

Bear-caused human fatalities in Yellowstone National Park: characteristics and trends

KERRY A. GUNTHER, Bear Management Office, P.O. Box 168, Yellowstone National Park, WY 82190, USA kerry_gunther@nps.gov

Abstract: Three fatal bear (*Ursus* spp.) attacks in Yellowstone National Park (YNP), USA, from 2011 to 2015 were a catalyst for YNP managers to evaluate the circumstances of bear-caused fatalities as well as the bear safety messages it distributes to park visitors. I reviewed records of all fatal bear attacks that occurred in YNP from 1872 to 2018. Seven of the 8 fatalities were caused by grizzly bears (*U. arctos horribilis*). The per capita risk of being killed by a grizzly bear was 1 fatality for every 26.2 million park visits. Most fatal bear attacks in YNP involved surprise encounters and/or bears conditioned to human foods. Only 1 fatal bear attack was classified as predatory. Most fatal bear attacks involved men (75%), small party sizes of <3 people (88%), and occurred in remote backcountry areas (75%). Although the frequency of fatal bear attacks appears to have increased in recent years, the per capita risk of fatal bear attacks has declined. A few human behavioral modifications for recreating in bear country, including hiking with minimum group sizes ≥3 people, remaining on designated trails when hiking, not running from bears during encounters, and carrying bear spray when recreating in bear country have the potential to reduce the risk of fatal bear attacks in the park. Preventing bears from becoming conditioned to anthropogenic foods and garbage is another important factor in reducing bear-caused human fatalities.

Key words: American black bear, bear management, bear safety, fatal bear attacks, food-conditioned bears, grizzly bear, outdoor recreation, *Ursus americanus*, *Ursus arctos horribilis*, Yellowstone National Park

YELLOWSTONE NATIONAL PARK (YNP) has sympatric populations of grizzly bears (*Ursus arctos horribilis*; Figure 1) and American black bears (*U. americanus*; hereafter black bear; Figure 2). The park also attracts millions of human visitors annually, leading to frequent encounters between bears and people. On rare occasions, human–bear encounters result in fatal bear attacks. Although bear-caused human fatalities are rare, they generate worldwide media attention (television, radio, outdoor magazines, internet blogs, and social media posts) when they occur. Sensationalistic media coverage of these incidents, especially by social media outlets, often leads to fear and supposition being the primary influence on the public’s perceptions of the risk of being killed by bears (Craighead and Craighead 1972, Miller and Tutterrow 1999, Herrero et al. 2011, Penteriani et al. 2016, Smith and Herrero 2018, Støen et al. 2018, Conover 2019, Nanni et al. 2020). Review of the circumstances of fatal bear attacks, their causes and trends, can provide accurate information regarding the risk of fatal bear attacks. Knowledge of the factors contributing to fatal bear attacks may also

influence the public’s perceptions of the risk, motivate human behavioral changes to mitigate the risk, and generate further support for bear conservation (Gore et al. 2007, Herrero et al. 2011, Smith and Herrero 2018, Støen et al. 2018). If the public trusts that bear managers have rigorously tried to reduce the chances of fatal bear attacks through science-based management, they may better accept decisions regarding post-fatality bear management actions (Herrero et al. 2011), including lethal removal of bears involved in fatalities when necessary. In addition, science-based management decisions combined with comprehensive efforts to warn the public of the potential dangers incurred while recreating in bear country can protect state and federal land and wildlife management agencies from liability lawsuits that sometimes result from bear-caused human fatalities (Herrero 1976, Stringham 2013).

Here, I review all known fatal bear attacks that occurred inside YNP from its establishment in 1872 through 2018. My objectives were to: (1) identify potential causes and contributing factors in bear-caused human fatalities, (2) identify



Figure 1. A grizzly bear (*Ursus arctos horribilis*) in Yellowstone National Park, Wyoming, USA. Having evolved to exploit large non-forested landscapes, grizzly bears are behaviorally much more aggressive than American black bears (*U. americanus*) and more likely to defend themselves, their cubs, and their food when threatened by other bears, wolves (*Canis lupus*), or people (photo courtesy of D. Schneider, National Park Service).



Figure 2. An American black bear (*Ursus americanus*) in Yellowstone National Park, Wyoming, USA. Having evolved in forested habitats, black bears are much more timid than grizzly bears (*U. arctos horribilis*) and more likely to climb trees or flee into forest cover when reacting to perceived threats (photo courtesy of J. Hadley, National Park Service).

trends in the frequency of fatal bear attacks, and, (3) recommend potential actions to mitigate the risk of fatal bear attacks in the park.

Study area

Established in 1872, YNP encompasses 8,991 km² in the states of Wyoming (96%), Montana (3%), and Idaho (1%), USA (Figure 3). Most (~

99%) of YNP is relatively pristine, undeveloped land; 92% of the park has been recommended for wilderness designation and by National Park Service (NPS) policy is managed so as not to preclude that designation in the future (NPS 1974, 2006). Construction of roads and developments has altered <1% of the park's bear habitat.

During the study period (1872–2018), visitation to the park gradually increased from ~3,000 visits in 1872 to >4.1 million visits in 2018. The majority (>96%) of visitation occurred from May through October, the same time period when most bears of all sex and age classes were out of winter dens and active on the landscape (Haroldson et al. 2002). The YNP backcountry and its trail system are used extensively by overnight and day-use recreationists for hiking, horseback riding, sightseeing, fishing, bird watching, and photography.

The topography of YNP consists of high elevation plateaus and the mountain ranges that encircle them. Elevations range from 1,590–3,360 m; timberline occurs at 3,000 m (Despain 1990). Most of the park is between 2,100 and 2,750 m in the subalpine zone (Despain 1990). Approximately 80% of YNP is forested and 20% sagebrush/grasslands and graminoid/forb meadows. Vegetation cover types vary with elevation (Despain 1990). Lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) are typical on lower elevations (1,900–2,200 m). Subalpine fir (*Abies lasiocarpa*) stands predominate on mid-slopes (2,200–2,600 m). Whitebark pine (*Pinus albicaulis*) stands dominate on high elevation forested slopes (2,600–2,900 m). Non-forested, sagebrush dominated (*Artemisia tridentata*) complexes are prevalent on mid-elevation plateaus and low elevation valley bottoms. Mixed grass-sedge (*Carex* spp.) or grass-forb meadows are common along stream courses occurring at lower to mid-elevations.

Methods

Bear-caused human fatality data

I analyzed all recorded fatal bear attacks that occurred inside YNP from 1872 to 2018. I focused on fatal bear attacks because detailed descriptions of those events were readily available, even for incidents that occurred >100 years ago. During the early history of the park, its remoteness made communications difficult, and record keeping was not as high a priority



Figure 3. Yellowstone National Park is in portions of the states of Wyoming (96%), Montana (3%), and Idaho (1%), in the western United States.

as it is today; therefore, some early fatal attacks may not have been recorded (Whittlesey 2014) and thus may not be included in this study. I collected information on fatal bear attacks that occurred prior to 1979 from Schullery (1992), Etling (1997), Herrero (2002), McMillion (2012), Whittlesey (2014), Smith (2016), and Snow (2016). I gathered data on fatal bear attacks that occurred from 1979 to 2018 from NPS case incident reports, forensic investigation reports (Gunther 2012, 2015) and Board of Review reports (NPS 1984, 1986; Frey et al. 2011, 2012; Wilmot et al. 2016).

Front country recreation statistics

Recreational visits. I obtained data on total recreational visits (front country park visits through entrance stations) to YNP from the NPS Visitor Use Statistics web page (<https://irma.nps.gov/Stats/SSRSReports/YELL/Yellowstone>). Counts or estimates of the total number of recreational visits to YNP were available for the years 1872 to 2018.

Roadside campground overnight stays. I obtained records of the number of overnight stays

in designated roadside campgrounds from the NPS Visitor Use Statistics web page. These data were available for the years 1930 to 1934, 1941, 1943 to 1949, the 1950s, 1960 to 1964, 1975 to 1979, and 1980 to 2018. The total number of overnight stays in campgrounds was calculated by adding together the number of overnight stays in tent and RV sites in NPS-managed campgrounds, the number of tent and RV overnight stays in concessioner-operated campgrounds, and the number of overnight stays in campground group campsites.

Backcountry recreation statistics

Backcountry overnight stays. I obtained records of the number of people that traveled by foot, horse (*Equus caballus*), or boat to camp overnight in backcountry campsites and dispersed camping zones from the YNP Central Backcountry Office. Backcountry permit records of the number of people and number of nights spent in the backcountry were available for the years 1972 to 2018. Records of backcountry overnight stays for the years prior to 1992 did not distinguish the mode of travel used by backcountry camp-

ers (e.g., records of travel by foot, horse, and boat were all combined). Records from 1992 to 2018 distinguished the mode of travel for overnight backcountry recreationists. Backcountry overnight stays were calculated by multiplying the number of people in each group obtaining a backcountry permit by the number of nights spent camping in backcountry campsites. For example, a group of 3 people spending 2 nights in the backcountry is recorded as 6 overnight stays (3 people \times 2 nights in the backcountry = 6 overnight stays).

Hiker backcountry recreation days. Records of the number of overnight hikers that traveled by foot were available for the years 1992 to 2018. From those records, I was able to calculate the number of backpacker recreation days and to estimate the number of day-use recreation days for people traveling by foot. To calculate the number of recreation days backpackers spent hiking in the backcountry, I added the number of people in each party to the number of person use nights for each party. This method accounts for the last day of backpacking trips when backpackers hiked out to trailheads without spending the night. For example, 3 backpackers spending 2 nights in the backcountry would be spending 3 days on the trail or a total of 9 recreation days (number of people \times number of nights, plus number of people = backpacker recreation days; $3 \times 2 + 3 = 9$) in backcountry bear habitat.

Although YNP does not keep records of the number of people that day-hike in backcountry areas (including day-hiking for fishing, bird watching, sightseeing, photography, etc.), I was able to estimate the number of day-use backcountry recreation days. From bear spray surveys conducted at trailheads, Gunther et al. (2019) observed 13,782 day-use recreationists and 1,035 overnight backpackers, a ratio of 13.3 day-use recreationists for every 1 overnight backpacker. Multiplying the known number of backpackers (384,697) from backcountry permit records for the years 1992 to 2018, by 13.3, provided an estimate of the number of day-use backcountry recreation days (5,116,470) for that period. Combining the estimated number of day-use backcountry recreation days (5,116,470) with the number of backpacker recreation days (1,163,065) provided an estimate of the total number of backcountry recreation days (6,279,535) by foot travelers for the years

1992 to 2018. My estimate of backcountry recreation days assumes the ratio of day use to overnight use remained constant during the period 1992 to 2018.

Backcountry human–bear encounters. The YNP Bear Management Office maintains records of bear sightings by park visitors and staff voluntarily reported to visitor centers, ranger stations, and the Bear Management Office. Bear sighting records from 1991 to 2018 contain information on human–bear encounters. Not all bear sightings or human–bear encounters are reported to YNP.

Comparing bear-caused fatalities to other causes of death in YNP

To put the risk of fatal bear attack in YNP into perspective, I compared the number of people killed by bears in the park to the number of people that died inside the park from other causes, excluding heart attacks and motor vehicle accidents. Heart attacks and motor vehicle accidents are the most common causes of human fatalities in YNP; however, records of these fatalities were not readily available because the victims often die days later after being transported to hospitals outside the park for treatment. Statistics on non-bear related human fatalities within YNP from 1872 to 2013 are from Whittlesey (2014). I obtained records of non-bear related human fatalities that occurred in YNP from 2014 to 2018 from the YNP Emergency Services Office.

Trends in fatal bear attacks

To determine trends in the frequency of bear-caused fatalities, I grouped fatalities into 6 approximate quarter century time periods and calculated the per capita risk of fatal bear attack for each time period. I grouped the data into quarter century periods because the total number of fatalities was small ($n = 8$), the fatalities occurred over a long period of time (147 years), and park visitation has increased every decade but 1 since the park's establishment.

Definitions of terms used

Throughout this paper, the terms backcountry, front country, human–bear encounter, and park visit are defined as follows:

- *Backcountry:* all lands in YNP proposed for wilderness designation and all undevel-

oped lands >250 m from paved or gravel roads, developments, auto campgrounds, and roadside pull-outs (NPS 1994). Areas classified as backcountry included backcountry trails, backcountry campsites, and off-trail backcountry areas.

- *Front country*: all areas within or \leq 250 m of the impacted footprints of developments, auto campgrounds, paved or gravel roads, and roadside pull-outs (NPS 1994).
- *Human–bear encounter*: all reported incidents where people observed bears in backcountry areas and believed that the bear was mutually aware of their presence.
- *Park visit*: the number of recreational visitors entering YNP by road through one of the park’s 5 entrance stations. Visitors entering by bus, motorcycle, bicycle, foot, cross country skis, snowmobile, and snow coach were individually counted. Visitors entering by car or camper were estimated by using an inductive traffic counter and multiplying the number of vehicles entering the park by a seasonal person-per-vehicle multiplier (<https://irma.nps.gov/STATS/Reports/Park/YELL>). The seasonal multiplier is periodically recalibrated by conducting actual counts of the number of people-per-vehicle entering the park.

Categorizing the circumstances of fatal bear attacks

For each bear-caused fatality, I categorized the circumstances of the attack based on the bear’s behavior prior to, during, and after the attack. I classified the circumstances of fatal attacks as: (1) surprise encounter/defensive aggression, (2) defense of food/defensive aggression, (3) predation, (4) offensive aggression to gain access to people’s food, and (5) unknown. Definitions were modified from Herrero and Higgins (2003) and Herrero et al. (2011). Definitions are as follows:

- *Surprise encounter/defensive aggression*: incidents where the victim startled the bear, and the bear’s reaction to being startled led to the initial contact by the bear.
- *Defense of food/defensive aggression*: incidents where bears killed people while defending food they had possession of immediately prior to the encounter with the person they killed.

- *Predation*: incidents where the victim was followed or stalked prior to the attack. Fatality incidents were also classified as “predation” if the victim was not aware of the bear’s presence, the bear was aware of the victim’s presence, the bear was not startled by the victim, and the victim was then attacked, killed, and consumed by the bear.
- *Offensive aggression to gain access to anthropogenic foods*: incidents where the bear had a known previous history of seeking and obtaining human foods or garbage, there was anthropogenic food at the attack site, and the bear had directed some behavior toward exploring or consuming the food or edible garbage during, immediately prior, or after the attack.
- *Unknown*: in some incidents there were no witnesses to fatal attacks, and available evidence was insufficient to infer potential motivation for the attack. These incidents were classified as “unknown.”

Results and discussion

During the 147-year (1872–2018) study period, 8 people were killed by bears inside YNP (Table 1). Grizzly bears caused 7 of the fatalities and in 1 fatality the bear was never conclusively identified to species (some witnesses claimed it was a grizzly bear and others a black bear). There were no fatalities known to be caused by black bears during the study period. Six of the fatalities occurred in backcountry areas, 1 within a development, and 1 adjacent to a road corridor.

Common characteristics of fatal bear attacks

Geographic location. All 8 fatalities occurred in 3 geographic areas of the park. Four of the fatalities occurred within or near Hayden Valley, 2 within or near Pelican Valley, and 2 within or near the Old Faithful development complex. Hayden Valley and Pelican Valley are both large non-forested sagebrush-grassland/forb meadow land cover types with a diversity and abundance of bear foods, and both are known to support high densities of grizzlies (Hornocker 1962, Knight 1975, Graham 1978, Gunther 1991, Gunther and Haroldson 2020). The Old Faithful development complex is one of the largest

Table 1. Fatal bear (*Ursus* spp.) attacks that occurred inside of Yellowstone National Park, Wyoming, Montana, and Idaho, USA, 1872–2018.

Date, time	Gender, age	Location	Description of incident	Source
September 8, 1916; 0100 hours	Male, 61	Ten Mile Spring, near Turbid Lake at the southern end of Pelican Valley	Killed by a grizzly bear (<i>U. arctos horribilis</i>) while camping with 2 companions along road. The bear had been raiding campsites and had previously injured 2 people.	Whittlesey 2014, Snow 2016
August 23, 1942; 0145 hours	Female, 45	Old Faithful development rental cabins	Attacked and killed by a bear while walking alone from rental cabin to out-house in park development. The species of bear was never conclusively determined. The same bear was observed feeding on garbage near the rental cabin earlier that same day.	Whittlesey 2014, Snow 2016
June 25, 1972; 0100 hours	Male, 25	~200 m from boardwalk near Grand Geyser, Old Faithful area, Yellowstone National Park	Attacked and killed by a grizzly after returning with 1 companion to a clandestine backcountry camp and surprising a female grizzly that was eating camp food that they had left unsecured from bears.	Etling 1997, Herrero 2002, Whittlesey 2014, Smith 2016, Snow 2016
July 30, 1984; ~2230 hours	Female, 25	Astringent Creek drainage, Pelican Valley, Yellowstone National Park, Wyoming	Pulled from her tent at night, killed, and partially consumed by a subadult grizzly bear while camping alone in a designated backcountry campsite.	National Park Service (NPS) 1984, Etling 1997, Herrero 2002, Whittlesey 2014, Snow 2016
October 4, 1986; ~1100 hours	Male, 38	Otter Creek Drainage, Hayden Valley, Yellowstone National Park, Wyoming	Killed and partially consumed by an adult female grizzly bear, while hiking alone off-trail in the backcountry and likely while attempting to photograph the bear.	NPS 1986, McMillion 2012, Whittlesey 2014, Snow 2016
July 6, 2011; 1050 hours	Male, 57	Wapiti Lake Trail, Hayden Valley, Yellowstone National Park, Wyoming	Killed by a female grizzly with 2 cubs after a surprise encounter while hiking with his wife on a designated backcountry hiking trail.	Frey et al. 2011, Whittlesey 2014, Snow 2016
August 25, 2011; ~late morning	Male, 59	Mary Mountain Trail, Hayden Valley, Yellowstone National Park, Wyoming	Killed and partially consumed by an adult female grizzly bear while hiking alone on a designated backcountry trail.	Frey et al. 2012, Gunther 2012, Whittlesey 2014, Snow 2016
August 6, 2015; ~mid-afternoon	Male, 63	Elephant Back Mountain, Yellowstone National Park, Wyoming	Killed and partially consumed by an adult female grizzly bear with 2 cubs while hiking alone, off-trail in the backcountry.	Gunther 2015, Snow 2016, Wilmot et al. 2016

in the park and historically had an abundance of unsecured anthropogenic foods and garbage available (i.e., Rabbit Creek dump, unsecured garbage from hotel, lodge, rental cabins, restaurants, campground) to attract bears until implementation of a new Bear Management Program in 1970 (Cole 1976, Meagher and Phillips 1983).

Time of year. All 8 fatalities occurred from June to October, with 3 occurring in August. August is a period when bears are hyperphagic and increase diurnal activity as they intensify their search for food to gain weight for hibernation (Bjornlie and Haroldson 2017). There were no bear-caused fatalities from November to May, months when YNP visitation is relatively low and most bears in YNP are hibernating in winter dens (Haroldson et al. 2002), therefore reducing the likelihood of human–bear encounters.

Time of day. Most attacks that occur at night are likely motivated by bears seeking access to human foods or are predatory (Herrero 1989, 2002). Half of the fatal bear attacks in YNP occurred in late evening/early morning time periods (2200–0500 hours), and half occurred during the day. All 3 incidents involving bears known to be conditioned to human foods or garbage and the only incident classified as predation occurred under the cover of darkness during the late evening or early morning between 2230 and 0145 hours. All the fatality incidents that did not involve predation or anthropogenic foods occurred during daylight hours.

Gender of people killed by bears. Six of the 8 people killed by bears in YNP were adult men and 2 were adult women. The data from YNP are consistent with those of Smith and Herrero (2018), who reported that in Alaska, USA, bears attacked adult men considerably more often than women, and children comprised only a small proportion of attacks. Because YNP does not keep records of the gender of park visitors, I had no data with which to calculate exposure rate by gender. A survey of front country recreationists in YNP indicates an approximate equal number of men and women frequent roadsides and developments. Richardson et al. (2015) reported a male:female ratio of 51:49 when surveying park visitors in front country areas of YNP. Fatal bear attacks in front country areas of YNP involved a similar ratio of 1 male and 1 female victim since 1872. In contrast, pe-

riodic surveys of backcountry recreationists in YNP indicate that more men than women recreate in backcountry areas of the park. Gracia-Longares (2005) reported male:female ratios of 59:41 in the Hellroaring drainage and 67:33 in the Slough Creek drainage. Trahan (1987) reported a male:female ratio of 84:16 for backcountry recreationists in the northeastern region of YNP, and Oosterhous (2000) reported a male:female ratio of 71:29 in a parkwide survey of backcountry recreationists. The male:female ratio of bear-caused human fatalities that occurred in backcountry areas of YNP was 83:17. I speculate that in the early history of YNP, when the first fatality occurred (male wagon teamster in 1916), men were more likely than women to engage in outdoor jobs where there was greater risk of encountering bears. I also speculate that throughout most of the history of YNP, males were more likely than females (although this is changing) to engage in outdoor backcountry recreational activities where the risk of encountering bears is high. This may account for the preponderance of men being involved in fatal bear attacks in YNP.

Group size of people killed by bears. Of the 8 people killed by bears in both front country and backcountry areas combined, 5 were alone when attacked, 2 were in parties of 2 people, and 1 incident involved a party of 3. The average group size for all bear-caused fatalities combined was 1.5 (± 0.8 SD) people per party. The average group size for the 6 fatalities that occurred in backcountry areas was 1.3 (± 0.5 SD) people per party. The incident with 3 people occurred in an undesignated roadside campsite and involved a grizzly bear conditioned to human foods that was a known camp raider. No groups larger than 3 people had a member killed by a bear in the park.

In YNP's backcountry, parties of 2 or fewer are the most prone of all different party sizes to encounter grizzly bears (Chester 1976). Periodic surveys of backcountry hikers in YNP indicate the most common group size is 2 people per party (Oosterhous 2000, Gracia-Longares 2005, Coleman et al. 2013, Gunther et al. 2019). Approximately 44% of backcountry hikers travel in groups of 2 (Oosterhous 2000). Only ~10% of backcountry hikers in YNP travel solo (Oosterhous 2000, Gunther et al. 2019). Of the 6 fatal bear attacks that occurred in backcountry ar-

Table 2. Characteristics of fatal bear (*Ursus* spp.) attacks in Yellowstone National Park, Wyoming, Montana, and Idaho, USA, 1872–2018.

Date, location	Circumstances of attack	Contributing factors	Other relevant factors	Body consumed	Body cached
September 8, 1916; adjacent to road	Seeking human foods, known camp raider	Bear conditioned to human foods, camp food not secured from bears, victim sleeping with food	Same bear likely injured 2 and possibly 3 people earlier the same year	Not applicable, bear chased off by companions, victim died in hospital	Not applicable
August 23, 1942; within Old Faithful	Startled/defense of food, surprise encounter in development	Victim turned and ran during surprise encounter, bear feeding on garbage near cabin during encounter	Human food-conditioned bear, same bear observed eating garbage near attack site earlier the same day	Not applicable, bear chased off by other people, victim died in hospital	Not applicable
June 25, 1972;	Startled/defense of food, surprise encounter in camp	Food in camp not secured from bears, unsecured food held bear in camp	Human food-conditioned bear, illegal camp in off-trail area	Yes	No, bear may have been scared away from body by rescue team
July 30, 1984;	Predation	Proper food storage attempted but bear pulled hung food down from improvised food hang	Camping alone	Yes	No
October 4, 1986;	Unknown	Hiking alone, off-trail	Possibly approached bear for picture, possibly blew elk (<i>Cervus canadensis</i>) call to get bear to look at camera	Yes	Yes, buried with dirt and grass
July 6, 2011;	Startled, surprise encounter on trail	Ran from bear after encounter	Hiking with <3 people, not carrying bear spray	No, bear left immediately after attack, body removed from field within 47 minutes of attack	No
August 25, 2011;	Unknown	Hiking alone	Not carrying bear spray, old bison (<i>Bison bison</i>) carcass nearby	Yes	Yes, buried with dirt and grass
August 6, 2015;	Unknown	Hiking alone, off-trail	Not carrying bear spray	Yes	Yes, buried with dirt and grass

eas, 4 (67%) involved solo hikers and 2 (33%) involved groups of 2 people. No backcountry groups of ≥ 3 people had a member killed by a bear. Small group sizes of 1 or 2 people have also been shown to be more prone to fatal bear attacks in Canada (Herrero et al. 2011) and to non-fatal bear attacks in YNP (Gunther and Hoekstra 1998), Alaska (Smith and Herrero 2018), and throughout North America (Herrero 2002). Numerically larger group sizes are probably louder and more intimidating to bears, reducing the chances of surprise encounters and the chances that bears will attack during defensive reactions to encounters (Herrero 2002, Herrero and Higgins 2003, Herrero et al. 2011, Smith and Herrero 2018). In addition, larger groups generally have better vigilance (the many eyes effect) than smaller groups (Penteciani et al. 2017), thereby reducing the chances of surprise encounters at close distances where defensive aggression by bears is more likely (Herrero 2002).

Fatal attacks in on-trail versus off-trail areas. The danger of surprise encounters with grizzly bears decreases if bears know where to expect people (Herrero 2002). Because most hikers in YNP stay on designated trails (Coleman et al. 2013), bears are less likely to anticipate encounters with people who are traveling off-trail and, therefore, more likely to react with defensive aggression to off-trail encounters (Gunther and Hoekstra 1998). In a survey of backcountry recreationists in YNP, off-trail travelers observed grizzlies 3–4 times more frequently than on-trail travelers (Chester 1980). Of the 6 bear-caused fatalities in YNP that occurred in backcountry areas, 3 occurred in off-trail areas, 2 occurred on designated trails, and 1 in a designated campsite adjacent to a trail. Coleman et al. (2013) found that 67% of the parties of backcountry recreationists surveyed in YNP never left designated trails, 27% spent some time traveling both on and off-trails, and 6% traveled completely off-trail. Although most (67%) backcountry recreationists in YNP never leave designated trails, half of the people killed by bears in backcountry areas of YNP were traveling off-trail when they encountered the bears that killed them. This supports the conclusions of Herrero (2002) as well as Gunther and Hoekstra (1998) that off-trail travel increases the risk of surprise encounters and bear attacks.

Use of bear spray. Bear spray has proven effective at stopping aggressive behavior by bears during surprise encounters and in reducing the length and severity of attacks when they occur (Herrero and Higgins 1998, Smith et al. 2008). None of the people killed by bears in YNP had capsaicin-based bear deterrent spray when attacked. Because bear spray was not commercially available until the early 1980s, it could not have been used in the 1916, 1942, and 1972 fatalities. The first documented use of bear spray in YNP occurred in 1984. However, bear spray did not have widespread acceptance or use within the park until after its efficacy had been proven by Herrero and Higgins (1998). Therefore, very few recreationists carried bear spray when the 1984 and 1986 fatalities occurred. Once the efficacy of bear spray was established, YNP and other state and federal agencies in the Greater Yellowstone Ecosystem (GYE) began information campaigns promoting its use. Although the efficacy of bear spray was known prior to the 3 fatal attacks that occurred inside YNP from 2011 to 2015, none of those 3 victims were carrying bear spray when they encountered the bears that killed them (Frey et al. 2011, 2012; Wilmot et al. 2016). It is not known if those 3 victims would have had time to deploy bear spray or if bear spray would have changed the outcomes of those attacks.

Circumstances of fatal attacks. Of the 8 fatal bear attacks, 3 involved surprise encounters, 1 involved a bear seeking human foods, and 1 appeared predatory (Table 2). In 3 incidents there were no witnesses, and available evidence did not allow the exact cause of attack to be determined. Seeking human foods was ruled out in those 3 incidents. In 2 of the fatal surprise encounters, the bears involved were known to be conditioned to human foods, which likely contributed to the proximity and possibly the outcome of those encounters. In 1 of the 3 incidents where the primary cause of the attack could not be determined, the bear may have been provoked by the victim, a photographer who may have approached within the bear's defensible personal space for a photograph and/or mimicked elk (*Cervus canadensis*) vocalizations to get the bear's attention. Imitating the sounds of prey may attract bears and cause attack (Herrero and Fleck 1990).

Role of food-conditioned behavior in fatal bear attacks. Bears conditioned to human foods or garbage are often involved in fatal attacks in

national parks (Herrero 1970a, 1970b, 1976, 1989; Gniadek and Kendall 1998; Herrero and Higgins 2003). In 3 of 8 fatalities, the bears had known histories of feeding on human food or garbage. However, attempting to obtain human foods was considered the primary motivation in only 1 of those 3 attacks and a secondary factor in 2 incidents. In 5 fatalities, the bears involved were not known to be conditioned to human foods (NPS 1984, 1986; Frey et al. 2011, 2012; Wilmot et al. 2016). The first 3 fatal bear attacks in YNP (the 1916, 1942, and 1972 incidents) all involved bears that were conditioned to anthropogenic foods, which likely contributed to the circumstances and outcomes of those fatal encounters. After implementing a new bear management program in 1970 designed to prevent bears from obtaining anthropogenic attractants (Leopold et al. 1969; Cole 1971, 1976; Schullery 1992), park managers believed that by 1979 no highly human food-conditioned bears remained in YNP (Meagher and Phillips 1983). None of the bears responsible for the 5 human fatalities after 1979 had known histories of feeding on human foods or garbage. Therefore, managers should be aware that preventing bears from becoming conditioned to human foods can reduce but not eliminate the risk of fatal bear attacks. Even in the absence of human food-conditioned bears, some fatal bear attacks may still occur due to surprise encounters or defense of cubs or natural foods.

Bear consumption of human flesh. Bears partially consumed the bodies of 5 of the 8 people they killed. In 2 fatalities where the victims were not consumed, they died of their injuries while in hospitals, days after they were attacked. In both of those incidents, companions or other nearby people scared the bears away from the victims by yelling and throwing objects at the attacking bears, allowing rescuers to transport the victims to local hospitals. In the third fatality where the body was not consumed (which involved a surprise encounter), the bear gathered its cubs and left immediately after the fatal attack. In this incident, rescuers responding to emergency calls arrived within 47 minutes after the attack and removed the body from the field. Therefore, the bear did not have much of an opportunity to return and scavenge the body. There was no way to determine if the bear would have returned to feed on the body in that incident. Of the 5

incidents where the bodies were consumed, only 1 could be classified as a predatory attack. In that incident, a bear ripped into a woman's tent at night, pulled her out by her head and neck, killed, and consumed her. Therefore, known predatory attacks in YNP are extremely rare (1 in 147 years or 1 per 183,464,899 recreational park visits). In 1 of the incidents involving consumption of the body, the bear initially attacked following a surprise encounter at an anthropogenic food source, then killed and partially consumed the victim. This incident suggests that even if a bear kills someone in a defensive reaction to a surprise encounter, or while defending a food source, it may scavenge the body if given the opportunity. In 3 incidents with human consumption, there were no witnesses, so the exact cause of the attacks could not be determined. These 3 incidents may have been defensive reactions to surprise encounters followed by consumption of the bodies, or they may have been true predatory attacks.

Bear caching of human bodies. Yellowstone grizzly bears derive much of their energy from ungulate carcasses (Mattson 1997) and consume more ungulate meat than most other North American bear populations (Mattson et al. 1991). In YNP, black bears, wolves (*Canis lupus*), coyotes (*C. latrans*), bald eagles (*Haliaeetus leucocephalus*), golden eagles (*Aquila chrysaetos*), ravens (*Corvus corax*), and magpies (*Pica hudsonia*) are significant competitors with grizzly bears for ungulate carrion (Green et al. 1997). To inhibit detection and scavenging of ungulate carcasses by competing avian and mammalian scavengers, bears commonly cache carcasses by covering them with dirt, grass, duff, and brush. When feeding on human flesh, bears also sometimes cache the bodies. Of the 6 people killed by grizzly bears that died in the field, bears fed on 5 of the bodies and cached 3 of these. Although the caching of a human body indicates the bear considers the body as food and intends to return, it is not necessarily an indication of predation by the bear. Although grizzlies frequently cache the carcasses of ungulates they prey on, they also often cache the carcasses of ungulates they scavenge but did not kill, such as those that died from wolf predation, disease, or winter starvation. Therefore, the caching of a human body by a bear is not proof that the bear killed that person.

Table 3. Number of fatal bear attacks by grizzly bears (*Ursus arctos horribilis*), black bears (*U. americanus*), and undetermined species of bear (*Ursus* spp.) and number of fatal bear attacks per 1 million recreational visits in Yellowstone National Park, Wyoming, Montana, and Idaho, USA, 1872–2018.

Species	Number of fatal bear attacks	Fatal bear attacks per 1 million recreational visits
Grizzly bear	7	0.038
Black bear	0	0
Bear - undetermined species	1	<0.001
Total fatal bear attacks	8	0.044

Frequency and risk of fatal bear attacks

During the 147-year period from 1872 to 2018, there were 183,464,899 recreational visits to YNP, and 7 people were killed by grizzly bears (~1 fatality every 21 years). Therefore, the per capita risk of being killed by a grizzly bear was 1 fatality for every 26,209,271 visits (Table 3). There were no known black bear-caused human fatalities in YNP from 1872 to 2018. Studies in other ecosystems demonstrate that fatal bear attacks are also rare in Glacier National Park, Montana (Gniadek and Kendall 1998), and throughout Alaska (Miller and Tutterrow 1999, Smith and Herrero 2018), Canada (Herrero and Higgins 1999, 2003; Herrero et al. 2011), Austria (Rauer 1999), Turkey (Ambarli and Can Bilgin 2008), Scandinavia (Swenson et al. 1999, Støen et al. 2018), and Slovakia (Haring 2018). In combination, all these studies indicate that regardless of frequent opportunity, and despite their ferocious reputations, bears, grizzly or black, rarely kill people.

The risk of fatal grizzly bear attack was not equal between different types of recreational activities (hiking or camping) and broadscale geographic regions (front country or backcountry) of the park. For visitors frequenting front country areas (developments and road corridors) from 1872 to 2018, there was 1 bear-caused fatality for every 91,732,450 visits. No visitors were killed by bears in >37,664,417 overnight stays in designated roadside campgrounds from 1930 to 2018. From 1972 to 2018, permitted visitors recorded 1,975,917 overnight stays in backcountry campsites and dispersed camping zones, and 1 permitted visitor was killed while in their campsite. The risk of fatal grizzly bear attack for recreationists camping in designated backcountry campsites or dis-

persed camping zones was 1 fatality for every 1,975,917 overnight stays. One person camping illegally without a permit was also killed by a grizzly. From 1992 to 2018, park visitors spent an estimated 6,394,944 recreation days hiking in backcountry bear habitat in the park, and 3 backcountry recreationists were killed by grizzlies while hiking during that time period. The risk of fatal grizzly bear attack for backcountry recreationists traveling on foot was 1 fatality for every 2,131,648 backcountry recreation days.

Another method to measure the risk of fatal bear attack is the number of bear encounters that occur per fatality. From 1991 to 2018, 1,851 encounters between backcountry recreationists and grizzly bears were recorded, and 3 people were killed by grizzlies during that period for a calculated fatality rate of 1 fatality per 617 reported grizzly bear encounters. I believe that estimate is biased high because incidents resulting in fatalities are much more likely to be reported or discovered than non-injurious or benign encounters.

Comparing the number of people killed by grizzly bears in YNP to the number of people dying in the park from other causes provides perspective on the risk of fatal bear attack. During the 147-year period from 1872 to 2018, 7 people were killed by grizzly bears inside YNP. During the same time period, 121 people in YNP died by drowning, 39 by falling off of cliffs, 26 by suicide, 22 in airplane crashes, 21 from thermal burns (after falling into boiling thermal pools), and 19 in horse-related accidents (Whittlesey 2014; YNP Emergency Services unpublished data). The frequency of fatal grizzly bear attacks in the park ($n = 7$) was similar to the frequency of deaths caused by hypothermia ($n = 10$), murder ($n = 9$), falling trees ($n = 7$), avalanches ($n = 6$), and lightning strikes (n

Table 4. Number of recreational visits to the park, recreational visits per year, number of fatal bear (*Ursus* spp.) attacks, and number of fatal bear attacks per 1 million park visits during different quarter-century time periods in Yellowstone National Park, Wyoming, Montana, and Idaho, USA, 1872–2018.

Time period	Number of years	Number of recreational visits	Recreational visits per year	Number of fatal bear attacks	Fatal bear attacks per 1 million visits
1872–1894 ^a	23	69,000	3,000	0	0.00
1895–1919 ^b	25	526,241	21,050	1	1.90
1920–1944	25	6,258,692	250,348	1	0.16
1945–1969 ^c	25	37,182,070	1,487,283	0	0.00
1970–1994	25	60,699,179	2,427,967	3	0.05
1995–2018	24	78,729,717	3,280,405	3	0.04
1872–2018	147	183,464,899	1,248,061	8	0.04

^aThe number of park visits from the establishment of the park through 1894 was estimated by park administrators as not <1,000 nor >5,000 visits per year. I used the mid-point (3,000) of that estimate to calculate the annual number of visits for the time period.

^bThe number of visits from 1895–1951 were recorded based on the federal fiscal year of October 1 through September 30.

^cThe number of visits from 1952 to 2018 were recorded based on the calendar year.

= 5; Whittlesey 2014; YNP Emergency Services, unpublished data). Park visitors do not all have equal exposure to each of these causes of death while recreating in the park.

Trends in fatal bear attacks

Although fatal bear attacks in YNP are rare, there has been an increase in the frequency in recent years, with 3 (all by grizzly bears) occurring in the 8-year period from 2011 to 2018, whereas there had been only 5 fatal bear attacks (4 grizzlies, 1 unknown species) in YNP during the previous 139 years (1872 to 2010). However, analyzing the data on a per capita basis indicated that the per capita risk of fatal bear attack in YNP has generally decreased over time (Table 4). The per capita risk of fatal bear attack was highest during the 1895 to 1919 (1 fatality per 526,241 park visits) and 1920 to 1944 (1 fatality per 6,258,692 park visits) time periods. Those time periods were characterized by relatively low visitation (3,000 and 21,050 visits per year, respectively) but with many opportunities for bears to obtain human foods and garbage (Cole 1976, Schullery 1992, Wondrak Biel 2006, Garshelis et al. 2017). In comparison, during the most recent 24-year period (1995–2018), which included 3 fatalities in 8 years, the risk of fatal bear attack was only 1 fatality per 26,243,239 visits. The 1995 to 2018 time period was characterized by high visitation (3,280,405 visits

per year) but with few opportunities for bears to acquire human foods or garbage within the park (Garshelis et al. 2017, White et al. 2017). This suggests that increases in visitation may be responsible for the recent increase in frequency of fatal bear attacks. Herrero et al. (2011) provided some evidence that increased recreational activities in bear habitat contributed toward an increase in fatal bear attacks in Canada and Alaska. The decrease in per capita rate of fatal bear attacks in YNP is likely attributable to installation of bear-proof infrastructure and other efforts to prevent bears from obtaining human foods and garbage and becoming conditioned to anthropogenic foods (Meagher and Phillips 1983, Schullery 1992, Garshelis et al. 2017). Improved information and education campaigns targeting bear safety for people who hike and camp in bear country have likely also contributed toward reductions in the per capita rate of fatal bear attacks in YNP over time.

Management response to fatal bear attacks

When bears in YNP injure or kill someone without consuming the body, after reacting with typical defensive aggression during surprise encounters, park managers generally do not take any action against the bear. In those types of incidents, park managers implement temporary recreational closures around the attack sites to

give the bears involved time to leave the area before reopening to the public. However, in incidents where bears both kill and consume people, even in defensive reactions to surprise encounters, YNP managers generally kill the bears involved (White 2016). Park managers killed the bears responsible for 5 of the 8 fatalities that occurred in YNP. In 1 additional incident, the bear would have been killed, but capture attempts were not successful. The objective of killing bears involved in the killing and consumption of people is not for punishment or retribution; it is to prevent them from killing and consuming other park visitors in the future (Gunther 2016, White 2016). Bears are highly intelligent, learn complex adaptations throughout their lives, have well-developed memory, and are capable of learning from a single food reward (Gilbert 1999). Even if an attack was due to defensive aggression after a surprise encounter, followed by consumption of the body, the bears involved may have learned that people provide a considerable food reward, but exhibit poor vigilance and are relatively slow, weak, and defenseless as prey. Bears are highly opportunistic and quickly learn to exploit new food resources, especially foods that are efficient to acquire and contain concentrated sources of fat and protein. Because bears readily learn new foods and remember the locations, situational context, and seasonal and diel timing of food availability, the possibility of bears that had been involved in both the killing and consumption of humans treating people as prey in the future cannot be ruled out.

There is no evidence that bears that scavenge carcasses of cattle (*Bos taurus*) they did not kill, but found dead on the landscape, become cattle depredators (Claar et al. 1986, Madel 1996, Anderson et al. 2002). In YNP, commercial outfitters occasionally have horses, mules (*Equus mulus*), or llamas (*Lama glama*) die while on backcountry trips. The carcasses of these animals are usually scavenged by grizzly bears and black bears, but there are no recorded incidents of bears subsequently preying on horses, mules, or llamas in the park. Therefore, bears that scavenge the remains of people they did not kill, but found dead on the landscape from other causes, may not necessarily treat live humans as prey in future encounters. However, national parks with millions of visitors are not ideal places to test that theory. Except for extremely endangered

populations, leaving a bear in the wild that may consider humans as food is an unnecessary risk to park visitors and public trust (White 2016). Because there are >700 grizzly bears in the GYE (Haroldson and Frey 2020), an individual bear is not critical to population viability and can be removed without significant impact to the population (White 2016).

When females accompanied by cubs kill people and consume human flesh, many people request that the cubs not be killed or sent to zoos even if the mother bear is killed. They argue that the cubs involved had no role in killing the person and were only following their mother's example in consuming the body. They want the cubs placed into rehabilitation centers and later released back into the wild once they are large and old enough to survive on their own. However, bears exhibit social learning (Meagher and Fowler 1989, Gilbert 1999, Mazur and Seher 2008, Morehouse et al. 2016); cubs learn foods by watching their mothers and sharing their mother's food during the 1.5–3.5 years spent under her care. Therefore, cubs that observe their mother both kill and consume people may themselves consider humans as food in the future, whether that was their mother's original intention for attacking the person or not. For this reason, cubs of mother bears that both kill and consume people, even in defensive reactions following surprise encounters, are permanently removed (killed or sent to captive zoos for life) from YNP.

Killing bears that have killed and consumed people may not only save people's lives, it may potentially save the lives of other bears as well (Gunther 2016, White 2016). Many recreationists on public lands in the GYE, including those managed by the National Forest Service, NPS, Bureau of Land Management, and state agencies, carry firearms. Self-defense kills of grizzly bears during backcountry encounters is one of the highest causes of grizzly bear mortality in the GYE outside of national parks (Gunther et al. 2004, Haroldson et al. 2006). Nervous hunters, hikers, and outdoor recreationists might kill many more bears if managers allowed bears that killed and consumed people to remain free on the landscape (Gunther 2016, White 2016). In addition, if bears regularly killed and consumed people on public lands, it might diminish society's willingness to protect grizzly bears

and the large tracts of habitat they need to survive (Gunther 2016, White 2016, Støen et al. 2018, Conover 2019).

Management implications

The number of fatal bear attacks that occurred in YNP was very small, making them difficult to analyze statistically and too small to draw definitive conclusions. However, the results of this small-scale study are consistent with and support the findings of other bear attack studies that had larger sample sizes. Human behavior can influence the risk of bear attack. The data from YNP suggest that a few human behavioral modifications for recreating in bear country, including hiking with minimum party sizes ≥ 3 people, remaining on designated trails when hiking, not running from bears during encounters, and carrying bear spray have the potential to reduce the risk of fatal bear attacks in the park. Preventing bears from becoming conditioned to anthropogenic foods and garbage is another important factor in reducing bear-caused human fatalities in the park. These bear safety concepts are well known and have already been described and promoted in the scientific and popular literature, as well as by many state and federal land and wildlife management agencies. The difficulty for bear managers is not in knowing best practices to prevent human–bear encounters or how people should react to encounters when they occur, but in getting higher compliance among park visitors to these well-established safety recommendations for hiking, camping, and recreating in habitat occupied by grizzly bears and black bears.

Acknowledgments

Yellowstone Forever and YNP provided support for this research. I thank C. Sholly, superintendent, P. White, chief of the Wildlife and Aquatic Resources Branch, and J. Carpenter, director of the Yellowstone Center for Resources, YNP for encouraging science-based management of bears in YNP. Review and comments by the HWI editors and 2 anonymous reviewers significantly improved the manuscript. I also acknowledge the long-term commitment of bear management biological technicians M. Biel, R. Danforth, E. Reinertson, and T. Wyman for their dedication and assistance in collecting field data and managing the human–bear

interface in YNP. This paper does not set or determine NPS policy, but rather conveys the general bear management philosophy, and supporting evidence for that philosophy, of current YNP bear managers. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature cited

- Ambarli, H., and C. Can Bilgin. 2008. Human–brown bear conflicts in Artvin, northeastern Turkey: encounters, damage, and attitudes. *Ursus* 19:146–153.
- Anderson, C. R., M. A. Ternent, and D. S. Moody. 2002. Grizzly bear–cattle interactions on two grazing allotments in northwest Wyoming. *Ursus* 13:247–256.
- Bjornlie, D. B., and M. A. Haroldson. 2017. Movements and occupied range. Pages 63–73 in P. J. White, K. A. Gunther, and F. T. van Manen, editors. *Yellowstone grizzly bears: ecology and conservation of an icon of wildness*. Yellowstone Forever, Yellowstone National Park, and the U.S. Geological Survey, Northern Rocky Mountain Science Center, Wyoming, USA.
- Chester, J. M. 1976. Human–wildlife interactions in the Gallatin Range, Yellowstone National Park, 1973–74. Thesis, Montana State University, Bozeman, Montana, USA.
- Chester, J. M. 1980. Factors influencing human–grizzly bear interactions in a backcountry setting. *International Conference on Bear Research and Management* 4:351–357.
- Claar, J. J., R. W. Klaver, and C. W. Servheen. 1986. Grizzly bear management on the Flathead Indian Reservation, Montana. *International Conference on Bear Research and Management* 6:203–208.
- Cole, G. F. 1971. Preservation and management of grizzly bears in Yellowstone National Park. *BioScience* 21:858–864.
- Cole, G. F. 1976. Progress in restoring a natural grizzly bear population in Yellowstone National Park. Pages 183–193 in *Research in the parks: transactions of the National Park Centennial Symposium*. National Park Service Symposium Series, Number 1. U.S. Department of the Interior, Washington, D.C., USA.
- Coleman, T. H., C. C. Schwartz, K. A. Gunther, and S. Creel. 2013. Grizzly bear and human interaction in Yellowstone National Park: an

- evaluation of bear management areas. *Journal of Wildlife Management* 77:1311–1320.
- Conover, M. R. 2019. Numbers of human fatalities, injuries, and illnesses in the United States due to wildlife. *Human–Wildlife Interactions* 13:264–276.
- Craighead, J. J., and F. C. Craighead, Jr. 1972. Grizzly bear–man relationships in Yellowstone National Park. *BioScience* 21:845–857.
- Despain, D. G. 1990. *Yellowstone vegetation: consequences of environment and history in a natural setting*. Roberts Rinehart Publishers, Boulder, Colorado, USA.
- Etling, K. 1997. *Bear attacks: classic tales of dangerous North American bears*. Safari Press Incorporated, Long Beach, California, USA.
- Frey, K., D. Tyers, M. Haroldson, C. Servheen, M. Brusolino, K. Gunther, and N. Herring. 2011. Investigation team report: fatality of Mr. Brian Matayoshi from a bear attack on the Wapiti Lake Trail in Yellowstone National Park on July 6, 2011. U.S. Fish and Wildlife Service, Grizzly Bear Recovery Coordinator's Office, Missoula, Montana, USA, <www.fws.gov/mountain-praire/es/species/mammals/grizzly/archive/bors/MatayoshiInvestigationReport>. Accessed November 6, 2019.
- Frey, K., D. Tyers, M. Haroldson, C. Servheen, M. Brusolino, K. Gunther, and N. Herring. 2012. Board of review report: fatality of Mr. John L. Wallace from a bear attack on the Mary Mountain Trail in Yellowstone National Park on August 25, 2011. U.S. Fish and Wildlife Service, Grizzly Bear Recovery Coordinator's Office, Missoula, Montana, USA, <<http://www.fws.gov/mountain-praire/es/species/mammals/grizzly/archive/bors/WallaceBoardofReviewReport030212>>. Accessed November 6, 2019.
- Garshelis, D. L., S. Baruch-Mordo, A. Bryant, K. A. Gunther, and K. Jerina. 2017. Is diversionary feeding an effective tool for reducing human–bear conflicts? Case studies from North America and Europe. *Ursus* 28:31–55.
- Gilbert, B. K. 1999. Opportunities for social learning in bears. Pages 225–235 *in* H. O. Box and K. R. Gibson, editors. *Mammalian social learning: comparative and ecological perspectives*. Cambridge University Press, Cambridge, United Kingdom.
- Gniadek, S. J., and K. C. Kendall. 1998. A summary of bear management in Glacier National Park, Montana, 1960–1994. *Ursus* 10:155–159.
- Gore, M. L., B. A. Knuth, P. D. Curtis, and J. E. Shananan. 2007. Factors influencing risk perception associated with human–black bear conflict. *Journal of Wildlife Management* 75:596–603.
- Gracia-Longares, M. 2005. Study of spatial patterns of visitors using mechanical counters, GPS and GIS technology in the Slough Creek subregion of Yellowstone National Park. Thesis, University of Montana, Missoula, Montana, USA.
- Graham, D. C. 1978. Grizzly bear distribution, use of habitats, food habits, and habitat characterization in Pelican and Hayden Valleys, Yellowstone National Park. Thesis, Montana State University, Bozeman, Montana, USA.
- Green, G. I., D. J. Mattson, and J. M. Peek. 1997. Spring feeding on ungulate carcasses by grizzly bears in Yellowstone National Park. *Journal of Wildlife Management* 61:1040–1055.
- Gunther, K. A. 1991. Grizzly bear activity and human induced modifications in Pelican Valley, Yellowstone National Park. Thesis, Montana State University, Bozeman, Montana, USA.
- Gunther, K. A. 2012. Forensic evidence—human fatality on the Mary Mountain Trail of Yellowstone National Park, August 25, 2011. Bear Management Office, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, USA.
- Gunther, K. A. 2015. Forensic evidence—human fatality on Elephant Back Mountain, Yellowstone National Park, August 6, 2015. Bear Management Office, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, USA.
- Gunther, K. A. 2016. Why the Park Service killed a grizzly bear in Yellowstone. *Backpacker*. January 14, 2016. Outside Interactive, Inc., Boulder, Colorado, USA, <<https://www.backpacker.com/survival/why-the-park-service-killed-a-grizzly-bear-in-yellowstone-2/>>. Accessed November 6, 2019.
- Gunther, K. A., and M. A. Haroldson. 2020. Potential for recreational restrictions to reduce grizzly bear-caused human injuries. *Ursus* 2020:31e6.
- Gunther, K. A., M. A. Haroldson, K. Frey, S. L. Cain, J. Copeland, and C. C. Schwartz. 2004. Grizzly bear–human conflicts in the Greater Yellowstone Ecosystem, 1992–2000. *Ursus* 15:10–22.
- Gunther, K. A., and H. Hoekstra. 1998. Bear-inflicted human injuries in Yellowstone National Park, 1970–1994. *Ursus* 10:377–384.
- Gunther, K. A., E. Reinertson, and T. Wyman. 2019. Visitor compliance with bear spray and hiking group size bear safety recommenda-

- tions in Yellowstone National Park. Pages 85–90 in F. T. van Manen, M. A. Haroldson, and B. E. Karabensh, editors. *Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team*, 2018. U.S. Geological Survey, Bozeman, Montana, USA.
- Haring, M. 2018. Bear attacks on people in Slovakia in 2000–2016. Thesis, University of South-Eastern Norway, Kongsberg, Norway.
- Haroldson, M. A., and K. L. Frey. 2020. Documented grizzly bear mortalities in the GYE and estimated percent mortality for the demographic monitoring area. Pages 28–34 in F. T. van Manen, M. A. Haroldson, and B. E. Karabensh, editors. *Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team*, 2019. U.S. Geological Survey, Bozeman, Montana, USA.
- Haroldson, M. A., C. C. Schwartz, and G. C. White. 2006. Survival of independent grizzly bears in the Greater Yellowstone Ecosystem, 1983–2001. Pages 33–42 in C. C. Schwartz, M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen, editors. *Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem*. *Wildlife Monographs* 161:1–68.
- Haroldson, M. A., M. A. Ternent, K. A. Gunther, and C. C. Schwartz. 2002. Grizzly bear denning chronology and movements in the Greater Yellowstone Ecosystem. *Ursus* 13:29–37.
- Herrero, S. 1970a. Human injury inflicted by grizzly bears. *Science* 170:593–598.
- Herrero, S. 1970b. Man and the grizzly bear (present, past, but future?). *BioScience* 20:1148–1153.
- Herrero, S. 1976. Conflicts between man and grizzly bears in the National Parks of North America. Pages 121–145 in M. Pelton, J. W. Lentfer, and G. E. Folk, editors. *Bears—their biology and management*. International Union for Conservation of Nature, New Series Number 40, Morges, Switzerland.
- Herrero, S. 1989. The role of learning in some fatal grizzly bear attacks on people. Pages 9–14 in M. Bromly, editor. *Bear–people conflicts*. Proceedings of a Symposium on Management Strategies, Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.
- Herrero, S. 2002. Bear attacks: their causes and avoidance. Second edition. Lyons Press, Guilford, Connecticut, USA.
- Herrero, S., and S. Fleck. 1990. Injury to people inflicted by black, grizzly, or polar bears: recent trends and new insights. *International Conference on Bear Research and Management* 8:25–32.
- Herrero, S., and A. Higgins. 1998. Field use of capsaicum spray as a bear deterrent. *Ursus* 10:533–537.
- Herrero, S., and A. Higgins. 1999. Human injuries inflicted by bears in British Columbia: 1960–97. *Ursus* 11:209–218.
- Herrero, S., and A. Higgins. 2003. Human injuries inflicted by bears in Alberta: 1968–1998. *Ursus* 14:44–54.
- Herrero, S., A. Higgins, J. E. Cardoza, L. I. Hajduk, and T. Smith. 2011. Fatal attacks by American black bears on people: 1900–2009. *Journal of Wildlife Management* 75:596–603.
- Hornocker, M. G. 1962. Population characteristics and social and reproductive behavior of the grizzly bear in Yellowstone National Park. Thesis. University of Montana, Missoula, Montana, USA.
- Knight, R. R. 1975. Interagency grizzly bear study team annual report, 1974. Interagency Grizzly Bear Study Team, Bozeman, Montana, USA.
- Leopold, A. S., S. Cain, C. Olmsted, and S. Olson. 1969. A bear management program and policy for Yellowstone National Park. Report to the director by the National Science Advisory Committee. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Wyoming, USA.
- Madel, M. J. 1996. Rocky Mountain Front grizzly bear management program: four-year progress report. Montana Department of Fish, Wildlife and Parks, Helena, Montana, USA.
- Mattson, D. J. 1997. Use of ungulates by Yellowstone grizzly bears (*Ursus arctos*). *Biological Conservation* 81:161–177.
- Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977–1987. *Canadian Journal of Zoology* 69:1619–1629.
- Mazur, R., and V. Seher. 2008. Socially learned foraging behaviour in wild black bears, *Ursus americanus*. *Animal Behaviour* 75:1503–1508.
- McMillion, S. 2012. *Mark of the grizzly*. Second edition. Lyons Press, Guilford, Connecticut, USA.
- Meagher, M. M., and S. Fowler. 1989. The con-

- sequences of protecting problem grizzly bears. Pages 141–144 in M. Bromley, editor. Bear–people conflicts. Proceedings of a Symposium on Management Strategies, Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.
- Meagher, M. M., and J. R. Phillips. 1983. Restoration of natural populations of grizzly and black bears in Yellowstone National Park. *International Conference on Bear Research and Management* 5:152–158.
- Miller, S. D., and V. L. Tutterrow. 1999. Characteristics of nonsport mortalities to brown and black bears and human injuries from bears in Alaska. *Ursus* 11:239–252.
- Morehouse, A. T., T. A. Graves, N. Mikle, and M. S. Boyce. 2016. Nature vs. nurture: evidence for social learning of conflict behavior in grizzly bears. *PLOS ONE* 11(11): e0165425.
- Nanni, V., E. Caprio, G. Bombieri, S. Schiaparelli, C. Chiorri, S. Mammola, P. Pedrini, and V. Penteriani. 2020. Social media and large carnivores: sharing biased news on attacks on humans. *Frontiers in Ecology and Evolution* 8:71.
- National Park Service (NPS). 1974. Master plan, Yellowstone National Park/Wyoming-Montana-Idaho. Yellowstone National Park, Wyoming, USA.
- National Park Service (NPS). 1984. Board of inquiry into the death of: Brigitta Fredenhagen, July 30, 1984. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Wyoming, USA.
- National Park Service (NPS). 1986. Board of inquiry into the death of: William John Tesinsky, October 4, 1986. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Wyoming, USA.
- National Park Service (NPS). 1994. Draft Yellowstone National Park Backcountry Management Plan. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Wyoming, USA.
- National Park Service (NPS). 2006. Management policies 2006. U.S. Department of Interior, National Park Service, Washington, D.C., USA.
- Oosterhous, T. S. 2000. Attitudes, opinions, characteristics, and management preferences of backcountry campers in Yellowstone National Park. Thesis, Stephen F. Austin State University, Nacogdoches, Texas, USA.
- Penteriani, V., G. Bombieri, J. M. Fedriani, J. V. López-Bao, P. J. Garrote, L. F. Russo, and M. D. Delgado. 2017. Humans as prey: coping with large carnivore attacks using a predator–prey interaction perspective. *Human–Wildlife Interactions* 11:192–207.
- Penteriani, V., M. D. Delgado, F. Pinchera, J. Naves, A. Fernández-Gil, I. Kojola, S. Härkönen, H. Norberg, J. Frank, J. M. Fedriani, V. Sahlén, O. G. Støen, J. E. Senson, P. Wabakken, M. Pellegrini, S. Herrero, and J. V. López-Bao. 2016. Human behavior can trigger large carnivore attacks in developed countries. *Scientific Reports* 6:20552.
- Rauer, G. 1999. Bear–human encounters in Austria. *Ursus* 11:201–208.
- Richardson, L., K. Gunther, T. Rosen, and C. Schwartz. 2015. Visitor perceptions of roadside bear viewing and management in Yellowstone National Park. *The George Wright Forum* 32:299–306.
- Schullery, P. 1992. *The bears of Yellowstone*. High Plains Publishing, Worland, Wyoming, USA.
- Smith, J. F. 2016. *Engineering Eden: the true story of a violent death, a trial, and the fight over controlling nature*. Random House LLC, New York, New York, USA.
- Smith, T. S., and S. Herrero. 2018. Human–bear conflict in Alaska: 1880–2015. *Wildlife Society Bulletin* 42:254–263.
- Smith, T. S., S. Herrero, T. D. Debruyn, and J. M. Wilder. 2008. Efficacy of bear deterrent spray in Alaska. *Journal of Wildlife Management* 72:640–645.
- Snow, K. 2016. *Taken by bear: more than a century of harrowing encounters between grizzlies and humans*. Lyons Press, Guilford, Connecticut, USA.
- Støen, O.-G., A. Ordiz, V. Sahlen, J. M. Arnemo, S. Saebø, G. Mattsing, M. Kristoferson, S. Brunberg, J. Kindberg, and J. E. Swenson. 2018. Brown bear attacks resulting in human casualties in Scandinavia 1977–2016; management implications and recommendations. *PLOS ONE* 13(5): e0196876.
- Stringham, S. F. 2013. Managing risk from bears and other potentially lethal wildlife: predictability, accountability, and liability. *Human–Wildlife Interactions* 7:5–9.
- Swenson, J. E., F. Sandegren, A. Söderberg, M. Heim, O. J. Sørensen, A. Bjärvall, R. Franzén, S. Wikan, and P. Wabakken. 1999. Interactions between brown bears and humans in Scandi-

navia. *Biosphere Conservation* 2:1–9.

Trahan, R. G. 1987. Wilderness user's attitudes, information use and behaviors in relation to grizzly bear dangers in the backcountry: a survey of backcountry users in the northeastern section of Yellowstone National Park summer of 1985. University of Northern Colorado, Greeley, Colorado, USA.

White, P. J. 2016. Can't chew the leather anymore: musings on wildlife conservation in Yellowstone from a broken-down biologist. The Yellowstone Association, Yellowstone National Park, Wyoming, USA.

White, P. J., K. A. Gunther, and F. T. van Manen. 2017. Yellowstone grizzly bears: ecology and conservation of an icon of wildness. *Yellowstone Forever*, Yellowstone National Park, and the U.S. Geological Survey, Northern Rocky Mountain Science Center, Wyoming, USA.

Whittlesey, L. H. 2014. *Death in Yellowstone: accidents and foolhardiness in the first national park*. Roberts Rinehart Publishers, Lanham, Maryland, USA.

Wilmot, K., K. Frey, D. Tyers, M. Haroldson, F. van Manen, C. Servheen, B. DeBolt, D. Thompson, D. Bjornlie, and K. Gunther. 2016. Board of review report: fatality of Mr. Lance Crosby from a bear attack on Elephant Back Mountain in Yellowstone National Park on August 6, 2015. U.S. Fish and Wildlife Service, Missoula, Montana, USA, <www.fws.gov/mountain-praire/es/crosby%20BOR%20Report%20final>. Accessed November 6, 2019.

Wondrak Biel, A. 2006. *Do (not) feed the bears: the fitful history of wildlife and tourists in Yellowstone*. University Press of Kansas, Lawrence, Kansas, USA.

KERRY A. GUNTHER received his B.S. degree in biology and earth science from Northland



College and his M.S. degree in fish and wildlife management from Montana State University. He began his career with the U.S. Forest Service working with black bears on the Superior National Forest in

Minnesota and has also worked with Weddell seals in Antarctica. He is currently the bear management biologist and program leader for the Yellowstone National Park Bear Management Office and a member of both the Interagency Grizzly Bear Study Team for the Greater Yellowstone Ecosystem and the North American Bear Expert Team. He has worked in grizzly bear and black bear research, monitoring, and conflict management in Yellowstone for 40 years. His interests include the conservation of bears and finding practical solutions for reducing human–bear conflicts.

Associate Editor: Carl W. Lackey