observed several climbing groups with no bear deterrent (bear spray or firearms) and most had <4 people (64/70). Solo travelers were common (24/70). The recommended group size when traveling through bear country is a minimum of 4 people (Parks Canada 2017). Herrero (2002) reported that bear-related injuries were more common in small parties of 1 or 2 people than larger parties. In an exhaustive review of bear attacks across North America, Herrero (2002) found no reports of attacks on groups of 6 or more people.

For some visitors, we were able to provide education at the trailheads, which resulted in groups changing plans or leaving. We documented potentially negative interactions between humans and bears among groups that did not receive this information. For example, a solo climber, climbing a peak of 12,000+ feet (3,658 m) for the first time, was unaware of the concentrated bear use until gaining the peak and reading the peak log. After reading how many people mentioned bears, the climber immediately noticed 3 bears on the slopes below. The clouds were low and dense that day, resulting in poor visibility, he was alone, had no bear spray, and was unaware of the concentrated bear use. This anecdote highlights the real concerns associated with human use at this site and underscores why solo hikers are especially vulnerable to bear attacks in North

America (Herrero 2002).

Bear disturbance was apparent in most human–bear interactions (visitors: 34/43; crews: 23/25). In these cases, we observed bears strongly avoiding human presence by running away, including >1 km flight distance. Bears were disturbed not only when they saw humans but also by lingering scent of urine or human tracks, as we documented in 3 cases. Importantly, disturbance can result in loss of calories from time spent not foraging and from the movements to avoid human presence. Considering grizzly bears have been estimated to eat up to 2,500 calories an hour, even a short period of disturbance could have a negative impact (White 1996, White et al. 1999). Anecdotally, many of the interactions we documented with public groups appeared to be with the same subadult pair or family group near the south site peak. If disturbance occurs repeatedly for the same individuals, as we documented, the calories lost over the course of a season are even more likely to have negative impacts.

In 20% of the interactions we documented, bears clearly noticed human presence but did not react, which raises concerns about potential habituation (Klaver et al. 1985). However, habituation is typically associated with much higher levels of human presence (i.e., along roadways), and we are uncertain whether the non-reactions we observed were actually human-habituated behavior or just a lack of concern due to the abundant food source. Alternatively, this non-reactionary behavior could be related to bear-to-bear habituation (Smith et al. 2005). Bear-to-bear habituation has been described where abundant food resources create high densities of bears, such as salmon streams, and can facilitate human habitation (Smith et al. 2005). Either way, human habituation may be a future concern if human use continues to increase.

If human use does continue to increase, more interactions will likely occur along the primary route and in areas currently seeing little or no human use. We anticipate this being particularly evident in vegetation feeding areas peripheral to moth sites that are also convenient for human travel. Similarly, travel routes between vegetative and moth resources where we observed copious amount of bear sign (tracks, scat, and observations) will likely see more overlap in human and bear use.

From our experience, any human use in or around vegetative areas or on well-used travel routes resulted in a high likelihood of bear disturbance. Crew members spent more time in these areas conducting surveys and experienced higher displacement rates (92% vs. 80%) than visitors. Our observations suggest that bears were sensitive and reactive to human presence in vegetative areas and travel routes. We speculate that distance to escape terrain and increased sense of vulnerability combined with high visibility contribute to this observation in the vegetation areas. Along the primary travel routes, we suspect the elevated chance of a surprise encounter (with another bear or humans) due to the blind corners and narrow travel corridors could also make bears more alert and consequently more reactive. During our field work, crew members ended up avoiding some of the larger vegetative areas where we found bear disturbance to be nearly unavoidable and limited our use of routes that were heavily used by bears. Similar observations were noted by O'Brien and Lindzey (1994) at other moth sites in the GYE.

Although many interactions were unpredictable or unavoidable in certain areas, several differences between public and crew interactions highlighted the advantage of understanding bear use patterns. For example, most public interactions occurred with bear family groups near the south site peak and were unexpected by public users. We had several groups report reactions such as, "we immediately turned around and left before reaching the peak." However, crew members learned to avoid most interactions around the peak, having routinely observed bears and their travel routes. As a result of increased awareness and preparedness, our crew had an average interaction distance of 269 m, which was nearly 100 m greater than the average distance of 171 m reported for public users. Furthermore, our closest encounters were 40 m versus the 9 m reported for public users. Regardless of user group, the closest encounters were invariably related to blind hill crests or corners near the peak or along the primary route at the south site.

Management implications

We saw different levels of human use between our study sites. Consequently, we suggest commensurate management responses. We documented 3 visitor groups per year at the north site. Most of this use was later in the season and involved bighorn sheep hunting. We did not record human use close to areas where bears were foraging for moths. Consequently, there is no apparent need for management intervention at this site. However, because it is one of the most human-accessible moth sites in the GYE, we recommend continued human-use monitoring.

We found that human safety, disturbance of bears, and possibly human habituation are legitimate management concerns at high human-use sites. In these areas, we recommend increased public education to inform visitors of the risks involved in traveling through the moth site as well as strategies to minimize these risks. This could be accomplished by information kiosks to warn visitors about bear densities and the potential for surprise encounters and to recommend a travel route to the peak that minimizes bear disturbance and human risk. The kiosk should also recommend carrying bear spray and hiking in groups of 3 or more. Climbing guides and other online resources are another mechanism for describing safe practices for traveling in bear country. This information should be crafted to avoid attracting bear viewing interest. This combination of strategies should increase the awareness of visitors traveling through the moth site. We also recommend continued human-use monitoring at moth and high human-use sites on weekends in July and August.

Although human-use levels are currently a management concern only at the south site, significant increases in recreational use levels have been observed across the GYE in recent years. Therefore, some level of human-use monitoring at moth sites will be necessary to inform management actions.

More direct methods of managing human use at moth sites could be considered in addition to educational efforts. Options could include restrictions on motorized access to moth sites to deter some users. A permit system might be considered to ensure future recreational opportunities. Seasonal closure of human access at specific sites could be considered. Under any scenario, public support for such restrictions would be an important factor in determining their success.

Grizzly bear hunting could be a future concern for moth site management if Endangered Species Act (ESA) protections for GYE grizzly bears are removed. Bears at moth sites could be vulnerable to hunting because they are concentrated at discrete sites and are highly visible. These concerns could be mitigated by setting hunting season dates that minimize overlap with bear use at moth sites. Bear hunting seasons typically do not occur during the July and August period when most bear use at moth sites occurs. For example, the Wyoming Game and Fish Department proposed a grizzly bear hunting season in 2018 during a period when bears had been delisted. The proposed season opening date was September 15, which is well past peak bear use, when most grizzly bears have left the moth sites. The hunt was not held due to a court ruling that reinstated ESA protections for the GYE grizzly bear population. There likely would have been little impact to bears using moth sites if the season had started as proposed.

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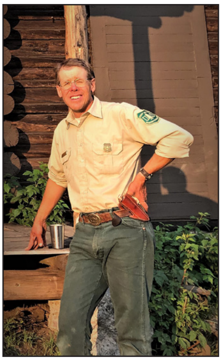

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