Yellowstone Grizzly Bear Investigations 2016

Annual Report of the Interagency Grizzly Bear Study Team

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YELLOWSTONE GRIZZLY BEAR

INVESTIGATIONS

Annual Report of the Interagency Grizzly Bear Study Team

2016

U.S. Geological Survey
Wyoming Game and Fish Department
National Park Service
U.S. Fish and Wildlife Service
Montana Fish, Wildlife and Parks
U.S. Forest Service
Idaho Department of Fish and Game
Eastern Shoshone and Northern Arapaho Tribal Fish and Game Department

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U.S. Department of the Interior

U.S. Geological Survey

2017

IGBST Partner Websites

Interagency Grizzly Bear Study Team (U.S. Geological Survey):
http://www.usgs.gov/norock/igbst

Grizzly Bear Recovery Program (U.S. Fish and Wildlife Service):
https://www.fws.gov/mountain-prairie/es/grizzlyBear.php

Yellowstone and Grand Teton National Parks (National Park Service):
http://www.nps.gov/yell/planyourvisit/bearsafety.htm
http://www.nps.gov/grte/planyourvisit/bearsafety.htm

Wyoming Game and Fish Department:
https://wgfd.wyo.gov/Wildlife-in-Wyoming/More-Wildlife/Large-Carnivore/Grizzly-Bear-Management

Montana Fish, Wildlife and Parks:
http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/grizzlyBears/default.html

Idaho Department of Fish and Game:
http://fishandgame.idaho.gov/public/wildlife/?getPage=248

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Introduction

Frank T. van Manen and Mark A. Haroldson, Interagency Grizzly Bear Study Team, U.S. Geological Survey

This Report

This Annual Report summarizes results of grizzly bear (*Ursus arctos*) monitoring and research conducted in the Greater Yellowstone Ecosystem (GYE) by the Interagency Grizzly Bear Study Team (IGBST) during 2016. The report also contains a summary of grizzly bear management actions to address conflict situations.

The Big Picture

There was much policy activity regarding grizzly bears in the Greater Yellowstone Ecosystem (GYE) in 2016. In March, the U.S. Fish and Wildlife Service published a Proposed Rule to remove the Yellowstone population from the Federal list of endangered and threatened wildlife (USFWS 2016). In conjunction with the Proposed Rule, the Yellowstone Ecosystem Subcommittee of the Interagency Grizzly Bear Committee revised and finalized the 2016 Conservation Strategy for the grizzly bear in the Greater Yellowstone Ecosystem (Yellowstone Ecosystem Subcommittee 2016). A Final Rule to delist the population was published in June 2017 (USFWS 2017). Long-term research data collected by IGBST have been instrumental towards a science-based approach to population recovery. This would not change under a delisted scenario. The IGBST will continue to monitor the population with the same effort and intensity of previous years, and as specified in the 2016 Conservation Strategy.

People from around the world are extremely interested in grizzly bears in the GYE but opinions vary on their management, role on the landscape, and population status. Given these wide-ranging opinions, a thorough understanding of the underlying issues is important, including stakeholder values, and rigorous science will remain critical for managers to make informed decisions for the continued conservation of grizzly bears. We recognize that some dispute the scientific findings of the IGBST. For example, some have argued that the population is declining, and that declines in food resources have forced bear to leave the core of the ecosystem. Whereas one can debate interpretations regarding cause-and-effect relationships and the complexities of interpreting ecological data, there is little dispute regarding a number of data sources collected by the IGBST. Here, we take a broad view and provide a brief summary of such data. We cover the following topics: 1) population status and trend; 2) range expansion; 3) distribution of bears within the GYE; 4) mortality rates; and 5) human-bear conflicts.

Population Status and Trend.—Based on data from known-fate analyses, we documented vigorous population growth of 4.2% to 7.6% starting in the 1980s and continuing into the 1990s (Schwartz et al. 2006). We documented a slowing of population growth since the early 2000s but no evidence of a population decline (0.3% to 2.2% annual growth during 2002–2011; IGBST 2012). Similarly, Chao2 estimates of the number of females with cubs-of-the-year (hereafter, cubs) showed robust growth until the late 1990s, but no evidence of a statistical trend since the early 2000s (see Fig. 4 [page 12]; $F = 0.485$, 1 df, $P = 0.498$). Mark-resight estimates further confirm that interpretation (see Fig. 5 [page 24]). Combined, these data suggest the population within the Demographic Monitoring Area (DMA) has been relatively constant or slightly increasing for the last 15 years. Given that population estimates derived from Chao2 are known to be increasingly underestimated as population size increases (Schwartz et al. 2008), these interpretations are likely conservative.

Expansion of Occupied Range.—The IGBST updates the estimate of occupied range every 2 years and recently released a new map based on data from 2002–2016 (Fig. 1). The area of occupied range is 64,849 km^2, an 11% increase from 2000–2014 data. Almost all (94%) of the DMA is now considered occupied range, including much of the Wind River Range. Expansion beyond the DMA continues, now representing more than a quarter (27%) of occupied range. An animation of range expansion is available on the IGBST website and shows that range expansion since 1990 has occurred on the entire periphery of the ecosystem and is most pronounced towards the south and east.

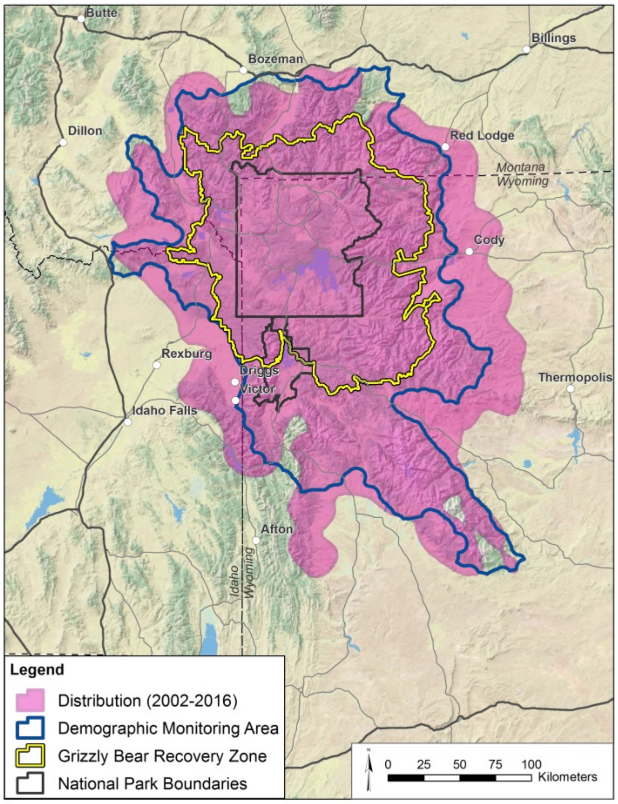

Fig. 1. Occupied range of grizzly bears, Greater Yellowstone Ecosystem, 2002–2016 data. Estimation based on Bjornlie et al. (2014a).

Distribution of Bears within the GYE.—Some have suggested that bears are leaving the core of the GYE because of declining food resources. A decline of food resources would cause bears to increase movements and expand home ranges as they search for alternative foods. However, our data do not support this assertion. For example, extensive VHF and GPS telemetry data indicate that the intensity of grizzly bear use of the core area remains high, and show no evidence of bears moving their home ranges from the core to the periphery of the GYE. Data on the distribution of females with cubs or females with offspring (cubs, yearlings, or 2-year-olds) similarly suggest that numbers in the core area (Grizzly Bear Recovery Zone/Primary Conservation Area) remain stable. Additionally, data from Bjornlie et al. (2014*b*) indicated that female home ranges are smallest and least variable in areas with higher densities, which occur primarily in the core of the GYE. Female bears have high site fidelity and these data suggested that female bears are responding to higher population densities, rather than declining food resources, by decreasing home-range sizes.

Mortality Rates.—The number of known and probable mortalities varies over time and concerns have been raised about the high number of mortalities in recent years. However, an increasingly larger proportion of mortalities are occurring outside the DMA (35% in 2016), and many are subadult or young adult males. Additionally, mortality should be evaluated as a function of population size (i.e., mortality rate) and not based on absolute numbers. Accounting for changes in population size over time, total mortality rates (including an estimate of unknown/unreported mortality) for independent-age females (2 years or older) peaked in 2008 and has averaged 7.3% for the period 2002–2016. Thus, the average mortality rate for independent females during the past 15 years within the DMA has been below the 7.6% threshold for maintaining a stable population.

Human-Bear Conflicts.—Concerns have been expressed about the high number of human-bear conflicts in recent years, and some have suggested it supports the notion that food resources are declining. However, the data suggest otherwise. An increasing proportion of human-bear conflicts now occur outside the DMA: during 2014–2016, for example, 37% of all management captures associated with human-bear conflicts occurred beyond the DMA boundaries. Similar to the pattern associated with mortalities, a large proportion of these conflicts involved subadult or young adult males.

The picture that emerges from these combined data is that population recovery started in 1980s, likely facilitated by the coordinated, interagency conservation efforts implemented through the Interagency Grizzly Bear Committee that was formed in 1983. Data collected since that time suggest population growth started in the core protected area of Yellowstone National Park, followed by slowing of population growth as grizzly bear densities increased (Schwartz et al. 2006, IGBST 2012, van Manen et al. 2016). The range expansion we have observed was initially driven by males, with females typically lagging approximately 5 years behind (D. Bjornlie, WGFD, unpublished data). Observations of slowing population growth within the DMA are not incompatible with the continued range expansion we have documented; as bear densities increase, dispersal of bears, and males in particular, stimulates range expansion. However, recent range expansion increasingly includes habitats of lower quality due to human influences, resulting in greater number of human-bear conflicts and mortalities, sometimes well beyond the boundaries of the DMA. Indeed, we are documenting shifts in the causes of human-bear conflicts and mortalities, with greater proportions associated with hunter-related incidents, developed areas, and livestock depredations. Regardless of the legal status of the population, the combination of these 5 basic data sources alone provide evidence that the Yellowstone grizzly bear population has reached biological recovery, now occupying almost all areas that were identified as suitable habitat and where presence of grizzly bears was deemed socially acceptable (USFWS 2016).

Population and Habitat Monitoring

We followed monitoring protocols established under the Revised Demographic Recovery Criteria (USFWS 2007*a*) and the demographic monitoring section of the Final Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Area (USFWS 2007*b*). In 2016, we estimated 50 unique females with cubs in the ecosystem, 45 of which were within the Demographic Monitoring Area; this resulted in a model-averaged estimate of 54 females with cubs, from which we derived a total population size of 695 (see "***Estimating Number of Females with Cubs***"; due to a correction of sighting frequencies that changed the Chao2 estimate in 2015, this estimate is slightly higher than the estimate of 690 presented to the Yellowstone Ecosystem Subcommittee in Fall 2016 and Spring 2017). These estimates were similar to those from 2015 and continue to support our assertion that the population is stable and near carrying capacity in portions of the ecosystem. More importantly, we may be seeing the first signs that the population is oscillating around a long-term mean, which we predicted in previous annual reports and other publications (e.g., van Manen et al. 2016). We continue to present estimates of the number of females with cubs based on the mark-resight technique. However, based on findings we reported in the 2015 Annual Report, the IGBST decided not to adopt the mark-resight technique as a primary monitoring tool because sample sizes were insufficient to provide early detection of changes in population trend.

Although monitoring requirements under the Conservation Strategy (USFWS 2007*b*) do not apply since the GYE grizzly bear population was relisted in 2009, the U.S. Forest Service continues to report on items identified in the Conservation Strategy including changes in secure habitat, livestock allotments, and developed sites from the 1998 baseline levels in each Bear Management Unit (BMU) subunit. This year, the 9th report detailing this monitoring program is provided by documenting: 1) changes in secure habitat, open motorized access route density, and total motorized route density inside the Primary Conservation Area (PCA; equivalent to the USFWS Recovery Zone); 2) changes in number and capacity of developed sites inside the PCA; and 3) changes in number of commercial livestock allotments, changes in the number of permitted domestic sheep animal months inside the PCA, and livestock allotments with grizzly bear conflicts during the last 5 years (Appendix A).

Habitat monitoring includes documenting the abundance of 4 high-calorie foods throughout the GYE: 1) winter ungulate carcasses, 2) cutthroat trout (*Oncorhynchus clarkii*) spawning numbers, 3) bear use of army cutworm moth (*Euxoa auxiliaris*) sites, and 4) whitebark pine (*Pinus albicaulis*) cone production. Results of these monitoring efforts have been reported by the IGBST for numerous years and are reported here for 2016. Additionally, monitoring of the health of whitebark pine in the ecosystem continued with the cooperation of the Greater Yellowstone Whitebark Pine Monitoring Working Group. We reference these monitoring efforts in Appendix B. The protocol has been modified to document mortality rate in whitebark pine from all causes, including mountain pine beetle (*Dendroctonus ponderosae*).

The annual reports of the IGBST summarize annual data collection. Because additional information may be obtained after publication, data summaries are subject to change. Data, analyses, and summaries presented in this report supersede previously published data and analyses and interpretations may be subject to change contingent on future manuscript publication and the peer review process. Descriptions of the study area and sampling techniques are reported by Blanchard

(1985), Mattson et al. (1991*a*), Haroldson et al. (1998), and Schwartz et al. (2006).

History and Purpose of the IGBST

It was recognized as early as 1973 that a better understanding of the dynamics of grizzly bears in the GYE would best be accomplished by a centralized research group responsible for collecting, managing, analyzing, and distributing information. To meet this need, agencies formed the IGBST, a cooperative effort among the U.S. Geological Survey, National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, and the state wildlife agencies of Idaho, Montana, and Wyoming. The Eastern Shoshone and Northern Arapaho Tribes formally joined the study team in 2009. Responsibilities of the IGBST are to: 1) conduct short- and long-term research projects addressing information needs for bear management; 2) monitor the bear population, including status and trend, numbers, reproduction, and mortality; 3) monitor grizzly bear habitats, foods, and impacts of humans; and 4) provide technical support to agencies and other groups responsible for the immediate and long-term management of grizzly bears in the GYE. Additional details can be obtained at our web site: http://www.usgs.gov/norock/igbst.

Quantitative data on grizzly bear abundance, distribution, survival, mortality, nuisance activity, and bear foods are critical to formulating management strategies and decisions. Moreover, this information is necessary to evaluate the recovery process. The IGBST coordinates data collection and analysis on an ecosystem scale, prevents duplication of effort, and pools limited economic and personnel resources.

Previous Research

Some of the earliest research on grizzlies within Yellowstone National Park was conducted by John and Frank Craighead. Their book, "The Grizzly Bears of Yellowstone" provides a detailed summary of this early research (Craighead et al. 1995). With the closing of open-pit garbage dumps and cessation of the ungulate reduction program in Yellowstone National Park in 1967, bear demographics (Knight and Eberhardt 1985), food habits (Mattson et al. 1991*a*), and growth patterns (Blanchard 1987) for grizzly bears changed. Since 1975, the IGBST has produced annual reports and numerous scientific publications summarizing the team's monitoring and research efforts within the GYE. We have obtained substantial insights into the historic distribution of grizzly bears within the GYE (Basile 1982, Blanchard et al. 1992), movement patterns (Blanchard and Knight 1991), food habits (Mattson et al. 1991*a*, IGBST 2013), habitat use and habitat security (Knight et al. 1984, Schwartz et al. 2010), population dynamics (Knight and Eberhardt 1985, Eberhardt et al. 1994, Eberhardt 1995, Schwartz et al. 2006, IGBST 2012, van Manen et al. 2016), and genetics (Haroldson et al. 2010, Kamath et al. 2015). Development and enhancement of data collection and analysis techniques continues. As our summaries of recent longitudinal studies underscore, through long-term research and monitoring we continue to collect detailed data to support a variety of analyses, providing researchers and managers with a comprehensive assessment of population dynamics.

Acknowledgments

This report is a combined effort of the partner agencies and individual members of the IGBST and many individuals contributed either directly or indirectly to its preparation. To that end, we have identified author(s). We also wish to thank the following individuals for their contributions to data collection, analysis, and other phases of IGBST research. **IDFG**: C. Anderson, P. Atwood, C. de Caussin, R. Cavallaro, L. Cepenzski, J. Farr, K. Guy, C. Hendricks, D. Kelsey, L.Lane , G. Losinski, J. Nicholson, D. Petersen, J. Rydalch, A. Sorenson: **MSU**: M. Higgs; **MTFWP**: S. Brozovich, C. Costello, J. Cunningham, C. Kerin, B. Lloyd, A. Nelson, J. Ramsey, J. Smith, D. Scott, J. Smolczynski, S. Stewart; **NPS**: N. Adams, K. Atkins, B. Bennett, J. Bennett, D. Bergum, N. Bowersock, E. Boyd, S. Consolo-Murphy, R. Coscarelli, S. Dewey, C. Flaherty, D. Gustine, J. Haas, A. Hanna, J. Harmer, K. Harrigan, D. Harris, S. Hegg, D. Houck, J. Jakicic, E. Johnston, P. Kirchner, M.

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We also want to acknowledge Dr. Steve Cherry, statistician and Professor at Montana State University who retired in May 2017. Steve has been a valued colleague and collaborator on the team for more than 20 years. He is author and co-author on numerous peer-reviewed publications and reports produced by the Study Team. His statistical insights and expertise, and especially his pragmatism when working with often difficult ecological problems and limited data, have been critical to the team's success. Additionally, many students at Montana State University benefited from his participation in the Interagency Grizzly Bear Study Team. His easy manner working with others, his down-to-earth attitude, and his unique humor made it a pleasure to work with Steve. The Study Team will miss his many contributions. We wish him well in his retirement.

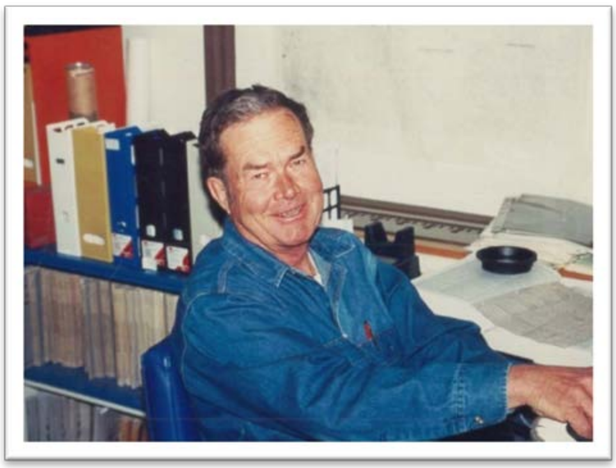
Lastly, 2 former contributors to the study team passed away during the last year. On March 15, 2017, David Stradley passed away at the age of 80. Dave was a primary pilot for the Interagency Grizzly Bear Study Team for nearly 3 decades, conducting both observation and radio telemetry flights throughout the Yellowstone Ecosystem. He began his flying career with the family business Gallatin Flying Service in 1953 at the age of 16 and retired in 1999.

David Stradley was the main pilot for IGBST for nearly 3 decades.

Dave loved to fly and he loved to find grizzly bears. After he retired from the pilot seat he continued to act as an observer during IGBST bear observation flights until 2009. He was a legendary mountain flyer and contributed greatly to the efforts of the study team. Dave's friendship and skill in the air will be missed.

On October 12, 2016, Dr. Richard R. Knight passed away at the age of 82. "Dick" grew up on a ranch near Great Falls, Montana. He began his college studies in Geology at the School of Mines in Butte, Montana. After one year at the School of Mines and with a genuine interest in the outdoors and wildlife, Dick transferred to Montana State University to major in Fish and Wildlife Management. After graduation Dick serve two years in the military. He then returned to Montana State University to pursue a Master's Degree in Fish and Wildlife, completing his Master's Degree in 1960. He was hired by the Montana Fish and Game Department as a research biologist studying the Sun River elk herd. This research led to his dissertation for a PhD at the University of Minnesota. In 1966, Dr. Knight returned to Montana to begin range studies, but then decided to take a faculty teaching position at the University of Idaho in Moscow, where he remained for five years.

In 1972, Dr. Knight was approached by Glen Cole regarding grizzly bear research in the Yellowstone Ecosystem. In 1973, Dr. Knight became the first leader of the Interagency Grizzly Bear Study Team. He was appointed by Nathaniel P. Reed, Assistant Secretary of Interior for Fish, Wildlife, and National Parks under Interior Secretary Rogers C. B. Morton. This was soon after the closure of the open-pit garbage dumps in Yellowstone National Park when controversy regarding that action and its impact on the grizzly bear population was ongoing, as was uncertainty regarding the status and trend for the population. Designing a scientific strategy to study grizzly bears was a difficult task in the beginning. There were numerous administrative and logistical hurdles, in addition to obtaining commitments from all the state and federal agencies. Dr. Knight had the strong no-nonsense character that was needed to set the study and programs in the direction for population recovery.



Dr. Richard Knight in his office, circa 1996.

Dr. Knight and his collaborators identified survivorship of female grizzly bears as a primary driver influencing the population's negative trajectory following dump closures, and were instrumental in proposing strategies to reverse that trend. As an outgrowth of radio-tracking bears, they designed the aerial observation surveys and standards. These observations flights are still conducted annually and are used in the analysis of the annual population estimates and trend. From the mid-1980s through today, the grizzly bear population in the Yellowstone Ecosystem has increased in numbers and range extent. Dick was a positive guiding force in the conservation and recovery of the Yellowstone's grizzly bear population. Dr. Knight and his wife Bonnie retired from the Interagency Grizzly Bear Study Team in 1997 and moved to Oregon.

Bear Monitoring and Population Trend

Marked Animals *(Mark A. Haroldson and Chad Dickinson, Interagency Grizzly Bear Study Team, U.S. Geological Survey; and Daniel D. Bjornlie, Wyoming Game and Fish Department)*

During the 2016 field season, we captured 96 individual grizzly bears on 108 occasions (Table 1), including 32 females (14 adult), 62 males (42 adult) and 2 yearlings of unknown sex that were released without handling. Fifty-seven (59%) individuals were bears not previously marked. The percent of previously unmarked individual grizzly bears captured annually during 1998–2016 has remained relatively constant, averaging 62%, with no evidence ($F = 0.672$, 1 df, $P = 0.424$) of a change in trend (Fig. 2). This result continues to support the notion that bears are recruiting into the population at a relatively constant rate. In this closed population we would expect the number of new individuals encountered annually to decline if bears were not recruiting into the population.

We conducted research trapping efforts for a total 626 trap days (1 trap day = 1 trap set for 1 day). During research trapping operations we had 59 captures of 50 individual grizzly bears for a trapping success rate of 1 bear capture every 10.6 trap days.

There were 49 management captures of 48 individual bears during 2016 (Tables 1 and 2), including 18 females (6 adults), and 30 males (17 adults). Eighteen individual bears (6 females, 12 males), were relocated because of conflict situations (Table 1). Three of the transported bears (all males) were considered non-target captures; 2 (#699 and #872, Table 1) were captured at cattle depredation sites, and 1 (#847, Table 1) was captured at a site were property damage had occurred. One additional non-target male (#866, Table 1) captured at a cattle depredation was released on site, as was a female (#871, Table 1) that was released on site after her cubs could not be captured. Two bears, 1 adult female (#857, Table 1) and 1 adult male (#858, Table 1), were captured at both research and management trap sites. Both were initially captured at research trap sites and subsequently captured at cattle depredations. Bear #857 was released on site whereas bear #858 was transported. In total there were 26 management captures that resulted in removals (9 females, 17 males) during 2016 (Table 1). One bear (#846, Table 1) was initially captured and transported for property damages and obtaining food rewards; she was subsequently captured and removed for similar conflicts. Additionally, 1 female cub (Unm4, Table 1) captured at a cattle depredation site died during handling.

We radiomonitored 106 individual grizzly bears during the 2016 field season, including 38 (26 adults) females (Tables 2 and 3). Sixty-five grizzly bears entered their winter dens wearing active transmitters. Since 1975, 868 individual grizzly bears have been radio-marked in the GYE.

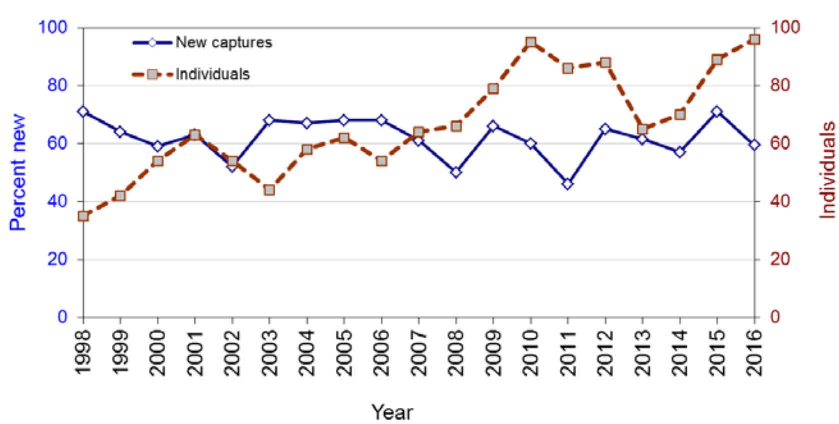


Fig. 2. Percent of previously unmarked and total number of grizzly bears captured annually in the Greater Yellowstone Ecosystem, 1998–2016.

Table 1. Grizzly bears captured in the Greater Yellowstone Ecosystem, 2016.							
Bear	Sex	Age	Date	General location[a]	Capture type	Release site[a]	Handler[b]
839	Male	Adult	4/16/2016	South Fork Shoshone, PR-WY	Management	Removed	WGFD
845	Male	Adult	4/27/2016	Rawhide Crk, PR-WY	Management	Trail Crk, SNF	WGFD
846	Male	Adult	5/5/2016	Brown Crk, PR-WY	Management	Pacific Crk, BTNF	WGFD
846	Male	Adult	5/22/2016	Brown Crk, PR-WY	Management	Removed	WGFD
Unm1	Male	Adult	5/6/2016	Pat O'Hara Crk, PR-WY	Management	Removed	WGFD
G206	Male	Subadult	5/12/2016	Wind River, PR-WY	Management	Removed	WGFD
227	Male	Adult	5/18/2016	Fairy Crk, YNP	Research	On site	IGBST
227	Male	Adult	5/20/2016	Gibbon River, YNP	Research	On site	IGBST
699	Male	Adult	5/19/2016	Brown Crk, PR-WY	Management	Flagstaff Crk, BTNF	WGFD
847	Male	Subadult	5/22/2016	Brown Crk, PR-WY	Management	North Fork Shoshone, SNF	WGFD
814	Male	Adult	5/26/2016	Stephens Crk, YNP	Research	On site	IGBST
848	Female	Adult	5/29/2016	East fork Wind River, WRIR	Research	On site	WGFD
769	Male	Adult	6/1/2016	Stephens Crk, YNP	Research	On site	IGBST
849	Male	Adult	6/1/2016	Red Crk, WRIR	Research	On site	WGFD
849	Male	Adult	6/7/2016	Meadow Crk, WRIR	Research	On site	WGFD
803	Male	Subadult	6/4/2016	Beaver Crk, WRIR	Research	On site	WGFD
850	Female	Adult	6/4/2016	Gardner River, YNP	Research	On site	IGBST
733	Male	Adult	6/6/2016	Crow Crk, WRIR	Research	On site	WGFD
G215	Male	Adult	6/12/2016	Crow Crk, WRIR	Research	On site	WGFD
851	Female	Subadult	6/13/2016	Crow Crk, WRIR	Research	On site	WGFD
556	Male	Adult	6/17/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
852	Male	Adult	6/19/2016	Pelican Crk, YNP	Research	On site	IGBST
853	Male	Adult	6/20/2016	Monument Bay, YNP	Research	On site	IGBST
854	Male	Adult	6/21/2016	Pelican Crk, YNP	Research	On site	IGBST
427	Male	Adult	6/21/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
742	Male	Adult	6/25/2016	Paint Crk, PR-WY	Management	Removed	WGFD
855	Male	Adult	7/3/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
855	Male	Adult	7/6/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
855	Male	Adult	10/6/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
856	Male	Adult	7/3/2016	Monument Bay, YNP	Research	On site	IGBST
678	Female	Adult	7/5/2016	Grouse Crk, BTNF	Research	On site	WGFD
857	Female	Adult	7/6/2016	Horse Crk, PR-MT	Research	On site	IGBST
857	Female	Adult	8/8/2016	Horse Crk, PR-MT	Management	On site	WS
858	Male	Adult	7/6/2016	Horse Crk, PR-MT	Research	On site	IGBST
858	Male	Adult	8/28/2016	Tom Miner, PR-MT	Management	Tepee Crk, ST-MT	WS/MTFWP
859	Male	Subadult	7/6/2016	South Fork Spread Crk, BTNF	Research	On site	WGFD
836	Female	Subadult	7/10/2016	Tepee Crk, BTNF	Management	Removed	WGFD
843	Male	Subadult	7/10/2016	Wind River, PR-WY	Management	Removed	WGFD
844	Male	Subadult	7/10/2016	Wind River, PR-WY	Management	Removed	WGFD
807	Male	Adult	7/8/2016	South Fork Shoshone, PR-WY	Management	Blackrock Crk, BTNF	WGFD
860	Male	Adult	7/12/2016	Horse Crk, PR-MT	Research	On site	IGBST
861	Female	Subadult	7/12/2016	South Fork Spread Crk, BTNF	Research	On site	WGFD
755	Female	Adult	7/12/2016	Wagon Crk, BTNF	Management	Removed	WGFD
819	Male	Subadult	7/13/2016	Blackrock Crk, BTNF	Research	On site	WGFD

Table 1. Continued.

Bear	Sex	Age	Date	General location[a]	Capture type	Release site[a]	Handler[b]
G216	Male	Adult	7/14/2016	Arnica Crk, YNP	Research	On site	IGBST
G216	Male	Adult	7/17/2016	Arnica Crk, YNP	Research	On site	IGBST
G216	Male	Adult	7/18/2016	Bridge Crk, YNP	Research	On site	IGBST
862	Male	Subadult	7/15/2016	Arnica Crk, YNP	Research	On site	IGBST
G217	Male	Subadult	7/15/2016	Grouse Crk, BTNF	Research	On site	WGFD
338	Male	Adult	7/16/2016	Bridge Crk, YNP	Research	On site	IGBST
749	Female	Adult	7/16/2016	Stephens Crk, YNP	Research	On site	IGBST
506	Male	Adult	7/17/2016	South Fork Spread Crk, BTNF	Research	On site	WGFD
863	Female	Subadult	7/17/2016	Blackrock Crk, BTNF	Research	On site	WGFD
864	Female	Subadult	7/18/2016	Arnica Crk, YNP	Research	On site	IGBST
865	Male	Subadult	7/18/2016	Sheridan Crk, CTNF	Research	On site	IDFG
865	Male	Subadult	8/9/2016	Blind Crk, CTNF	Research	On site	IDFG
866	Male	Yearling	7/19/2016	Dago Crk, BTNF	Management	On site	WGFD
867	Female	Subadult	7/20/2016	South Fork Spread Crk, BTNF	Research	On site	WGFD
868	Female	Subadult	7/23/2016	Middle Fork Owl Crk, PR-WY	Management	Mormon Crk, SNF	WGFD
219	Male	Adult	7/23/2016	Moose Crk, CTNF	Management	Removed	IDFG
785	Male	Adult	8/6/2016	Red Crk, BTNF	Management	Removed	WGFD
869	Female	Adult	8/7/2016	Colley Crk, CGNF	Research	On site	IGBST
870	Male	Subadult	8/7/2016	Colley Crk, CGNF	Research	On site	IGBST
871	Female	Adult	8/7/2016	Camp Crk, SNF	Management	On site	WGFD
872	Male	Adult	8/7/2016	Horse Crk, PR-MT	Management	On site	WS
679	Male	Adult	8/13/2016	Bailey Crk, GTNP	Research	On site	IGBST
Unm2	Unk	Yearling	8/13/2016	Pilgrim Crk, GTNP	Research	On site	IGBST
Unm2	Unk	Yearling	8/16/2016	Pilgrim Crk, GTNP	Research	On site	IGBST
Unm3	Unk	Yearling	8/16/2016	Pilgrim Crk, GTNP	Research	On site	IGBST
Unm3	Unk	Yearling	9/9/2016	Snake River, GTNP	Research	On site	IGBST
765	Male	Adult	8/15/2016	Willow Crk, PR-WY	Management	Removed	WGFD
873	Male	Adult	8/17/2016	Bootjack Crk, CTNF	Research	On site	IDFG/IGBST
874	Male	Adult	8/20/2016	Bootjack Crk, CTNF	Research	On site	IDFG
875	Female	Adult	8/20/2016	Soda Fork, BTNF	Research	On site	WGFD
399	Female	Adult	8/25/2016	Pacific Crk, GTNP	Research	On site	IGBST
676	Female	Adult	8/28/2016	Lime Crk, BTNF	Management	North Fork Shoshone, SNF	WGFD
G218	Female	Cub	8/29/2016	Lime Crk, BTNF	Management	North Fork Shoshone, SNF	WGFD
G219	Female	Cub	8/29/2016	Lime Crk, BTNF	Management	North Fork Shoshone, SNF	WGFD
Unm4	Female	Cub	8/29/2016	Lime Crk, BTNF	Management	Handling mortality	WGFD
G220	Male	Subadult	8/30/2016	Soda Fork, BTNF	Research	On site	WGFD
Unm5	Female	Subadult	8/31/2016	Snowshoe Crk, PR-MT	Management	Removed	WS/MTFWP
876	Female	Subadult	9/1/2016	Fish Crk, BTNF	Management	North Fork Shoshone, SNF	WGFD
877	Male	Subadult	9/7/2016	South Fork Shoshone, PR-WY	Management	Middle Boone Crk, CTNF	WGFD
878	Male	Adult	9/9/2016	Tosi Crk, BTNF	Management	Mormon Crk, SNF	WGFD
789	Male	Adult	9/13/2016	Snake River, GTNP	Research	On site	IGBST
879	Male	Subadult	9/13/2016	Horse Crk, PR-WY	Management	Deadman Crk, SNF	WGFD
880	Male	Subadult	9/15/2016	South Fork Shoshone, PR-WY	Management	Blackrock Crk, BTNF	WGFD

Table 1. Continued.

Bear	Sex	Age	Date	General location[a]	Capture type	Release site[a]	Handler[b]
Unm6	Male	Subadult	9/17/2016	Cottonwood Crk, PR-MT	Management	Removed	MTFWP
G221	Male	Subadult	9/18/2016	Sunlight Crk, PR-WY	Management	Grassy Lake, CTNF	WGFD
881	Male	Adult	9/22/2016	Cascade Crk, YNP	Research	On site	IGBST
394	Male	Adult	9/22/2016	Cascade Crk, YNP	Research	On site	IGBST
799	Female	Adult	9/26/2016	Trout Crk, YNP	Research	On site	IGBST
369	Male	Adult	9/29/2016	Carter Crk, PR-WY	Management	Removed	WGFD
829	Male	Adult	9/29/2016	Carter Crk, PR-WY	Management	Removed	WGFD
703	Female	Adult	9/30/2016	Sage Crk, BLM-WY	Management	Removed	WGFD
G222	Male	Subadult	10/4/2016	North Fork Shoshone, PR-WY	Management	Blackrock Crk, BTNF	WGFD
Unm7	Female	Adult	10/7/2016	South Fork Shoshone, PR-WY	Management	Removed	WGFD
Unm8	Male	Cub	10/7/2016	South Fork Shoshone, PR-WY	Management	Removed	WGFD
Unm9	Male	Cub	10/7/2016	South Fork Shoshone, PR-WY	Management	Removed	WGFD
Unm10	Female	Cub	10/8/2016	South Fork Shoshone, PR-WY	Management	Removed	WGFD
Unm11	Male	Adult	10/9/2016	Pat O'Hara Crk, PR-WY	Management	Removed	WGFD
882	Male	Adult	10/10/2016	Jasper Crk, YNP	Research	On site	IGBST
883	Female	Subadult	10/10/2016	Flat Mountain Arm, YNP	Research	On site	IGBST
465	Male	Adult	10/15/2016	Bear Crk, PR-WY	Management	Removed	WGFD
Unm12	Female	Cub	10/21/2016	Boulder Crk, SNF	Management	Removed	WGFD
Unm13	Female	Cub	10/21/2016	Boulder Crk, SNF	Management	Removed	WGFD
Unm14	Female	Cub	10/21/2016	Boulder Crk, SNF	Management	Removed	WGFD
800	Female	Subadult	11/3/2016	Yellowstone River, PR-MT	Management	Tepee Crk, ST-MT	MTFWP

[a] BLM = Bureau of Land Management; BTNF = Bridger-Teton National Forest, CTNF = Caribou-Targhee National Forest, CGNF = Custer-Gallatin National Forest, SNF = Shoshone National Forest, YNP = Yellowstone National Park, WRIR = Wind River Reservation, PR = private.

[b] IDFG = Idaho Fish and Game; IGBST = Interagency Grizzly Bear Study Team, USGS; MTFWP = Montana Fish, Wildlife and Parks; WS = Wildlife Services; WGFD = Wyoming Game and Fish Department; YNP = Yellowstone National Park.

Chad Dickinson (USGS) fits a radio collar on an adult male grizzly #881 in Yellowstone National Park, 2016(photo Frank T. van Manen/IGBST).

Table 2. Annual number of grizzly bears monitored, captured, and transported in the Greater Yellowstone Ecosystem, 1980–2016.

Year	Number monitored	Individuals trapped	Total captures		Transports
			Research	Management	
1980	34	28	32	0	0
1981	43	36	30	35	31
1982	46	30	27	25	17
1983	26	14	0	18	13
1984	35	33	20	22	16
1985	21	4	0	5	2
1986	29	36	19	31	19
1987	30	21	15	10	8
1988	46	36	23	21	15
1989	40	15	14	3	3
1990	35	15	4	13	9
1991	42	27	28	3	4
1992	41	16	15	1	0
1993	43	21	13	8	6
1994	60	43	23	31	28
1995	71	39	26	28	22
1996	76	36	25	15	10
1997	70	24	20	8	6
1998	58	35	32	8	5
1999	65	42	31	16	13
2000	84	54	38	27	12
2001	82	63	41	32	15
2002	81	54	50	22	15
2003	80	44	40	14	11
2004	78	58	38	29	20
2005	91	63	47	27	20
2006	92	54	36	25	23
2007	86	65	54	19	8
2008	87	66	39	40	30
2009	97	79	63	34	25
2010	85	95	36	75	52
2011	92	86	61	46	24
2012	112	88	47	56	35
2013	88	65	58	30	20
2014	94	70	51	30	20
2015	101	89	34	72	41
2016	106	96	59	49	18

Table 3. Grizzly bears radiomonitored in the Greater Yellowstone Ecosystem, 2016.						
				Monitored		Current
Bear	Sex	Age	Offspring[a]	Out of den	Into den	status
193	F	Adult	None	Yes	No	Cast
227	M	Adult		No	Yes	Active
299	M	Adult		Yes	No	Dead
399	F	Adult	1 cub, lost	No	Yes	Active
427	M	Adult		No	Yes	Active
439	F	Adult	1 yearling, weaned - GB 866	Yes	Yes	Active
506	M	Adult		Yes	Yes	Active
556	M	Adult		No	No	Cast
610	F	Adult	2 yearlings	Yes	No	Cast
627	F	Adult	2 2-year-olds, weaned/lost?	Yes	Yes	Den/Cast?
644	M	Adult		Yes	No	Cast
655	M	Adult		Yes	No	Killed
672	F	Adult	2 3-year-olds	Yes	No	Cast
676	F	Adult	3 cubs, 1 died during handling	No	Yes	Active
678	F	Adult	None	No	Yes	Active
679	M	Adult		Yes	Yes	Active
699	M	Adult		No	No	Cast
704	M	Adult		Yes	No	Cast
728	F	Adult	3 yearlings	Yes	Yes	Active
732	F	Adult	None	Yes	No	Cast
733	M	Adult		No	Yes	Active
743	F	Adult	2 yearlings, 1 lost	Yes	Yes	Active
747	F	Adult	None	Yes	Yes	Active
749	F	Adult	None	No	Yes	Active
762	F	Adult	1 cub, lost	Yes	Yes	Active
769	M	Adult		No	No	Cast
773	F	Adult	None	Yes	Yes	Active
779	F	Adult	None	Yes	No	Cast
782	M	Adult		Yes	Yes	Active
783	M	Adult		Yes	No	Cast
786	F	Subadult	None	Yes	Yes	Active
788	M	Subadult		Yes	Yes	Active
789	M	Adult		No	No	Cast
790	M	Adult		No	No	Cast
791	M	Adult		Yes	No	Cast
793	F	Adult	None	Yes	No	Cast
799	F	Adult	3 cubs, 1 lost	No	No	Active
800	F	Subadult	Not seen	No	Yes	Active
803	M	Subadult		Yes	Yes	Active
804	M	Adult		Yes	No	Cast
805	M	Adult		Yes	No	Cast
807	M	Adult		Yes	No	Cast
808	M	Subadult		Yes	Yes	Active

Table 3. Continued.						
				Monitored		Current
Bear	Sex	Age	Offspring[a]	Out of den	Into den	status
810	M	Adult		Yes	No	Cast
813	M	Adult		Yes	No	Cast
814	M	Adult		No	No	Cast
815	F	Adult	3 cubs, 2 lost	Yes	Yes	Active
816	M	Adult		Yes	No	Cast
817	M	Subadult		Yes	No	Cast
818	M	Adult		Yes	No	Killed
819	M	Adult		Yes	Yes	Active
821	M	Adult		Yes	Yes	Active
824	M	Adult		Yes	Yes	Active
825	M	Adult		Yes	Yes	Active
828	M	Adult		Yes	Yes	Active
830	M	Adult		Yes	No	Cast
831	F	Adult	1 yearling	Yes	Yes	Active
833	F	Adult	None	Yes	Yes	Active
834	M	Adult		Yes	No	Cast
836	F	Subadult	None	Yes	No	Removed
838	M	Adult		Yes	No	Cast
839	M	Adult		Yes	No	Removed
840	M	Adult		Yes		Den/Cast?
841	M	Adult		Yes	No	Cast
842	M	Adult		Yes	Yes	Active
843	M	Subadult		Yes	No	Removed
844	M	Subadult		Yes	No	Removed
845	M	Subadult		No	No	Cast
846	M	Adult		No	No	Removed
847	M	Subadult		No	No	Cast
848	F	Adult	1 yearling	No	Yes	Active
849	M	Adult		No	No	Cast
850	F	Adult	None	No	Yes	Den/Cast?
851	F	Subadult	None	No	Yes	Active
852	M	Adult		No	Yes	Active
853	M	Adult		No	Yes	Active
854	M	Adult		No	No	Cast
855	M	Subadult		No	Yes	Active
856	M	Subadult		No	Yes	Active
857	F	Adult	None	No	Yes	Active
858	M	Adult		No	Yes	Active
859	M	Subadult		No	Yes	Active
860	M	Adult		No	No	Cast
861	F	Subadult	None	No	Yes	Active
862	M	Subadult		No	No	Cast
863	F	Subadult	None	No	Yes	Active
864	F	Subadult	None	No	Yes	Active

Table 3. Continued.						
				Monitored		Current
Bear	Sex	Age	Offspring[a]	Out of den	Into den	status
865	M	Subadult		No	Yes	Active
866	M	Yearling		Yes	Yes	Active
867	F	Subadult	None	No	Yes	Active
868	F	Adult	None	No	Yes	Active
869	F	Adult	2 2-year-olds	No	Yes	Active
870	M	Subadult		No	Yes	Active
871	F	Adult	2 cubs	No	Yes	Active
872	M	Adult		No	Yes	Active
873	M	Subadult		No	Yes	Active
874	M	Adult		No	Yes	Active
875	F	Adult	None	No	Yes	Active
876	F	Subadult	None	No	Yes	Active
877	M	Subadult		No	Yes	Active
878	M	Adult		No	Yes	Active
879	M	Subadult		No	Yes	Active
880	M	Subadult		No	Yes	Active
881	M	Adult		No	Yes	Active
882	M	Adult		No	Yes	Active
883	F	Subadult	Not seen	No	Yes	Active

Radio-collared grizzly bear in a whitebark pine stand (photo courtesy of IGBST)

Estimating Number of Females with Cubs *(Mark A. Haroldson and Frank T. van Manen, Interagency Grizzly Bear Study Team, U.S. Geological Survey; and Daniel D. Bjornlie, Wyoming Game and Fish Department)*

I. Assessing Trend and Estimating Population Size from Observations of Unique Females with Cubs

Background

Under the Revised Demographic Recovery Criteria (USFWS 2007*b*) of the Grizzly Bear Recovery Plan (USFWS 1993), IGBST is tasked with annually estimating the number of female grizzly bears with cubs in the GYE population, determining trend for this segment of the population, and estimating size of specific population segments to assess annual mortalities relative to population size. In 2011, results of our trend analysis indicated the trajectory for this annual estimate was changing (Haroldson 2012). This result triggered a demographic review (USFWS 2007*b*), which was held during February 2012. Data from 2002–2011 indicated that several vital rates for the population had changed (IGBST 2012). A consequence of these changed vital rates was that the rate of increase for the grizzly bear population had also changed. Trend estimates using 2002–2011 vital rates suggested the population was stable to slightly increasing during the period (IGBST 2012). Because vital rates and trend had changed, it followed that age structure for the population had also changed. Thus, it is appropriate to use updated vital rates and ratios for specific population segments to estimate size of those segments when assessing annual mortality limits presented in the application protocols (USFWS 2013). Here, we present our 2016 findings for counts of unique females with cubs, and the population estimate derived from numbers of females with cubs observed within the Demographic Monitoring Area (DMA) and 2002–2011 vital rates (IGBST 2012).

Methods

Specific procedures used to accomplish the above-mentioned tasks under the previous protocols are presented in IGBST (2005, 2006) and Harris (2007). Under the updated protocols only females with cubs observed within the DMA (Fig. 3) are counted for the Chao2 estimate. Updated vital rates and ratios for numerical estimation of specific population segments under the updated criteria are specified in IGBST (2012).

Briefly, the Knight et al. (1995) rule set is used to estimate the number of unique females with cubs and tabulate sighting frequencies for each family. We then apply the Chao2 estimator (Chao 1989, Wilson and Collins 1992, Keating et al. 2002, Cherry et al. 2007) to sighting frequencies for each unique family. This estimator accounts for individual sighting heterogeneity and produces an estimate for the total number of females with cubs present in the population. Next, we estimate trend and rate of change (») for the number of unique females with cubs in the population from the natural log (*Ln*) of the annual $\hat{N}_{Chao2}$ estimates using linear and quadratic regressions with model averaging (Burnham and Anderson 2002). The quadratic model is included to detect changes in trend. Model AIC_c (Akaike Information Criterion) will favor the quadratic model if the rate of change levels off or begins to decline (IGBST 2006, Harris et al. 2007). This process smoothes variation in annual estimates that result from sampling error or pulses in numbers of females producing cubs due to natural processes (i.e., process variation). Some changes in previous model-averaged estimates for unique females with cubs ($\hat{N}_{MAFC}$) are expected with each additional year of data. Retrospective adjustments to previous estimates are not done (IGBST 2006). Demographic Recovery Criterion 1 (USFWS 2007*b*) specifies a minimum requirement of 48 females with cubs for the current year ($\hat{N}_{MAFC}$). Model-averaged estimates below 48 for 2 consecutive years will trigger a biology and management review, as will a shift in AIC_c that favors the quadratic model (i.e., AIC_c weight > 0.50, USFWS 2007*b*). Given the assumption of a reasonably stable sex and age structure, trend for the females with cubs represents the rate of change for the entire population (IGBST 2006, Harris et al. 2007). It follows that estimates for specific population segments can be derived from $\hat{N}_{MAFC}$ and the estimated stable age distribution for the population. Estimates for specific population segments and associated confidence intervals follow IGBST (2005, 2006) for the previous protocol and IGBST (2012) for the updated protocol, which incorporates observed changes in vital rates during 2002–2011 and is based on the DMA.

2016 Sightings of Females with Cubs and number Unique

We documented 144 verified sightings of females with cubs during 2016 in the GYE. Nine of the sighting (6.25%) occurred outside the DMA; none occurred outside the previous count line (i.e., Conservation Management Area [CMA], Fig. 3). Observations were almost evenly split between ground (51.9%) and aerial (48.1%) sources (Table 4). We were able to differentiate 50 unique females from the 144 sightings using the rule set described by Knight et al. (1995). Five of the 50 unique females were observed entirely (*n* = 6 sightings) outside the DMA. Three of these females had a 1-cub litter, one had a 2-cub litter, and one had a 3-cub litter during their initial observation. Fifty-two (36.1%) observations from an estimated 9 unique females with cubs occurred within the boundary of Yellowstone National Park (YNP).

The total number of cubs observed during initial sightings of the 50 unique females with cubs was 98 and mean litter size was 1.96 (Table 5). There were 15 single cub litters, 22 litters of twins, and 13 litters of triplets (Table 5). No quadruplets were observed during 2016 (Table 5). Including only initial observations that occurred inside the DMA, there were 45 unique females with a total of 89 cubs and a mean litter size of 1.98.

2016 DMA Chao2 and Population Estimate

Excluding the 5 families (6 sightings) only observed outside the DMA, there were 121 observations of 45 families obtained without the aid of telemetry. Using sighting frequencies for these families produced an estimate for unique females with cubs within the DMA of $\hat{N}_{DMAChao2}$ = 50. Using this estimate in our linear and quadratic regression analyses produced a model-averaged estimate for 2016 of $\hat{N}_{DMAChao2}$ = 55 (95% CI = 43–69). This estimate does not retrospectively exclude unique families observed outside the DMA for years prior to 2012. However, if those sighting of unique families observed outside the DMA were excluded, changes in our estimates of trend and population size would be small because nearly all females with cubs are sighted within the DMA. This was especially true during years prior to 2012 (IGBST 2012). Applying the updated 2002–2011 vital rates to $\hat{N}_{DMAChao2}$ produces a total population estimate for the DMA of 695 (Table 7).

We used the annual $\hat{N}_{Chao2}$ for the period 1983–2016 (Table 6) to estimate the rate of population change (Fig. 4) for the female with cubs segment of the population. With the 2016 addition, AIC_c weights (Table 8) exhibited unambiguous support for the quadratic (88.6%) over the linear (11.4%) model. Additionally, the estimated quadratic effect (² = -0.00109) was significant (*P* = 0.014, Table 8). This is the second year we have reported model results using Chao2 estimates from 2012–2015 that were restricted to the DMA. We note that findings from Schwartz et al. (2008) indicated the Chao2 estimate is biased low and becomes more biased with increasing population size. We again observed strong support for a leveling off of population growth for the more restricted geographic area of the DMA; this was not unexpected and is consistent with other results. Indeed, linear regression of $\hat{N}_{Chao2}$ values with year for the period 2002• 2016 shows no support for either a positive or negative trend (*F* = 0.485, 1 df, *P* = 0498).

Table 4. Method of observation for female grizzly bears with cubs sighted in the Greater Yellowstone Ecosystem, 2016.

Method of observation	Frequency	%	Cumulative %
Fixed wing aircraft – other researcher	3	2.1	2.1
Fixed wing aircraft – observation flight	46	31.9	34
Fixed wing aircraft – telemetry flight	11	7.6	41.6
Fixed wing aircraft – ferry time	5	3.5	45.1
Helicopter – other researcher	3	2.1	47.2
Ground sighting	74	51.4	98.6
Trap	2	1.4	100
Total	144	100	

Table 5. Number of unique females with cubs ($\hat{N}_{Obs}$), litter frequencies, total number of cubs, and average litter size at initial observation, Greater Yellowstone Ecosystem, 1983–2016.

Year	$\hat{N}_{Obs}$	Total # sightings	Litter size: 1 cub	2 cubs	3 cubs	4 cubs	Total # cubs	Mean litter size
1983	13	15	6	5	2	0	22	1.69
1984	17	41	5	10	2	0	31	1.82
1985	9	17	3	5	1	0	16	1.78
1986	25	85	6	15	4	0	48	1.92
1987	13	21	1	8	4	0	29	2.23
1988	19	39	1	14	4	0	41	2.16
1989	16	33	7	5	4	0	29	1.81
1990	25	53	4	10	10	1	58	2.32
1991[a]	24	62	6	14	3	0	43	1.87
1992	25	39	2	12	10	1	60	2.40
1993	20	32	4	11	5	0	41	2.05
1994	20	34	1	11	8	0	47	2.35
1995	17	25	2	10	5	0	37	2.18
1996	33	56	6	15	12	0	72	2.18
1997	31	80	5	21	5	0	62	2.00
1998	35	86	9	17	9	0	70	2.00
1999	33	108	11	14	8	0	63	1.91
2000	37	100	9	21	7	0	72	1.95
2001	42	105	13	22	7	0	78	1.86
2002	52	153	14	26	12	0	102	1.96
2003	38	60	6	27	5	0	75	1.97
2004	49	223	14	23	12	0	96	1.96
2005	31	93	11	14	6	0	57	1.84
2006	47	172	12	21	14	0	96	2.04
2007	50	335	10	22	18	0	108	2.16
2008	44	118	10	28	6	0	84	1.91
2009	42	117	10	19	11	2	89	2.12
2010	51	286	15	23	12	1	101	1.98
2011	39	134	13	17	9	0	74	1.90
2012	49	124	14	25	10	0	94	1.92
2013	58	183	8	35	14	3	126	2.17
2014	50	119	16	22	12	0	96	1.92
2015	46	156	15	17[b]	14[b]	0	91[b]	1.98[b]
2016	50	144	15	22	13	0	98	1.96

[a] One female with unknown number of cubs; average litter size was calculated based on 23 females.
[b] Corrected values for 2015; online version of 2015 Annual Report has also been corrected.

Table 6. Annual Chao2 estimates for the numbers of female grizzly bears with cubs in the Greater Yellowstone Ecosystem, 1983–2016. Estimates in parenthesis for 2012–2016 are specific to the Demographic Monitoring Area (DMA). The number of unique females observed ($\hat{N}_{Obs}$) includes those located using radio telemetry; *m* is the number of unique females observed using random sightings only; and $\hat{N}_{Chao2}$ gives the nonparametric bias-corrected estimate, per Chao (1989). Also included are the number of females with cubs sighted once (f_1) or twice (f_2), and the annual estimate of relative sample size ($n/\hat{N}_{Chao2}$), where *n* is the total number of observations obtained without the aid of telemetry. Female with cubs sighted e3 time can be derived ($f_3+ = m - (f_1 + f_2)$).

Year	$\hat{N}_{Obs}$	m	f_1	f_2	$\hat{N}_{Chao2}$	n	$n/\hat{N}_{Chao2}$
1983	13	10	8	2	19	12	0.6
1984	17	17	7	3	22	40	1.8
1985	9	8	5	0	18	17	0.9
1986	25	24	7	5	28	82	3.0
1987	13	12	7	3	17	20	1.2
1988	19	17	7	4	21	36	1.7
1989	16	14	7	5	18	28	1.6
1990	25	22	7	6	25	49	2.0
1991	24	24	11	3	38	62	1.6
1992	25	23	15	5	41	37	0.9
1993	20	18	8	8	21	30	1.4
1994	20	18	9	7	23	29	1.3
1995	17	17	13	2	43	25	0.6
1996	33	28	15	10	38	45	1.2
1997	31	29	13	7	39	65	1.7
1998	35	33	11	13	37	75	2.0
1999	33	30	9	5	36	96	2.7
2000	37	34	18	8	51	76	1.5
2001	42	39	16	12	48	84	1.7
2002	52	49	17	14	58	145	2.5
2003	38	35	19	14	46	54	1.2
2004	49	48	15	10	58	202	3.5
2005	31	29	6	8	31	86	2.8
2006	47	43	8	16	45	140	3.3
2007	50	48	12	12	53	275	5.1
2008	44	43	16	8	56	102	1.8
2009	42	39	11	11	44	100	2.3
2010	51	51	11	9	56	256	4.6
2011	39	39	14	10	47	123	2.6
2012	49 (48)	44 (43)	16 (15)	7 (7)	59 (56)	110 (108)	1.9 (1.9)
2013	58 (57)	53 (52)	13 (14)	11 (11)	60 (60)	160 (152)	2.6 (2.5)
2014	50 (47)	46 (44)	23 (21)	13 (13)	64 (59)	92 (90)	1.4 (1.5)
2015	46 (44)	43 (41)	14 (13) [a]	10 (11) [a]	51 (47) [a]	135 (131)	2.6 (2.8)
2016	50 (45)	50 (45)	15 (12)	15 (13)	56 (50)	129 (121)	2.3 (2.4)

[a] Corrected sighting frequencies and Chao2 estimate in 2015; online version of 2015 Annual Report has also been corrected.

Table 7. Estimates and 95% confidence intervals (CI) for population segments and total grizzly bear population size derived using the Chao2 estimate for females with cubs within the Demographic Monitoring Area, 2016.

		95% CI	
Segment	Estimate	Lower	Upper
Independent females (e2 years old)	240	191	289
Independent males (e2 years old)	240	187	293
Dependent young (cubs and yearlings)	215	193	236
Total	695	620	770

Table 8. Parameter estimates and model selection results from fitting linear and quadratic models for $Ln(\hat{N}_{Chao2})$ (number of female grizzly bears with cubs) with year for the time period 1983–2016. Chao2 estimates were restricted to the Demographic Monitoring Area during 2012–2016.

Model	Parameter	Estimate	Standard error	*t* value	*P*
Linear					
	β_0	3.00572	0.08031	37.43	<0.0001
	β_1	0.03428	0.00400	8.56	<0.0001
	SSE	1.67792			
	AIC_c	-95.50			
	AIC_c weight	0.114			
Quadratic					
	β_0	2.77644	0.11520	24.10	<0.0001
	β_1	0.07249	0.01517	4.78	<0.0001
	β_2	-0.00109	0.00042	-2.60	0.014
	SSE	1.37835			
	AIC_c	-99.61			
	AIC_c weight	0.886			

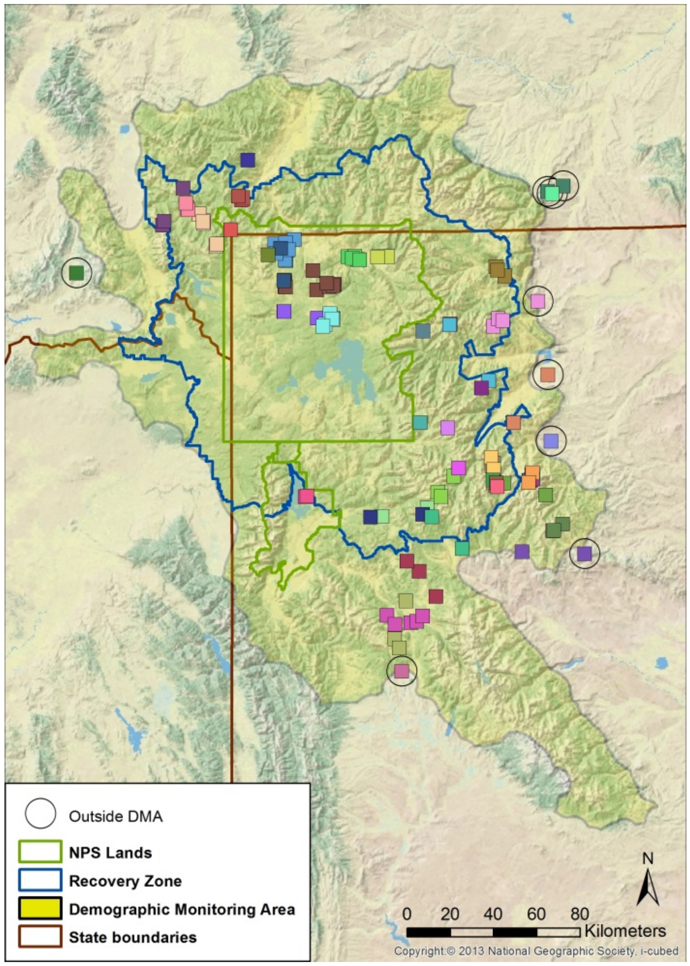


Fig. 3. Distribution of 144 sightings of 46 (indicated by unique colors) unduplicated female grizzly bears with cubs observed in the Greater Yellowstone Ecosystem, 2016. Only sightings from females with cubs occurring within the Demographic Monitoring Area (DMA) are used for population estimation. During 2016, 9 sightings (black circles around symbols) from 8 unique females with cubs occurred outside the DMA. Five of these females (6 observations) were only observed outside the DMA.

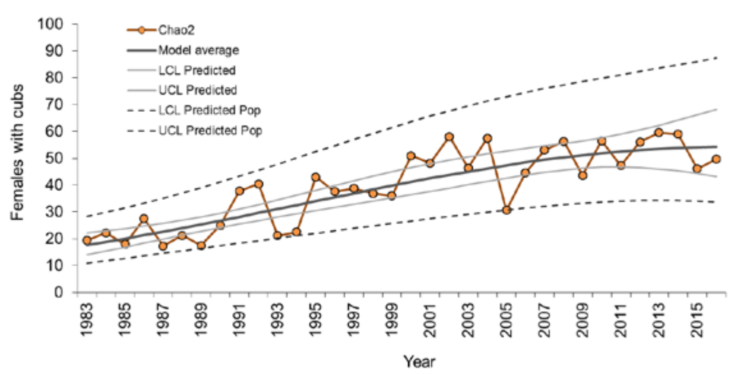


Fig. 4. Model-averaged estimates for the number of unique female grizzly bears with cubs, 1983–2016, where the linear and quadratic models of $Ln(\hat{N}_{Chao2})$ *were fitted. Estimates for 2012–2016 were restricted to the Demographic Monitoring Area (DMA). The inner set of light solid lines represents a 95% confidence interval on the predicted population size, whereas the outer set of dashed lines represents a 95% confidence interval for the individual population estimates.*

II. Mark-Resight Technique to Estimate Females with Cubs

Schwartz et al. (2008) demonstrated biases inherent in the method of estimating population size based on the Chao2 estimator (see previous section) using counts of unique females with cubs and the associated rule set of Knight et al. (1995). The IGBST invited partner agencies and quantitative ecologists to participate in 3 workshops held in February 2011, July 2011, and February 2012 to consider alternative approaches. An important product of these workshops was a recommendation to transition from the current protocol for estimating abundance to a mark-resight estimator using systematic flight observation data conducted since 1997. The mark-resight estimator yields an annual estimate of the number of females with cubs based on 1) the presence of a radio-marked sample, and 2) 2 systematic observation flights/year, during which all bears observed are recorded and, following observation, checked for marks (i.e., radio collar) using telemetry. Pilots note whether family groups observed include cubs, yearlings, or 2-year-old offspring. Mark-resight designs for population estimation are commonly used for wildlife monitoring because they can provide a cost-efficient and reliable monitoring tool. However, inference from such designs is limited when data are sparse, either from a low number of marked animals, a low probability of detection, or both. In the GYE, annual mark-resight data collected for female grizzly bears with cubs suffer from both limitations. As an important outcome of the 3 workshops, Higgs et al. (2013) developed a technique to overcome difficulties due to data sparseness by assuming homogeneity in sighting probabilities over 16 years (1997–2012) of biannual aerial surveys. They modeled counts of marked and unmarked grizzly bears with cubs as multinomial random variables, using the capture frequencies of marked females with cubs for inference regarding the latent multinomial frequencies for unmarked females with cubs (Fig. 5).

One important assumption of the mark-resight technique is that the geographic distribution of radio-marked female bears is generally representative of the geographic distribution and relative density of female bears in the population. Conclusions from workshop discussions were that this assumption is likely not violated within the GYE, with one exception. A subset of bears in the southeastern portion of the GYE annually spend 6 to 10 weeks in late summer (mid-Jul to late Sep) in alpine scree slopes feeding on army cutworm moths (*Euxoa auxiliaris*; Mattson et al. 1991*b*, Bjornlie and Haroldson 2011). These bears are highly visible and constitute a substantial proportion of bears seen during observation flights. However, capturing and marking of bears is difficult because these remote, high-elevation areas are snow-covered early in the capture season and access is limited. When access improves later in the season, most bears have already begun feeding on army cutworm moths and are difficult to capture. Thus, the proportion of radio-marked females with cubs among those feeding on these high-visibility sites is lower than in the remainder of the ecosystem. Applying mark-resight estimates to the entire ecosystem without considering these moth sites would result in overestimation bias. However, moth sites are now well defined and the study team annually monitors these sites. Thus, the decision was made to exclude confirmed moth sites (defined as areas within 500 m from sites where multiple observations of bears feeding occurred >1 year) from the mark-resight analyses and conduct separate aerial census surveys of confirmed moth sites to add the observed number of females with cubs (marked and unmarked) to the mark-resight estimate for that year.

Higgs et al. (2013) performed simulations based on a known population of 50 females with cubs and resighting frequencies and proportions of bears sighted 0, 1, and 2 times from the observation flight data to determine accuracy and precision of the mark-resight technique. Accuracy was high, indicating that this technique addressed the bias concerns associated with estimates based on the Chao2 estimator. However, the simulations also indicated that precision was relatively low. In our 2015 annual report, Peck (2016, Appendix C) reported on reported poor ability of the mark-resight technique to detect declines of 1% and 2% per year, but was moderately effective at detecting a 5% per year decline in annual estimates of females with cubs. Although the IGBST concluded that this was insufficient for effective monitoring of population trend, we continue applying the method because it does provided relatively unbiased estimates and would likely detect large changes in numbers of females with cubs.

2016 Mark-Resight Results

Two female grizzly bears with cub(s) wore functioning radio-transmitters during June-August 2016 when aerial observation flights were conducted and were available for sighting. One of these families was observed once during observation flights >500 m from a moth site. The second radio-marked female with 1 cub was not sighted during observation. Both females were included in the Mark-Resight analysis. We observed 19 unmarked females wit cubs >500 m from moth sites (Table 9). Using the method of Higgs et al. (2013) with updated 1997–2016 data, and excluding observations at army cutworm moth aggregation sites, our 2016 mark-resight estimate for unique females with cubs was 81 (95% inter-quartile range = 45–138) with a low probability of d48 females with cubs ($P < 0.040$; Table 10, Fig. 5). The mark-resight 3-year-moving average for 2015 (i.e., using 2014–2016 results) was 76 unique females with cubs (95% inter-quartile range = 47–117), with a $P = 0.030$ probability of d48 females with cubs (Table 11, Fig. 5). We did not conduct moth site-only flights to count females with cubs on army cutworm moth aggregation sites during 2016.

Table 9. Data used in mark-resight analysis on female grizzly bears with cubs, Greater Yellowstone Ecosystem, 1997–2016, including number of radio-marked female grizzly bears available for sighting during observation flights (*m*), the number seen zero time (Y_0), seen once (Y_1), the number seen twice (Y_2), and the number of unmarked females bears with cubs (*S*). Estimates exclude females with cubs observed <500 m of army cutworm moth aggregation sites.

Year	*m*	Y_0	Y_1	Y_2	*S*
1997	6	4	2	0	4
1998	4	2	2	0	7
1999	6	5	1	0	7
2000	7	7	0	0	11
2001	8	4	4	0	17[a]
2002	5	5	0	0	29[a]
2003	4	3	1	0	7
2004	4	2	2	0	20
2005	3	3	0	0	14
2006	7	7	0	0	23[a]
2007	5	3	2	0	23[b]
2008	5	3	1	1	19[a]
2009	6	6	0	0	14
2010	3	3	0	0	23[a]
2011	3	2	1	0	16
2012	5	3	2	0	12
2013	10	10	0	0	28
2014	5	4	1	0	12
2015	1	0	1	0	22
2016	2	1	1	0	19

[a] Numbers decreased from 2013 data due to boundary changes of moth sites.

[b] Numbers increased from 20 to 23 due to boundary changes of moth sites.

Table 10. Results from mark-resight analysis of female grizzly bears with cubs, Greater Yellowstone Ecosystem, 1997–2016. Data from all years were used to inform sightability, and previous years' posterior distributions were updated based on data from radio-marked females with cubs in 2016. Estimates exclude females with cubs observed <500 m of army cutworm moth aggregation sites.

					Quartile		
Year	Sighted	Marked	Mean	Median	0.025	0.975	*P* d 48
1997	4	6	18	16	5	40	0.99
1998	7	4	31	29	12	61	0.9
1999	7	6	31	28	12	61	0.9
2000	11	7	48	45	23	88	0.55
2001	17	8	75	71	39	128	0.09
2002	29	5	127	122	74	207	0
2003	7	4	31	29	12	61	0.9
2004	20	4	88	84	48	149	0.02
2005	14	3	61	58	31	108	0.26
2006	23	7	101	97	56	167	0
2007	23	5	101	97	57	167	0
2008	19	5	83	80	45	142	0.04
2009	14	6	61	58	31	108	0.26
2010	23	3	101	97	57	168	0
2011	16	3	70	67	37	122	0.13
2012	12	5	53	50	25	96	0.45
2013	28	10	122	118	71	199	0
2014	12	5	53	50	26	95	0.45
2015	22	1	96	92	54	162	0.01
2016	19	2	81	78	45	138	0.04

Observation of a female grizzly bear and her 3 cubs, Grand Teton National Park (photo courtesy of Jake Davis/RevealedinNature.com).

Table 11. Three-year moving average for mark-resight estimates of female grizzly bears with cubs, Greater Yellowstone Ecosystem, 1998–2015. Estimates exclude females with cubs observed <500 m of army cutworm moth aggregation sites.

				Quartile		
Year	Mean	Median	Mode	0.025	0.975	*P* d 48
1998	26.3	25	23	14	45	0.99
1999	36.5	35	33	21	60	0.88
2000	51.1	49	46	30	82	0.46
2001	83.1	81	76	52	129	0.01
2002	77.4	75	69	48	121	0.03
2003	81.7	79	74	51	127	0.01
2004	59.9	58	56	36	95	0.22
2005	83.2	81	76	52	129	0.01
2006	87.6	85	81	55	135	0
2007	94.9	92	86	60	146	0
2008	81.8	79	74	51	127	0.01
2009	81.8	79	75	51	127	0.01
2010	77.4	75	70	48	120	0.03
2011	74.5	72	66	46	116	0.04
2012	81.7	79	74	51	126	0.01
2013	75.8	73	72	47	118	0.03
2014	90.4	88	84	57	139	0
2015	75.6	73	71	47	117	0.03

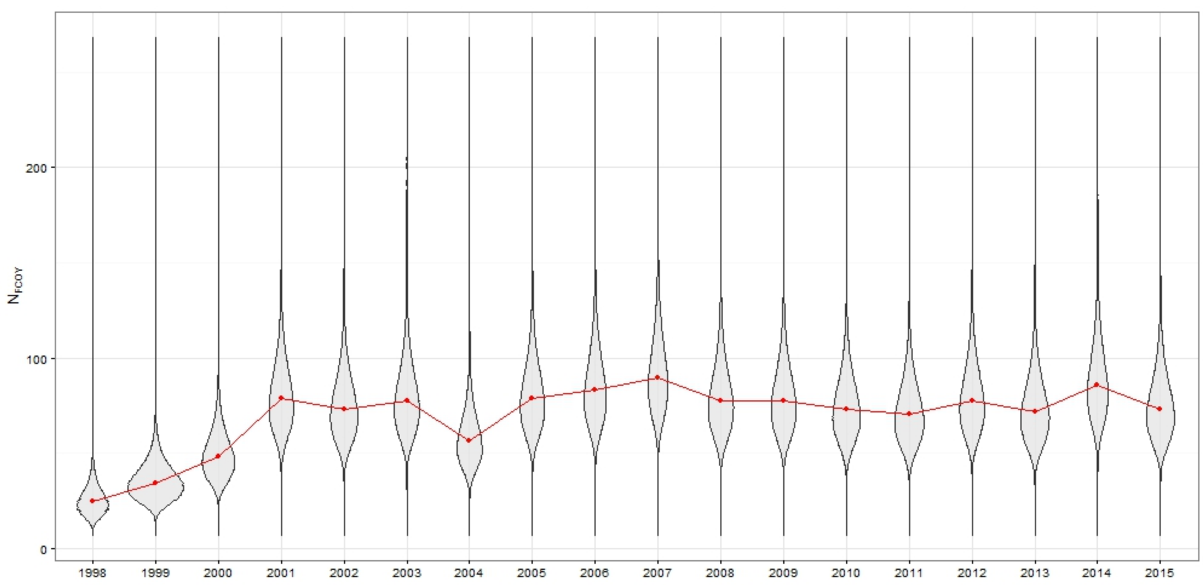


Fig. 5. Annual mark-resight estimates (3-year moving average [red dots], 95 % inter quartile [gray area]) of the number of female grizzly bears with cubs, Greater Yellowstone Ecosystem, 1997–2015. Estimates exclude females with cubs observed <500 m of army cutworm moth aggregation sites.

Occupancy of Bear Management Units (BMU) by Females with Young *(Mark A. Haroldson, Interagency Grizzly Bear Study Team, U.S. Geological Survey)*

Dispersion of reproductive females throughout the ecosystem is assessed by verified observations of female grizzly bears with young (cubs, yearlings, 2-year-olds, or young of unknown age) by BMU. The requirements specified in the Demographic Recovery Criteria (USFWS 2007*b*) state that 16 of the 18 BMUs must be occupied by females with young on a running 6-year sum with no 2 adjacent BMUs unoccupied. Eighteen of 18 BMUs had verified observations of female grizzly bears with young during 2016 (Table 12). Eighteen of 18 BMUs contained verified observations of females with young in at least 4 years of the last 6-year (2010–2015) period.

Table 12. Bear Management Units in the Greater Yellowstone Ecosystem occupied by females with young (cubs, yearlings, 2-year-olds, or young of unknown age), as determined by verified reports, 2011–2016.

Bear Management Unit	2011	2012	2013	2014	2015	2016	Years occupied
1) Hilgard	X	X	X	X	X	X	6
2) Gallatin	X	X	X	X	X	X	6
3) Hellroaring/Bear	X	X	X	X	X	X	6
4) Boulder/Slough	X	X	X	X	X	X	6
5) Lamar	X	X	X	X	X	X	6
6) Crandall/Sunlight	X	X	X	X	X	X	6
7) Shoshone	X	X	X	X	X	X	6
8) Pelican/Clear	X	X	X	X	X	X	6
9) Washburn		X	X	X	X	X	5
10) Firehole/Hayden	X	X	X	X	X	X	6
11) Madison	X		X	X	X	X	5
12) Henry's Lake	X	X	X	X	X	X	6
13) Plateau			X	X	X	X	4
14) Two Ocean/Lake	X	X	X	X	X	X	6
15) Thorofare	X	X	X	X	X	X	6
16) South Absaroka	X	X	X	X	X	X	6
17) Buffalo/Spread Creek	X	X	X	X	X	X	6
18) Bechler/Teton	X		X	X		X	4
Total	16	15	18	18	17	18	

Observation Flights *(Bryn E. Karabensh, Interagency Grizzly Bear Study Team, U.S. Geological Survey)*

Fifty-four Bear Observation Areas (BOAs, Fig. 6) were established in 2014. In 2016, two rounds of observation flights were conducted: 53 BOAs were surveyed during Round 1 (2 Jun–24 Jul) and 42 during Round 2 (7 Jul–28 Aug). Total duration of observation flight time was 106.8 hours for Round 1 and 86.5 hours for Round 2; average duration of individual flights was 2.0 hours (Table 13). Excluding dependent young, 307 bear sightings were recorded during observation flights. This included 11 radio-marked bears (5 females with young, 3 females without young, and 3 males), 228 solitary unmarked bears, and 68 unmarked females with young (Table 13). Our observation rate was 1.59 bears/hour for all bears. A total of 135 young (89 cubs, 37 yearlings, and 9 2-year-olds) were observed (Table 14). Observation rates for females with dependent young were 0.40 females with young/hour and 0.24 females with cubs/hour (Table 13).

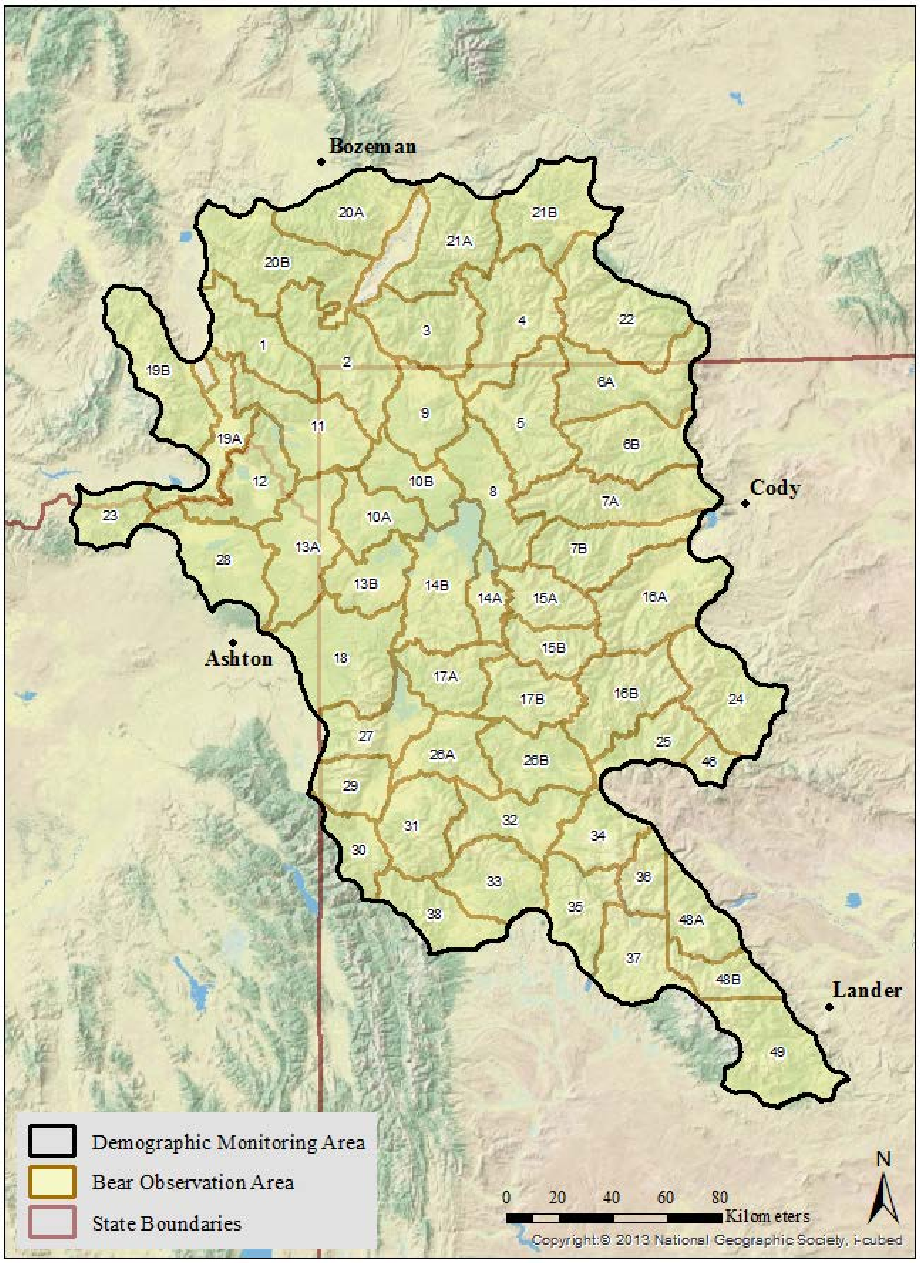


Fig. 6. Grizzly bear observation areas for aerial surveys, Greater Yellowstone Ecosystem, 2016. Numbers represent the 54 Bear Observation Areas, with larger areas split into 2 sections (A and B).

Table 13. Annual summary statistics for grizzly bear observation flights, Greater Yellowstone Ecosystem, 2002–2016.

					Bears seen					Observation rate (bears/hour)		
					Marked		Unmarked					
Date	Observation period	Total hours	Number of flights	Average hours/flight	Lone	With young	Lone	With young	Total number of groups	All groups	With young	With cubs
2002[a]	Round 1	84.0	36	2.3	3	0	88	34	125	1.49		
	Round 2	79.3	35	2.3	6	0	117	46	169	2.13		
	Total	163.3	71	2.3	9	0	205	80	294	1.80	0.49	0.40
2003[a]	Round 1	78.2	36	2.2	2	0	75	32	109	1.39		
	Round 2	75.8	36	2.1	1	1	72	19	93	1.23		
	Total	154.0	72	2.1	3	1	147	51	202	1.31	0.34	0.17
2004[a]	Round 1	84.1	37	2.3	0	0	43	12	55	0.65		
	Round 2	76.6	37	2.1	1	2	94	38	135	1.76		
	Total	160.8	74	2.2	1	2	137	50	190	1.18	0.32	0.23
2005[a]	Round 1	86.3	37	2.3	1	0	70	20	91	1.05		
	Round 2	86.2	37	2.3	0	0	72	28	100	1.16		
	Total	172.5	74	2.3	1	0	142	48	191	1.11	0.28	0.13
2006[a]	Round 1	89.3	37	2.4	2	1	106	35	144	1.61		
	Round 2	77.0	33	2.3	3	1	76	24	104	1.35		
	Total	166.3	70	2.3	5	2	182	59	248	1.49	0.37	0.27
2007[a]	Round 1	99.0	44	2.3	2	1	125	53	181	1.83		
	Round 2	75.1	30	2.5	0	4	96	20	120	1.60		
	Total	174.1	74	2.4	2	5	221	73	301	1.73	0.45	0.29
2008[a]	Round 1	97.6	46	2.1	2	1	87	36	126	1.29		
	Round 2	101.5	45	2.3	2	3	185	53	243	2.39		
	Total	199.1	91	2.2	4	4	272	89	369	1.85	0.47	0.23
2009[a]	Round 1	90.3	47	1.9	1	0	85	21	107	1.18		
	Round 2	93.6	47	2.0	2	0	157	34	193	2.06		
	Total	183.9	94	2.0	3	0	242	55	300	1.63	0.30	0.15
2010[a]	Round 1	101.1	48	2.1	0	2	93	22	117	1.16		
	Round 2	93.3	46	2.0	0	0	161	41	202	2.17		
	Total	194.4	94	2.1	0	2	254	63	319	1.64	0.33	0.20
2011[a]	Round 1	88.9	47	1.9	2	1	153	31	187	2.10		
	Round 2	71.0	35	2.0	4	0	109	23	136	1.92		
	Total	159.8	82	1.9	6	1	262	54	323	2.02	0.34	0.18
2012[a]	Round 1	95.4	48	2.0	4	2	178	35	219	2.30		
	Round 2	73.7	35	2.1	2	1	117	30	150	2.04		
	Total	169.1	83	2.0	6	3	295	65	369	2.18	0.40	0.23
2013[a]	Round 1	97.0	48	2.0	2	1	152	44	199	2.05		
	Round 2	72.8	35	2.1	4	1	171	48	224	3.08		
	Total	169.8	83	2.1	6	2	323	92	423	2.49	0.55	0.39
2014[a]	Round 1	104.0	52	2.0	2	2	170	47	221	2.13		
	Round 2	88.6	43	2.1	3	1	188	60	252	2.84		
	Total	192.6	95	2.0	5	3	358	107	473	2.46	0.57	0.27
2015[a]	Round 1	104.0	52	2.0	4	1	126	34	165	1.59		
	Round 2	88.6	44	2.0	1	2	142	41	186	2.10		
	Total	192.7	96	2.0	5	3	268	75	351	1.82	0.40	0.23
2016[a]	Round 1	106.8	53	2.0	5	3	133	36	177	1.66		
	Round 2	86.5	42	2.1	1	2	95	32	130	1.50		
	Total	193.3	95	2.0	6	8	228	68	307	1.59	0.40	0.24

[a] Dates of flights (Round 1, Round 2): 2002 (12 Jun–22 Jul, 13 Jul–28 Aug); 2003 (12 Jun–28 Jul, 11 Jul–13 Sep); 2004 (12 Jun–26 Jul, 3 Jul–31 Aug); 2005 (4 Jun–26 Jul, 1 Jul–31 Aug); 2006 (5 Jun–9 Aug, 30 Jun–28 Aug); 2007 (24 May–2 Aug, 21 Jun–14 Aug); 2008 (12 Jun–26 Jul, 1 Jul–23 Aug); 2009 (26 May–17 Jul, 8 Jul–27 Aug); 2010 (8 Jun–22 Jul, 10 Jul–24 Aug); 2011 (15 Jun–17 Aug, 21 Jul–29 Aug); 2012 (29 May–30 Jul, 9 Jul–23 Aug); 2013 (6 Jun–25 Jul, 7 Jul–20 Aug); 2014 (10 Jun–25 Jul, 7 Jul–29 Aug); 2015 (1 Jun–21 Jul, 1 Jul–31 Aug); 2016 (2 Jun–24 Jul, 7 Jul–28 Aug).

Table 14. Size and age composition of grizzly bear family groups seen during observation flights, Greater Yellowstone Ecosystem, 2002–2016.

		Females with cubs (number of cubs)			Females with yearlings (number of yearlings)			Females with 2-year-olds or young of unknown age (number of young)		
Year	Round	1	2	3	1	2	3	1	2	3
2002[a]	Round 1	8	15	5	3	2	0	0	0	1
	Round 2	9	19	9	2	4	2	0	1	0
	Total	17	34	14	5	6	2	0	1	1
2003[a]	Round 1	2	12	2	2	6	2	3	3	0
	Round 2	2	5	3	2	5	0	2	0	1
	Total	4	17	5	4	11	2	5	3	1
2004[a]	Round 1	4	1	3	1	1	0	2	0	0
	Round 2	6	16	7	4	7	0	0	0	0
	Total	10	17	10	5	8	0	2	0	0
2005[a]	Round 1	5	5	3	2	3	1	0	1	0
	Round 2	4	4	1	3	6	3	5	2	0
	Total	9	9	4	5	9	4	5	3	0
2006[a]	Round 1	8	12	7	4	2	2	1	0	0
	Round 2	5	11	2	2	1	0	2	2	0
	Total	13	23	9	6	3	2	3	2	0
2007[a]	Round 1	7	21	9	8	6	0	2	1	0
	Round 2	2	6	6	3	2	3	0	2	0
	Total	9	27	15	11	8	3	2	3	0
2008[a]	Round 1	3	10	0	9	5	2[b]	6	2	0
	Round 2	9	21	3	7	8	3	3	2	0
	Total	12	31	3	16	13	5[b]	9	4	0
2009[a]	Round 1	0	6	4	2	3	1	3	1	0
	Round 2	6	11	1	3	7	1	4	1	1
	Total	6	17	5	5	10	2	7	1	1
2010[a]	Round 1	2	7	2	2	6	1	4	0	0
	Round 2	10	10	7	5	4	3	1	4	3
	Total	12	17	9	7	10	4	5	4	3
2011[a]	Round 1	4	8	3	3	6	1	2	2	3
	Round 2	2	8	4	2	2	1	1	3	0
	Total	6	16	7	5	8	2	3	5	3
2012[a]	Round 1	5	19	1	2	3	4	0	2	1
	Round 2	5	9	0	4	6	2	1	3	1
	Total	10	28	1	6	9	6	1	5	2
2013[a]	Round 1	8	20	4	1	5	0	3	4	0
	Round 2	11	21	3[c]	2	7	0	0	5	0
	Total	19	41	7[c]	3	12	0	3	9	0
2014[a]	Round 1	8	17	3	6	14	0	1	0	0
	Round 2	1	15	8	11	18	3	2	2	1
	Total	9	32	11	17	32	3	3	2	1
2015[a]	Round 1	6	18	15	2	20	6	0	2	0
	Round 2	9	22	12	2	24	6	2	0	4[d]
	Total	15	40	27	4	44	12	2	2	4[d]
2016[a]	Round 1	3	16	2	5	8	1	2	2	0
	Round 2	8	11	6	2	4	1	1	1	0
	Total	11	27	8	7	12	2	3	3	0

[a] Dates of flights (Round 1, Round 2): 2002 (12 Jun–22 Jul, 13 Jul–28 Aug); 2003 (12 Jun–28 Jul, 11 Jul–13 Sep); 2004 (12 Jun–26 Jul, 3 Jul–31 Aug); 2005 (4 Jun–26 Jul, 1 Jul–31 Aug); 2006 (5 Jun–9 Aug, 30 Jun–28 Aug); 2007 (24 May–2 Aug, 21 Jun–14 Aug); 2008 (12 Jun–26 Jul, 1 Jul–23 Aug); 2009 (26 May–17 Jul, 8 Jul–27 Aug); 2010 (8 Jun–22 Jul, 10 Jul–24 Aug); 2011 (15 Jun–17 Aug, 21 Jul–29 Aug); 2012 (29 May–30 Jul, 9 Jul–23 Aug); 2013 (6 Jun–25 Jul, 7 Jul–20 Aug); 2014 (10 Jun–25 Jul, 7 Jul–29 Aug); 2015 (1 Jun–21 Jul, 1 Jul–31 Aug); 2016 (2 Jun–24 Jul, 7 Jul–28 Aug).

[b] Includes 1 female with 4 yearlings.

[c] Includes 1 female with 4 cubs.

[d] Includes 1 female with 4 young of unknown age.

Telemetry Location Flights *(Bryn E. Karabensh, Interagency Grizzly Bear Study Team, U.S. Geological Survey)*

Seventy-eight telemetry location flights were conducted during 2016, resulting in 252.5 hours of search time (excluding ferry time to and from airports; Table 15). Flights were conducted at least once during all months, with 81% of telemetry flights in May–November. During telemetry flights, 777 locations of bears equipped with radio transmitters were collected, 202 (26%) of which included a visual sighting. Twenty-four sightings of unmarked bears were also obtained during telemetry flights, including 21 solitary bears, 2 females with cubs, and 1 female with 2-year-olds. Rate of observation for all unmarked bears during telemetry flights was 0.10 bears/hour; and 0.80 bears/hour for marked bears. The observations rate during telemetry flights for unmarked females with cubs was 0.01 females with cubs/hour.

In an effort to reduce flight time and costs associated with aerial telemetry and obtain higher-frequency data, we began deploying satellite GPS collars in 2012 using Argos and Iridium platforms. Since 2014, only Iridium satellite collars have been deployed. These GPS collars are different from those that store GPS locations onboard, which we have deployed since 2000, by providing the ability to download GPS location data via satellites. Only Iridium platforms were on the air in 2016. We deployed 26 Iridium GPS collars in 2016, obtaining 96,403 GPS locations from 47 grizzly bears (newly and previously deployed GPS collars).

Table 15. Summary statistics for radio-telemetry flights to locate grizzly bears, Greater Yellowstone Ecosystem, 2016.

				Radioed bears			Unmarked bears observed					
								No. of females			Observation rate (no. of groups/hour)	
Month	No. of hours	No. of flights	Mean no. of hours/ flight	No. of locations	No. seen	Observation rate (no. of groups/hr)	Lone bears	With cubs	With yearlings	With young	All groups	Females with cubs
Jan	9.4	3	3.13	44	0	---	0	0	0	0	---	---
Feb	10.1	3	3.37	47	0	---	0	0	0	0	---	---
Mar	10.1	3	3.37	48	2	0.20	0	0	0	0	---	---
Apr	23.6	5	4.72	83	19	0.81	0	0	0	0	---	---
May	29.5	8	3.69	64	36	1.22	10	1	0	0	0.37	0.03
June	24.9	12	2.08	67	30	1.20	4	0	0	1	0.20	0.00
July	20.0	8	2.50	72	23	1.15	4	0	0	0	0.20	0.00
Aug	27.1	9	3.01	77	25	0.92	1	1	0	0	0.07	0.04
Sept	33.9	9	3.77	88	26	0.77	1	0	0	0	0.03	0.00
Oct	32.5	9	3.61	97	32	0.98	1	0	0	0	0.03	0.00
Nov	23.4	8	2.93	63	8	0.34	0	0	0	0	---	---
Dec	8.0	1	8.00	27	1	0.13	0	0	0	0	---	---
Total	252.5	78	3.24	777	202	0.80	21	2	0	1	0.10	0.01

Documented Grizzly Bear Mortalities in the GYE and Estimated Percent Mortality for the Demographic Monitoring Area *(Mark A. Haroldson, Interagency Grizzly Bear Study Team, U.S. Geological Survey; and Kevin L. Frey, Montana Fish, Wildlife and Parks)*

The IGBST is tasked with documenting grizzly bear mortalities occurring in the GYE, and since 2012 we have been evaluating mortality levels for the Demographic Monitoring Area (DMA; USFWS 2013). We evaluate mortalities for population segments within the DMA by deriving estimates of total mortality for independent-age (e2 years old) females and independent-age males, which includes estimates of unknown/unreported mortalities (Cherry et al. 2002). We then determine the total annual mortality rate for these segments as a percent of their respective population estimates. For dependent bears (d2 years old), we determine the percent of human-caused mortality relative to size of the population segment but do not include estimates of unknown/unreported mortality. Here, we report numbers of known and probably mortalities in the GYE, numbers by sex and age class inside and outside the DMA, and provide estimates of percent total mortality relative to population segments within the DMA.

We use the definitions provided in Craighead et al. (1988) to classify grizzly bear mortalities in the GYE relative to the degree of certainty regarding each event. Cases in which a carcass is physically inspected or when a management removal occurs are classified as "known" mortalities. Instances are classified as "probable" where evidence strongly suggests a mortality has occurred but no carcass is recovered. When evidence is circumstantial, with no prospect for additional information, a "possible" mortality is designated. Possible mortalities are excluded from assessments of percent annual mortalities. We continue to tabulate possible mortalities because they provide an additional source of location information for grizzly bears and possible causes of mortalities in the GYE.

2016 Mortality Results

We documented 58 known and probable mortalities in the GYE during 2016; 51 were attributable to human causes (Table 16, Fig. 7). Thirteen of the 58 known and probable losses that occurred during 2016 remain under investigation by USFWS and state law enforcement agencies (Table 16). Specific information related to these mortalities is not provided because of ongoing investigations. However, these mortality events are included in the following summary. Twenty-seven (52.9 %) of the 51 human-caused losses involved management removals due to either livestock depredations (n = 14) or site conflicts (n = 13). One additional livestock-related loss included an accidental handling mortality of a cub captured with its mother at a sheep depredation trap site. Eight (15.7 %) of the human-caused losses were hunting related, including 1 mistaken identity kill by a black bear hunter and 7 losses from self-defense kills. One of the reported hunting related self-defense kills involved a female accompanied by 3 cubs, all of which were subsequently removed. Other human-caused losses included vehicle strikes (n = 9), bears that drowned in a man-made concrete canal that animals are unable to climb out of in swift water (n = 3), and bears that were maliciously shot (n = 2). Additionally, 1 cub was killed by another bear while its mother was caught in a culvert trap during a research capture operation. We documented 5 natural mortalities (Table 16). Three of the natural mortalities were cubs lost from 2 radio-marked females. Another independent-age subadult was killed by another bear. Lastly a 25-year-old male likely died from poor condition associated with old age and wounds from a fight with another bear. We also documented 2 mortalities from undetermined causes (Table 16). These included the found remains of a subadult male that had been consumed by scavengers, and the skull of an adult bear found during the spring of 2016 that likely died during 2015. Sex determination for this latter bear is pending DNA analysis.

We documented 2 incidents considered possible mortalities during 2016 (Table 16). One was related to vehicle collision where the bear left the scene and no carcass was found. The other involved a female with 2 cubs that was shot at during an encounter with archery hunters. No evidence was present at the site to suggest the bear had been hit.

We evaluated known and probable mortalities relative to population estimates only for the Demographic Monitoring Area (DMA;

USFWS 2013). Of the 57 known and probable mortalities documented during 2016, 37 occurred within the boundaries of the DMA (Table 17, Fig. 7). We documented 6 mortalities for independent-age females within the DMA during 2016 (Table 17). There were 2 management removals and 4 reported losses for independent-age females (Table 18). Estimated total mortality for independent-age females was 5.0 % of the 2016 estimate for this segment of the population (Table 18). Nineteen known and probable mortalities for independent-age males occurred within the DMA (Table 17). We documented 6 management removals; 2 radioed, and 11 reported losses of independent-age males within the DMA (Table 17). Estimated total mortality for independent aged males was 15.6 % of the 2016 estimate for this segment of the population (Table 18). There were 9 known and probable human-caused losses of dependent young documented in the DMA during 2016 (Table 18). Estimated human-caused loss for dependent young was 4.2 % within the DMA (Table 18).

One documented mortality from 2012 remains under investigation, as do 3 from 2013, 3 from 2014, and 5 from 2015. None of the mortalities documented during 2009, 2010, or 2011 remain under investigation. Specific information pertaining to closed mortality investigations will be updated in the respective annual Mortality Lists (https://www.usgs.gov/science/igbst) as they become available. We remind readers that some cases can remain open and under investigation for extended periods. The study team cooperates with federal and state law enforcement agencies and cannot release information that could compromise ongoing investigations.

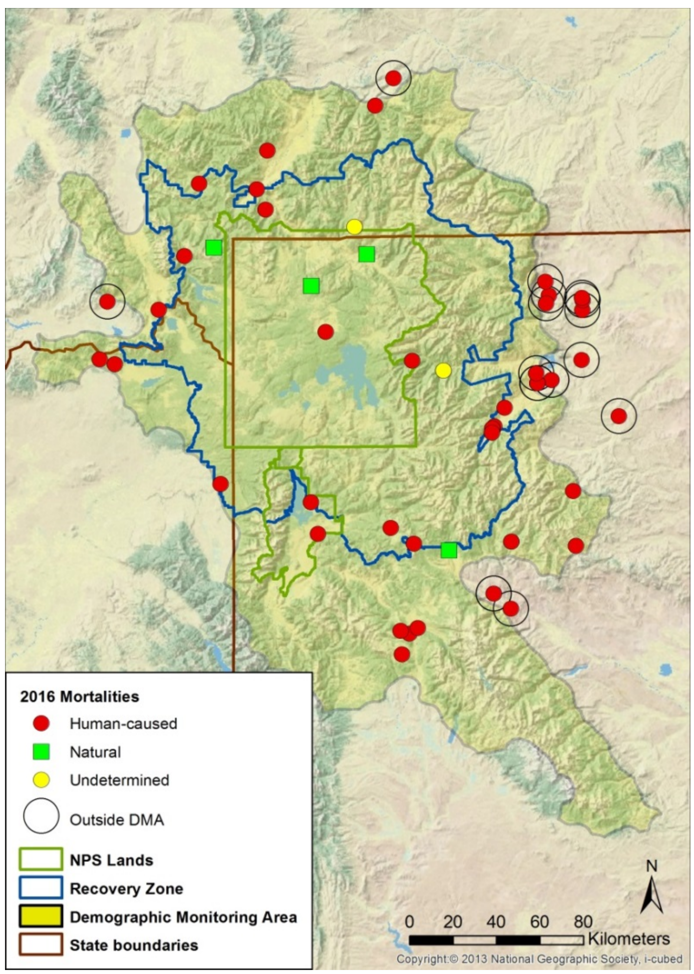


Fig. 7. Distribution of 58 known and probable grizzly bear mortalities documented in the Greater Yellowstone Ecosystem, 2016. Thirty-eight mortalities occurred within the Demographic Monitoring Area (DMA), of which 31 were attributed to human causes. Twenty mortalities were outside the DMA (black circles around symbols) with all 20 of those attributed to human causes.

Table 16. Grizzly bear mortalities documented in the Greater Yellowstone Ecosystem, 2016.								
Unique number	Bear [a]	Sex [b]	Age [c]	Date	Location [d]	Monitoring area [e]	Certainty	Cause
201601				2016	-MT	Outside DMA	Known	Under investigation
201602	Unm	Unk	Adult	2015	Fishhawk Crk, SNF-WY	In DMA	Known	Undetermined cause; horn hunter found skull of old adult bear in April that likely died during 2015. Sex determination pending DNA results.
201603	839	M	Adult	4/16/2016	South Fork Shoshone, PR-WY	In DMA	Known	Human cause; management removal of bear #839 for repeated cattle depredations. Was wearing an active collar when removed.
201604	Unm	M	Adult	5/6/2016	Pat O'Hara Crk, PR-WY	Outside DMA	Known	Human cause; management removal for cattle depredations, numerous fight wounds including damaged eye.
201605	655	M	Adult	5/5/2016	Timber Crk, CTNF	In DMA	Known	Human cause; mistaken identity kill of bear #655 by black bear hunter. Bear was not collared when killed.
201606	G206	M	Subadult	5/12/2016	Wind River, PR-WY	Outside DMA	Known	Human cause; management removal of bear #G206 for repeated property damage.
201607	299	M	Adult	5/12/2016	Lamar River, YNP	In DMA	Known	Natural cause; bear #299 likely due to a combination of poor condition associated with old age and fight wounds. Was wearing an active collar.
201608	846	M	Adult	5/22/2016	Wood River, PR-WY	In DMA	Known	Human cause; management removal of bear #846 for repeated property damages and obtaining food rewards. Was wearing a functioning collar when removed.
201609	798	M	Adult	5/26/2016	Heart Mountain Canal, PR-WY	Outside DMA	Known	Human cause; bear #798 drowned in a canal siphon, was not wearing collar when carcass was found.
201610				2016	WY	In DMA	Known	Under investigation.
201611				2016	WY	In DMA	Known	Under investigation.
201612				2016	ID	In DMA	Known	Under investigation
201613	Unm	M	Cub	6/19/2016	Pilgrim Crk, GTNP	In DMA	Known	Human cause; cub hit and killed by vehicle.
201614	742	M	Adult	6/25/2016	Paint Crk, PR-WY	Outside DMA	Known	Human cause; management capture and removal or bear #742 for cattle depredation. Was not collared when removed.
201615	642	M	Adult	6/30/2016	Heart Mountain Canal, PR-WY	Outside DMA	Known	Human cause; bear #642 drowned in a canal siphon, was not wearing collar when carcass was found.
201616	Unm	M	Subadult	7/5/2016	Gallatin River, PR-MT	In DMA	Known	Human cause; vehicle strike.

Table 16. Continued.

Unique	Bear [a]	Sex [b]	Age [c]	Date	Location [d]	Monitoring area [e]	Certainty	Cause
201617	836	F	Subadult	7/10/2016	Tepee Crk, BTNF	In DMA	Known	Human cause; management removal of bear #836 for cattle depredations. Bear was collared when removed.
201618	843	M	Subadult	7/10/2016	Wind River, PR-WY	Outside DMA	Known	Human cause; management removal of bear #843 for repeated nuisance activity and anthropogenic food rewards in developed areas. Bear was collared when removed.
201619	844	M	Subadult	7/10/2016	Wind River, PR-WY	Outside DMA	Known	Human cause; management removal of bear #844 for repeated nuisance activity and anthropogenic food rewards in developed areas. Bear was collared when removed.
201620	755	F	Adult	7/12/2016	Wagon Crk, BTNF	In DMA	Known	Human cause; management removal of bear #755 for repeated cattle depredations. Bear was not collared when removed.
201621	Unm	F	Cub	7/20/2016	Blackrock Crk, BTNF	In DMA	Known	Human cause; vehicle strike.
201622	219	M	Adult	7/23/2016	Moose Crk, CTNF	In DMA	Known	Human cause; management removal of bear #219 for multiple sheep depredations. Bear was not collared when removed.
201623	Unm	M	Subadult	7/1/2016	Buffalo Crk, CGNF	In DMA	Known	Undetermined cause; YNP personnel found scavenged remains of a subadult grizzly bear. Grizzly bears and wolves had been at the site, carcass was mostly consumed.
201624	Unm	M	Subadult	8/1/2016	DuNoir Crk, PR-WY	In DMA	Known	Natural cause; killed by another grizzly bear.
201625	785	M	Adult	8/6/2016	Red Crk, BTNF	In DMA	Known	Human cause; management removal of bear #785 for cattle depredations. Was not collared when removed.
201626	Unm	M	Subadult	8/8/2016	Greybull River, BLM-WY	Outside DMA	Known	Human cause; vehicle strike.
201627	765	M	Adult	8/15/2016	Willow Crk, PR-WY	In DMA	Known	Human cause; management removal of bear #765 for cattle depredations. Was not collared when removed.
201628				2016	MT	In DMA	Known	Under investigation.
201629	Unm	F	Cub	8/29/2016	Lime Crk, BTNF	In DMA	Known	Human cause; accidental handling mortality during management capture for sheep depredations.
201630	Unm	F	Subadult	8/31/2016	Snowshoe Crk, PR-MT	Outside DMA	Known	Human cause; management removal for cattle depredations.
201631	Unm	M	Adult	9/10/2016	Wind River, SNF	In DMA	Known	Human cause; reported archery hunting-related defense of life kill. UNDER INVESTIGATION
201632	443	M	Adult	9/14/2016	Boulder River, CGNF	In DMA	Known	Human cause; vehicle strike of bear #443. Bear was not collared when killed.
201633	Unm	M	Subadult	9/17/2016	Cottonwood Crk, PR-MT	In DMA	Known	Human cause; property damage on houses and outbuilding, and livestock depredations.

Table 16. Continued.

Unique	Bear [a]	Sex [b]	Age [c]	Date	Location [d]	Monitoring area [e]	Certainty	Cause
201634	Unm	M	Subadult	9/26/2016	South Fork Shoshone, PR-WY	In DMA	Known	Human cause; vehicle strike.
201635	Unm	Unk	Cub	9/25/2016	Trout Crk, YNP	In DMA	Known	Human cause; cub of trapped female (#799) was killed by another bear while its mother was captured.
201636	369	M	Adult	9/29/2016	Carter Crk, PR-WY	Outside DMA	Known	Human cause; management removal of bear #369 for multiple conflicts and frequenting developed areas. Was not collared when removed.
201637	829	M	Adult	9/29/2016	Carter Crk, PR-WY	Outside DMA	Known	Human cause; management removal of bear #829 for multiple conflicts and frequenting developed areas. Was not collared when removed.
201638	643	M	Adult	9/29/2016	Middle Crk, YNP	In DMA	Known	Human cause; vehicle strike of bear #643. Bear was not collared when killed.
201639	703	F	Adult	9/30/2016	Sage Crk, BLM-WY	Outside DMA	Known	Human cause; management removal of bear #703 for multiple conflicts and frequenting landfill. Was not collared when removed.
201640	Unm	M	Subadult	10/4/2016	Heart Mountain Canal, PR-WY	Outside DMA	Known	Human cause; drowned in a canal siphon.
201641	Unm	F	Adult	10/7/2016	South Fork Shoshone, PR-WY	Outside DMA	Known	Human cause; management removal of female with 3 cubs for cattle depredations.
201642	Unm	M	Cub	10/7/2016	South Fork Shoshone, PR-WY	Outside DMA	Known	Human cause; 1st of 3 cubs removed with mother for cattle depredations.
201643	Unm	M	Cub	10/7/2016	South Fork Shoshone, PR-WY	Outside DMA	Known	Human cause; 2nd of 3 cubs removed with mother for cattle depredations.
201644	Unm	F	Cub	10/8/2016	South Fork Shoshone, PR-WY	Outside DMA	Known	Human cause; 3rd of 3 cubs removed with mother for cattle depredations.
201645	Unm	M	Adult	10/9/2016	Pat O'Hara Crk, PR-WY	Outside DMA	Known	Human cause; management capture and removal for obtaining anthropogenic foods and poor condition.
201646	465	M	Adult	10/15/2016	Bear Crk, PR-WY	Outside DMA	Known	Human cause; management capture and removal of bear #465 for livestock depredations and property damage. Bear was not collared when removed.
201647				2016	WY	In DMA	Known	Under investigation.
201648				2016	WY	In DMA	Known	Under investigation.
201649				2016	WY	In DMA	Known	Under investigation.

Table 16. Continued.								
Unique	Bear [a]	Sex [b]	Age [c]	Date	Location [d]	Monitoring area [e]	Certainty	Cause
201650				2016	WY	In DMA	Known	Under investigation
201651	Unm	F	Subadult	10/27/2016	South Fork Shoshone, PR-WY	In DMA	Known	Human cause; vehicle strike.
201652				2016	ID	In DMA	Known	Under investigation.
201653	Unm	M	Subadult	10/30/2016	Snake River, GTNP	In DMA	Known	Human cause; vehicle strike.
201654				2016	MT	In DMA	Known	Under investigation.
201655				2016	MT	In DMA	Known	Under investigation.
201656	Unm	Unk	Cub	6/2/2016	Lava Crk, YNP	In DMA	Probable	Natural cause; 1st of 2 cubs of 3 cub litter from radio-collared female #815 lost between 5/12 and 6/24. Mortality date and location are approximate.
201657	Unm	Unk	Cub	6/2/2016	Lava Crk, YNP	In DMA	Probable	Natural cause; 2nd of 2 cubs of 3 cub litter from radio-collared female #815 lost between 5/12 and 6/24. Mortality date and location are approximate.
201658	Unm	Unk	Cub	9/17/2016	Snowslide Crk, CGNF	In DMA	Probable	Natural cause; cub of radio-collared female #762 lost between 9/9 and 9/26. Mortality date and location are approximate.
201659	783	M	Adult	6/24/2016	Snake River, GTNP	In DMA	Possible	Human cause; #783 was likely struck by a vehicle, the bear rolled then got up and ran off.
201660	Unm	F	Adult	9/14/2016	Bear Crk, BDNF	In DMA	Possible	Human cause; female with 2 cubs charged and was shot at 4 times by archery hunter, no evidence bear was hit.

[a] Number indicates bear number; Unm = unmarked bear; Mkd = previously marked bear but identity unknown.

[b] Unk = unknown sex.

[c] Cub = less than 1 year old; yearling = 1 to 2 years old; subadult = 2 to 4 years old; adult = 5 years or older; Unk = unknown age.

[d] BTNF = Bridger-Teton National Forest, BLM = Bureau of Land Management, CTNF = Caribou-Targhee National Forest, CGNF = Custer-Gallatin National Forest, GTNP = Grand Teton National Park, SNF = Shoshone National Forest, YNP = Yellowstone National Park, Pr = private.

[e] Location relative to the Demographic Monitoring Area.

Table 17. Counts of documented known and probably grizzly bear mortalities by sex, age class, and location relative to the Demographic Monitoring Area (DMA), Greater Yellowstone Ecosystem, 2016.

Area	Sex	Age class		Total
		Dependent (<2 years old)	Independent (e2 years old)	
Inside DMA	Female	6	6	12
	Male	2	19	21
	Unknown	4	0	4
	Total	12	25	37
Outside DMA	Female	1	3	4
	Male	2	14	16
	Unknown	0	0	0
	Total	3	17	20

Table 18. Annual estimates ($\hat{N}$) and mortality statistics by population segment for grizzly bears in the Demographic Monitoring Area (DMA), Greater Yellowstone Ecosystem 2016. Population estimates for the DMA were derived using the most recent vital rates (IGBST 2012). Only human-caused losses are counted against the mortality threshold for dependent young.

Population segment	$\hat{N}$	Human-caused loss	Sanctioned removals (a)	Radio-marked loss (b)	Reported loss	Estimated[a] reported + unreported loss (c)	Estimated total mortality (a + b + c)	Annual % mortality
Dependent young	215	9						4.2
Females 2+	240	6	2	0	4	10	12	5.0
Males 2+	240	16	6	2	11	29	37	15.6

[a] Method of estimating unknown, unreported mortality from Cherry et al. (2002).

Monitoring of Grizzly Bear Foods

Spring Ungulate Availability and Use by Grizzly Bears in Yellowstone National Park. *(Kerry A. Gunther and Travis C. Wyman Yellowstone National Park)*

Ungulate carrion is frequently consumed by grizzly bears in the GYE (Mealey 1975, Green 1994, Mattson 1997). The number of ungulate carcasses available to grizzly bears during the spring is correlated with measures of snow-water equivalency (depth, density, and moisture content) in the snowpack (Podruzny et al. 2012). Competition with reintroduced wolves (*Canis lupus*) for carrion and changes in bison (*Bison bison*) and elk (*Cervus elaphus*) management in the GYE have the potential to affect carcass availability and use by grizzly bears. For these and other reasons, we continue to survey historic carcass transects in Yellowstone National Park. In 2016, we surveyed 28 routes in ungulate winter ranges to monitor the relative abundance of spring ungulate carcasses (Fig. 8).

We surveyed each route once for carcasses between 21 March and 7 June. Because spring snow depths influence ungulate distribution and the area we can survey, we used a GPS to accurately measure the actual distance traveled on each route each year. At each carcass, we collected a site description (location, aspect, slope, elevation, habitat type, distance to forest edge), carcass data (species, age, sex, cause of death), and information about scavengers using the carcasses (evidence of scavenger species present, percent of carcass consumed). We were unable to calculate the actual biomass consumed by bears, wolves, or other large scavengers with our survey methodology.

In 2016, we recorded 37 ungulate carcasses on 278.8 km of survey routes, for a total of 0.13 ungulate carcasses/km surveyed (Table 19). The number of carcasses observed annually since 1992 have been highly variable among years (Fig. 9).

Northern Ungulate Winter Range

We surveyed 12 routes on Yellowstone's Northern Range totaling 158.0 km traveled (Fig. 9). One route was not surveyed to avoid disturbing an active wolf den. We counted 35 carcasses, including 15 elk, 15 mule deer (*Odocoileus hemionus*), 4 bison, and 1 pronghorn (*Antilocapra americana*), which equated to 0.22 ungulate carcasses/km of survey route (Table 19). Sex and age of carcasses found are shown in Tables 20 and 21. All of the 35 carcasses were 76–99% consumed by scavengers when found. Three of the elk, 3 of the bison, and 1 of the mule deer carcasses had evidence of feeding by wolves. Two of the bison, 1 of the elk, and 1 of the mule deer carcasses had evidence of being fed on by coyotes. One of the elk carcasses had been fed on by a mountain lion. None of the elk, bison, or mule deer carcasses had visible evidence of being scavenged by bears. The species of carnivore that scavenged 13 of the mule deer carcasses, 12 of the elk carcasses, 2 of the bison carcasses, and the pronghorn carcass could not be determined. Grizzly bears or their sign (e.g., tracks, scats, daybeds, rub trees, feeding activity) were observed along 4 of the 12 survey routes. Black bear activity was observed along 6 routes. We identified 3 bear feeding sites along the survey routes. Feeding activities included: 1) digging pocket gopher caches, 2) digging for an undetermined food, and 3) grazing an undetermined food.

Interior Winter Ranges

We surveyed a total of 120.8 km along 16 survey routes in 4 thermally influenced interior ungulate winter ranges including the Firehole River area, Norris Geyser Basin, Heart Lake area (Witch Creek and Rustic Geyser Basin and associated thermal areas), and Mud Volcano Geyser Basin. We documented 1 bison and 1 mule deer carcass for a total of 0.02 carcasses/km of survey route. Sex and age of carcasses found are shown in Table 20. Grizzly bear activity was documented along 12 of the 16 survey routes.

Firehole River Area

We surveyed 8 routes in the Firehole drainage in the central interior of the park covering 71.2 km. We found 1 bison carcass (0.01

carcasses/km). The species of carnivore that had fed on the bison carcasses could not be determined. Grizzly bears or their sign were observed along 7 of the 8 survey routes. No black bear activity was observed. We identified 9 bear feeding sites along the survey routes. Primary feeding activities identified at these locations included: 1) digging spring beauty (*Claytonia lanceolata*) corms, 2) digging earthworms (Lumbricidae), and 3) digging pocket gophers (*Thomomys talpoides*) and their food caches of plant roots.

Norris Geyser Basin

We surveyed 4 routes in the Norris Geyser Basin in the central interior of the park traveling 21.7 km. No ungulate carcasses were observed. Grizzly bear tracks and a feeding site were observed along 1 of the 4 survey routes. The grizzly had been digging earthworms. No black bear activity was observed.

Heart Lake

We surveyed 3 routes in the Heart Lake area in the south central interior of the park covering 21.2 km. No ungulate carcasses were observed. Grizzly bear sign were observed on all 3 survey routes. No black bear activity was observed. We identified 12 bear feeding sites along the survey routes. Primary feeding activities identified at these locations included: 1) digging oniongrass (*Melica spectabilis*) bulbs; 2) ripping open logs for ants; 3) grazing grasses, sedges, clover and dandelion; 4) consuming geothermal soil; 5) digging spring beauty corms; 6) digging earthworms; and 7) digging up pocket gophers and their food caches of plant roots.

Mud Volcano

We surveyed a single route in the Mud Volcano thermal area of the central interior of the park covering 6.7 km. One mule deer carcass were observed. Grizzly bear tracks, feeding sites, daybeds, and rub trees were observed along the survey route; no black bear activity was observed. We identified 4 bear feeding sites, including 2 sites where bears had been digging onion grass bulbs, 1 site where bears had dug earthworms, and 1 site where bears consumed geothermal soil.

Discussion

There were relatively few ungulate carcasses observed per km of survey route on both the northern ungulate winter range (0.22 carcasses/km) and on interior ungulate winter ranges (0.02 carcasses/km) in 2016. The low number of carcasses is likely due to the very mild winter experienced in the Greater Yellowstone Ecosystem in 2016. Although grizzly bear sign was observed along 16 of the 28 transect routes, no visual evidence of grizzly bears scavenging any of the 37 ungulate carcasses was found. Examination of 29 bear feeding sites along survey routes indicated that during the spring of 2016, grizzly bears dug for oniongrass bulbs, spring beauty corms, earthworms, and pocket gophers and their food caches; ripped open logs for ants; and grazed grasses, sedges, clover, and dandelion. In addition, bears also consumed geothermal soil during the spring season. Ingestion of geothermal soil may serve to restore mineral deficiencies because it contains high concentrations of potassium, magnesium, and sulfur (Mattson et al. 1999).

Table 19. Ungulate carcasses found along surveyed routes and visitation of carcasses by bears, wolves, and unknown large carnivores, Yellowstone National Park, spring 2016.

Survey area (no. of routes)	Elk				Bison				Bighorn sheep, pronghorn, and mule deer				Total carcasses /km
	No. of carcasses	No. visited by species			No.of carcasses	No. visited by species			Number Of Carcasses	No. visited by Species			
		Bear	Wolf	Unk		Bear	Wolf	Unk		Bear	Wolf	Unk	
Northern Range (12)	15	0	3	12	4	0	3	1	16[a]	0	1	16	0.22
Firehole (8)	0	0	0	0	1	0	0	1	0	0	0	0	0.01
Norris (4)	0	0	0	0	0	0	0	0	0	0	0	0	0
Heart Lake (3)	0	0	0	0	0	0	0	0	0	0	0	0	0
Mud Volcano (1)	0	0	0	0	0	0	0	0	1[b]	0	0	1	0.14
Total	15	0	3	12	5	0	3	2	17	0	1	17	0.13

[a] 15 mule deer and 1 pronghorn.
[b] 1 mule deer.

Table 20. Age classes and sex of elk and bison carcasses found, by area, along surveyed routes, Yellowstone National Park, 2016.

	Elk						Bison					
	Northern Range	Firehole	Norris	Heart Lake	Mud Volcano	Total	Northern Range	Firehole	Norris	Heart Lake	Mud Volcano	Total
Age												
Adult	12	0	0	0	0	12	4	1	0	0	0	5
Yearling	2	0	0	0	0	2	0	0	0	0	0	0
Calf	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	1	0	0	0	0	1	0	0	0	0	0	0
Sex												
Male	6	0	0	0	0	6	1	0	0	0	0	1
Female	6	0	0	0	0	6	3	1	0	0	0	4
Unknown	3	0	0	0	0	3	0	0	0	0	0	0

Table 21. Age classes and sex of mule deer and pronghorn carcasses found, by area, along surveyed routes, Yellowstone National Park, 2016.

	Mule deer						Pronghorn					
	Northern Range	Firehole	Norris	Heart Lake	Mud Volcano	Total	Northern Range	Firehole	Norris	Heart Lake	Mud Volcano	Total
Age												
Adult	4	0	0	0	0	4	1	0	0	0	0	1
Yearling	0	0	0	0	0	0	0	0	0	0	0	0
Calf	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	11	0	0	0	1	12	0	0	0	0	0	0
Sex												
Male	1	0	0	0	0	1	1	0	0	0	0	1
Female	1	0	0	0	0	1	0	0	0	0	0	0
Unknown	13	0	0	0	1	14	0	0	0	0	0	0

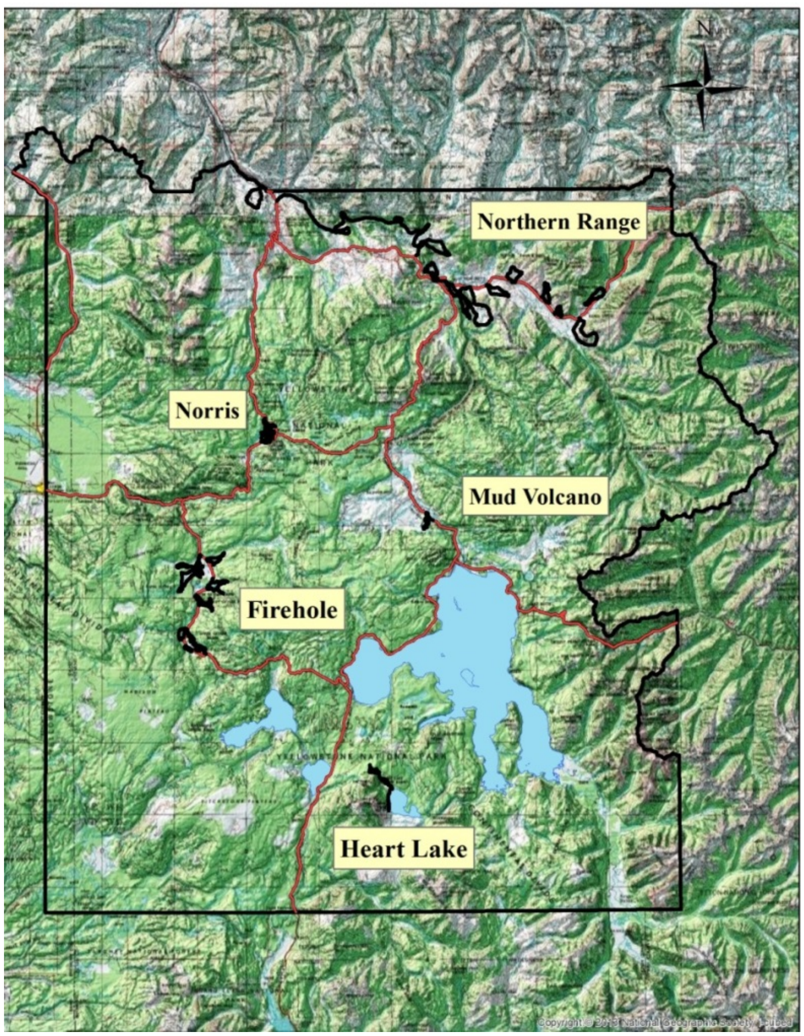


Fig. 8. Spring ungulate carcass survey routes in 5 ungulate winter ranges, Yellowstone National Park, 2016.

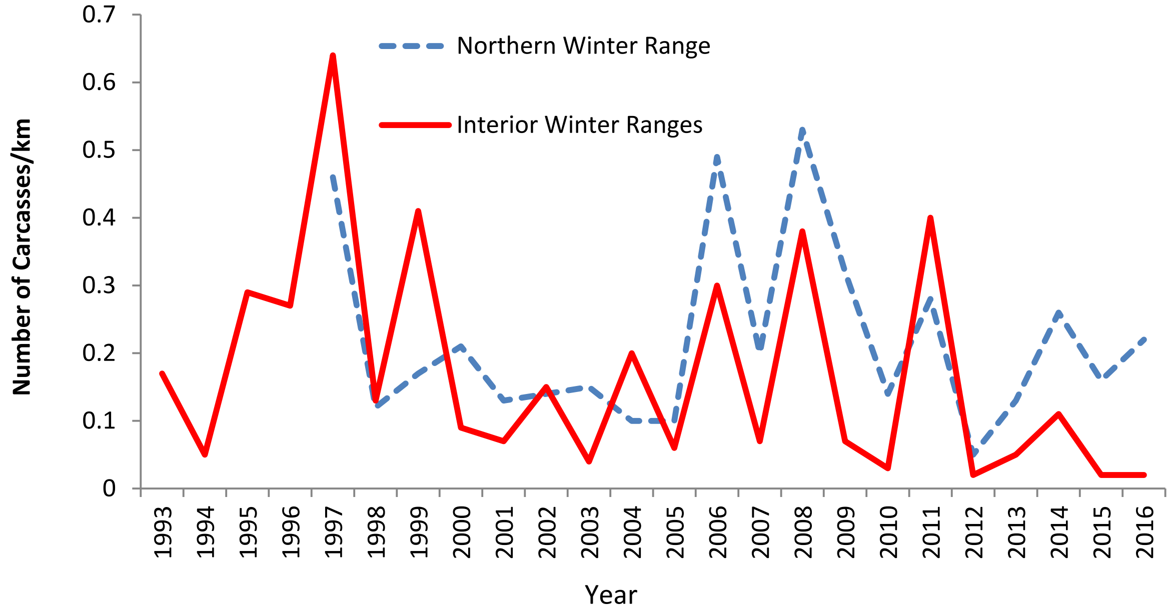


Fig. 9. Annual ungulate carcasses/km found on spring survey routes on the northern winter range and interior winter ranges, Yellowstone National Park, 1992–2016.

Adult grizzly bear on a winter kill, 24 March 2017, Blacktail Deer Creek, Yellowstone National Park (photo courtesy of Dan Stahler/NPS).

Spawning Cutthroat Trout Availability and Use by Grizzly Bears in Yellowstone National Park
(Kerry A. Gunther, Eric Reinertson, Todd M. Koel, Patricia E. Bigelow, and Brian Ertel, Yellowstone National Park)

In spring and early summer, grizzly bears with home ranges near Yellowstone Lake feed on spawning Yellowstone cutthroat trout (YCT, *Oncorhynchus clarkii*) during years when trout are abundant in tributary streams (Gunther et al. 2014). Bears also occasionally prey on cutthroat trout in other areas of the park, including Fan Creek (westslope cutthroat trout, YCT, or westslope × YCT hybrid) in the northwest section of the park and the inlet creek to Trout Lake (YCT or YCT × rainbow trout hybrids) located in the northeast section of the park.

Non-native lake trout (*Salvelinus namaycush*), whirling disease caused by an exotic parasite (*Myxobolus cerebralis*), and drought have substantially reduced the native YCT population in Yellowstone Lake and associated bear fishing activity (Haroldson et al. 2005; Koel et al. 2005, 2006). The combined effect of all these factors has reduced the Yellowstone Lake YCT population by 90% (Koel et al. 2010*a*). Because of the decline and past use of YCT as a food source by some grizzly bears, monitoring of the YCT population is a component of the bear foods and habitat monitoring program of the 2016 Conservation Strategy (Yellowstone Ecosystem Subcommittee 2016). The YCT population has been monitored through counts at a fish trap located on Clear Creek on the east-shore of Yellowstone Lake, and through visual stream surveys conducted along North Shore and West Thumb tributaries of the lake (Fig. 10). Visual stream surveys are also conducted along the Trout Lake inlet creek in the northeast section of the park. In 2014, we added 4 Yellowstone Lake backcountry spawning streams to our YCT monitoring program, including 3 streams on the west shore and 1 stream on the east side of Yellowstone Lake.

Yellowstone Lake

Fish Trap Surveys

Historically, the number of spawning YCT migrating upstream were counted most years from a weir with a fish trap located at the mouth of Clear Creek on the east side of Yellowstone Lake (Fig. 11; Koel et al. 2005). The fish trap was generally installed in May, the exact date depending on winter snow accumulation, weather conditions, and spring snow melt. Fish were counted by dip netting trout that entered the upstream trap box, visually as they swam through wooden chutes attached to the trap, or by swimming through an electronic counting box. In 2008, unusually high spring run-off damaged the Clear Creek weir and necessitated its removal. Due to removal of the weir, counts of the number of spawning cutthroat trout ascending Clear Creek were not obtained during 2008–2014. In the fall of 2012, the remnants of the weir were removed, stream banks stabilized, and a suitable platform for an electronic sonar fish counter was installed. Installation and calibration of the sonar fish counter began in the summer 2013 and continued through 2014. In 2015, the sonar fish counter at the Clear Creek weir became operational. The sonar station is installed in mid to late-April and runs through mid-July. In 2016, 801 spawning cutthroat trout were counted ascending Clear Creek.

Front Country Visual Stream Surveys

Beginning as early as mid-April depending on snowpack and ice-off, several streams including Lodge Creek, Hatchery Creek, Incinerator Creek, Wells Creek, and Bridge Creek, on the North Shore of Yellowstone Lake, and Sandy Creek, Sewer Creek, Little Thumb Creek, and unnamed stream #1167 in the West Thumb area are checked periodically to detect the presence of adult YCT (Andrascik 1992, Olliff 1992). Once adult YCT are found (i.e., onset of spawning), weekly surveys of YCT in these streams are conducted. Sample methods follow Reinhart (1990), as modified by Andrascik (1992) and Olliff (1992). In each stream on each sample day, a minimum of two people walk from the stream mouth to the upstream extent that fish have been observed in past years, and record the number of adult YCT counted. Sampling continues one day per week until two consecutive weeks when no trout are observed in the creek (i.e., end of spawn). The length of the spawning season is calculated as the number of days from the first day spawning trout are observed through the last day spawning trout are observed. The average number of spawning cutthroat trout counted per stream survey conducted during the spawning season is used to identify annual trends in the number of cutthroat trout spawning in Yellowstone Lake tributaries.

The ice went off of Yellowstone Lake on 18 May 2016. In 2016, we added unnamed stream #1090, a north shore tributary stream, as a monitored stream. Stream #1090 had confirmed grizzly bear fishing activity in 2015. Data collected in 2016 continued to show low numbers of spawning YCT in North Shore and West Thumb tributary streams (Table 22). In North Shore streams, only 62 spawning YCT were counted. Thirty-six spawning YCT were counted in Bridge Creek, 22 in Stream #1090, and 4 in Lodge Creek. No spawning YCT were observed in Hatchery Creek, Incinerator Creek, or Wells Creek. No evidence of bear fishing activity (i.e., observations of bears fishing, fish parts, bear scats containing fish parts) was observed along any of the monitored North Shore streams (Lodge Creek, Hatchery Creek, Incinerator Creek, Wells Creek, Bridge Creek or Stream #1090) in 2016. However, a grizzly bear track was observed on stream #1090 on 17 May, and a bear scat was observed along Stream #1090 on 26 May.

On West Thumb streams, 306 spawning YCT were counted, including 295 in Little Thumb Creek, 11 in Stream #1167, 1 in Sewer Creek, and 1 in Sandy Creek. Evidence of grizzly bear and black bear predation on YCT, including visual observations of bears fishing, bear scats containing fish, fish parts along the stream with associated grizzly bear and black bear tracks, and bear trails (matted vegetation along the creek) were observed on Little Thumb Creek on multiple surveys. At least 2 individual grizzly bears and 1 black bear were known to fish Little Thumb Creek in 2016. No evidence of grizzly bear or black bear fishing activity was observed along Sandy Creek, Sewer Creek, or stream #1167. However, grizzly bear tracks without evidence of fishing activity were found on Sewer Creek on 9 May.

The number of spawning YCT counted in the North Shore (Fig. C) and West Thumb (Fig. 13) streams has decreased significantly since 1989. Although the increased spawning activity in Little Thumb Creek in recent years is promising, very few spawning YCT have been observed in all other North Shore and West Thumb streams.

Backcountry Visual Stream Surveys

In 2016, we surveyed 3 backcountry tributary streams including Flat Mountain Creek, unnamed stream #1138, and unnamed stream #1141. Backcountry stream surveys followed the same methods used on frontcountry streams. In backcountry streams, 18 spawning YCT were counted. Seventeen spawning YCT were counted in stream #1138 and one in Flat Mountain Creek. No spawning YCT were observed in stream #1141. Evidence of grizzly bear predation on YCT was found along stream #1138. No conclusive evidence of bear fishing activity was observed along Flat Mountain Creek or stream #1141. However, grizzly bear tracks, vegetation scats, and non-fish meat scats were observed along Flat Mountain Creek and stream #1141 on multiple surveys.

Trout Lake

Visual Stream Surveys

Beginning in mid-May of each year, the Trout Lake inlet creek is checked once per week for the presence of spawning YCT (and cutthroat × rainbow trout hybrids). Once spawning trout are detected (i.e., onset of spawning), weekly surveys of adult trout in the inlet creek are conducted. On each sample day, two people walk from the stream mouth to the upstream extent that fish have been observed in past years, and record the number of adult trout counted. Sampling continues one day per week until two consecutive weeks when no trout are observed in the creek. The length of the spawning season is calculated as the number of days from the first day spawning trout are observed through the last day spawning trout are observed. The mean number of spawning trout observed per visit is calculated by dividing the total number of adult trout counted by the number of surveys conducted during the spawning season.

In 2016, the first movement of spawning trout from Trout Lake into the inlet creek was observed on 9 June. The spawn lasted approximately 27 days with the last spawning trout observed in the inlet creek on 5 July. During the once per week visual surveys, 317 spawning cutthroat (and cutthroat trout × rainbow trout hybrids) were counted, an average of 63 per visit during the spawning season (Table 22). The number of fish observed per survey has ranged from a low of 31 in 2004, to a high of 306 in 2010 (Fig. 14). No evidence of grizzly bear or black bear fishing activity was observed along Trout

Lake or the inlet creek during the surveys in 2016. However, grizzly bear tracks were observed in the mud next to the creek on 28 June.

Outlook for Cutthroat Trout

The number of spawning YCT counted in all surveyed tributary streams of Yellowstone Lake reached a nadir in approximately 2004 (Figures 15–17). A Native Fish Conservation Plan/Environmental Assessment was completed in 2011 (Koel et al. 2010*b*). The plan outlines a program of management efforts designed to protect the native YCT population through lake trout suppression and other methods. As part of these management efforts, park fisheries biologists and private-sector (contracted) netters caught and removed 366,457 lake trout from Yellowstone Lake in 2016. Population models indicate the removal program has slowed lake trout population growth and likely started to send the population into decline (Syslo et al. 2011, Gresswell et al., 2015). If the removal program results in a significant long-term reduction in predatory lake trout, native YCT will likely reestablish at higher numbers in Yellowstone Lake and its tributary streams and once again become a more important diet item for grizzly bears in the Yellowstone Lake watershed. In 2016, we documented grizzly bears fishing for YCT in Little Thumb Creek and un-named stream #1138, suggesting that the YCT population may be increasing at least in some streams. Evidence of grizzly bears fishing for YCT indicates that the Lake Trout removal program may be beginning to show signs of success.

Table 22. Summary statistics for spawning cutthroat trout surveys, Yellowstone National Park, 2016.

Stream	Start of spawn	Last day of spawn	Duration of spawn (days)	Number of surveys during spawning period	Number of fish counted	Average no. fish/survey
North Shore						
Lodge Creek	5/4/2016	5/20/2016	27	5	4	0.8
Hatchery Creek			No spawn			
Incinerator Creek			No spawn			
Wells Creek			No spawn			
Bridge Creek	5/4/2016	5/23/2016	20	4	36	9
#1090	5/11/2016	5/26/2016	16	3	22	7.3
West Thumb						
1167 Creek	5/4/2016	5/9/2016	6	2	9	4.5
Sandy Creek	5/15/2016	5/15/2016	1	1	1	1
Sewer Creek	5/9/2016	5/9/2016	1	1	1	1
Little Thumb Creek	5/11/2016	7/5/2016	56	9	295	32.8
Total frontcountry[a]				25	368	14.7
Backcountry						
Flat Mountain Creek	5/17/2016	5/17/2016	1	1	1	1
#1141 Creek			No spawn			
#1138 Creek	5/17/2016	6/6/2016	21	3	17	5.7
Columbine Creek			Not surveyed			
Total backcountry				4	18	4.5
Northern Range						
Trout Lake Inlet	6/9/2016	7/5/2016	27	5	317	63.4

[a] Total for North Shore and West Thumb streams that had a spawn.

Fig. 10. Locations of Yellowstone Lake cutthroat trout spawning streams surveyed in 2016.

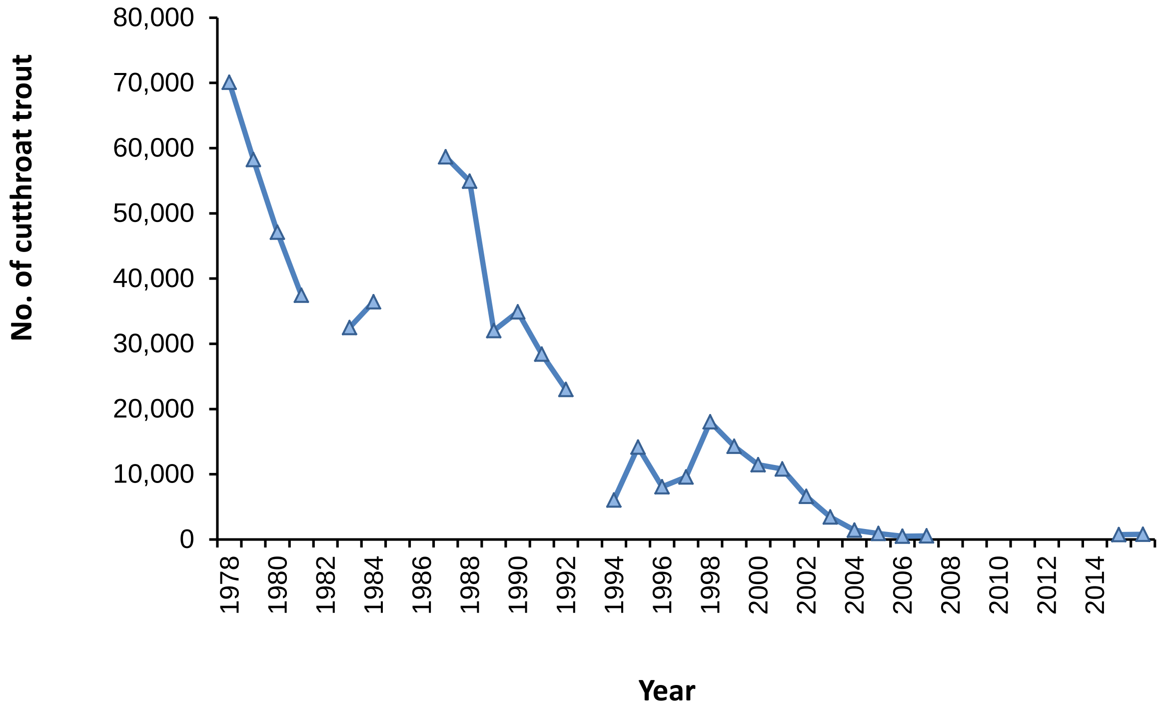


Fig. 11. Number of spawning cutthroat trout counted at the Clear Creek fish trap on the east shore of Yellowstone Lake, Yellowstone National Park, 1977–2016.

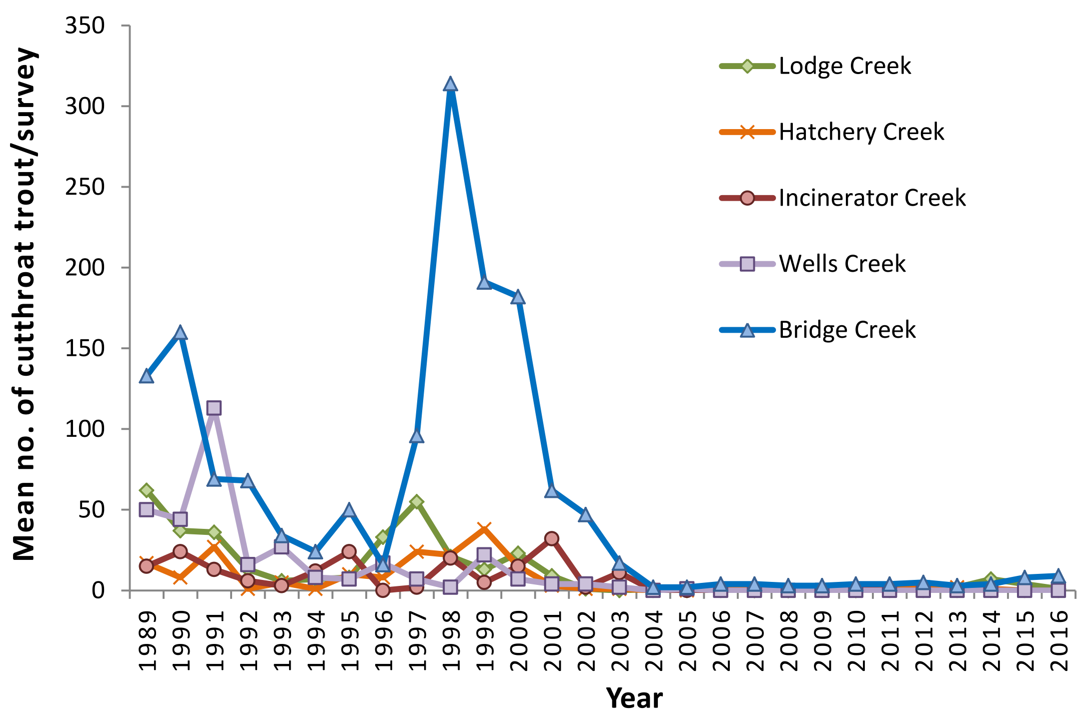


Fig. 12. Mean number of spawning cutthroat trout observed during weekly visual surveys of 5 North Shore spawning stream tributaries to Yellowstone Lake, Yellowstone National Park, 1989–2016.

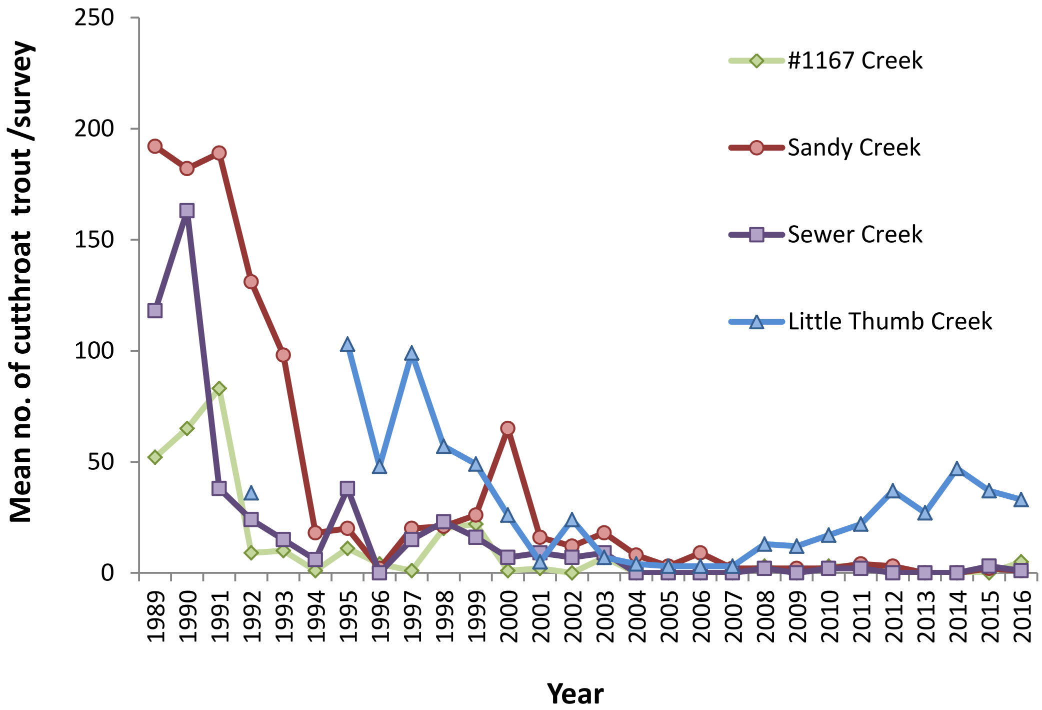


Fig. 13. Mean number of spawning cutthroat trout observed during weekly visual surveys of 4 West Thumb spawning stream tributaries to Yellowstone Lake, Yellowstone National Park, 1989–2016.

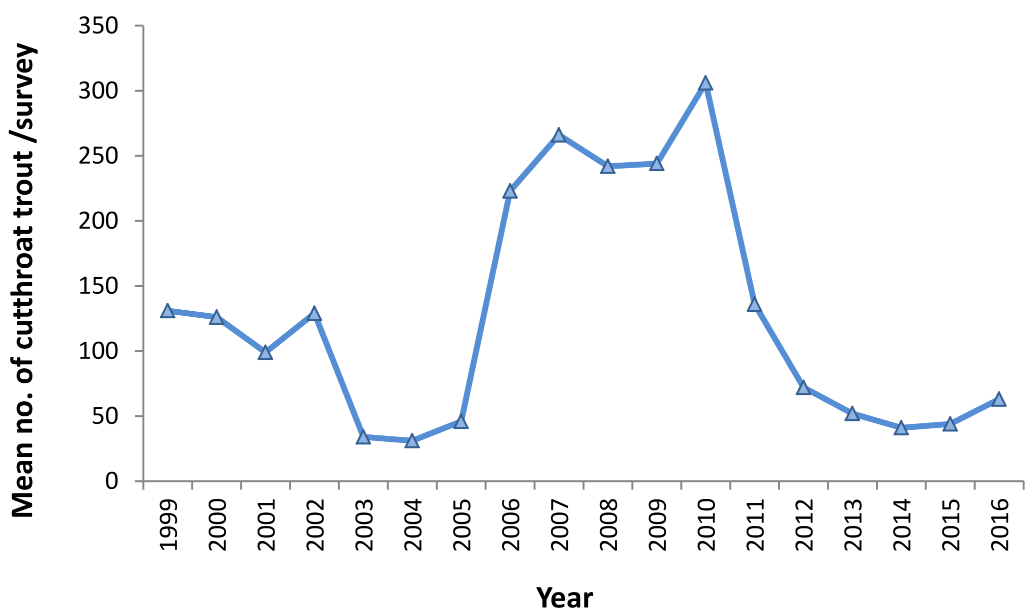


Fig. 14. Mean number of spawning cutthroat trout (including cutthroat × rainbow trout hybrids) observed during weekly visual spawning surveys of Trout Lake inlet creek, Yellowstone National Park, 1999–2016.

Grizzly Bear Use of Insect Aggregation Sites *(Daniel D. Bjornlie, Wyoming Game and Fish Department; and Mark A. Haroldson, Interagency Grizzly Bear Study Team, U.S. Geological Survey)*

Army cutworm moths (*Euxoa auxiliaris*) were first recognized as an important food source for grizzly bears in the GYE during the mid 1980s (Mattson et al. 1991*b*, French et al. 1994). Early observations indicated that moths, and subsequently bears, showed specific site fidelity. These sites are generally high alpine areas dominated by talus and scree adjacent to areas with abundant alpine flowers. Because insects other than army cutworm moths may be present and consumed by bears (e.g., ladybird beetles [Coccinellidae family]) as well, we generally refer to such areas as "insect aggregation sites." Within the GYE, observations indicate army cutworm moths are the primary food source at these sites.

Since their discovery, numerous bears have been counted on or near these aggregation sites due to excellent sightability from a lack of trees and simultaneous use by multiple bears. However, complete tabulation of grizzly presence at insect sites is extremely difficult. Only a few sites have been investigated by ground reconnaissance and the boundaries of sites are not clearly known. In addition, it is likely that the size and location of aggregation sites fluctuate from year to year with moth abundance and variation in environmental factors such as snow cover.

Since 1986, when insect aggregation sites were initially included in aerial observation surveys, our knowledge of these sites has increased annually. Our techniques for monitoring grizzly bear use of these sites have changed in response to this increase in knowledge. Prior to 1997, we delineated insect aggregation sites with convex polygons drawn around locations of bears seen feeding on moths and buffered these polygons by 500 m. However, this technique overlooked small sites due to the inability to create polygons around sites with fewer than 3 locations. During1997–1999, the method for defining insect aggregation sites was to inscribe a 1-km circle around the center of clusters of observations in which bears were seen feeding on insects in talus and scree habitats (Ternent and Haroldson 2000). This method allowed trend in bear use of sites to be annually monitored by recording the number of bears documented in each circle (i.e., site).

We developed a new technique in 2000 (D. Bjornlie, Wyoming Game and Fish Department, unpublished data) that delineates sites by buffering only the locations of bears observed actively feeding at insect aggregation sites by 500 m; this distance was used to account for error in aerial locations. The borders of the overlapping buffers at individual insect sites are dissolved to produce a single polygon for each site. These sites are identified as "confirmed" sites. Because these polygons are only created around feeding locations, the resulting site conforms to the topography of the mountain or ridge top where bears feed and does not include large areas of non-talus habitat that are not suitable for cutworm moths. Records from the grizzly bear location database from July 1 through September 30 of each year are then overlaid on these polygons and enumerated. This new technique substantially decreased the number of sites described in prior years, in which locations from both feeding and non-feeding bears were used. Therefore, we use this technique for the annual analysis completed for all years. Areas suspected as insect aggregation sites but dropped from the list of confirmed sites using this technique, and sites with only one observation of an actively feeding bear or multiple observations in a single year, are termed "possible" sites and will be monitored in subsequent years for additional observations of actively feeding bears. These sites may then be added to the confirmed sites list. When possible sites are changed to confirmed sites, analysis is done on all data back to 1986 to determine the historic use of that site. Therefore, the number of bears using insect aggregation sites in past years may change as new sites are added, and data from this annual report may not match that of past reports. In addition, as new observations of actively feeding bears are added along the periphery of existing sites, the polygons defining these sites increase in size and, thus, more overlaid locations fall within the site. This retrospective analysis brings us closer each year to the "true" number of bears using insect aggregation sites in past years.

Analysis of grizzly bear use of confirmed sites in 2016 resulted in an additional observation of actively feeding grizzly bears on one possible site, which resulted in this site being classified as confirmed. In addition, there was one observation of an actively feeding grizzly bear at a previously undocumented site and therefore, one new possible site was added in 2016. Thus, there were 31 confirmed sites and 14 possible sites for 2016.

Overall insect aggregation site use by grizzly bears in 2016 (n = 217) was very similar to 2015 (n = 222), but below peak the years of 2012–2014 (Table 23). The number of grizzly bears observed on sites and the percentage of confirmed sites with documented use by grizzly bears varies from year to year, suggesting that some years have higher moth activity than others (Fig. 15), which may be due to variable snow conditions or the number of moths migrating from the plains. In 1993, a year with unusually high snowpack, the percentage of confirmed sites used by bears (Fig. 15) and the number of observations recorded at insect sites (Table 23) were very low. In all other years, the percentage of insect aggregation sites used by grizzly bears varied between 50% and 80% (Fig. 15).

The slight decrease in use of insect aggregation sites by grizzly bears in 2016 is also apparent when bears observed only during regularly conducted observation flights (see "***Observation Flights***") are included (Fig. 16). Because effort, as measured by hours flown, in the bear management units containing all known insect aggregation sites has remained consistent since 1997, the change in the number of grizzly bears using insect aggregation sites suggests this decrease was not due to change in observation effort (Fig. 16). The increase in reported observations of grizzly bears using insect aggregation sites from ground-based observers and our increased use of GPS collars with satellite technology has resulted in the need to censor these locations to prevent a bias in comparisons with previous years. Therefore, the number of aerial telemetry locations and observations from Table 23 reflect this change and may differ from previous annual reports.

The IGBST maintains an annual list of unique females observed with cubs (see Table 5 in "***Estimating Number of Females with Cubs***"). Since 1986, 1,111 initial sightings of unique females with cubs have been recorded, of which 315 (28.4%) have occurred at (<500 m, n = 293) or near (<1,500 m, n = 22) insect aggregation sites (Table 24). In 2016, 13 of the 50 (26.0%) initial sightings of unique females with cubs were observed at insect aggregation sites; comparable to the mean of 26.9% for the previous five years (2011–2015, Table 24).

Survey flights at or near (<1,500 m) insect aggregation sites contribute to the count of unique females with cubs; however, it is typically low, with a 10-year mean of 13.5 initial sightings/year since 2007 (Table 24). If these sightings are excluded, a similar trend in the annual number of unique sightings of females with cubs is still evident (Fig. 17), suggesting that other factors besides observation effort at insect aggregation sites are responsible for the increase in sightings of females with cubs over time.

Grizzly bear foraging on army cutworm moths, Shoshone National Forest (photo Frank T. van Manen/IGBST).

Table 23. Summary statistics for grizzly bear use of confirmed insect aggregation sites , Greater Yellowstone Ecosystem, 1986–2016.

Year	Number of confirmed sites[a]	Number of sites used[b]	Number of aerial telemetry locations	Number of ground or aerial observations
1986	4	2	7	5
1987	5	3	3	17
1988	5	3	11	30
1989	9	7	9	41
1990	14	11	9	77
1991	16	12	12	169
1992	17	11	6	107
1993	18	3	1	2
1994	18	9	1	30
1995	20	11	7	38
1996	21	14	21	67
1997	22	15	17	83
1998	25	21	10	182
1999	25	14	26	156
2000	25	13	48	95
2001	26	18	23	127
2002	27	20	30	251
2003	27	20	9	163
2004	27	16	2	134
2005	29	19	16	195
2006	29	16	14	146
2007	29	19	19	160
2008	29	22	16	179
2009	31	23	8	170
2010	31	18	3	132
2011	31	19	9	162
2012	31	22	16	252
2013	31	22	25	294
2014	31	24	11	343
2015	31	21	13	209
2016	31	19	14	203
Total			413	4223

[a] The year of discovery was considered the first year a telemetry location or aerial observation was documented at a site. Sites were considered confirmed after additional locations or observations in a subsequent year and every year thereafter regardless of whether or not additional locations were documented.

[b] A site was considered used if e 1 location or observation was documented within the site during July–September of that year.

Table 24. Initial sightings of unique females with cubs on or near insect aggregation sites, Greater Yellowstone Ecosystem, 1986• 2016.

Year	Number of unique females with cubs[a]	Number of sites with an initial sighting[b]	Initial sightings			
			Within 500 m[b]		Within 1,500 m[c]	
			n	%	*n*	%
1986	25	0	0	0	0	0
1987	13	0	0	0	0	0
1988	19	1	2	10.5	2	10.5
1989	16	1	1	6.3	1	6.3
1990	25	4	4	16.0	5	20.0
1991	24	7	13	54.2	14	58.3
1992	25	5	7	28.0	9	36.0
1993	20	1	1	5.0	1	5.0
1994	20	3	5	25.0	5	25.0
1995	17	2	2	11.8	2	11.8
1996	33	7	7	21.2	8	24.2
1997	31	8	11	35.5	11	35.5
1998	35	10	13	37.1	13	37.1
1999	33	3	6	18.2	7	21.2
2000	37	6	9	24.3	10	27.0
2001	42	7	13	31.0	13	31.0
2002	52	11	18	34.6	18	34.6
2003	38	11	20	52.6	20	52.6
2004	49	11	17	34.7	17	34.7
2005	31	5	7	22.6	8	25.8
2006	47	11	15	31.9	16	34.0
2007	50	10	17	34.0	17	34.0
2008	44	7	11	25.0	14	31.8
2009	42	4	6	14.3	7	16.7
2010	51	7	9	17.6	9	17.6
2011	39	6	7	17.9	7	17.9
2012	49	6	13	26.5	13	26.5
2013	58	8	14	24.1	15	25.9
2014	50	11	21	42.0	23	46.0
2015	46	7	11	23.9	13	28.3
2016	50	7	13	26.0	17	34.0
Total	1,111		293		315	
Mean	35.8	6	9.5	24.2	10.2	25.8

[a] Initial sightings of unique females with cubs; see Table 5.

[b] Insect aggregation site is defined as a 500-m distance around a cluster of observations of bears actively feeding.

[c] This distance is 3 times what is defined as an insect aggregation site for this analysis because some observations may be of bears traveling to and from insect aggregation sites.

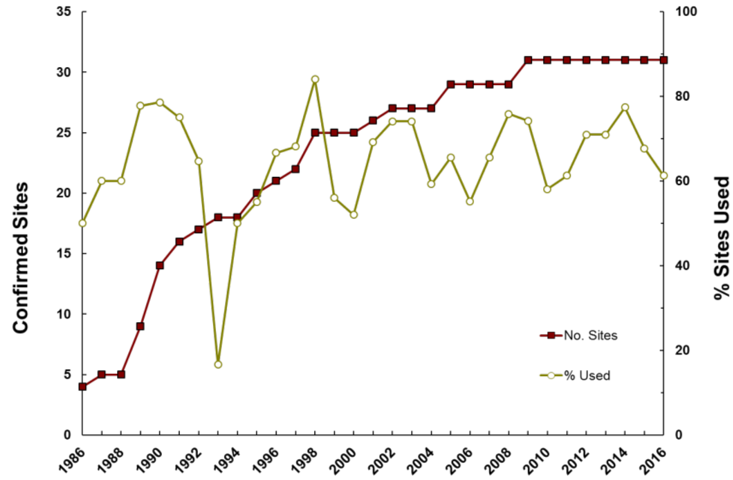


Fig. 15. Annual number of confirmed insect aggregation sites and percent of those sites at which telemetry relocations of marked bears or visual observations of unmarked bears were recorded, Greater Yellowstone Ecosystem, 1986-2016.

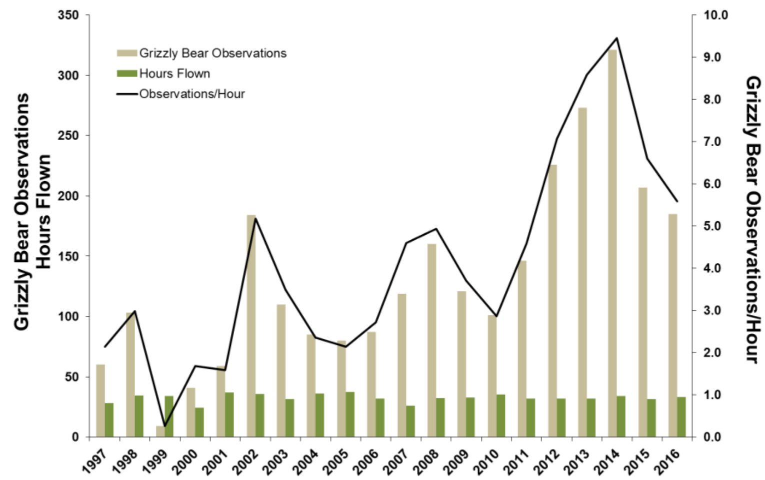


Fig. 16. Number of grizzly bears observed (tan bars) on insect aggregation sites during observation flights only, hours flown (green bars) for these bear management units (BMU), and grizzly bear observations per hour (black line) during observation flights of BMUs containing all known insect aggregation sites, Greater Yellowstone Ecosystem, 1997-2016.

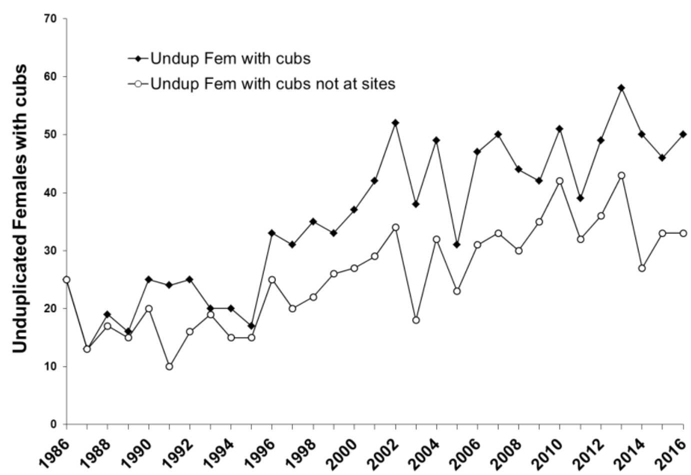


Fig. 17. Total number of unique females with cubs observed annually in the Greater Yellowstone Ecosystem and the number of unique females with cubs not found within 1,500 m of known insect aggregation sites, 1986–2016.

Whitebark Pine Cone Production *(Mark A. Haroldson, Interagency Grizzly Bear Study Team, U.S. Geological Survey)*

Whitebark pine (*Pinus albicaulis*) surveys on 21 established transects indicated above-average cone production during 2016 (Fig. 18). Overall, the mean number of observed cones/tree was 35.9 (Table 25), which is more than double the overall average for the period 1980–2016 (Fig. 19). Cone production was good on most transects with 11 transects >30 cones/tree and only 3 with <10 cones/tree (Table 25).

We continue to observe occasional tree mortality caused by mountain pine beetle (*Dendroctonus ponderosae*) in stands that contain our cone production transects. During 2016 we observed 1 additional beetle-caused mortality among individual trees surveyed since 2002. Total mortality on these transect trees since 2002 is now at 75.8% (144/190) with 100% (19/19) of transects containing beetle-killed trees. Although tree mortality from mountain pine beetle is still occurring, the rate of loss among our cone production transects has slowed (Fig. 20). These findings suggests that at least in the vicinity of these transects, the current beetle outbreak likely has run its course. Six of the 7 transects established during 2007 also exhibited beetle-caused mortality among transect trees.

Table 25. Summary statistics for whitebark pine cone production surveys, Greater Yellowstone Ecosystem, 2016.

Total			Trees				Transect			
Cones	Trees	Transects	Mean cones	SD	Min	Max	Mean cones	SD	Min	Max
6,649	185	21	35.94	45.04	0	314	316.62	233.1	49	808

Whitebark pine cone (photo courtesy of Shannon Pils)

Table 26. Results of whitebark pine cone production surveys, Greater Yellowstone Ecosystem, 2016.

Transect	Number of cones	Number of trees	Mean number of cones/tree	SD
A	86	5	17.2	27.4
B	487	10	48.7	15.4
C	318	10	31.8	20.1
D1	66	10	6.6	4.1
F1		-----Transect retired in 2008-----		
G	124	9	13.8	14.9
H		-----Transect retired in 2008-----		
J	225	10	22.5	34.3
K	239	7	34.1	19.6
L	104	8	13.0	11.8
M	167	10	16.7	15.4
N	540	10	54.0	25.0
P	68	10	6.8	7.8
Q1	49	10	4.9	6.9
R		-----Transect retired in 2009-----		
S		-----Transect retired in 2010-----		
T		-----Transect retired in 2008-----		
U		-----Transect retired in 2016-----		
U1	187	10	18.7	11.0
AA	808	10	80.8	39.6
CSA	513	10	51.3	49.1
CSB	435	10	43.5	52.2
CSC	796	10	79.6	105.9
CSD	427	10	42.7	37.1
CSE	387	2	193.5	99.7
CSF	51	4	12.8	7.1
CSG	572	10	57.2	24.7

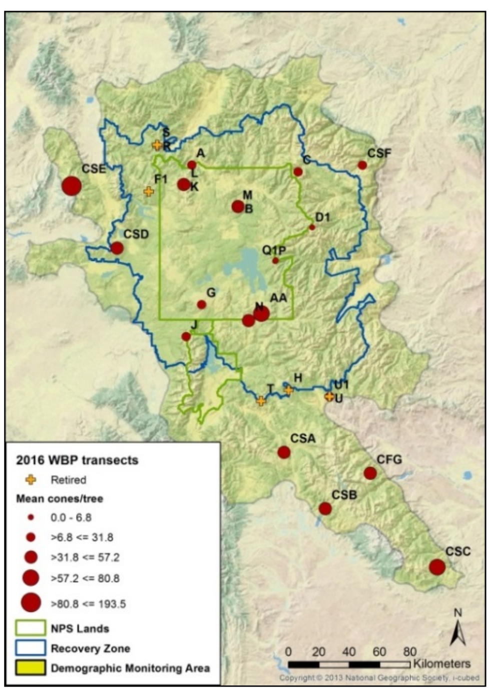


Fig. 18. Locations and mean number of cones/tree for 21 whitebark pine cone production transects, Greater Yellowstone Ecosystem, 2016. Labels reflect transect identifiers (see Table 26).

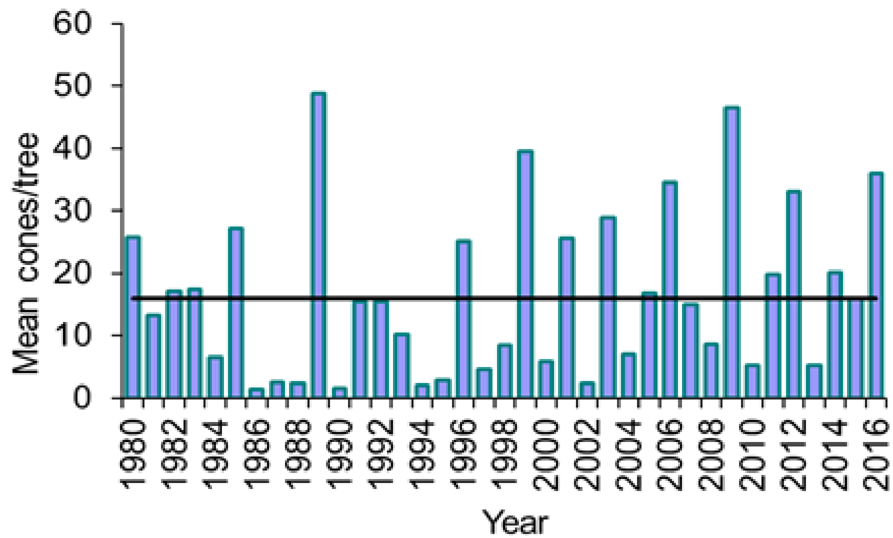


Fig. 19. Annual mean number of cones/tree observed along whitebark pine cone production transects, Greater Yellowstone Ecosystem, 1980–2016. The overall average for the time period (16 cones/tree) is shown as a solid line.

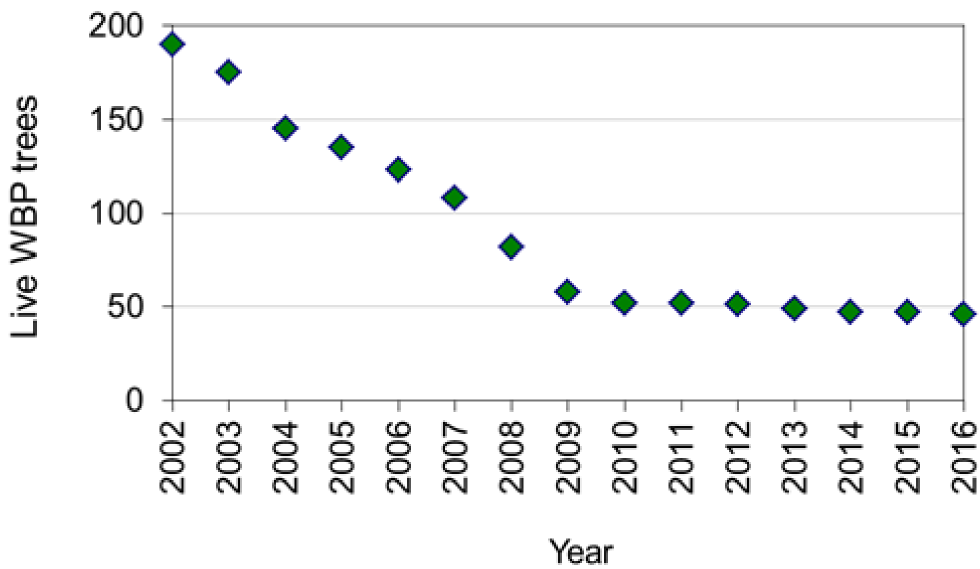


Fig. 20. Number of live whitebark pine (WBP) trees on cone production transects among 190 individual trees monitored since 2002, Greater Yellowstone Ecosystem, 2002–2016.

Habitat Monitoring

Grand Teton National Park Recreational Use
(Katharine R. Wilmot, Grand Teton National Park)

In 2016, total visitation in Grand Teton National Park was 4,822,972 people, including recreational, commercial (e.g., Jackson Hole Airport), and incidental (e.g., traveling through the Park on U.S. Highway 191 but not recreating) use. Recreational visits alone totaled 3,270,076. Backcountry user nights totaled 36,206. Long- and short-term trends of recreational visitation and backcountry user nights are shown in Table 27 and Fig. 21.

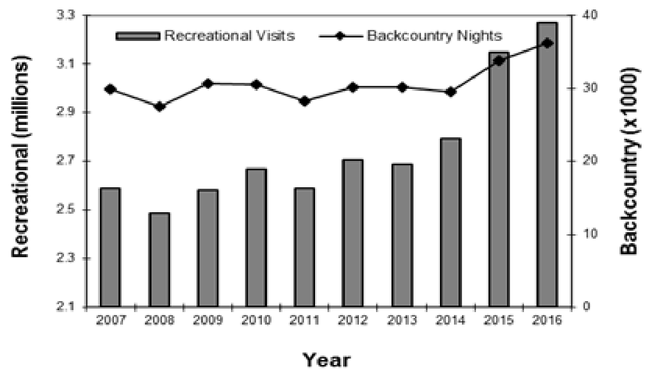


Fig. 21. Trends in recreational visitation and backcountry user nights in Grand Teton National Park, 2007–2016 (data from: https://irma.nps.gov/Stats).

Table 27. Average annual recreational visitation and average annual backcountry use nights in Grand Teton National Park by decade from 1951 through 2009, and the most recent 10-year average.

Decade	Average annual recreational visitation[a]	Average annual backcountry use nights
1950s	1,104,357	Data not available
1960s	2,326,584	Data not available
1970s	3,357,718	25,267
1980s	2,659,852	23,420
1990s	2,662,940	20,663
2000s	2,497,847	30,049
2007–2016	2,751,690	30,687

[a] In 1983 a change in the method of calculation for park-wide visitation resulted in decreased numbers. Another change in 1992 increased numbers. Thus, park-wide visitation data for the 1980s and 1990s are not strictly comparable.

Yellowstone National Park Recreational Use
(Kerry A. Gunther, Yellowstone National Park)

Total visitation to Yellowstone National Park was 5,455,081 visits in 2016 (https://irma.nps.gov/Stats/SSRSReports/Yell/Yellowstone) including recreational and non-recreational (e.g., traveling through the Park on U.S. Highway 191 but not recreating) use. Recreational visits in 2016 totaled 4,257,177 the highest visitation year on record and the 2nd straight year that recreational visitation has topped the 4 million mark. Nine of the top 10 visitation years have occurred in the last decade (Table 28). Most of the park's recreational visitation occurred during the 6 month period from May through October. In 2016, there were 4,063,657 recreational visits (96%) during those peak months, an average of 22,085 recreational visits per day. Park visitors spent 764,685 overnight stays in developed campgrounds, and 44,507 overnight stays in remote backcountry campsites in Yellowstone Park. The most notable change in visitation from previous years was the number of commercial tour buses entering the park. The number of buses entering in 2016 was 12,778 which was a 21% increase over 2015 and a 47% increase over 2014.

Average annual recreational visitation has increased each decade from an average of 7,378 visitors/year during the late 1890s to 3,012,653 visitors/year in the 1990s (Table 29, Fig. 22). Average annual recreational visitation decreased slightly during 2000–2009, to an average of 2,968,037 visitors/year. The decade 2000–2009 was the first in the history of the park that visitation did not increase from the previous decade. However, the decade beginning in 2010 is on pace to set a new park record high for visitation. Six of the 7 highest years of visitation ever recorded in Yellowstone National Park have occurred during 2010–2016. Although total park recreational visitation has increased steadily over time, the average number of overnight stays in backcountry campsites has been relatively stable, ranging from 39,280 to 45,615 overnight stays/year (Table 29, Fig. 23). The number of overnight stays in the backcountry is limited by both the number and capacity of designated backcountry campsites in the park. The average number of overnight stays in developed campgrounds in the park has increased considerably since 2010 (Table 29, Fig. 24).

Table 28. Ten highest years for visitation to Yellowstone National Park, 1895–2016.

Rank	Year	Visitation
1	2016	4,257,177
2	2015	4,097,710
3	2010	3,640,184
4	2014	3,513,484
5	2012	3,447,727
6	2011	3,394,321
7	2009	3,295,187
8	2013	3,188,030
9	2007	3,151,343
10	1992	3,144,405

Table 29. Average annual recreational visitation, auto campground overnight stays, and backcountry campsite overnight stays by decade, Yellowstone National Park, 1895–2016.

Decade	Average annual number of recreational visits	Developed campground average annual overnight stays	Backcountry campsite average annual overnight stays
1890s	7,378[a]	Data not available	Data not available
1900s	17,110	Data not available	Data not available
1910s	31,746	Data not available	Data not available
1920s	157,676	Data not available	Data not available
1930s	300,564	82,331[b]	Data not available
1940s	552,227	139,659[c]	Data not available
1950s	1,355,559	331,360	Data not available
1960s	1,955,373	681,303[d]	Data not available
1970s	2,240,698	686,594[e]	45,615[f]
1980s	2,344,485	656,093	39,280
1990s	3,012,653	647,083	43,605
2000s	2,968,037	624,450	40,362
2010s	3,648,378[g]	711,465[g]	41,957[g]

[a] Data from 1895 1899. During 1872 1894, visitation was estimated to be not less than 1,000 and no more than 5,000 each year.

[b] Data from 1930–1934.

[c] Average does not include data from 1940 and 1942.

[d] Data from 1960–1964.

[e] Data from 1975–1979.

[f] Backcountry use data available for 1972–1979.

[g] Data for the years 2010–2016.

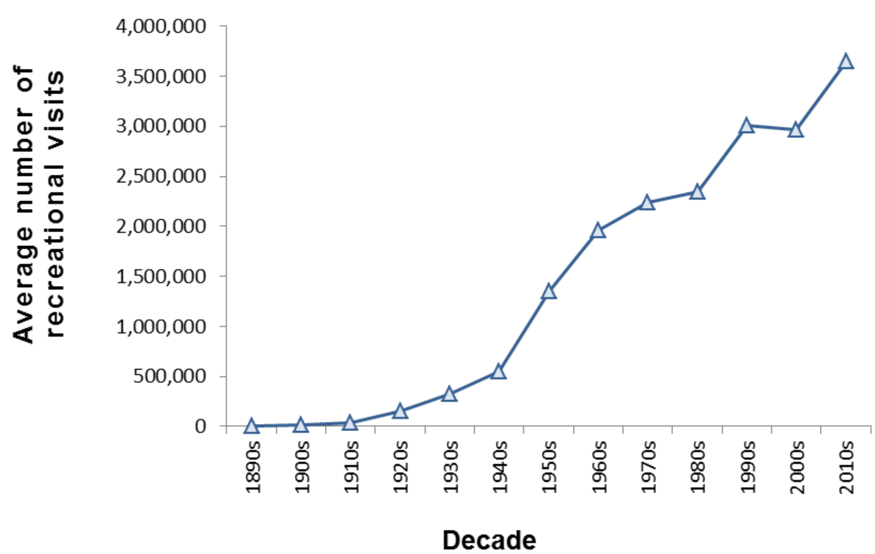


Fig. 22. Average annual number of recreational visitors by decade, Yellowstone National Park, 1895–2016.

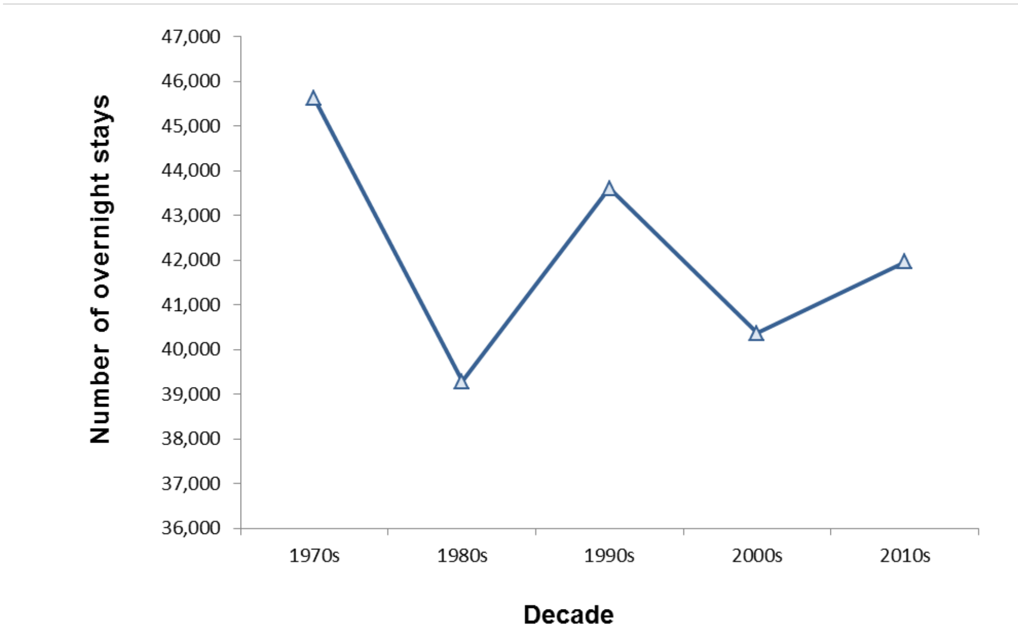


Fig. 23. Average annual number of overnight stays in backcountry campsites by decade, Yellowstone National Park, 1972–2016.

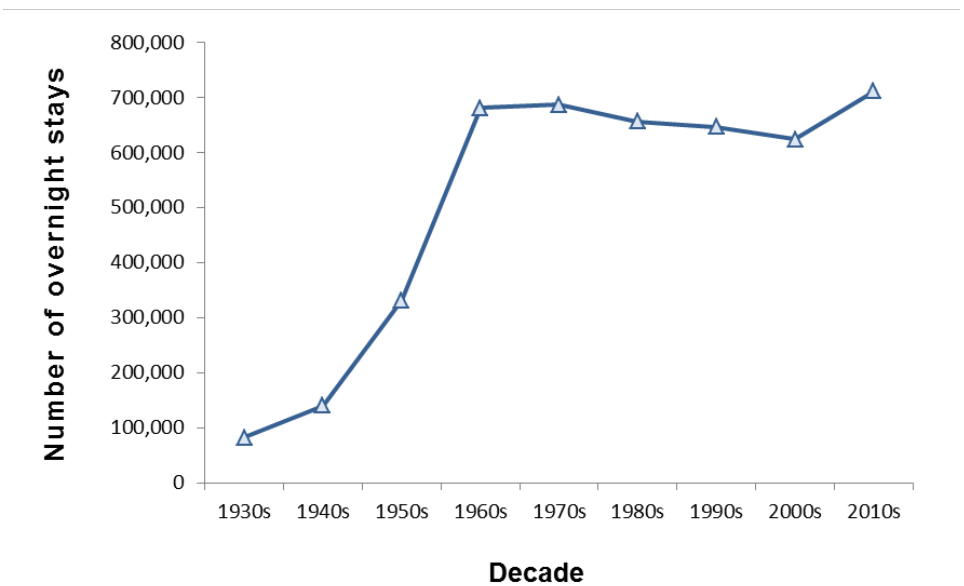


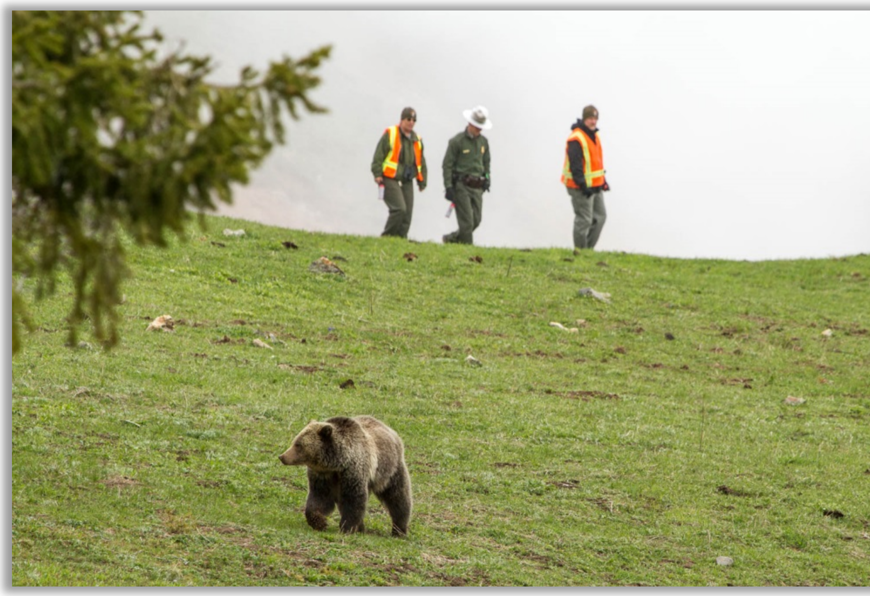
Fig. 24. Average annual number of overnight stays in roadside campgrounds by decade, Yellowstone National Park, 1930–2016.

Human-Grizzly Bear Conflicts in the Greater Yellowstone Ecosystem

Human-Grizzly Bear Conflicts in Grand Teton National Park (Katharine R. Wilmot, Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway)

No management actions were taken on grizzly bears in Grand Teton National Park in 2016. However, management of nonfood-conditioned, human-habituated bears required considerable effort to prevent conflicts from occurring. Grizzly bears were hazed off of park roads 7 times. Grand Teton National Park recorded a minimum of 228 bear jams (99 grizzly bear, 109 black bear, 20 species not recorded), created when habituated bears frequented roadsides or were near other developments, drawing crowds of onlookers. Grizzly bear jams peaked in May and black bear jams peaked in August and September. The park's Wildlife Brigade managed most of these bear jams and enforced food storage regulations at campgrounds, picnic areas, and other developments. Wildlife Brigade volunteers contributed 6,934 hours towards this bear conservation and public education program.

Grand Teton National Park hosted 155 bear safety programs park-wide. These presentations highlighted safety in bear country and concluded with a bear spray (inert) demonstration. The program was well received, with over 4,226 visitors attending over the summer. Grand Teton National Park continued its partnership with the Grand Teton National Park Foundation to cost-share expenses for the purchase and installation of bear-resistant food storage lockers. Fifty-two bear boxes (30 ft^3) were installed in 2016, bringing the total number of bear boxes in campgrounds and other developed sites to 599. Three of the parks 6 roadside campgrounds, including Jenny Lake, Signal Mountain, and Lizard Creek Campgrounds, now have a food storage locker in each site.



Park Rangers monitor a grizzly bear that was in close proximity to visitors. Human-grizzly bear conflicts in national park areas were low in 2016 but considerable management effort was dedicated toward preventing conflicts (photo courtesy of Jake Davis/RevealedinNature.com).

Human-Grizzly Bear Conflicts in Yellowstone National Park *(Kerry A. Gunther, Travis C. Wyman, and Eric Reinertson, Yellowstone National Park)*

To effectively allocate resources for implementing management actions designed to prevent human-grizzly bear conflicts, Yellowstone National Park managers need baseline information regarding the types, causes, locations, and recent trends of conflicts. To address this need, all reported human-grizzly bear conflicts are recorded annually. Conflicts are grouped into broad categories using standard definitions described by Gunther et al. (2012).

There were 3 human-grizzly bear conflicts reported in Yellowstone National Park in 2016 (Table 30, Fig. 25). On May 9, a subadult grizzly bear entered Canyon Village and obtained garbage from a bear-proof dumpster that had a broken locking mechanism. The bear also damaged an unoccupied Yurt located near the dumpster (Fig. 25). On July 14, subadult male grizzly bear G-205 ripped into a tent at Heart Lake Backcountry Campsite 8J1 and tore up the sleeping bag and sleeping pad. On August 19, Grizzly #G-205 ripped into 3 tents in Heart Lake Campsite 8H2. Grizzly G-205 had been involved in human-bear conflicts on the Shoshone National Forest in 2015, and had been captured and relocated to the Caribou – Targhee National Forest that year. The annual number of human-bear conflicts occurring in Yellowstone National Park is generally low, but can vary widely from year to year and is dependent on the availability of natural bear foods, grizzly bear population numbers, park visitation, park staffing levels, and other factors. The number of conflicts have decreased significantly after efforts to prevent bears from obtaining anthropogenic foods were implemented in the late 1960s and early 1970s (Fig. 26).

During 2016, there were 3 known grizzly bear mortalities in the Yellowstone National Park portion of the GYE. Mortalities included a 25 year-old male that died of complications of old age in Lamar Valley, a cub-of the-year killed by another bear at a research trap site in Hayden Valley, and a 19-year old adult male that was struck and killed by a vehicle on the East Entrance Road. Trends in causes of grizzly bear mortality inside Yellowstone National Park have changed significantly over time. From the late 1950s through the 1970s most grizzly mortality in the park was due to human causes (Fig. 27), primarily management removals of bears involved in human-bear conflicts. In recent decades (1980–2016) most grizzly mortality in the park is from natural causes, primarily old age and intraspecific strife and predation.

Although grizzly bears caused few conflicts in the park, considerable management effort was dedicated toward preventing conflicts (Table 31). In an effort to prevent the need to capture and relocate or remove bears, grizzly bears were hazed out of human use areas 29 times. Grizzly bears were hazed out of park developments 7 times, off of primary roads 18 times, and away from backcountry campsites 4 times. In addition, as part of the park's strategy for preventing bears from obtaining human foods, 116 bear-proof food storage boxes were purchased with National Park Service funds and donations raised by the Yellowstone Park Foundation and installed in roadside campgrounds and backcountry campsites. With the installation of 108 bear boxes in roadside campgrounds in 2016, 679 (36%) of the parks 1,891 campground campsites now have bear boxes. Six of the parks 11 campgrounds, including Pebble Creek, Slough Creek, Tower Falls, Indian Creek, Norris, and Lewis Lake, have bear boxes in 100% of their campsites. As part of the program some bear boxes have also been installed in the Mammoth (42% of sites), Canyon (27% of sites), Bridge Bay (20% of sites), Grant (20% of sites), and Madison (16% of sites) Campgrounds. It is the park's goal to provide park visitors with bear-proof food storage boxes in every roadside campsite. In addition, seven bear boxes were installed in backcountry campsites in 2016 to replace broken food poles. All 301 designated backcountry campsites in Yellowstone National Park currently have a food storage device (food hanging pole or bear-proof food storage box). One additional bear box was installed in the backcountry in the Slough Creek drainage for day-use by anglers.

Although there were few conflicts in Yellowstone National Park, management of non-food conditioned, human-habituated bears required considerable management effort. Habituation is the waning of a bear's response to people (McCullough 1982, Jope 1985, Herrero et al. 2005, Hopkins et al. 2010). Habituation is adaptive and reduces energy costs by reducing irrelevant behavior (McCullough 1982, Smith et al. 2005) such as fleeing from park visitors that are not a threat. Habituation allows bears to access and use habitat in areas with high levels of human activity, thereby increasing habitat effectiveness (Herrero et al. 2005). Habituation most commonly occurs in national parks where there are few human-caused bear mortalities, and exposure to humans is frequent and predictable and does not result in negative consequences for bears. Bears will readily habituate to people, human activities, roads, vehicles, traffic, and buildings. The large areas of non-forested habitat in Yellowstone National Park, combined with habituation of bears to park visitors has created exceptional bear viewing opportunities, resulting in significant growth of bear viewing as a local industry. Bear viewing is now one of the primary activities of visitors to Yellowstone National Park (Taylor et al. 2014, Richardson et al. 2015), and contributes millions of dollars to the economies of gateway communities annually (Richardson et al. 2014). In 2016, 216 roadside traffic-jams caused by visitors stopping to view habituated grizzly bears along roadsides were reported in Yellowstone National Park. Thousands of visitors viewed bears at these bear jams. Park staff responded to 170 (79%) of the grizzly bear jams and spent more than 457 personnel hours managing habituated bears, the traffic associated with bear jams, and the visitors that stopped to view and photograph habituated bears. On average, 2.7 hours of park staff time were spent managing each grizzly bear jam.

Visitation to Yellowstone National Park has increased almost every decade and a new record high for visitation was recorded in 2016 (see "***Yellowstone National Park Recreational Use***"). As visitation increases, park managers should expect an increasing number of bears to become habituated to people and a higher level of habituation among those bears, thereby causing more bear jams and jams of longer duration (Haroldson and Gunther 2013). As the level of habituation increases, the distance at which bears allow visitors to approach before fleeing will also become shorter. Therefore, concurrent with increasing visitation, park managers should anticipate the need for increased staff time and infrastructure (e.g., housing, vehicles, and equipment) dedicated management of bear jams.

Table 30. Number of incidents of human-grizzly bear conflict reported in Yellowstone National Park, 2016.

Conflict type	Number of conflicts
Property damage – without food reward	2
Property damage – with food reward	1
Human injury	0
Human fatality	0
Total conflict incidents	3

Table 31. Number of grizzly bear incidents where management actions were taken in Yellowstone National Park, 2016.

Management action	Number of incidents
Bear warnings posted	10
Temporary area closures	14
Bear-jam management	170
Management hazing	29
Attempt capture – unsuccessful	1
Capture, mark, and release on site	0
Capture and relocate	0
Capture and remove	0
Capture for humane reasons	0
Total management actions	224

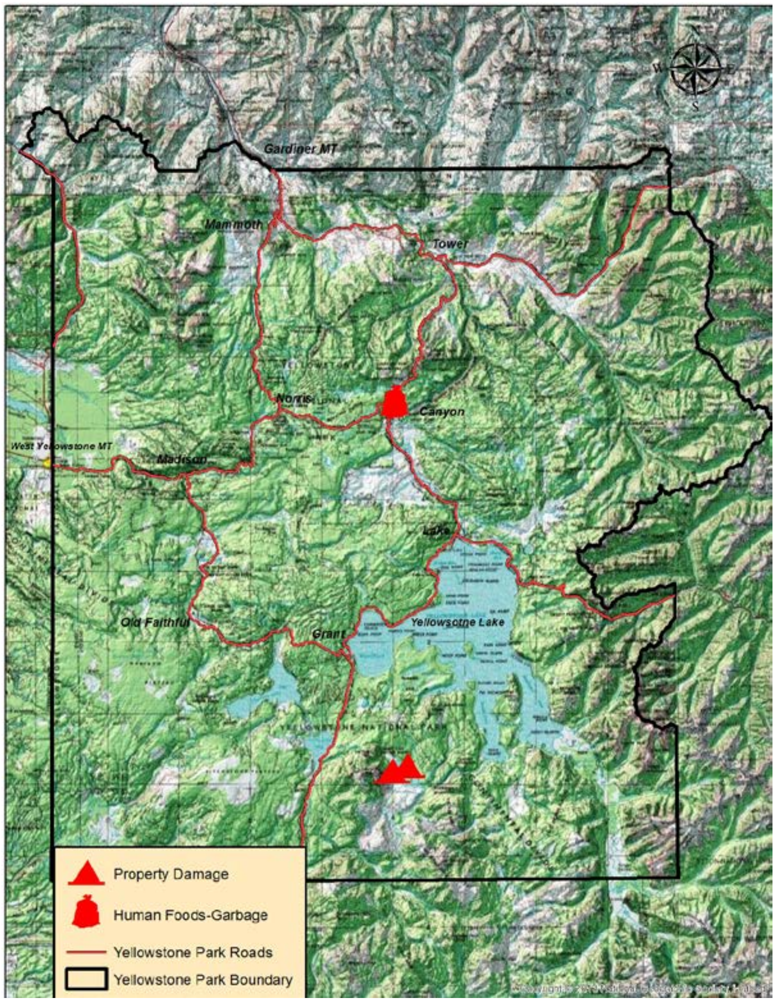


Fig. 25. Locations of human-grizzly bear conflicts, Yellowstone National Park, 2016.

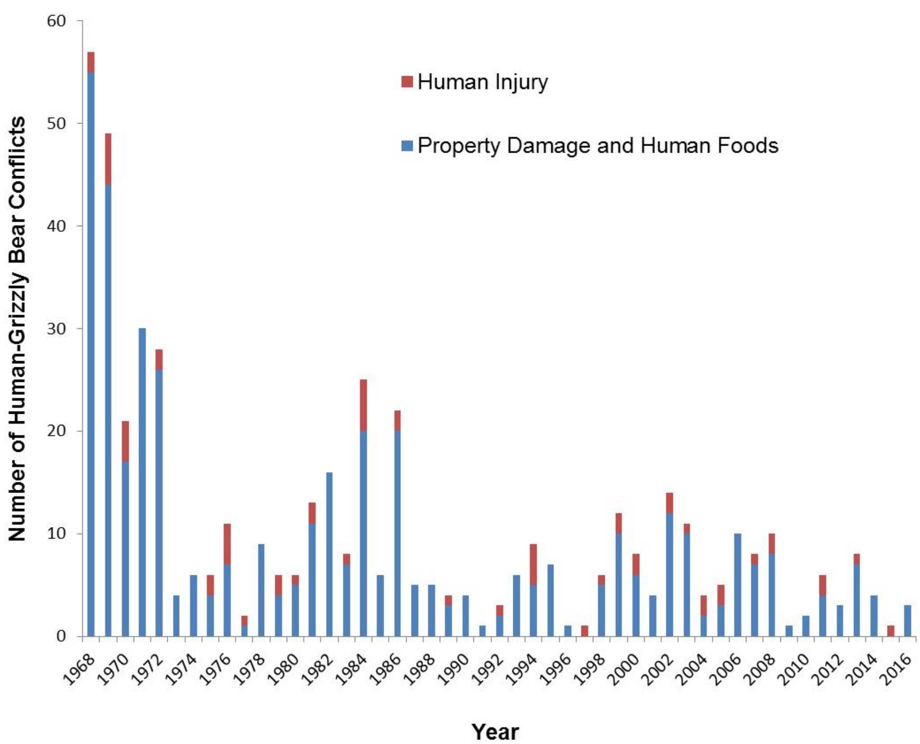


Fig. 26. Number of human-grizzly bear conflicts, Yellowstone National Park, 1968–2016.

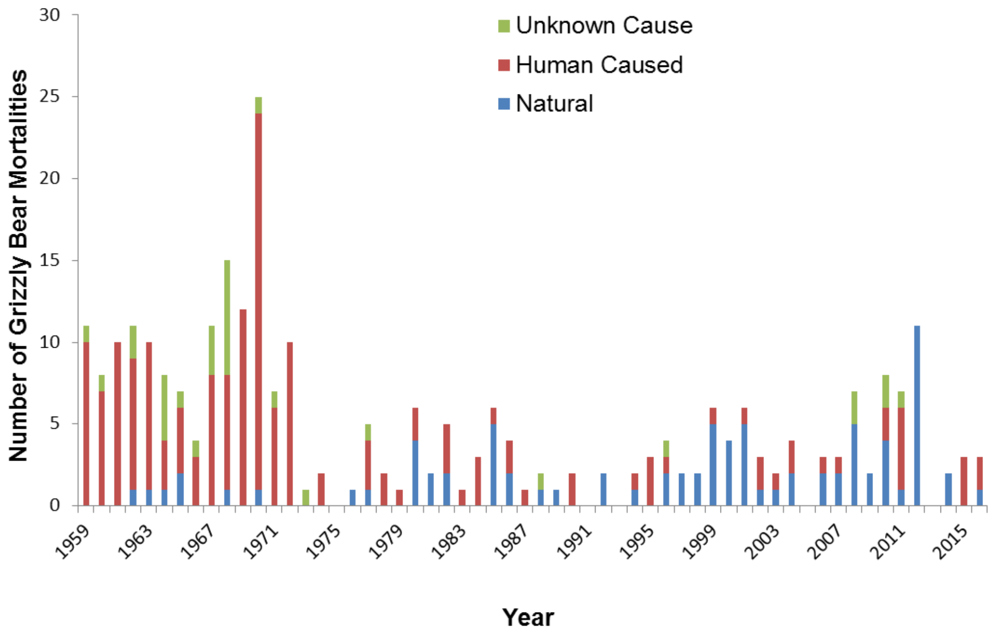


Fig. 27. Number of known and probable grizzly bear mortalities, Yellowstone National Park, 1959–2016.

In 2016, 216 bear jams caused by visitors stopping to view habituated grizzly bears along roadsides were reported in Yellowstone National Park (photo courtesy of Kerry Gunther/NPS).

Human-Grizzly Bear Conflicts in Idaho *(Jeremy Nicholson and Curtis Hendricks, Idaho Department of Fish and Game, February 2016)*

Idaho Fish and Game (IDFG) Upper Snake Wildlife Staff and Conservation Officers responded to 2 human-grizzly bear conflicts during 2016 (Table 32). Conflicts are incidents where bears injure people, damage property, obtain anthropogenic foods, kill or injure livestock, damage beehives, or obtain vegetables or fruit from gardens and orchards (Gunther et al. 2004). Annual variation occurs in the number and location of conflicts, influenced by natural food abundance, livestock use patterns, availability of unsecured anthropogenic foods and an expanding population (both geographic and numbers) of grizzly bears and black bears as well as humans.

The number of grizzly bear conflicts in 2016 was relatively low compared with recent years (Fig. 28). A combination of quality summer forage and above average whitebark pine cone production likely resulted in fewer bears seeking human food. We received reports of bears investigating, but not acquiring, food from bear-resistant garbage containers. The IDFG invests time and money in education and a cost-share program to purchase bear-resistant garbage containers in southeast Idaho. As a result, more businesses and residents are now better equipped to keep bears from obtaining human food than in years past.

The department staff assisted USDA Wildlife Services personnel in the investigation of 2 grizzly bear-related livestock depredations. A trap was set in the Duck Creek Drainage of Island Park for a bear that killed livestock on private land. The bear did not return and was not captured. Another capture event took place in the East Dry Creek area of Island Park due to domestic sheep depredation on a U.S. Forest Service allotment. A mature male bear was captured and euthanized. The bear was in poor condition and had severe tooth wear.

In addition to the euthanized bear, we had 3 confirmed grizzly mortalities in Idaho. Two grizzly bears were shot during the black bear hunting season near Island Park. One of the bears was a young male bear and may have been mistaken for a black bear. The other bear was a much larger male and less likely to be mistaken as a black bear. The last mortality was a young male bear shot in the abdomen and found by local residents, near Coyote Meadows in the Caribou-Targhee National forest.

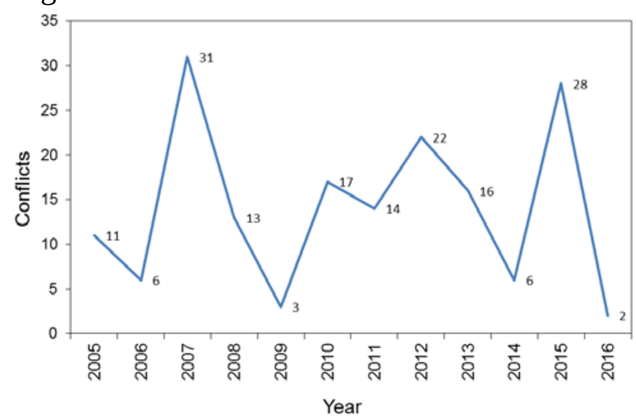


Fig. 28. Number of documented human-grizzly bear conflicts in Idaho portion of the Greater Yellowstone Ecosystem, 2005–2016.

Table 32. Human-grizzly bear conflicts in Idaho portion of the Greater Yellowstone Ecosystem, 2016.

Conflict type	Number	Land ownership
Human injury	0	
Aggression towards humans	0	
Livestock – cattle	1	Private
Livestock – poultry	0	
Livestock – sheep	1	U.S. Forest Service
Elk ranch official	0	
Anthropogenic foods	0	
Beehives/orchards	0	
Property damage	0	
Total	2	

Human-Grizzly Bear Conflicts in Montana

(Kevin L. Frey and Jeremiah Smith, Montana Fish, Wildlife and Parks)

During 2016, Montana Fish, Wildlife and Parks personnel investigated 113 human -grizzly bear conflicts in Montana's portion of the Greater Yellowstone Ecosystem (GYE). Incidents in which grizzly bears cause public safety concerns, property damage, livestock depredations, human injuries, obtain anthropogenic foods, or grizzly bear mortalities are considered conflicts that require agency response, which may involve management action. These conflicts usually vary from a bear being involved in a single incident to multiple incidents involving one or more bears over a period of time, before the conflicts can be resolved. The mean annual number of conflicts over the previous 10 years is 69. There were 113 reported and investigated human-grizzly bear conflicts in 2016 (Table 33). Most conflicts (82%) occurred on private land (Table 34). Annual efforts by Montana Fish, Wildlife and Parks continue to reduce conflicts, increase public safety, and reduce bear mortalities in areas of historic high conflicts, in new geographic areas, and at individual sites.

With the grizzly bear population expanding in geographic distribution and numbers, conflicts are occurring in a larger geographic area on public and private land (Fig. 29). Additionally, 5 grizzly bear conflicts and 8 confirmed grizzly bear sightings or tracks occurred in the geographic area between the GYE and the Northern Continental Divide Ecosystem (NCDE) in 2016 (Fig. 34). Two of the sightings technically occurred in the Bitterroot Ecosystem.

Three people were injured during an encounter situation with a grizzly bear in Montana's portion of the GYE, during 2016. All three of these injuries were related to elk hunting during the fall season. Two grizzly bears were killed in backcountry self-defense situations during the fall season and two other grizzly bears were killed in reported self-defense situations in the frontcountry on private land. During 2016, the most common conflict type was near developed sites with bear searching for or obtaining unnatural (anthropogenic) foods, with some having associated property damage. Cattle depredations, the most common conflict type in 2015, were the second most common conflict type in 2016. The majority (60%) of livestock depredations continued to occur in the greater Red Lodge area. This area had no livestock depredation conflicts until 2011. The area now experiences yearly depredations due to northerly expansion of grizzly bears, mostly from the eastern side of the ecosystem. The majority (84%) of these depredations have occurred on private ranch lands beyond the Demographic Monitoring Area (DMA), where these and other conflicts will likely remain a management challenge.

Historically, anthropogenic food-related conflicts were the most common type of human-bear conflict, which was also the main cause for bear captures, relocations, and mortalities. For more than twenty years, extensive effort has been made on private and public land to secure attractants and reduce these conflicts. Early in the recovery program this was a primary management emphasis for the Yellowstone grizzly bear population. Bears near developed sites often investigate the possibility of obtaining anthropogenic foods. In Montana and throughout the ecosystem, information and education programs, sanitation efforts, and experience have helped reduce the number of bears obtaining anthropogenic foods, thereby reducing the need for management actions involving capture, relocation, or sometimes removal. These efforts will need to continue to reduce conflicts, reduce mortalities, and maintain social tolerance of grizzly bears. There has been a 32% increase in conflicts during the most recent 10-year period. During 1997–2006, 510 human-grizzly bear conflicts were investigated. From 2007 through 2016, there were 754 reported and investigated human-grizzly bear conflicts in the Montana portion of the GYE (Fig. 30). This increase is attributed to the increase in grizzly bear population numbers, the expansion of occupied grizzly bear range, and the increase in human population and activity. However, if taken into consideration the 2011 U.S. Census data of increase in human population (25%), the increase in GYE grizzly bear population (32%) and the increase in overall bear distribution in Montana's portion of the GYE (36%), conflicts have been occurring at a relatively constant rate. Conflict reduction efforts have been successful on public and private lands.

Table 33. Human-grizzly bear conflicts in Montana portion of the Greater Yellowstone Ecosystem, 2016.	
Conflict type	Number of conflicts
Encounter situations	13 (3 human injuries)
Livestock – cattle	25 (24 cattle killed, 2 injured)
Livestock – sheep	0
Livestock – poultry	1
Property damage	7 (2 vehicle related)
Anthropogenic foods	17
Anthropogenic foods with property damage	15
Near developed sites- safety concerns	35
Total	113

Table 34. Private and public land grizzly bear conflicts in Montana portion of the Greater Yellowstone Ecosystem, 2016.	
Jurisdiction	Number of conflicts
Private	94 (82% of total)
State	2
County or local jurisdiction	1
Federal jurisdiction	3
Bureau of Land Management	1
Gallatin National Forest	5
Beaverhead National Forest	7
Custer National Forest	0
USFWS – National Wildlife Refuge	0
Total	113

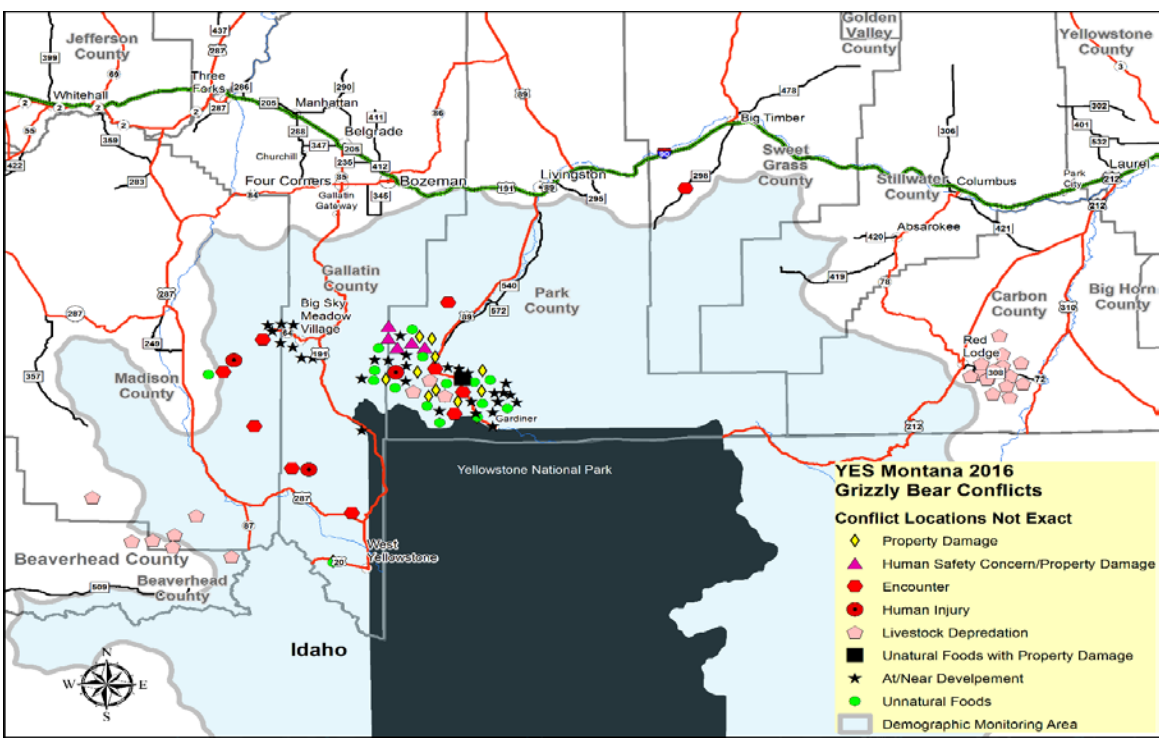


Fig. 29. Locations of human-grizzly bear conflicts in Montana portion of Greater Yellowstone Ecosystem, 2016.

Historically, livestock depredations by grizzly bears have been relatively low in southwest Montana. However, as bears expanded their distribution farther away from recognized suitable habitat, livestock depredations have greatly increased on private and public lands in these areas. During 2016, 84% of the livestock-related conflicts occurred on private land outside the DMA, in the northeast area of the ecosystem near Red Lodge. With an increase in grizzly bear density and distribution on the northwest side of the ecosystem, livestock depredations have also become more frequent in the southern Gravelly Mountains and Centennial Valley. During 1997–2006, there were 22 livestock-related conflicts investigated in southwest Montana. This conflict type increased to 135 investigated livestock related conflicts during 2007–2016; 50 of these 135 depredations were in 2015, mostly attributed to 1 adult female bear.

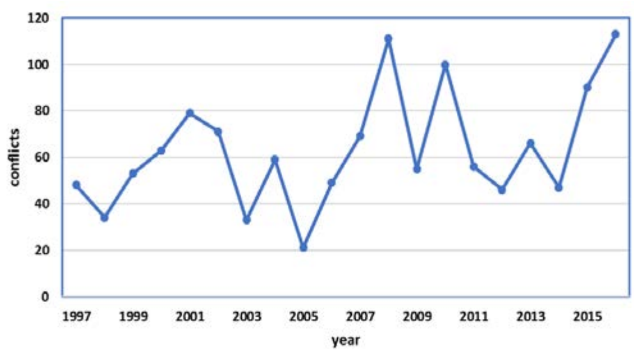


Fig. 30. Annual variation in total human-grizzly bear conflicts in Montana portion of the Greater Yellowstone Ecosystem, 1997–2016.

During 2016, there were 6 management captures of grizzly bears, with 5 of the captures occurring on private land (Fig. 31). The long-term average over the previous 20 years is 4.5 management captures per year. Four of the 2016 grizzly bear captures were due to livestock (cattle) depredations, which involved 2 adult males, and 2 adult females. One of the adult male bears was captured on public land within the DMA and was subsequently relocated. One adult female was removed for multiple livestock depredations on private land outside the DMA. The other adult female and adult male were released near their capture sites within the DMA. One adult female bear and 1 sub-adult male bear were captured in a conflict involving property damage and anthropogenic foods on private land within the DMA. The adult female was subsequently relocated and the subadult male was removed for multiple property damage issues and approaching people and houses.

During 2016, there were 9 known or probable grizzly bear mortalities in the Montana portion of the GYE (Fig. 32). Four of the mortalities occurred on private land and 5 mortalities occurred on various jurisdictions of public lands. Of the 5 mortalities on public land, one was a 3.5-year-old subadult female and one was a 17-year-old adult male grizzly involved in close encounters and defense of life (DL) incidents on public land within the DMA. The adult female killed in the DL incident had not been lactating and reportedly had no cubs at her side. Of the other mortalities on public land, 2 males were struck and killed by vehicles. One adult male was killed on a county road and 1 subadult male was killed on a federal highway. One grizzly bear mortality of unknown sex was discovered (skeleton, hair) in the backcountry. All 2016 mortalities are shown in Table 16. As for the grizzly bear mortalities on private land, 2 males were killed in reported DL situations, 1 sub-adult male was a management removal for human safety concerns, property damage, and livestock depredations. As previously stated, 1 adult female bear was removed on state land for multiple cattle depredations. The DL mortalities (private or public land) are currently under investigation.

Even as the Yellowstone grizzly bear population has been expanding throughout the entire ecosystem, Montana's long-term mortality trend has remained nearly constant since 1992, averaging 5 bear mortalities per year. Comparing time periods of 1995• 2005 to 2006• 2016, bear mortalities associated with anthropogenic foods have decreased from 47% to 15% of the total annual mortality in Montana, indicating that sanitation and education efforts have been successful. However, grizzly bear encounters resulting in human injuries and DL related bear mortalities have increased from 21% of the average annual bear mortality during 1995• 2005 to 41% during 2006• 2016. Additionally, management removals because of livestock depredations have increased from 5% to 18% of the average annual mortalities during these same two time periods. The increase in overall mortality and shifts in causes of mortality can be partially attributed to Yellowstone grizzly bear expansion in population numbers and distribution. The trend of grizzly bear mortalities due to management actions compared with all other mortality causes is shown in Fig. 33. The expectation is that grizzly bears will continue to expand their range into areas beyond the DMA, potentially resulting in an increase of total conflicts and bear mortalities. Evidence of grizzly bear expansion was again documented during 2016. Additionally, multiple occurrences of grizzly bears in the area between the GYE and the NCDE were confirmed (Fig. 34).

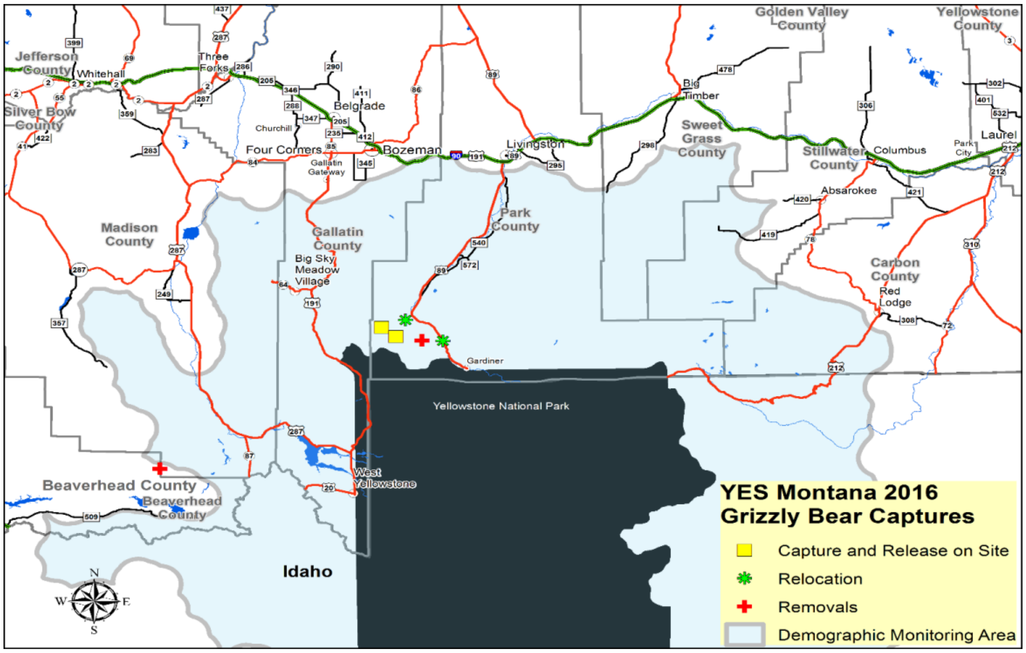


Fig. 31. Locations of grizzly bear management captures in Montana portion of Greater Yellowstone Ecosystem, 2016.

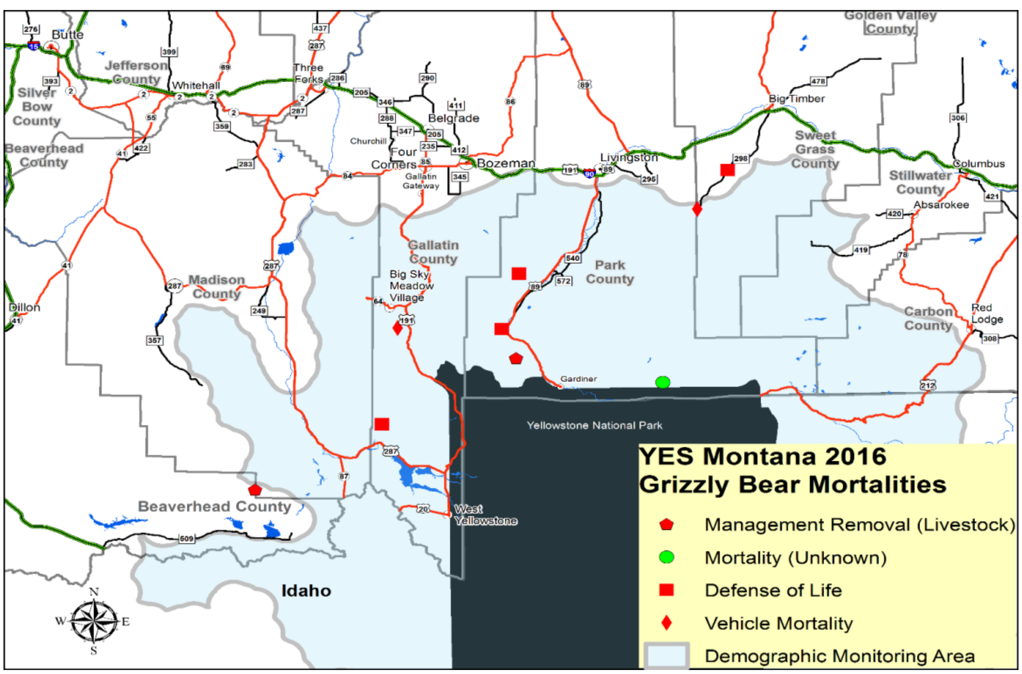


Fig. 32. Locations and causes of grizzly bear mortalities in Montana portion of Greater Yellowstone Ecosystem, 2016.

The 2016 summer climatic conditions were similar to 2014 and 2015, resulting in slightly higher precipitation during the summer months and relatively cooler temperatures compared with 2012 and 2013. A relatively mild spring/early summer allowed for early-stage plant growth and blossoms or setting fruit buds. This resulted in the availability of berry fruits persisting for late summer and fall foraging. Whitebark pine cone production was above average in the GYE during 2016 (see "***Whitebark Pine Cone Production***"). Bears were also feeding on vegetative roots, grazing, and scavenging animal carcasses during the summer and fall months.

Grizzly bear conflict numbers (n = 113) during 2016 were above the long-term (20 years) average (n = 65). The higher number of conflicts did not correlate to food stress for bears overall, but was mostly related to a high number of conflicts on private land inside and outside the DMA, which were mostly attributed to a small number (5 to 10) of bears involved in multiple conflicts. Grizzly bear conflicts in late summer and fall involving anthropogenic foods or being near developed sites can be partially related to the availability of natural, higher-quality (fats, carbohydrates, proteins, sugars) foods. However, during 2016 this was likely not the over-riding cause of conflicts. A major factor contributing to high conflict numbers is an annual high density of bears in relatively small geographic areas of conflict clusters. Bears in these areas are also habituated to human presence and activities, which leads to investigating food sources near people. Field investigations indicated grizzly bears were using heavy shaded timber, wet areas, and open areas during the summer months. This feeding strategy allows bears to find adequate vegetative and protein food sources. However, some bears caused a relative high number of conflicts near homes and most of the livestock depredations occurred on private land in marginal habitat. Summer vegetative foods were adequate in these shaded and mesic areas, as high-quality fall foods (e.g., berries, roots, seeds, carcasses) were in good quantity. No single factor can be attributed to low or high conflicts during a given year and it is always a combination of multiple factors. Natural food availability, climate conditions, bear numbers, individual bear behavior, previous bear removals, management efforts and human activities all factor into the annual variation in human-bear conflicts. Extensive efforts are made to reduce all types of conflicts and we have observed a measured success in the reduction of sanitation and anthropogenic food-related conflicts and associated bear mortalities. During 2016, eight conflicts were related to garbage with the remaining anthropogenic conflicts mostly involving apples and domestic animal feeds.

Conservation Strategy funding from the USFWS provided since the initial delisting (2007) of the Yellowstone grizzly bear population has allowed the acquisition of 346 bear-resistant refuse containers for placement on private and public land within the Grizzly Bear Recovery Zone/Primary Conservation Area. Since 2006, Montana Fish, Wildlife and Parks and local community efforts have distributed and placed 388 bear-resistant garbage containers in the upper Yellowstone River-Gardiner area, Cooke City, and upper Boulder River area, which has greatly reduced garbage related conflicts in these areas. Additionally, with the formation of a Bear Aware Council, representing private businesses, community developments, and agencies, Republic Services has distributed over 750 bear-resistant garbage containers in the Big Sky area. This sanitation effort will greatly help reduce black bear and grizzly bear conflicts in this portion of Gallatin and Madison Counties.

The most difficult conflict type to prevent is surprise encounter. Such encounters can lead to human injuries and are currently trending to be the leading cause of grizzly bear mortalities in the Montana portion of the GYE. During 2016, there were 3 human injuries due to a surprise encounter with a bear. All 3 people injured were males, required medical treatment, and were associated with elk hunting. Montana Fish, Wildlife and Parks continues to distribute bear conflict information to hunters through hunter (archery and rifle) education classes, license holders, postcards, letters, personal contacts, newspapers, websites, and televised news. In general, most of the public is aware of grizzly bear presence and potential encounter situations, but due to the unpredictable and random occurrence of surprise encounters, it is impossible to completely prevent these types of conflicts. The largest future challenge will be to effectively address bear management situations on lands beyond recognized suitable habitat and the DMA.

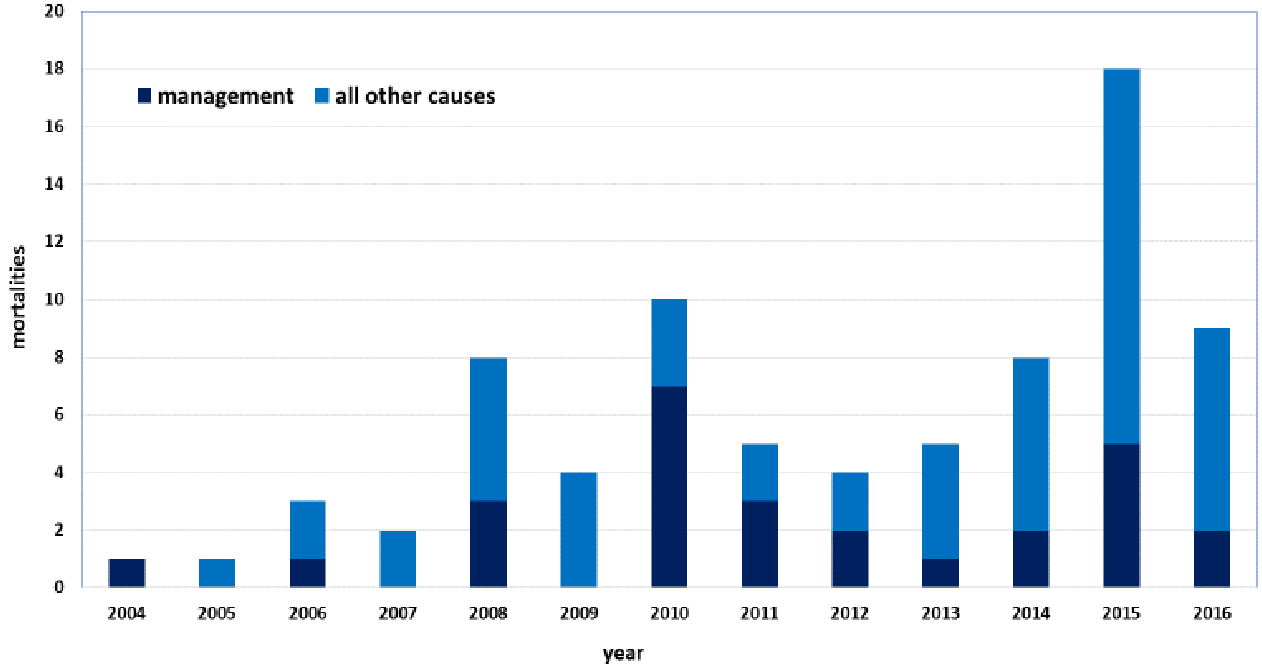


Fig. 33. Number of management removals and other mortalities in Montana portion of Greater Yellowstone Ecosystem, 2004–2016.

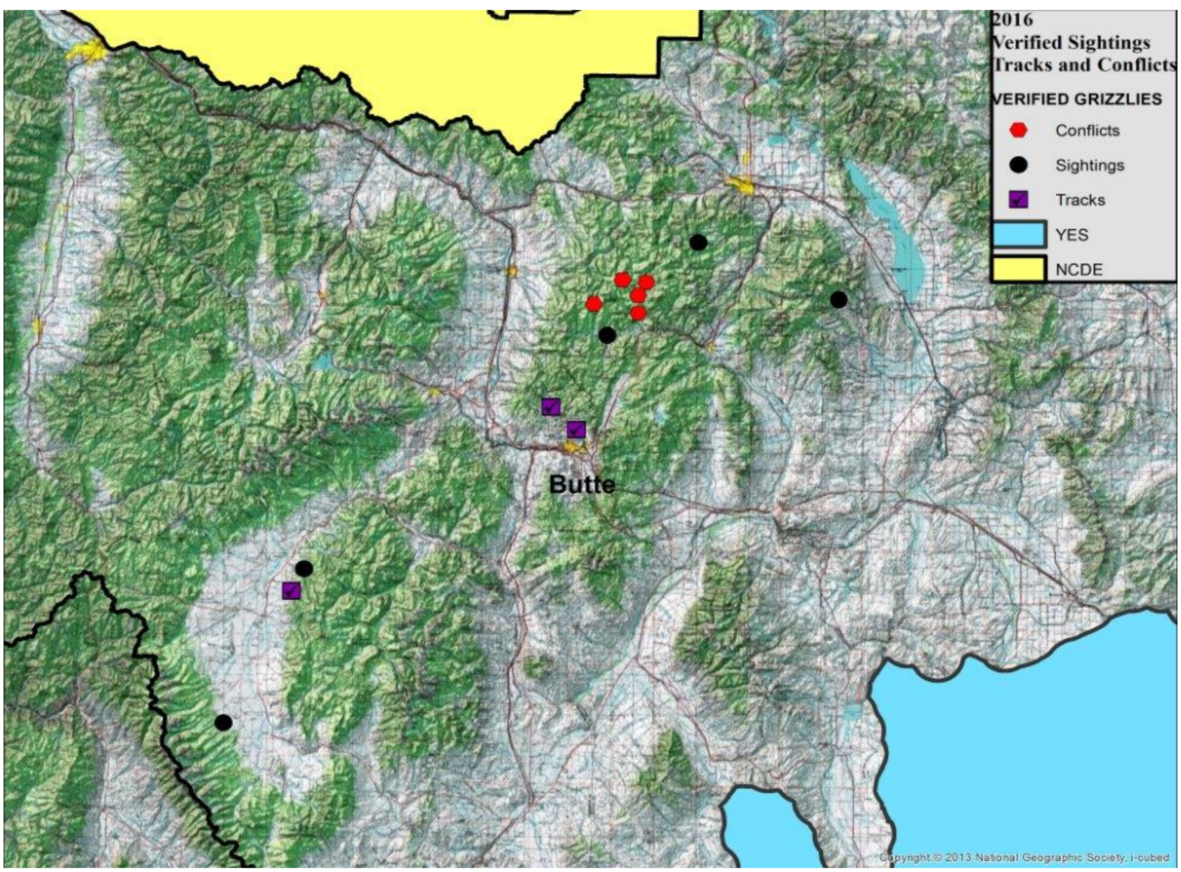


Fig. 34. Verified observations of grizzly bears between the Greater Yellowstone and Northern Continental Divide Ecosystems, 2016.

Human-Grizzly Bear Conflicts in Wyoming

(Brian DeBolt, Zach Turnbull, Luke Ellsbury, Michael Boyce, Sam Stephens, Dustin Lasseter, Phil Quick, Ryan Kindermann and Daniel J. Thompson; Large Carnivore Section, Wyoming Game and Fish Department)

Human-bear interactions and conflicts in Wyoming are typically a result of bears seeking unnatural foods in association with people and property, close encounters with humans, or when bears depredate livestock. The number and location of human-bear conflicts is influenced by unsecured unnatural attractants (e.g., human foods, garbage), natural food distribution and abundance, bear density and distribution, and human and livestock use patterns on the landscape.

The preferred resolution to minimize human-bear conflicts in Wyoming is through preventative measures or to secure the bear attractant. In addition, the Wyoming Game and Fish Department manages grizzly bears in accordance with state and federal law, regulation, and policy. Capturing bears in areas where they may come into conflict with people and relocating them to remote locations is a common practice throughout the world. Relocating bears achieves several social and conservation functions: 1) reduces the possibility of property damage, livestock damage, or human interactions in areas where the potential for conflict is high; 2) reduces the potential for bears to become food conditioned or human habituated, which often results in destructive and dangerous behaviors; 3) allows bears the opportunity to forage on natural foods and remain wary of people; and 4) may prevent removing bears from the population, which may be beneficial in meeting population management objectives. The practice of relocation has served as an integral conservation tool to provide for recovery for GYE grizzly bears for multiple decades. Removal refers to lethal or live removal (e.g., placement with a zoo or other captive bear facility) from the population.

During 2016, the Wyoming Game and Fish Department captured 39 grizzly bears in 40 capture events in an attempt to prevent or resolve conflicts (Fig. 35). Most captures were lone grizzly bears of all age classes, but 2 family groups (both females with 3 cubs), and 1 pair of sibling 2-year olds were also captured. Twenty-six (65%) of the 40 capture events were in Park County, 8 (20%) occurred in Sublette County, 4 (10%) in Fremont County, and 2 (5%) in Hot Springs County (Table 35).

Of the 40 capture events, 17 captures were a result of bears killing livestock (primarily cattle), 9 bears were captured for obtaining garbage, and 9 were captured for obtaining pet, livestock food, or damaging fruit trees. Two bears were non-target captures released on site, and 3 were orphaned cubs captured and removed for human safety/ethical reasons, and physical condition of the cubs. All relocated grizzly bears were released on U.S. Forest Service lands in or adjacent to the Grizzly Bear Recovery Zone/Primary Conservation Area (Fig. 36). Of the 16 relocation events, 9 (56%) bears were released in Park County, and 7 (44%) were released in Teton County (Table 35).

Twenty-two of the 40 capture events resulted in the removal of grizzly bears from the population (Table 35). These bears were removed due to a history of previous conflicts, a known history of close association with humans, or they were deemed unsuitable for release into the wild (e.g., orphaned cubs, poor physical condition, or human safety concern). Removals occur after deliberation with the U.S. Fish and Wildlife Service and ultimate decisions take into account multiple factors unique to each conflict situation.

All independent-age grizzly bears (e2 years old) that were relocated were fitted with a radio-tracking collar to evaluate their movements after release and into the future. Attempts to obtain locations on marked grizzly bears through aerial telemetry were made approximately every 14 days.

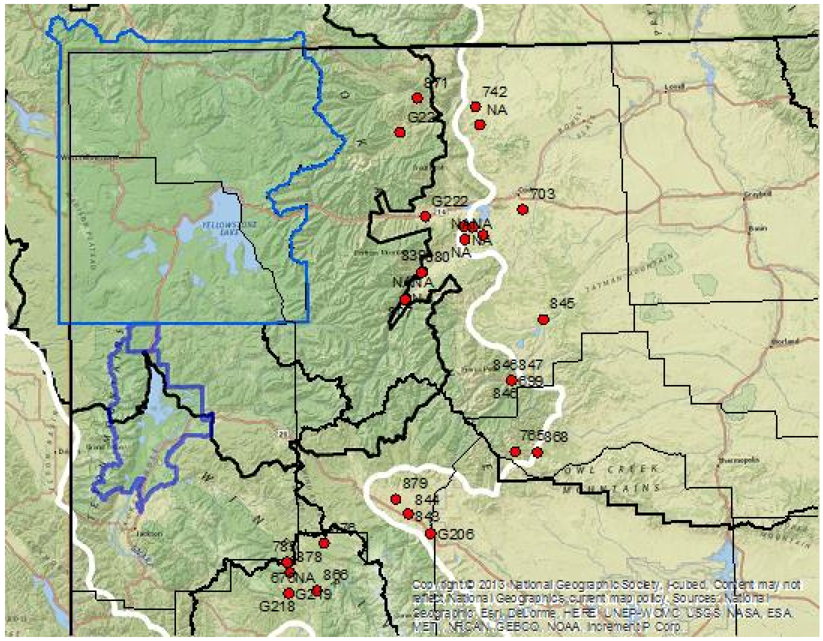


Fig. 35. Management capture locations (n = 40) for grizzly bears in Wyoming portion of the Greater Yellowstone Ecosystem, 2016. Grizzly bears with "G" in front of their number were ear-marked but not fitted with a radio collar upon release, typically because they were too young to be collared. Grizzly bears identified with "NA" were removed from the population without receiving an identification number. Because of the mapping scale, some locations are combined at one symbol and are not always distinct on the map. A complete list is provided in Table 35.

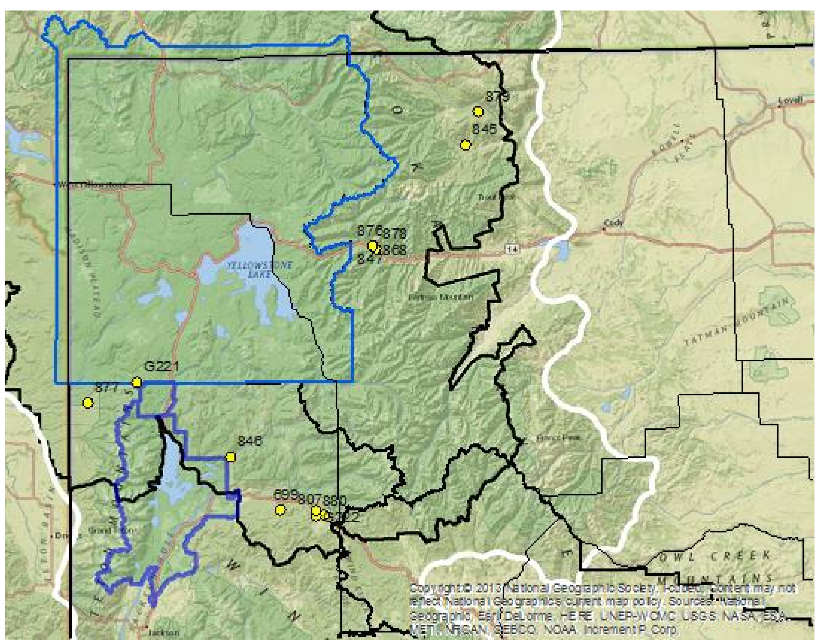


Fig. 36. Release locations (n = 16; 2 management capture bears were released on site) for grizzly bears captured, relocated, or released on site in conflict management efforts in Wyoming portion of the Greater Yellowstone Ecosystem, 2016. Grizzly bears with "G" in front of their number were ear-marked but not fitted with a radio collar upon release, typically because they were too young to be collared. Because of the mapping scale, some locations are combined at one symbol and are not always distinct on the map. A complete list is provided in Table 35.

Table 35. Summary of grizzly bear conflict management captures in Wyoming portion of the Greater Yellowstone Ecosystem, 2016. Grizzly bears identified with "NA" were removed from the population without receiving an identification number.

Date	ID	Capture county	Relocation site	Release county	Reason for capture
4/16/2016	839	Park			Removed for chronic cattle depredation
4/27/2016	845	Park	Trail Creek; WGFD WHMA	Park	Relocated for frequenting a developed area
5/5/2016	846	Park	Pacific Creek; Bridger-Teton National Forest	Teton	Relocated for property damage and food reward of fish food
5/6/2016	NA	Park			Removed for chronic cattle depredation.
5/12/2016	G206	Fremont			Removed for repeated conflicts and property damage
5/19/2016	699	Park	Flagstaff Creek; Bridger-Teton National Forest	Teton	Non-target capture
5/22/2016	846	Park			Removed for repeated property damage
5/22/2016	847	Park	Five Mile Creek; Shoshone National Forest	Park	Non-target capture, no conflict; relocated after injured by bear 846 in snare
6/25/2016	742	Park			Removed for chronic cattle depredation
7/8/2016	807	Park	Lost Lake Road; Bridger-Teton National Forest	Teton	Relocated for chicken depredation
7/10/2016	843	Fremont			Removed for chronic food rewards in developed area
7/10/2016	844	Fremont			Removed for chronic food rewards in developed area
7/19/2016	866	Sublette	On site; Bridger-Teton National Forest		Non-target at cattle depredation
7/23/2016	868	Hot springs	Mormon Creek; Shoshone National Forest	Park	Relocated for cattle depredation.
8/6/2016	785	Sublette			Removed for chronic cattle depredation
8/7/2016	871	Park	On site; Shoshone National Forest		Non-target for cattle depredation
8/15/2016	765	Hot springs			Removed for chronic cattle depredation
8/29/2016	676	Sublette	Five Mile; Shoshone National Forest	Park	Relocated for sheep depredations with dependent young (3 cubs)
8/29/2016	G218	Sublette	Five Mile; Shoshone National Forest	Park	Relocated with mother 676 and siblings for sheep depredations
8/29/2016	G219	Sublette	Five Mile; Shoshone National Forest	Park	Relocated with mother 676 and siblings for sheep depredations
8/29/2016	NA	Sublette			Captured with mother 676 and siblings for sheep depredations – accidental mortality
9/1/2016	876	Sublette	Five Mile; Shoshone National Forest	Park	Relocated for cattle depredation

Table 35. Continued.					
Date	ID	Capture county	Relocation site	Release county	Reason for capture
9/7/2016	877	Park	Boone Creek; Targhee National Forest	Teton	Relocated for apple tree damage and frequenting developed areas
9/9/2016	878	Sublette	Mormon Creek; Shoshone National Forest	Park	Relocated for cattle depredations
9/13/2016	879	Fremont	Deadman Creek; Shoshone National Forest	Park	Relocated for frequenting ranch buildings adjacent to town of Dubois
9/15/2016	880	Park	Blackrock Creek; Bridger-Teton National Forest	Teton	Relocated for frequenting developed areas
9/18/2016	G221	Park	Grassy Lake; JDR Memorial Parkway	Teton	Relocated for frequenting a guest ranch
9/29/2016	369	Park			Removed for chronic food rewards in developed area
9/29/2016	829	Park			Removed for chronic food rewards in developed area
9/30/2016	703	Park			Removed for frequenting landfill
10/3/2016	G222	Park	Holmes Cave; Bridger-Teton National Forest	Teton	Relocated for frequenting developed areas and damaging apple trees
10/7/2016	NA	Park			Removed for cattle depredation and frequenting developed areas
10/7/2016	NA	Park			Removed for cattle depredation and frequenting developed areas
10/7/2016	NA	Park			Removed for cattle depredation and frequenting developed areas
10/8/2016	NA	Park			Removed for cattle depredation and frequenting developed areas
10/9/2016	NA	Park			Removed for getting garbage and in poor condition
10/15/2016	465	Park			Removed for damaging chicken coops and killing 3 goats.
10/21/2016	NA	Park			Orphaned cub euthanized
10/21/2016	NA	Park			Orphaned cub euthanized
10/21/2016	NA	Park			Orphaned cub euthanized

Wyoming Game and Fish Department personnel investigated and recorded 223 human-grizzly bear conflicts in 2016 (Table 36, Fig. 37). As a result of numerous and diligent education and conflict prevention efforts, the general pattern of conflicts is relatively steady within currently occupied habitat (Fig. 38). However, as occupied grizzly bear range has expanded, conflicts continue to occur in areas further from the Grizzly Bear Recovery Zone/Primary Conservation Area and outside the DMA, often on private lands. Bears are increasingly coming into conflict with people in areas where grizzly bears have not been present in recent history. Although the joint efforts of the Wyoming Game and Fish Department, U.S. Forest Service, non-governmental organizations, and particularly the public have resulted in reducing conflicts through education and attractant storage in many areas, numbers of grizzly bear conflicts in Wyoming were very high this year. Bears frequented lower elevations and developed areas regularly during the non-denning period. Grizzly bear-cattle depredation was the most frequent type of conflict documented in 2016. The annual variation in livestock depredation incidents is not easily explained. Although most human-bear conflicts are correlated with natural food abundance, the number of cattle and sheep killed annually do not follow the same pattern. As grizzly bears expand further into human-dominated landscapes outside the DMA, the potential for conflict between bears and humans increases, potentially resulting in negative outcomes for both grizzly bears and people. The Wyoming Game and Fish Department continues to explore options to reduce grizzly bear-livestock conflicts.

The majority of conflicts in Wyoming occurred on public lands outside of the Grizzly Bear Recovery Zone/Primary Conservation Area (Figures 34 and 35). The increasing distribution of grizzly bears is reflected in the annual documentation of conflicts further from this area and continued expansion outside the DMA. As bears expand and occupy habitats commonly used by humans, there is a greater potential for conflicts to occur. Education and conflict-prevention efforts are used anywhere bears and people coexist, and management actions will be a function of human values and effects on the grizzly bear population in those areas.

Table 36. Type and number of human-grizzly bear conflicts in Wyoming portion of the Greater Yellowstone Ecosystem, 2016.

Conflict type	Number	Percent (%)
Cattle	122	54.7
Garbage	31	13.9
Pet-livestock-birdfeed	19	8.5
Property damage	16	7.2
Fruit trees	8	3.5
Animal death	7	3.1
Sheep	5	2.2
Human injury	4	1.8
Aggression toward humans	4	1.8
Poultry	2	0.9
Properly stored game	2	0.9
Unsecured attractant	1	0.4
Pet or guard animal	1	0.4
Other	1	0.4
Total	223	100

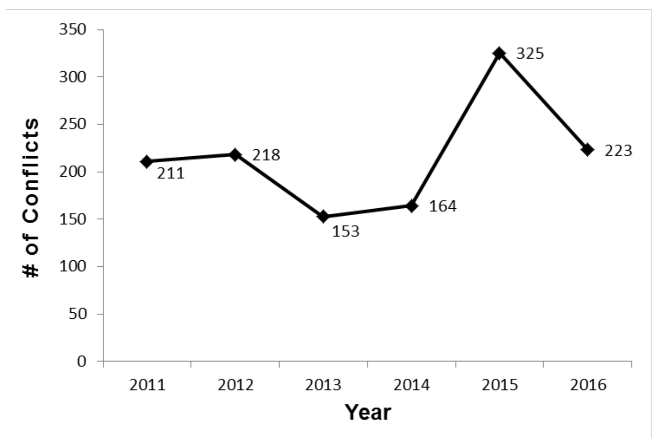


Fig. 37. Number of human-grizzly bear conflicts in Wyoming portion of the Greater Yellowstone Ecosystem, 2011–2016.

Long-term trends in the number of conflicts is likely a result of grizzly bears increasing in numbers and distribution and expanding into areas used by humans, including livestock production, on public and private lands. As the GYE grizzly bear population continues to grow and expand into less suitable habitat, bears encounter food sources such as livestock and livestock feed, garbage, and pet food, resulting in increased property damage and threats to human safety. Conflict prevention measures such as attractant storage, deterrence, and education are the highest priority for the Wyoming Game and Fish Department. In general, there is an inverse relationship between social tolerance and biological suitability for bear occupancy in areas further from the Recovery Zone due to development, land use patterns, and various forms of recreation. Although prevention is the preferred option to reduce conflicts, each situation is managed on a case-by-case basis with education, securing of attractants, relocation or removal of individual bears, or a combination of methods used for long-term conflict resolution.

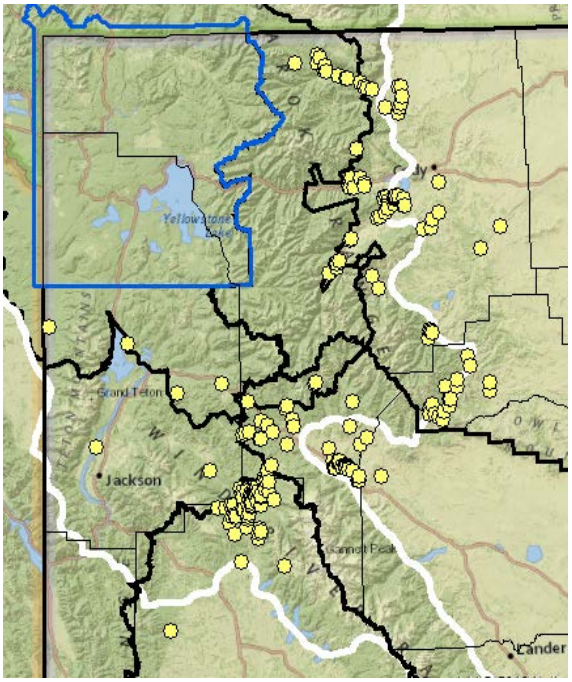


Fig. 38. Location of human-grizzly bear conflicts in Wyoming portion of the Greater Yellowstone Ecosystem outside of National Parks (n = 223) in relation to the Grizzly Bear Recovery Zone/Primary Conservation Area and the Demographic Monitoring Area, 2016.

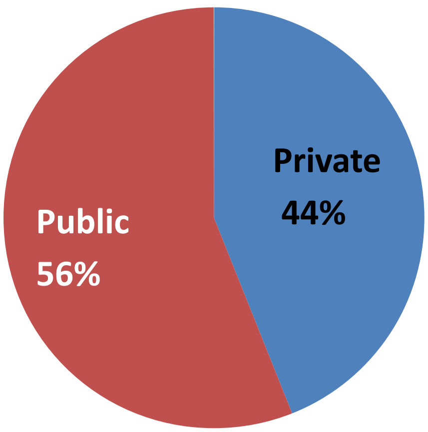


Fig. 39. Percent of human-grizzly bear conflicts on private and public lands in Wyoming portion of the Greater Yellowstone Ecosystem, 2016.

Human-Grizzly Bear Conflicts on the Wind River Reservation (*Pat Hnilicka, Lander Fish and Wildlife Conservation Office, U.S. Fish and Wildlife Service; and Ben Snyder, Eastern Shoshone and Northern Arapaho Tribal Fish and Game Department*)

No depredations of livestock were reported or documented on Wind River in 2016. No grizzly bears were removed or transported to or from Wind River in 2016 for any purpose, including human conflicts.

Electric fencing around potential bear attractants can provide an effective deterrent to reduce bear conflicts and prevent management actions (photo courtesy of Brian DeBolt/WGFD).

Human-Grizzly Bear Interactions in Yellowstone National Park *(Kerry A. Gunther and Travis C. Wyman, Yellowstone National Park)*

In an effort to make scientifically based decisions regarding the bear safety recommendations provided to park visitors, Yellowstone National Park managers are interested in the relative risk of grizzly bear attack on the public recreating in the park. To address this need, we recorded information on human-bear interactions in the park. Because the risk of a bear attack varies depending on visitor location and activity, we grouped human-bear interactions into 5 broad categories including: 1) frontcountry developments, 2) road-side corridors, 3) backcountry campsites, 4) backcountry trails, and 5) off-trail backcountry areas. We considered all encounters where the person believed the grizzly bear was aware of the person's presence as an interaction.

Human-Bear Interactions within Developed Frontcountry Sites

Bears enter frontcountry developments in the park for a variety of reasons including travel, foraging for natural foods, avoiding more dominant bears, and seeking human foods or garbage. However, since implementation of a new bear management program in 1970, it is rare for bears to obtain food rewards in park developments. Under the park's Bear Management Plan, frontcountry developments are managed for people and bears are actively excluded through hazing, capture and relocation, or capture and removal.

Activity of Bears in Frontcountry Developed Sites

In 2016, there were 29 incidents reported where grizzly bears were known to enter park developments (Table 37). The activity of the bear was reported in 28 of the 29 incidents. In in 61% (*n* = 17) of the incidents it appeared that the bear was just traveling through the development and in 25% (*n* = 7) bears foraged for natural foods within the developments. In 11% (*n* = 3) of the incidents, bears investigated sources of anthropogenic attractants (human food or garbage) but did not damage property or obtain a food reward. In 1 (4%) incident the bear damaged property and obtained a food reward.

Reactions of Bears to the Presence of People in Frontcountry Developments

Grizzly bears were known to have encountered people in all 29 of the incidents where they entered frontcountry developments and the bears' reaction was recorded in all of these incidents (Table 38). Bears reacted in a neutral manner in 59% (*n* = 17) of the incidents, with a flight response in 38% (*n* = 11), and with curious behavior in 1 (3%) encounter. Bears did not display aggressive behavior or attack people in any of the 29 encounters that occurred within developments.

Human-Bear Interactions along Roads

Bears frequent habitat adjacent to roads in the park for traveling, foraging for natural foods, avoiding more dominant bears, seeking human food handouts, and other reasons. In the past (1910–1969) bears commonly panhandled along park roads for food handouts from park visitors (Schullery 1992). Strict enforcement of regulations prohibiting the hand feeding of bears for recreational purposes since 1970 has mostly eliminated this behavior in park bears. However, bears are still regularly observed near park roads traveling and foraging for native foods. Unlike park developments that are managed solely for people and bears are actively excluded, under the park's Bear Management Plan, roadside habitats are managed for both human and bear uses. Although bears are not allowed to remain or linger on the paved road, roadside pull-outs, road shoulder, or adjacent drainage ditch, they are tolerated in roadside meadows and are not actively discouraged from using roadside habitats to forage for natural foods.

Bear Activity along Roadsides

In 2016, 216 reports of grizzly bears along park roads were recorded (Table 39). The primary activity of roadside bears was recorded in 212 of these reports. In the majority of these incidents, the roadside bears' primary activity was foraging for natural foods (82%, *n* = 174). Other activities reported included traveling (17%, *n* = 35), investigating vehicles (1%, *n* = 2), and swimming (<1%, *n* = 1).

Bear Reactions to the Presence of People Along Roadsides

Bears were noticeably aware of the presence of people in 161 of the 216 reports of bear activity along roads. The reaction of bears to people was reported for 158 of these 161 roadside encounters (Table 38) and were classified as neutral in 70% (n = 111) and a flight response in 30% (n = 47) of the incidents. Bears did not display aggressive behavior or attack people in any of the roadside encounters.

Human-Bear Interactions in Backcountry Areas

Bears are generally given priority in recreation management decisions where bear and human activities are not compatible in backcountry areas of the park. Yellowstone National Park implements seasonal closures and restrictions on recreational use of backcountry areas during periods when bear activity is concentrated on specific foods in predictable locations. In addition, short-term closures of backcountry trails, campsites, and off-trail areas to recreational use are implemented when human activities conflict with natural bear activities and behaviors.

Activity of Bears in Occupied Backcountry Campsites

Bears occasionally enter designated backcountry campsites while the campsites are occupied by recreational users. In 2016, there were 9 incidents reported where grizzly bears entered occupied backcountry campsites (Table 40). The bears' primary activity was reported for 8 of the incidents. Reported activities of bears in occupied campsites included foraging on native foods (n = 2), walking through the core campsite (n = 2), investigating the food pole without getting a food reward (n = 2), investigating the tent without causing damage or getting a food reward (n = 1), and lying down and resting in the campsite (n = 1).

Bears Reactions to the Presence of People in Backcountry Campsites

In 6 of the 9 incidents where grizzly bears entered occupied backcountry campsites, the campers believed that the bear knew people were present in the campsite. Bears had a neutral response in 5 of the encounters and a curious response in 1 encounter (Table 38). The bears did not react aggressively or attack people in any of the incidents where they entered occupied backcountry campsites in Yellowstone National Park in 2016.

Bears Reactions to Encounters with People on Backcountry Trails

In 2016, there were 37 incidents where people encountered grizzly bears on backcountry trails where the bear was aware of the human presence (Table 38). Reactions of bears to the encounters were reported for 36 of these incidents. Grizzly bears reacted to encounters with people along backcountry trails with neutral behaviors in 47% (n = 17), flight behaviors in 44% (n = 16), curious behaviors in 6% (n = 2), and stress behaviors in 3% (n = 1) of the encounters. Grizzly bears did not react aggressively in any of the incidents and no people were attacked by grizzly bears during encounters on backcountry trails in the park in 2016.

Bear Reactions to Encounters with People in Off-Trail Backcountry Areas

In 2016, there were 12 incidents where people encountered grizzly bears while traveling off-trail in backcountry areas, where they believed the bear was aware of their presence (Table 38). The reaction of the bears to the encounters were reported in all 12 of the incidents and included fleeing (58%; n = 7), neutral behaviors (25%; n = 3), and aggression without contact (17%, n = 2). Grizzly bears did not attack people in any of the off-trail encounters in Yellowstone National Park in 2016.

Summary

Grizzly bears instill fear in many Yellowstone National Park visitors and when they attack people in the park, it generates world-wide news further spreading their ferocious reputation. However, grizzly bears rarely reacted aggressively toward people during encounters in Yellowstone National Park in 2016 (Table 41). Results in 2016 are similar to overall results from the entire period human-bear interactions have been monitored in the park (1991–2016, Table 42). In the 5,819 encounters between grizzly bears and people where the bears reaction was reported, bears reacted with neutral behaviors in 58% (n = 3,345), by fleeing in 35% (n = 2,010), curious behaviors in 3% (n = 195), and with stress, bluster, or warning behaviors in 1% (n = 33) of the incidents. Grizzly bears reacted with aggression without contact in 4% (n = 215) of the encounters. Less than 1% (n = 21) of the 5,819 reported encounters between people and grizzly bears in Yellowstone National Park from 1991–2016 resulted in an attack. The frequency of attack was greatest during backcountry off-trail interactions (7 attacks in 393 reported encounters) and on-trail interactions (14 attacks in 1,376 encounters). Bear attacks were less frequent in areas where human presence was expected and predictable, such as along primary roads (0 attacks in 3,252 encounters), within developments (0 attacks in 610 encounters), and in designated backcountry campsites (0 attacks in 188 encounters). Despite their ferocious reputations, 26 years of human-bear interactions data in Yellowstone National Park suggests that grizzlies are quite tolerant of people in most encounters.

Table 37. Activity of bears that entered frontcountry developments, Yellowstone National Park, 2016.

Bears activity while inside development	Number of incidents
Not reported or unknown	1
Travel through	17
Forage for natural foods	7
Investigate anthropogenic foods but no food reward and no property damage	3
Investigate and damage property but no food reward	0
Investigate and obtain anthropogenic foods	1
Attack people	0
Other	0
Total	29

There were 37 human-grizzly bear encounters on backcountry trails in Yellowstone National Park in 2016, and none involved aggressive encounters (photo courtesy of Ray Paunovich).

Table 38. Reactions of grizzly bears to encounters with people, Yellowstone National Park, 2016.

Reaction of bear	Development	Along roadside	Backcountry campsite	On trail	Off trail	Total
Not reported/not known	0	3	0	1	0	4
Flight response						
Run away	6	11	0	10	6	33
Walk away	5	36	0	6	1	48
Adult climb tree	0	0	0	0	0	0
Cubs climb tree/adult remain	0	0	0	0	0	0
Flight behavior subtotal	11	47	0	16	7	81
Neutral behaviors						
No overt reaction	17	111	5	17	3	153
Stand up on hind legs	0	0	0	0	0	0
Circle down wind	0	0	0	0	0	0
Neutral behavior subtotal	17	111	5	17	3	153
Curious behaviors						
Walk towards stationary person	1	0	1	1	0	3
Follow mobile person	0	0	0	1	0	1
Investigate vehicle	0	0	0	0	0	0
Curious behavior subtotal	1	0	1	2	0	4
Stress/agitation/warning signals						
Salivate	0	0	0	0	0	0
Sway head side to side	0	0	0	0	0	0
Make huffing noises	0	0	0	0	0	0
Pop jaws/teeth clacking noises	0	0	0	1	0	1
Stood ground watched/stared	0	0	0	0	0	0
Slap ground with paw	0	0	0	0	0	0
Flatten ears/erect spinal hairs	0	0	0	0	0	0
Stiff legged walk/hop	0	0	0	0	0	0
Stress/warning behavior subtotal	0	0	0	1	0	1
Aggressive behaviors						
Growl	0	0	0	0	1	1
Stalk	0	0	0	0	0	0
Run towards/aggressive charge	0	0	0	0	1	1
Aggressive behavior subtotal	0	0	0	0	2	2
Attack behaviors						
Defensive attack	0	0	0	0	0	0
Predatory attack	0	0	0	0	0	0
Attack unknown cause	0	0	0	0	0	0
Attack behavior subtotal	0	0	0	0	0	0
Total	29	161	6	37	12	245

Table 39. Primary activity of grizzly bears along roadsides, Yellowstone National Park, 2016.

Activity of bear while inside development	Number of incidents
Not reported/unknown	4
Traveling	35
Foraging natural foods	174
Mating	0
Swimming	1
Sleeping	0
Investigating vehicles/seeking anthropogenic foods; no food reward	2
Obtain anthropogenic foods	0
Damage property	0
Attack people	0
Other	0
Total	216

Table 40. Primary activity of grizzly bears that entered occupied backcountry campsites, Yellowstone National Park, 2016.

Activity of bear	Number of incidents
Not reported/not known	1
Walked past edge of campsite	0
Walked through core camp	2
Forage native foods	2
Investigate tent without damage	1
Investigate food pole	2
Investigate fire ring	0
Attempt to get human foods (not successful)	0
Damage property	0
Obtain anthropogenic foods	0
Investigate latrine (buried human feces/toilet paper)	0
Lay down/rest in campsite	1
Aggressive approach/posture towards people in campsite	0
Total	9

Table 41. Grizzly bear reactions to interactions with people (*n* = 241) in different location settings, Yellowstone National Park, 2016.

Location of encounter	Reaction of bear											
	Flee		Neutral behavior		Curious		Stress/agitation		Aggression without contact		Attack	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Park development	11	38	17	59	1	3	0	0	0	0	0	0
Roadside corridor	47	30	111	70	0	0	0	0	0	0	0	0
Backcountry campsite	0	0	5	83	1	17	0	0	0	0	0	0
Backcountry trail	16	44	17	47	2	6	1	3	0	0	0	0
Backcountry off-trail	7	58	3	25	0	0	0	0	2	17	0	0
Total	81	34	153	64	4	2	1	<1	2	2	0	0

Table 42. Grizzly bears reactions to interactions with people (*n* = 5,819) in different location settings, Yellowstone National Park, 1991–2016.

Location of encounter	Reaction of bear											
	Flee		Neutral behavior		Curious		Stress/agitation		Aggression without contact		Attack	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Park development	291	48	292	48	17	3	2	<1	8	1	0	0
Roadside corridor	732	23	2,408	74	47	1	9	<1	56	2	0	0
Backcountry campsite	78	42	88	47	16	9	1	1	5	3	0	0
Backcountry trail	691	50	429	31	103	8	20	2	119	9	14	1
Backcountry off-trail	218	56	128	33	12	3	1	<1	27	7	7	2
Total	2,010	35	3,345	58	195	3	33	1	215	4	21	<1

Visitor Compliance with Bear Spray and Hiking Group Size Bear Safety Recommendations in Yellowstone National Park *(Kerry A. Gunther and Eric Reinertson, Yellowstone National Park)*

Large party sizes have been shown to reduce the risk of bear attack (Herrero 2002). In addition, bear spray has proven to be effective as a deterrent during surprise encounters when the person involved has time to deploy it (Herrero and Higgins 1998, Smith et al. 2008). To reduce the risks of bear attack in Yellowstone National Park, safety information distributed to visitors recommends that backcountry recreationists traveling by foot maintain group sizes of at least 3 people and carry bear spray. To evaluate visitor compliance with these safety recommendations, we conduct annual surveys to determine the proportion of recreationists that hike in groups of 3 or more people and the proportion that carry bear spray or use other deterrents, such as firearms, or warning devices, such as bear bells. Although it is legal to carry firearms inside Yellowstone National Park, it is illegal to discharge them within the park, so they are not considered a viable bear deterrent. Although bear bells may provide some benefit in alerting bears to the presence of approaching hikers (Jope 1982), they are generally not considered effective at preventing surprise encounters when hiking in strong winds, near rushing water, or in dense forest (Herrero 2002).

Due to time, budget, and staffing constraints, we conducted surveys of convenience. While working on other bear research, monitoring, and management projects throughout the park, we recorded how many recreationists that we encountered at trailheads and on trails and boardwalks were carrying bear spray or other deterrents. We also recorded information on group size and type of recreational activity. We grouped recreational activity into 6 broad categories: 1) day hikers, 2) overnight backpackers, 3) boardwalk trail users, 4) stock (horse or mule) day-riders, 5) stock overnight-riders, and 6) day-use bicyclist trail riders. Our surveys were conducted visually. We recorded the presence of bear spray and other deterrents that were visible and therefore quickly retrievable. Bear spray or other deterrents stored in backpacks, saddle bags, paniers, or carried under coats would likely not be retrievable fast enough for use during surprise encounters with bears.

In 2016, we surveyed 3,312 people in 1,206 groups at 34 different backcountry trails and 5 boardwalk trails. Our surveys included 1,575 backcountry day hikers, 1,527 people walking on boardwalk trails, 188 overnight backpackers, 11 stock day-riders, 9 day-use bicyclists, and 2 overnight stock riders.

Day Hikers

Yellowstone National Park contains >1,000 miles of backcountry hiking trails accessible from 92 trailheads located throughout the park (Yellowstone National Park 2014). We surveyed 1,575 day hikers traveling in 550 groups on 28 different trails. Average party size was 2.9 people per group (Table 43). The most common group size (mode) and the median group size were 2 people per party. Sixty-one percent of day hiking parties had less than the recommended party size of 3 people and 15% hiked alone. Of the 1,575 day hikers, 301 (19%) carried bear spray, 33 (2%) had bear bells, and 4 (<1%) carried firearms (Table 44). Of the 550 groups of day hikers, 238 (43%) had at least 1 member that carried bear spray, 27 groups (5%) had at least 1 person wearing bear bells, and 3 groups (<1%) had at least one person carrying a firearm.

Overnight Backpackers

Yellowstone National Park has 301 designated backcountry campsites (Yellowstone National Park 2014). We surveyed 188 backpackers in 65 groups on 15 different trails. Average party size was 2.9 people per party (Table 43). The most common group size (mode) and the median group size were 2 people per party. Seventy-seven percent (n = 50) of the backpacking groups had less than the recommended party size of 3 people and 15% (n = 10) hiked alone. Of the 188 backpackers, 97 (52%) carried bear spray, 6 (3%) had bear bells, and 4 (2%) carried firearms (Table 44). Of the 65 groups of backpackers, 51 (79%) had at least 1 person in the party that carried bear spray, 3 groups (5%) had at least 1 person wearing bear bells, and 3 groups (5%) had at least one person carrying a firearm.

Stock Day-Riders

We surveyed 11 stock day-riders in 4 groups on 4 different trails. One (9%) of the 11 day-riders carried a firearm. None of the day-riders carried bear spray or wore bear bells.

Stock Overnight-Riders

We surveyed 2 people in 1 group that were riding stock and camping overnight. Of the 2 overnight stock riders, both carried bear spray (Table 44). None of the overnight stock riders carried bear bells or openly carried firearms.

Day Use Bicycle Trail Riders

Yellowstone National Park contains 13 designated bike trails. One of the 13 trails has access to a designated backcountry campsite. We surveyed 9 people in 5 groups riding bicycles on day trips on 2 different bike trails. None of the bicyclists carried bear spray, bear bells, or firearms.

Boardwalk Trails

Yellowstone National Park contains approximately 15 miles of boardwalk trails (Yellowstone National Park 2014). Boardwalk trails are short trails found near park roads that contain interpretive signs providing visitors with information about geysers or other natural features. Boardwalks are constructed to provide a stable walking surface with gentle grades or steps to get up and down hills, allowing use by visitors of a wide-range of ages, physical abilities, and backcountry hiking experience. Stock animals and overnight camping are not allowed on boardwalk trails. We surveyed 1,527 people in 581 groups on 6 different boardwalk trails in 2016. Average party size was 2.6 people per group (Table 43). The most common group size (mode) and the median group size were both 2. Sixty-two percent of boardwalk users had less than the recommended party size of 3 people and 18% hiked alone. Only 1% ($n = 13$) of the individuals surveyed carried bear spray (Table 44). Two percent of the groups ($n = 9$) surveyed had at least one person in the party that carried bear spray. One individual observed on a boardwalk trail had bear bells; none carried firearms.

Discussion

In 2016, overnight backpackers had the highest level of compliance with the park's bear spray recommendation (among recreational groups with a sample size >1); 52% of backpackers carried bear spray. Overnight backpackers have had the highest proportion of individuals that carried bear spray during the 6 years surveys have been conducted (Table 45) We suspect the high level of compliance by this type of recreationist is due to the methods used to convey bear safety information to overnight backpackers. In Yellowstone National Park, permits are required for camping in the backcountry. During the permit process, backpackers are given face-to-face verbal information about bears and bear spray from the ranger issuing the permit and are also required to watch a safety video containing information on hiking and camping in bear country and how to use bear spray. Backpackers are also given the "Beyond Roads End" safety booklet containing information on bear spray and hiking and camping in bear country. Surveys indicate that Yellowstone National Park visitors retain verbal information from uniformed park staff better than written information from signs or brochures (Taylor et al. 2014). In addition, we speculate that many backpackers may have a high level of experience in bear country. The most common party size observed (mode) among backpackers was 2 people per party, indicating that many backpackers did not follow the park's recommended group size of 3 people for hiking in bear country. The most common party size (mode) for overnight backpackers has been 2 people per party each year surveys were conducted (Table 46).

Only 19% of day hikers carried bear spray. Fewer than 20% of day hikers carried bear spray in each of the 6 years surveys have been conducted (Table 45). Permits are not required for day hiking so day hikers may not receive the same level of bear safety information as backpackers, such as the verbal safety information from a park ranger. Visitor's day hiking in Yellowstone National Park can seek and obtain bear safety information from the Yellowstone National Park web page, park newspaper, day hike trip planners, safety cards and brochures, and from rangers at visitor centers.

However, the only bear safety information day hikers are exposed to if they do not seek it out themselves is from signs posted at trailheads. We also suspect that many day hikers in Yellowstone National Park may have a lower level of experience in bear country than many backpackers have. The most frequently observed group size (mode) among day hikers was 2 people per group indicating that many day hikers did not comply with the recommended group size of 3 for hiking in bear country. Since most grizzly bear attacks in Yellowstone National Park involve day hikers (26 of 40 backcountry attacks since 1970), getting more day hikers to carry bear spray or hike in groups of 3 or more people is a priority for park managers.

In 2016, the most common group size encountered on boardwalk trails was 2 people per party and <1% of boardwalk hikers carried bear spray. Recreationists on boardwalk trails have had very low compliance with bear safety recommendations each year surveys were conducted (Tables 45 and 46). However, only 2 grizzly bear attacks in the last 47 years have occurred on or near boardwalk trails, therefore the risk of attack during this type of recreational activity is very low.

None of the day-use stock riders surveyed in 2016 carried bear spray. Bear spray is not very useful while in the saddle, as deploying it from horseback may result in the rider being thrown from their horse. However bear spray is useful and encouraged for carry by stock groups during rest stops along the trail. In general, people riding stock are less likely to be involved in surprise encounters and bear attacks. Horses usually sense a bear's presence before a person does (Herrero 2002), alerting the rider and reducing the chances of surprise encounters at close distances. The large size of horses is also more intimidating to bears. In addition, unlike humans, when charged by bears, horses have enough speed and agility to outrun bears, thus providing an added margin of safety as long as the rider can stay in the saddle.

In 2016, none of the bicycle groups we observed on designated bike trails carried bear spray. Bicyclists incur greater risk of surprise encounters because bicycles are fast and relatively quiet.

Although some backcountry recreationists in Yellowstone National Park carry firearms, and it is legal to do so, it is illegal to discharge them within the park, so they are not considered a viable bear deterrent. Firearms were openly carried by <1% of the recreationists we observed in 2016. Stock day-riders (9%) had the highest frequency of firearms carry. Firearms were openly carried by only a small proportion of all types of recreationists in the 6 years of the survey. Recreationists riding horses often carry firearms for euthanizing injured stock, however if these firearms were carried in saddle bags or panniers they would not have been visible during our surveys and would not have been readily available as a bear deterrent during surprise encounters.

Bear bells were used by approximately 1% of all recreationists surveyed in Yellowstone National Park in 2016. Backpackers (3%) had the highest frequency of bear bell use. The low use of bear bells likely reflects the lack of demonstrated effectiveness as an auditory warning device (Herero 2002).

Table 43. Group size characteristics for different types of recreationalists surveyed in Yellowstone National Park, 2016.

Type of recreational activity	Total people	Total groups	Average group size	Median group size	Mode group size
Boardwalk trail (foot travel walking)	1,527	581	2.6	2	2
Day hiker (day use foot travel-hiker, angler, photographer, etc.)	1,575	550	2.9	2	2
Overnight backpacker (foot travel camping overnight)	188	65	2.9	2	2
Stock – day use	11	4	2.8	2	1,2,3,5
Stock – overnight use	2	1	2	2	2
Day bicycle trip	9	5	1.8	2	2
Totals	3,312	1,206	2.7	2	2

Table 44. Number and percent (%) of people and groups of recreationalists surveyed that carried bear spray, firearms, or bear bells, Yellowstone National Park, 2016.

	Type of recreation/mode of travel						
	Boardwalk trail	Day hiker	Day use bicycle	Overnight backpacker	Stock - day use	Stock - overnight use	Totals (all types)
Total people surveyed	1,527	1,575	9	188	11	2	3,312
(# of parties surveyed)	(581)	(550)	(5)	(65)	(4)	(1)	(1206)
People with bear spray							
Total	13	301	0	97	0	2	413
Percent	0.9	19.1	0	51.6	0	100	12.5
Parties with bear spray							
Total	11	238	0	51	0	1	301
Percent	1.9	43.3	0	78.5	0	100	25
People with firearms							
Total	0	4	0	4	1	0	9
Percent	0	0.3	0	2.1	9.1	0	0.3
Parties with firearms							
Total	0	3	0	3	1	0	7
Percent	0	0.5	0	4.6	25	0	0.6
People with bear bells							
Total	1	33	0	6	0	0	40
Percent	0.1	2.1	0	3.2	0	0	1.2
Parties with bear bells							
Total	1	27	0	3	0	0	31
Percent	0.2	4.9	0	4.6	0	0	2.6

Table 45. Percent (%) of different types of backcountry recreationalists that carried bear spray, Yellowstone National Park, 2011–2016.

Year	Overnight backpackers	Day hiker	Boardwalk	Stock day-use	Stock-overnight use	Day-use bicycle
2011	53	15	Not surveyed	0	60	Not surveyed
2012	47	11	0	9	44	0
2013	60	16	0	11	22	0
2014	48	13	<1	0	35	33
2015	50	14	<1	Not surveyed	14	0
2016	52	19	<1	0	100	0
2011–2016 combined data	52	15	<1	6	37	9

Table 46. Group size characteristics for different types of recreationalists surveyed, Yellowstone National Park, 2011–2016.

Type of recreational activity	Total people	Total groups	Average group size	Median group size	Mode group size
Boardwalk	4,765	1,781	2.7	2	2
Day hiker (e.g., day foot travel- hiker, angler, photographer)	9,345	3,219	2.9	2	2
Overnight backpacker (overnight-foot travel)	575	208	2.8	2	2
Horse – day use	70	12	5.8	4	3
Horse – overnight use	79	16	4.9	5	2, 5 and 6
Day bicycle trip	43	20	2.2	2	2
Totals	14,877	5,256	2.8	2	2

Among day hikers in Yellowstone National Park, 19% carried bear spray in 2016 (photo courtesy of Neal Herbert/NPS).

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Appendix A

2016 Grizzly Bear Habitat Monitoring Report

Grizzly Bear Habitat Modeling Team, Greater Yellowstone Ecosystem

Background

This report is the collective response from the National Forests and National Parks within the Greater Yellowstone Ecosystem (GYE) to obligations for grizzly bear habitat monitoring and reporting established in the *Final Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Area* (U.S. Fish and Wildlife Service [USFWS] 2007). The Conservation Strategy requires annual monitoring and reporting to evaluate federal adherence of habitat standards for the Yellowstone grizzly bear population. These monitoring requirements and habitat standards were formalized for the 6 national forests (now 5) in the *Forest Plan Amendment for Grizzly Bear Habitat Conservation for the Greater Yellowstone Area National Forests, Record of Decision* (herein referred to as Amendment, USDA 2006). Likewise, the Superintendents' Compendia (Grand Teton National Park 2007 and Yellowstone National Park 2007) incorporated the Strategy habitat standards into legal plans for the 2 respective national parks in the GYE.

Habitat standards and monitoring protocol identified in the Conservation Strategy went into effect in 2007 when federal protections under the Endangered Species Act (ESA) were removed for the Yellowstone population. However, the legal status of the Yellowstone grizzly bear remains a contentious issue and the delisting rule was challenged and overturned in a Montana District Court in 2009. The 2009 ruling was upheld by the 9th Circuit Court of Appeals in 2011, and Federal protections were restored to the Yellowstone population as a threatened species under the ESA. Concerns raised by the courts were addressed when the Interagency Grizzly Bear Study Team (IGBST) conducted comprehensive studies to evaluate the adaptive response of Yellowstone grizzly bears to changing food resources (IGBST 2013). The USFWS subsequently determined that the GYE population of grizzly bears has recovered and no longer meets the definition of a Threatened or Endangered species. Consequently, in March 2016, the USFWS proposed a rule to once again remove the Yellowstone population from the Federal list of endangered and threatened wildlife (USFWS 2016). At this date, a final rule is still pending. Regardless of the legal status of the Yellowstone grizzly bear, land managers throughout the GYE are committed to abiding by habitat standards identified in the Conservation Strategy for the long-term protection and health of the grizzly bear population.

Introduction

The intent of habitat standards established in the Conservation Strategy is to preserve adequate secure habitat for grizzly bears and reduce negative impacts of human presence in occupied habitat throughout the core area of the GYE. Three distinct habitat standards were enumerated in the Conservation Strategy pertaining to motorized access, human development, and commercial livestock grazing. All three are known to contribute to grizzly bear mortality and displacement in occupied areas across the landscape. The three habitat standards specifically call for no net decrease in secure habitat (a metric for the absence of motorized access), and no net increase in the number of human developed sites and grazing allotments from that which existed in 1998. This 1998 baseline is predicated on evidence that habitat conditions at that time, and for the preceding decade, contributed to the 4–7% population growth of the Yellowstone grizzly bear population observed between 1983 and 2001. Habitat standards apply only within the Grizzly Bear Recovery Zone (GBRZ)[1], which is located at the core of the GYE (Fig. A1).

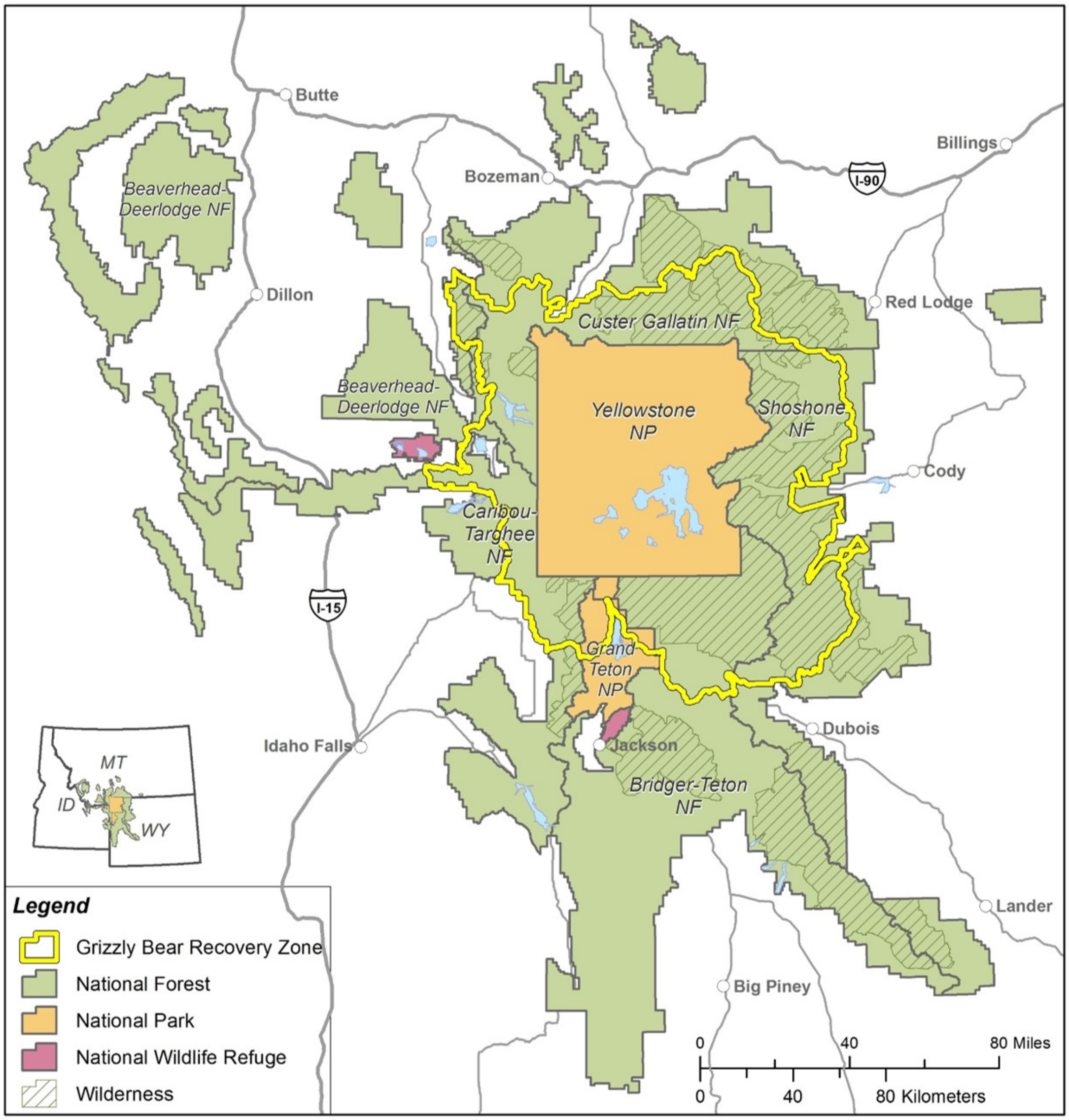

Fig. A1. Federal lands comprising the Greater Yellowstone Ecosystem (GYE) and the Grizzly Bear Recovery Zone (GBRZ).

Annual Monitoring Requirements inside the GBRZ

In compliance with annual habitat monitoring protocol, this report summarizes habitat changes incurred annually inside the GBRZ and compares current habitat status with that of 1998 for the following monitored parameters: 1) number and acreage of commercial livestock grazing allotments and permitted domestic sheep animal months, 2) number of developed sites, 3) percent secure, and 4) habitat motorized access route densities. In addition, all incidental and recurring grizzly bear conflicts associated with livestock allotments occurring on public land are summarized annually for the ecosystem, both inside and outside the GBRZ. Current status of these 4 habitat monitoring parameters, except for livestock allotments, are evaluated, summarized, and reported annually for each of the 40 subunits within the 18 Bear Management Units (BMU; Fig. A2) and are compared against 1998 levels. The number and status of livestock allotments is reported annually for each national Forest and Park

[1] The Grizzly Bear Recovery Zone (GBRZ) is a term used when the Yellowstone grizzly bear is under federal protection. The same area is referred to as the Primary Conservation Area when the bear is removed from federal protection. The GBRZ term is used in this 2016 report to reflect the current legal status of the Yellowstone grizzly bear as a threatened population.

unit. The 1998 baseline of habitat measurements represent the most current and accurate information available documenting habitat conditions inside the GBRZ during 1998. Forest and Park personnel continue to improve the quality of their information to more accurately reflect what was on the landscape in 1998.

Additional habitat monitoring for spring ungulate availability, spawning cutthroat trout, insect aggregation sites, and whitebark pine cone production are reported in the section "***Monitoring of Grizzly Bear Foods"*** found in the main body of this IGBST annual report.

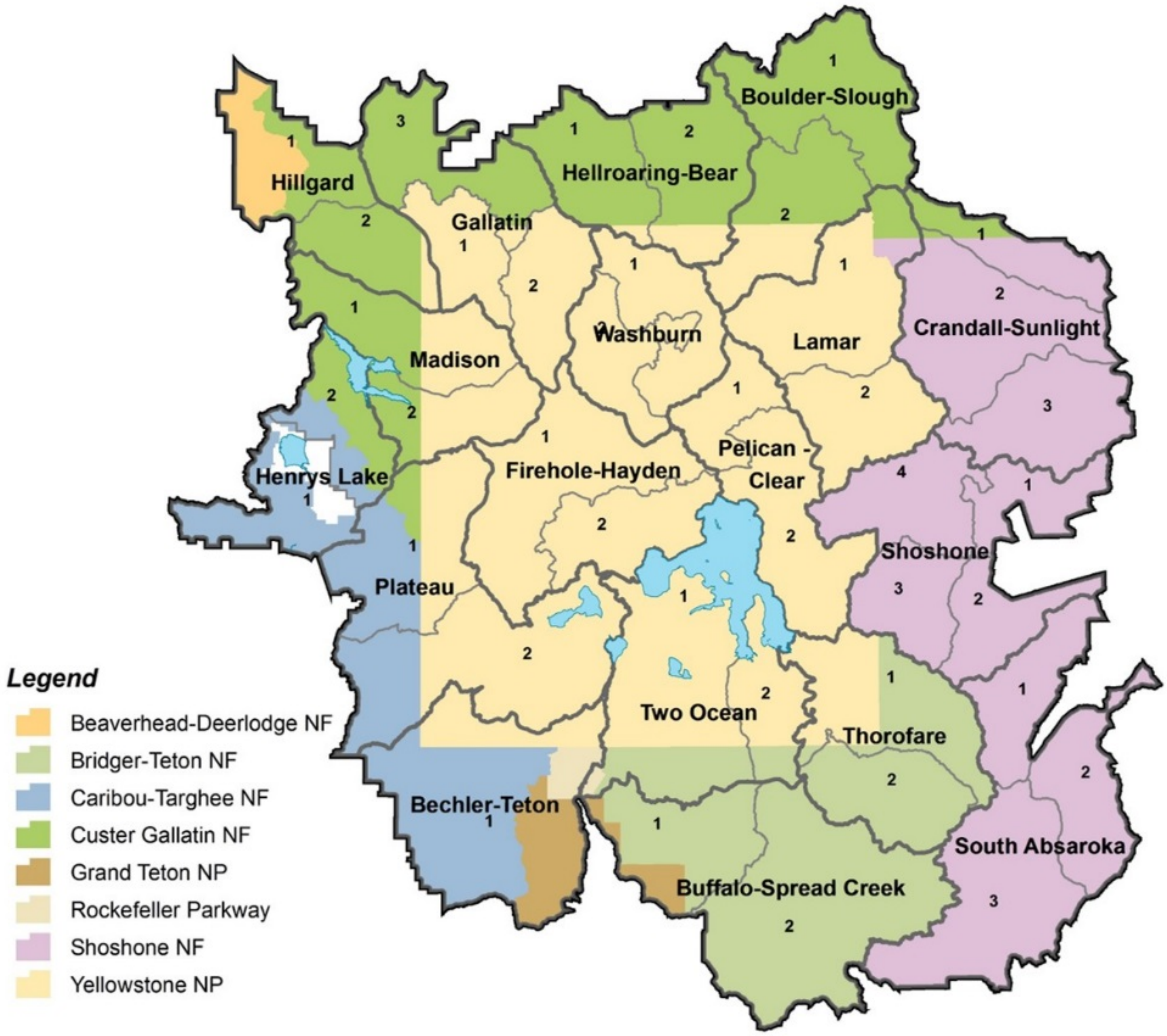

Fig. A2. Bear Management Units (BMUs) and subunits comprising the Grizzly Bear Recovery Zone in the Yellowstone Ecosystem.

Biennial Monitoring Requirements outside the GBRZ

In addition to annual monitoring requirements specified by the Conservation Strategy, the 2006 Forest Plan Amendment requires biennial monitoring and reporting of changes in secure habitat on lands outside the GBRZ deemed to be biologically suitable and socially acceptable for grizzly bear occupancy according to State plans. Although habitat standards apply only inside the GBRZ, percent secure habitat outside this boundary is reported on even years per Bear Analysis Unit (BAU). There are 43 BAUs (Fig. A3), each the approximate size of BMU subunits inside the GBRZ.

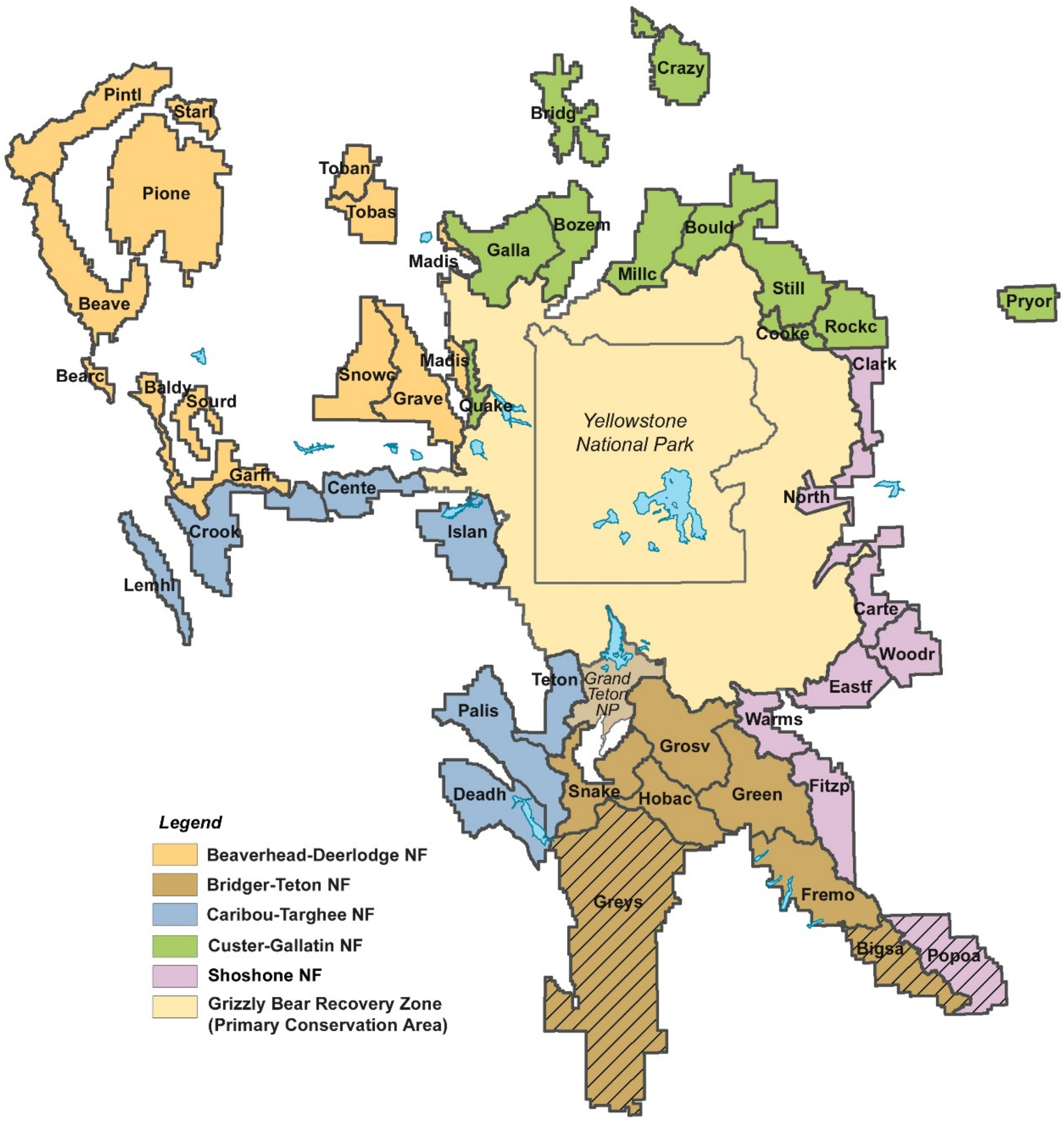

Fig. A3. Bear Analysis Units outside the Grizzly Bear Recovery Zone on the 5 national forests in the Greater Yellowstone Ecosystem. Hatched areas are not currently reported as they are considered socially unacceptable for grizzly bear occupancy in Wyoming.

Monitoring of Livestock Grazing

The habitat standard for livestock allotments established in the Conservation Strategy requires that there be no net increase in the number of active commercial livestock grazing allotments or any increase in permitted sheep animal months (AMs) inside the GBRZ from that which existed in 1998. Sheep AMs are derived by multiplying the permitted number of sheep times the months of permitted grazing on a given allotment. Existing sheep allotments are to be phased out as opportunity arises with willing permittees. The change in number of active and vacant livestock allotments cited in this report account for all commercial grazing allotments occurring on National Forest land within the GBRZ. With closure of the last cattle allotment inside Grand Teton National Park in 2011 there are no grazing allotments today on National Park land inside the GYE. Livestock grazing on private inholdings and horse grazing associated with recreational use and backcountry outfitters are not covered by the grazing standard and are not included in this report. Operational status of allotments is categorized as *active*, *vacant*, or *closed*. An active allotment is one with a current grazing permit. However, an active allotment can be granted a "no-use" permit on a year-by-year basis when a permittee chooses not to graze livestock or when management seeks a resolution to grazing conflicts. Vacant allotments are those without an active permit, but which may be grazed periodically by other permittees at the discretion of the land management agency. Such reactivation of vacant allotments is typically on a temporary basis to resolve resource issues or other concerns. Vacant allotments can be assumed non-active unless otherwise specified. When chronic conflicts occur on cattle allotments inside the GBRZ and an opportunity exists with a willing permittee, cattle can be moved to a vacant allotment where there is a lower likelihood of conflict. A closed allotment is one that has been permanently deactivated such that commercial grazing will not be permitted to occur anytime in the future.

Commercial grazing allotments on public lands inside the GBRZ are tracked through time to quantify change in amount of lands grazed today against levels of grazing that existed in 1998. The number of commercial livestock allotments is not a very meaningful metric of change because individual allotments can be combined or divided without affecting the overall footprint of commercially grazed land. Likewise, allotment boundaries can be reconfigured or modified over time to enclose smaller or larger areas. Thus, total acreage of commercially grazed lands constitutes a more meaningful metric of overall change on the landscape. See Table A1 for 2016 status of livestock allotments compared against the 1998 baseline.

Change in cattle allotments since 1998

Since 1998, there has been a net reduction of 31% in the acreage of active cattle commercial grazing on public lands inside the GBRZ (Table A1). Approximately 93% of this net reduction was the result of permanent closures (865 km^2, 213,673 acres), and 7% was from active allotments that were vacated (65 km^2, 16,025 acres). Meanwhile, 100% of the acreage that was vacant cattle/horse grazing lands in 1998, have since been permanently closed to all livestock grazing.

Change in sheep allotments since 1998

Domestic sheep allotments inside the GBRZ have mostly been phased out since 1998. There were 11 active sheep allotments in 1998, amounting to 600 km^2 (148,368 acres) of public lands inside the GBRZ. Since 1998, there has been a 98% net reduction in the acreage of public lands inside the GBRZ grazed by sheep. Of the 11 actively grazed sheep allotments, 8 have been permanently closed, accounting for 92% reduction. Two of the 11 active sheep allotments (Pearson and Beartooth on the Shoshone NF) were converted to active cattle allotments in 2003 and remain active today. The Meyers Creek sheep allotment on the Caribou-Targhee National Forest is the only active sheep allotment currently remaining on public lands inside the GBRZ. This allotment, part of the USDA Sheep Experiment Station (USSES), has been issued a no-use permit since 2008, and consequently, there has been no domestic sheep grazing on public lands inside the GBRZ for the past 9 years. Meanwhile, all 312 km^2 (77,066 acres) of sheep allotments that were vacant in 1998 have been permanently closed. Of the 23,090 sheep AMs issued in 1998, only 1,970 (Meyers Creek) are permitted (non-use) today.

Change in livestock allotments during 2016

Two vacant cattle grazing allotments inside the GBRZ were permanently closed in 2016. Both closures (Beaver Creek and Ousel Falls) are on the Custer-Gallatin National Forest and account for a net reduction of 35.9 km^2 (8,871 acres) of commercial livestock grazing on federal lands inside the GBRZ. No other changes to the number, status, or acreage of commercial livestock allotments were reported to occur on federal lands inside the GBRZ during 2016.

Table A1. Number of commercial livestock grazing allotments and sheep animal months (AMs) inside the Grizzly Bear Recovery Zone in 1998 and 2016.

Administrative unit	Cattle allotments				Sheep allotments				Sheep animal months	
	Active		Vacant		Active		Vacant			
	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016
Beaverhead-Deerlodge National Forest	3	3	2	0	0	0	0	0	0	0
Bridger-Teton National Forest	9	5	0	1	0	0	0	0	0	0
Caribou-Targhee National Forest [a]	11	7	1	1	7	1	4	0	14,163	1,970
Custer-Gallatin National Forest	23	14	10	5	2	0	4	0	3,540	0
Shoshone National Forest	25	25	0	0	2	0	2	0	5,387	0
Grand Teton National Park	1	0	0	0	0	0	0	0	0	0
Total count in GBRZ	72	54	13	7	11	1	10	0	23,090	1.970
Total area in GBRZ (acres)	660,845	456,012	67,894	31,679	148,368	3,504	77,066	0		
Total area in GBRZ (km^2)	2,674	1,845	275	128	600	14	312	0		

[a] The Meyers Creek allotment, the only active sheep grazing unit remaining inside the GBRZ, took a "no use" permit in 2016.

Livestock-related Conflicts throughout the GYE

Conflicts between grizzly bears and livestock have historically led to the capture, relocation, and removal of grizzly bears in the GYE. This section summarizes the reported grizzly bear conflicts associated with livestock grazing on all commercial sheep and cattle/horse grazing allotments and forage reserves authorized under special use permits on national forest land within the GYE. Livestock conflicts associated with outfitters in backcountry situations, and conflicts occurring on private or state land are not included in this report.

Livestock conflicts in 2016

In 2016, a total of 94 grizzly bear-livestock conflicts associated with cattle and sheep grazing on U.S. Forest Service lands were reported within the GYE. These conflicts occurred on 23 distinct commercial grazing allotments throughout the ecosystem (Table A2). Ninety-seven percent (n = 91) involved cattle depredation, and 3% (*n* = 3) involved sheep depredation. Fifteen of the 94 livestock-related conflicts (16%) occurred inside the GBRZ. During 2016, grizzly bear depredations accounted for at least102 livestock mortalities, including calves or yearlings (*n* = 79), cows or steers (*n* = 11), and sheep (*n* e 12). Additionally, 2 calves and 1 cow sustained non-fatal injuries. Of the 94 livestock-related conflicts reported during 2016, 57% (*n* = 54) occurred on the Upper Green River cattle allotment located outside the GBRZ on the north portion of the Bridger-Teton National Forest. Management actions in direct response to livestock-related conflicts on public land led to the removal of 2 female (1 adult, 1 subadult) and 2 adult male grizzly bears. Also, 1 accidental female cub fatality occurred during a 2016 management capture for sheep depredations. Of the 4 grizzly bear management removals, 3 were due to depredation incidents on the Upper Green River cattle allotment.

Recurring livestock conflicts 2012–2016

Allotments with 'recurring' conflicts are those that sustain grizzly bear-livestock conflicts for 3 or more years during the past 5-year period. During the past 5 years (2012–2016), 459 livestock-related conflicts occurred on grazing allotments on national forest lands within the GYE (Table A2, Fig. A3). Approximately 8% (*n* = 38) of these conflicts occurred inside the GBRZ. Of the 459 conflicts, 61% (*n* = 279) occurred on the Upper Green River cattle allotment located outside the GBRZ on the Bridger-Teton National Forest. During this same 5-year period, 11 distinct allotments sustained recurring conflicts: 3 on the Bridger-Teton National Forest and 8 on the Shoshone National Forest (Table A2). Over the past 5 years, 19 grizzly bears were removed from the population because of commercial livestock-related conflicts on U.S. Forest Service allotments. These 19 management removals included 5 female (4 adult, 1 subadult) and 14 male (12 adult, 2 subadult) grizzly bears. In addition to the 19 management removals, 2 accidental female cub mortalities occurred during livestock-related management captures, and 1 adult male grizzly bear was fatally shot in self-defense by a sheepherder. Of the 19 management sanctioned grizzly bear removals, 16 (84%) were due to cattle depredations on the Upper Green River allotment.

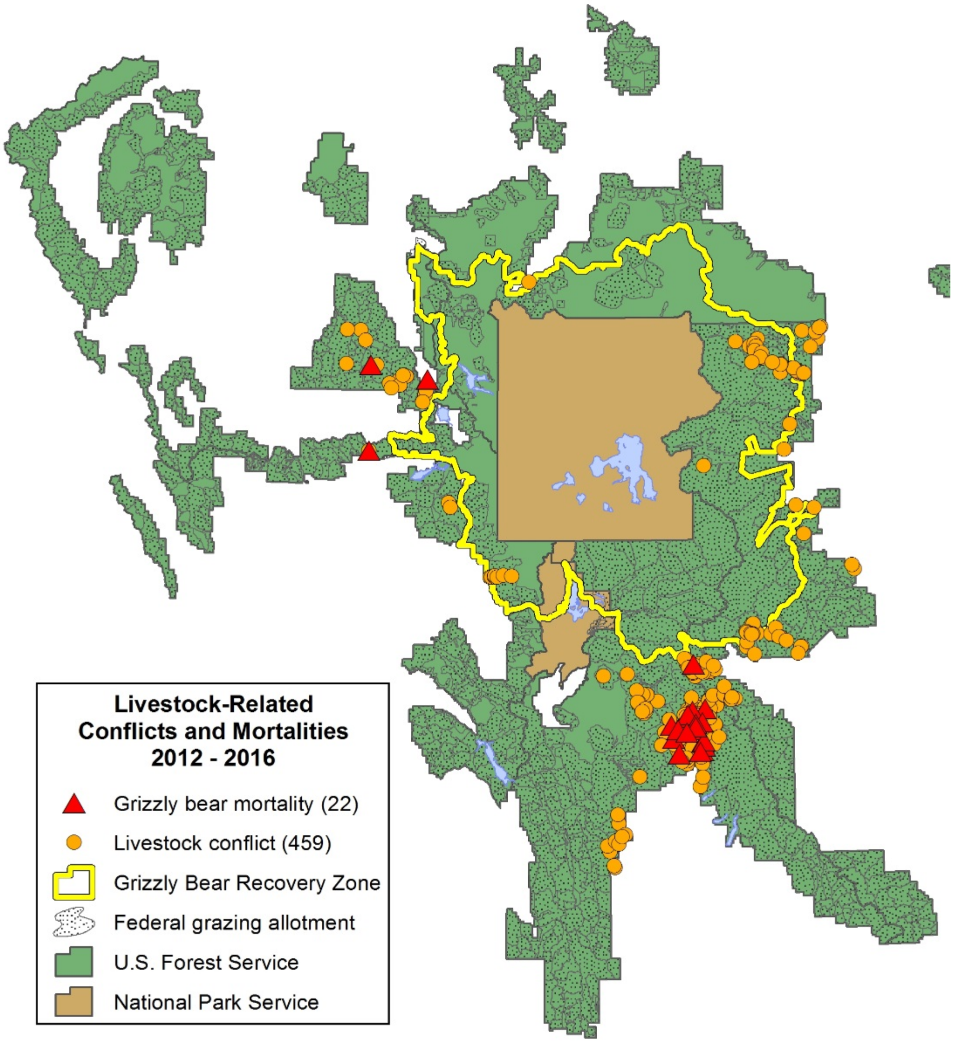

Fig. A4. Grizzly bear conflicts and mortalities related to commercial livestock grazing on Federal lands in the GYE during 2012–2016.

Table A2. Commercial livestock allotments on public lands with documented grizzly bear conflicts during the past 5 years. Allotments with conflicts in 3 or more of the past 5 years are considered to be recurring conflicts.

U.S. Forest Service allotment name	Total acres	Livestock-related conflicts					Total conflicts (2012–2016)	Recurring conflicts
		2012	2013	2014	2015	2016		
Beaverhead –Deerlodge National Forest								
Antelope Basin	4,430	0	0	0	2	0	2	No
Barnett	6,454	0	1	0	0	0	1	No
Clover Meadows	3,081	0	0	0	1	0	1	No
North Saddle	3,454	0	0	0	0	1	1	No
Poison Basin	6,863	0	0	0	0	1	1	No
Red Tepee	8,256	0	1	0	0	0	1	No
Upper Ruby	44,395	0	1	0	0	0	1	No
West Fork	53,096	0	0	0	4	2	6	No
Bridger-Teton National Forest								
Beaver-Horse	25,359	2	0	0	0	0	2	No
Elk Ridge	6,365	1	0	0	0	0	1	No
Fish Creek [a]	76,217	0	0	0	0	1	1	No

Table A2. Commercial livestock allotments on public lands with documented grizzly bear conflicts during the past 5 years. Allotments with conflicts in 3 or more of the past 5 years are considered to be recurring conflicts.

U.S. Forest Service allotment name	Total acres	Livestock-related conflicts					Total conflicts (2012–2016)	Recurring conflicts
		2012	2013	2014	2015	2016		
Jack Creek	32,387	1	0	0	0	0	1	No
Kinky Creek	22,834	1	0	0	0	0	1	No
Kohl Ranch	483	1	0	0	0	0	1	No
Lime Creek	4,973	0	0	0	5	1	6	No
New Fork-Boulder	10,976	0	2	0	0	0	2	No
Noble Pasture	762	0	1	0	1	0	2	No
North Cottonwood	28,177	0	1	0	2	0	3	No
Pot Creek	4,499	0	1	0	0	0	1	No
Prospect Peak	8,917	1	0	0	0	0	1	No
Redmond/Bierer Cr	7,109	0	1	0	0	0	1	No
Roaring Fork	8,416	1	0	0	0	0	1	No
Rock Creek	5,148	1	1	2	0	0	4	Yes
Sherman C&H	8,287	1	1	1	0	1	4	Yes
Tosi Creek	14,090	1	0	0	0	1	2	No
Union Pass [a]	39,497	1	0	0	0	0	1	No
Upper Green River	131,94	41	40	66	78	54	279	Yes
Upper Gros Ventre	67,497	5	1	1	5	0	12	Yes
Wagon Creek	182	0	1	0	1	0	2	No
Caribou-Targhee National Forest								
Ching Creek	3,911	0	0	0	0	1	1	No
Grandview	43,478	0	0	0	2	0	2	No
Squirrel Meadows	28,797	7	0	0	0	1	8	No
Gallatin National Forest								
Wigwam	2,762	0	0	0	0	1	1	No
Shoshone National Forest								
Basin	73,119	0	0	0	1	0	1	No
Bear Creek	33,672	1	1	0	1	0	3	Yes
Beartooth	30,317	0	2	3	1	0	6	Yes
Beartooth Highway	9,350	0	1	0	0	0	1	No
Bench (Clarks Fork)	28,751	0	0	8	3	4	15	Yes
Crandall	30,089	0	1	0	0	0	1	No
Deep Lake	6,486	0	0	1	0	0	1	No
Dick Creek	9,569	0	0	0	1	0	1	No
Dunn Creek	4,520	0	0	0	0	1	1	No
Ghost Creek	11,579	6	0	0	0	3	9	No
Horse Creek	29,980	1	0	1	0	2	4	Yes
Lake Creek	21,399	0	1	0	0	0	1	No
Parque Creek	13,528	2	0	2	4	0	8	Yes
Piney	14,287	0	0	0	0	1	1	No
Ramshorn	16,005	0	0	0	1	0	1	No
Reef Creek	11,449	0	0	0	0	3	3	No
Rock Creek	16,833	1	0	1	0	0	2	No
Salt Creek	8,263	0	0	0	0	5	5	No
South Absaroka Trans	152,256	0	1	0	0	0	1	No

Table A2. Commercial livestock allotments on public lands with documented grizzly bear conflicts during the past 5 years. Allotments with conflicts in 3 or more of the past 5 years are considered to be recurring conflicts.

U.S. Forest Service allotment name	Total acres	Livestock-related conflicts					Total conflicts (2012–2016)	Recurring conflicts
		2012	2013	2014	2015	2016		
Sunshine	2,152	0	0	0	1	0	1	No
Table Mountain	13,895	0	0	0	0	4	4	No
Trout Creek	12,799	0	0	0	0	1	1	No
Union Pass	39,497	6	2	0	0	0	8	No
Warm Springs.	16,875	4	2	1	2	3	12	Yes
Wiggins Fork	37,653	1	0	1	2	1	5	Yes
Wind River	44,158	1	0	3	4	1	9	Yes
Total conflicts		88	64	91	122	94	459	

[a] The Fish Creek and Union Pass grazing units on the Bridger-Teton National Forest are forage reserves that are grazed only occasionally as a short-term solution to reduce conflict, protect resources, or compensate for natural landscape hazards (i.e., fire) in other grazing areas.

Monitoring of Developed Sites inside the GBRZ

Habitat standards identified in the Conservation Strategy require that the number of developed sites and capacity of human-use of developed sites on public lands inside the GBRZ be maintained at or below levels existing in 1998. Administrative site expansions are exempt from mitigation if such developments are deemed necessary for enhancement of public lands and when other viable alternatives are not plausible. Developed sites include all sites or facilities on public land with features intended for human use that accommodate administrative needs and public recreational use. Examples of developed sites include, but are not limited to, campgrounds, trailheads, lodges, administrative structures, service stations, summer homes, restaurants, visitor centers, and permitted natural resource development sites such as oil and gas exploratory wells, production wells, mining activities, and work camps. Developments on private land are not counted against this standard.

For a complete itemized list of developed sites comprising the 1998 baseline per subunit, please refer to Supplemental Table S1 linked to this report (available online: Table S1 Developed Sites 1998 Baseline and Current Status).

Corrections to the 1998 developed sites baseline

The 1998 developed sites baseline is the best available measure of human development existing on public lands throughout the GBRZ during 1998. Although this represents a static snapshot in time, the baseline continues to evolve as errors are identified and corrected. In 2016 three errors in the 1998 baseline were identified and corrected for developed sites in Grand Teton National Park.

1) *Bechler-Teton #1 subunit*: The Moran Inlet campsite at Jackson Lake was erroneously reported in the baseline as a backcountry camp under the category of "other developed sites". This campsite was closed by 1998 and has been removed from the baseline.

2) *Buffalo-Spread Creek #1 subunit*: The Jackson Lake Ranger Station administrative site was closed prior to1998 and converted to employee housing. The converted housing is already accounted for as part of the Jackson Lake employee housing major developed site. This correction accounts for a decrease of 1 developed site in the 1998 baseline.

3) *Two Ocean – Lake #1 subunit*: The Sheffield Creek trailhead was erroneously reported as a trailhead on the Grand Teton portion of the subunit. The correct location of this campsite is on the Bridger-Teton National Forest and is accounted for as part of the Sheffield campground

(including trailhead) on the Two Ocean-Lake subunit. This accounts for a decrease of 1 trailhead developed site in the baseline.

Changes in developed sites since 1998

At the time of this report, the most reliable number of developed sites known to exist in 1998 is 592. In the intervening years, a number of sites have been condemned or permanently closed and dismantled. New sites that were built have been mitigated for by closing one or more sites of equivalent human use within the same subunit. Today, the number of known developed sites on public lands inside the GBRZ is 575, accounting for a net decrease of 14 sites between 1998 and 2016. From 1998 to the present, the number of developed sites have remained at or below 1998 counts for all subunits inside the GBRZ except for the Hilgard #2 subunit, which increased by a count of one. This increase occurred in 2005 when the Taylor Falls/Lightning trailhead, originally located in subunit #1 of the Hilgard BMU, was moved from one side of a road to the other, placing it in subunit #2 of the Hilgard BMU. In this case, the loss in one subunit yielded a gain in the other. Although this transfer technically accounted for an increase in developed sites on Hilgard #2, it was determined to have no detrimental effect on grizzly bears and did not violate the intent of the developed site standard. Please refer to Table A3 for a comparison of developed site counts between 1998 and 2016.

Changes in developed sites in 2016:

During 2016 there were no changes in the number of developed sites on federal lands inside the GBRZ.

Future review of developed sites

Visitor use in National Parks and Forest Service lands in the GYE has increased significantly since 1998. This increased visitation has the potential to negatively impact natural resources in fragile areas of high use. A multi-agency review of the 1998 habitat baseline has been proposed in the 2016 Conservation Strategy to identify potential solutions to alleviate administrative pressures in a way that allows for strategic management of grizzly bear habitat with minimal deviations from the baseline. This re-evaluation effort will be completed before the end of calendar year 2018 and released for public review.

Table A3. Number of developed sites in 1998 and 2016 on public lands per bear management subunit in the Greater Yellowstone Ecosystem.

Bear management subunit	Admin unit [1]	Summer home complexes		Developed campgrounds		Trailheads		Major developed sites [2]		Administrative or maintenance sites		Other		Plans of operation [3]		Total count developed sites	
		1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016
Bechler-Teton #1	CTNF	0	0	1	1	5	5	2	2	4	4	16	16	0	0	58	58
	GTNP	0	0	8	8	3	3	1	1	3	3	9	9	0	0		
	YNP	0	0	0	0	2	2	0	0	2	2	2	2	0	0		
Boulder-Slough #1	CGNF	0	0	1	1	7	7	0	0	1	1	3	3	8	2	20	14
Boulder-Slough #2	CGNF	0	0	0	0	0	0	0	0	2	2	0	0	0	0	9	9
	YNP	0	0	1	1	3	3	0	0	2	2	1	1	0	0		
Buffalo-Spread Creek #1	BTNF	0	0	1	1	1	1	0	0	0	0	2	2	0	0	18	18
	GTNP	0	0	1	1	7	7	2	2	1	1	3	3	0	0		
Buffalo-Spread Creek #2	BTNF	1	1	4	2	3	5	3	3	5	5	5	3	1	1	22	20
Crandall-Sunlight #1	CGNF	0	0	2	2	2	2	0	0	0	0	5	5	0	0	23	23
	SNF	0	0	2	2	5	5	1	1	1	1	5	5	0	0		
Crandall-Sunlight #2	CGNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	18
	SNF	0	0	5	5	4	4	1	1	2	2	5	5	1	1		
Crandall-Sunlight #3	SNF	0	0	2	2	3	3	0	0	1	1	2	2	0	0	11	11
	WG&F	0	0	2	2	0	0	0	0	1	1	0	0	0	0		
Firehole-Hayden #1	YNP	0	0	1	1	5	5	1	1	6	6	13	13	0	0	26	26
Firehole-Hayden #2	YNP	0	0	1	1	3	3	1	1	2	2	8	8	0	0	15	15
Gallatin #1	YNP	0	0	0	0	3	3	0	0	1	1	0	0	0	0	4	4
Gallatin #2	YNP	0	0	2	2	5	5	1	1	12	12	1	1	0	0	21	21
Gallatin #3	CGNF	0	0	2	2	9	9	0	0	1	1	6	6	0	0	18	18
	YNP	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Hellroaring-Bear #1	CGNF	0	0	4	4	11	11	0	0	3	3	8	8	8	8	36	36
	YNP	0	0	0	0	1	1	0	0	0	0	1	1	0	0		
Hellroaring-Bear #2	CGNF	0	0	0	0	1	1	0	0	1	1	0	0	0	0	4	4
	YNP	0	0	0	0	0	0	0	0	2	2	0	0	0	0		
Henrys Lake #1	CTNF	2	2	3	3	1	1	0	0	3	3	10	10	1	0	20	19

Table A3. Number of developed sites in 1998 and 2016 on public lands per bear management subunit in the Greater Yellowstone Ecosystem.

Bear management subunit	Admin unit (1)	Summer home complexes		Developed campgrounds		Trailheads		Major developed sites (2)		Administrative or maintenance sites		Other		Plans of operation (3)		Total count developed sites	
		1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016
Henrys Lake #2	CGNF	5	5	3	3	4	4	0	0	0	0	2	3	0	0	18	18
	CTNF	0	0	0	0	1	1	0	0	1	0	1	1	1	1		
Hilgard #1	BDNF	0	0	0	0	0	0	0	0	3	1	0	0	0	0	14	11
	CGNF	0	0	0	0	6	5	1	1	2	2	2	2	0	0		
Hilgard #2	CGNF	0	0	0	0	4	5	0	0	1	1	1	1	0	0	9	10
	YNP	0	0	0	0	3	3	0	0	0	0	0	0	0	0		
Lamar #1	CGNF	0	0	2	2	7	7	0	0	6	6	3	3	8	8	37	36
	SNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	YNP	0	0	1	1	5	5	0	0	3	3	2	1	0	0		
Lamar #2	YNP	0	0	0	0	0	0	0	0	4	4	0	0	0	0	4	4
Madison #1	CGNF	0	0	1	1	11	11	0	0	1	1	8	7	0	0	21	20
	YNP	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Madison #2	CGNF	8	8	2	2	1	1	1	1	4	4	5	5	0	0	25	25
	YNP	0	0	0	0	1	1	0	0	2	2	1	1	0	0		
Pelican-Clear #1	YNP	0	0	0	0	2	2	0	0	0	0	0	0	0	0	2	2
Pelican-Clear #2	YNP	0	0	1	1	4	4	1	1	4	4	3	3	0	0	13	13
Plateau #1	CGNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
	CTNF	1	1	0	0	0	0	0	0	0	0	1	1	0	0		
	YNP	0	0	0	0	0	0	0	0	1	1	0	0	0	0		
Plateau #2	CTNF	0	0	0	0	1	1	0	0	1	1	1	1	0	0	7	7
	YNP	0	0	0	0	0	0	0	0	4	4	0	0	0	0		
Shoshone #1	SNF	1	1	2	2	0	0	0	0	0	0	6	5	0	0	9	8
Shoshone #2	SNF	0	0	0	0	1	1	1	1	0	0	0	0	0	0	2	2
Shoshone #3	SNF	2	2	0	0	1	0	1	1	0	0	0	0	0	0	4	3
Shoshone #4	SNF	3	3	3	2	3	3	6	6	0	0	8	9	0	0	23	23
South Absaroka #1	SNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Absaroka #2	SNF	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	2

Table A3. Number of developed sites in 1998 and 2016 on public lands per bear management subunit in the Greater Yellowstone Ecosystem.

Bear management subunit	Admin unit [1]	Summer home complexes		Developed campgrounds		Trailheads		Major developed sites [2]		Administrative or maintenance sites		Other		Plans of operation [3]		Total count developed sites	
		1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016	1998	2016
South Absaroka #3	SNF	1	1	3	3	4	4	1	1	1	1	5	4	0	0	15	14
Thorofare #1	BTNF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	YNP	0	0	0	0	0	0	0	0	4	4	0	0	0	0		
Thorofare #2	BTNF	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	2
	YNP	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Two Ocean Lake #1	BTNF	0	0	1	1	0	0	0	0	0	0	0	0	0	0	14	13
	GTNP	0	0	0	0	0	0	0	0	1	1	1	0	0	0		
	YNP	0	0	2	2	3	3	1	1	3	3	2	2	0	0		
Two Ocean Lake #2	BTNF	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4	4
	YNP	0	0	0	0	0	0	0	0	1	1	1	1	0	0		
Washburn #1	YNP	0	0	2	2	8	8	2	2	7	7	6	6	0	0	25	25
Washburn #2	YNP	0	0	1	1	6	6	0	0	1	1	4	4	0	0	12	12
Total count in GBRZ		**24**	**24**	**68**	**65**	**160**	**161**	**28**	**28**	**117**	**114**	**167**	**162**	**28**	**21**	**592**	**575**

Note: The 1998 baseline values in this table may vary from those tabulated in the 2007 Conservation Strategy since corrections have been made with time. The numbers in this table represent the best estimates currently available for developed sites on public lands inside the Grizzly Bear Recovery Zone of the Greater Yellowstone Ecosystem.

[1] Abbreviations for administrative units: BDNF = Beaverhead-Deerlodge National Forest, BTNF = Bridger-Teton National Forest, CGNF = Custer Gallatin National Forest, CTNF = Caribou-Targhee, GTNP = Grand Teton National Park, SNF = Shoshone National Forest, WG&F = Wyoming Game and Fish, YNP = Yellowstone National Park.

[2] Major developed areas such as Grant, Lake, Fishing Bridge, Old Faithful, Canyon, and Mammoth in YNP and are comprised of a combination of recreation and administrative facilities. All buildings and facilities at a given major developed area are tracked collectively as a single developed site.

[3] A single plan of operation may have multiple mining claims and not all plan sites have active projects.

Monitoring Secure Habitat and Motorized Access inside the GBRZ

Habitat standards identified in the Conservation Strategy require that grizzly bear secure habitat be maintained at or improved upon levels existing in 1998 for each of the 40 subunits inside the GBRZ. The sole exception to the 1998 baseline applies to the 3 subunits identified in the 2007 Conservation Strategy (Gallatin #3, Henrys Lake #2, and Madison #2) as in need of improvement above 1998 levels. The new baseline for these 3 subunits, formalized in the Gallatin Cleanup Amendment of 2015, are established at secure habitat levels achieved with full implementation of the Gallatin National Forest 2006 Travel Management Plan.

Secure habitat serves as a metric of the level of human presence in grizzly bear habitat and is based entirely on proximity to motorized routes (roads and trails). Secure habitat is defined as any contiguous area e 10 acres in size and more than 500 m from an open or gated motorized route. Lakes larger than 1 square mile (2.59 km^2) in size are excluded from habitat calculations.

The monitoring protocol established in the Conservation Strategy and Forest Plan Amendment requires that secure habitat, seasonal open motorized access route density (OMARD), and total motorized access route density (TMARD) be reported annually per subunit inside the GBRZ. Values for secure habitat are compared against baseline levels inside the GBRZ to ensure adherence to the secure habitat standard. Gains in secure habitat are achieved primarily through decommissioning of open, motorized access routes. In context to the measurement of grizzly bear secure habitat, a route is considered decommissioned when it has been effectively treated on the ground so that motorized access by the public and administrative personnel is effectively restricted. Road decommissioning can range from complete obliteration of the road prism to physical barriers permanently and effectively blocking all access points to motorized traffic. Any route open to motorized used by the public or administrative staff during any portion of the non-denning season (March 1 through November 30) detracts from secure habitat. This includes routes that are gated to the public yearlong but which may potentially be accessed by administrative personnel.

The Conservation Strategy and Forest Plan Amendment do not impose mandatory standards on motorized route density; however, changes in this parameter are monitored and reported annually. Seasonal OMARD is reported per subunit at thresholds >1 mile/mi^2 (>0.62 km/km^2) and TMARD at levels >2 miles/mi^2 (>1.2 km/km^2). OMARD is measured for two non-denning seasons: Season 1 (March 1–July 15), and Season 2 (July 16–November 30). Gated routes that effectively prohibit public motorized access for an entire season do not count toward seasonal route density for the season of closure but do contribute toward TMARD. All motorized routes open to the public and or administrative personnel during any portion of the non-denning season contribute to TMARD. Decommissioned routes that are managed for long-term closure to all motorized use do not contribute to OMARD or TMARD and do not detract from secure grizzly bear habitat.

Permanent changes in secure habitat since 1998

The standard for “no net loss” in secure habitat with respect to 1998 baseline levels has been consistently met in all 40 subunits inside the GBRZ since it was initially formalized in the 2003 Conservation Strategy. For the 3 impoverished subunits identified in the 2007 Conservation Strategy as in need of improvement above 1998 levels (Gallatin #3, Henrys Lake #2, and Madison #2), new baseline thresholds ensure that secure habitat will be maintained well into the future at levels higher than what was attained in 1998. Since 1998 a net gain of approximately 339 km^2 (83,769 acres) in secure habitat has been attained inside the GBRZ. This gain is comparable in size to that of Yellowstone Lake. The greatest improvement in secure habitat is a 17.2 % increase occurring on the Gallatin #3 Bear Management Subunit (BMS) on the Custer-Gallatin National Forest. The gain in secure habitat for this subunit, as well as Henrys Lake #2 (5.8%) and Madison #2 (1.0%) achieved by implementation of the

Gallatin Travel Management Plan will constitute new baselines against which future change will be measured. Other notable gains in secure habitat, ranging from 3.4% on the Hellroaring-Bear #1 subunit to 13.4% on the Hilgard #1 subunit, are also identified in Table A4. Changes in secure habitat, when averaged over all 40 subunits, account for a mean gain of 1.5% since 1998. All gains in secure habitat throughout the GBRZ were achieved by the decommissioning of motorized routes on public lands. Permanent changes in secure habitat, OMARD, and TMARD inside the GBRZ are reported with respect to baseline levels in Table A4.

Permanent changes in secure habitat during 2016

During 2016 several changes in the configuration of motorized routes on public land and a couple corrections to the Motorized Access Database yielded minor changes to secure habitat.

- *Boulder-Slough #1*: Approximately 4.7 km of the Iron Mountain road, located on the Custer-Gallatin National Forest in the north portion of the subunit, was erroneously dropped from the access database during Travel Plan edits in 2012. This error led to incorrect reports (2012–2015) that secure habitat had improved above 1998 levels in the subunit. Correction to the Motorized Access Database, however, confirms that secure habitat for the Boulder-Slough #1 subunit remains at the 1998 level of 96.6%. This represents no change in ground conditions.
- *Buffalo-Spread Creek #2*: Approximately 5.2 km of motorized routes in the vicinity of Baldy Mountain in the Blackrock Ranger District of the Bridger-Teton National Forest were decommissioned and permanently closed to motorized use. These decommissions led to no measurable change in secure habitat for the subunit.
- *Crandall-Sunlight #3*: Approximately 1.6 km of system road 945 in the Little Sunlight area on the Shoshone National Forest was reconfigured to prevent resource damage. Also, in the same general area, the motorized status of 1.4 km of an old ranch road on U.S. Forest Service Land in the same general area was corrected in the Motorized Access Database to reflect current status of no motorized use. This road has been closed to all motorized traffic and has been inaccessible for many years. The route reconfiguration and correction to the database accounts for an increase of 0.2% in secure habitat for the subunit.
- *Henrys Lake #2*: A 0.9-km portion of U.S. Forest Service route 423 on the Ashton-Island Park ranger district of the Caribou-Targhee National Forest was seasonally closed to the public by special order. Gates were installed at each end (junction with road 059 to road 482) to comply with DEQ public safety regulations to maintain 300 feet from active sewer spay from adjacent fields. This led to no measurable change in secure habitat for the subunit.

Table A4. *1998 Baseline and 2016 percentages per subunit of open motorized access route density (OMARD), total motorized access route density (TMARD), and secure habitat for 40 Bear Management Unit subunits in the Grizzly Bear Recovery Zone, Greater Yellowstone Ecosystem.*

Bear management subunit	**OMARD (% > 1 mile / mile²)**						**TMARD (% > 2 miles / mile²)**			**% Secure habitat**			**Area (miles²) (excluding lakes)**		
	Season 1 (Mar 1 – Jul 15)			**Season 2 (Jul 16 – Nov 30)**									**Subunit**	**Secure habitat**	
	1998	**2016**	**% chg**	**1998**	**2016**	**% chg**	**1998**	**2016**	**% chg**	**1998**	**2016**	**% chg**		**1998**	**2016**
Bechler/Teton	17.0	17.0	-0.1	17.0	17.0	-0.1	5.8	5.8	0.1	78.1	78.1	0.0	534.3	417.0	417.2
Boulder/Slough #1	3.2	3.3	0.0	3.2	3.3	0.0	0.3	0.4	0.1	96.6	96.6	0.1	281.9	272.2	272.4
Boulder/Slough #2	2.1	2.1	0.0	2.1	2.1	0.0	0.0	0.0	0.0	97.7	97.7	0.0	232.4	227.1	227.1
Buffalo/Spread Creek #1	11.4	11.4	0.0	11.5	11.4	-0.1	5.3	6.1	0.8	88.3	88.6	0.4	219.9	194.1	194.9
Buffalo/Spread Creek #2	14.5	14.9	0.5	15.6	14.4	-1.1	12.7	11.4	-1.3	74.3	74.4	0.1	507.6	377.2	377.5
Crandall/Sunlight #1	13.3	12.5	-0.9	19.3	18.5	-0.8	7.2	6.3	-0.9	81.1	81.9	0.8	129.8	105.2	106.2
Crandall/Sunlight #2	15.6	14.8	-0.8	16.6	16.0	-0.6	11.7	11.2	-0.5	82.3	82.7	0.4	316.2	260.3	261.5
Crandall/Sunlight #3	14.4	14.1	-0.1	19.2	18.6	-0.4	10.6	10.4	-0.2	80.4	81.3	0.7	221.8	178.3	180.3
Firehole/Hayden #1	10.4	10.5	0.1	10.4	10.5	0.1	1.7	1.7	0.0	88.3	88.3	0.0	339.2	299.7	299.6
Firehole/Hayden #2	8.9	8.9	0.0	9.0	9.0	0.0	1.5	1.5	0.0	88.4	88.4	0.0	172.2	152.3	152.3
Gallatin #1	3.6	2.5	-1.0	3.6	2.5	-1.0	0.5	0.1	-0.4	96.3	97.0	0.7	127.7	122.9	123.9
Gallatin #2	9.5	9.1	-0.4	9.5	9.1	-0.4	4.5	4.5	0.0	90.2	90.2	0.0	155.2	139.9	139.9
Gallatin #3 *	46.0	18.6	-27.4	46.0	27.4	-18.5	22.9	12.5	-10.4	**55.3**	72.5	17.2	217.6	**120.2**	157.7
Hellroaring/Bear #1	22.4	18.4	-4.0	23.1	18.4	-4.7	15.8	12.1	-3.7	77.0	80.4	3.4	184.7	142.2	148.5
Hellroaring/Bear #2	0.1	0.0	-0.1	0.1	0.0	-0.1	0.0	0.0	0.0	99.5	99.6	0.1	228.9	227.8	228.0
Henry's Lake #1	49.0	49.2	0.2	49.0	49.2	0.2	31.2	31.1	-0.1	45.4	46.1	0.7	191.2	86.8	88.2
Henry's Lake #2 *	49.9	41.3	-8.6	49.9	41.3	-8.6	35.2	30.7	-4.5	**45.7**	51.5	5.8	140.2	**64.1**	72.2
Hilgard #1	29.0	8.2	-20.8	29.0	13.3	-15.7	15.3	4.4	-10.9	69.8	83.1	13.4	201.2	140.3	167.2
Hilgard #2	21.0	8.8	-12.2	21.0	16.1	-4.9	13.6	4.6	-8.9	71.4	80.2	8.8	140.5	100.4	112.7
Lamar #1	9.9	9.7	-0.1	9.9	9.7	-0.1	3.8	4.0	0.2	89.4	89.9	0.5	299.9	268.1	269.6
Lamar #2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	180.8	180.8	180.8
Madison #1	29.2	13.2	-16.0	29.5	20.3	-9.2	12.5	7.5	-5.0	71.5	80.7	9.2	227.9	162.9	183.9
Madison #2 *	33.7	32.0	-1.8	33.7	32.0	-1.7	24.0	21.6	-2.4	**66.5**	67.5	1.0	149.4	**99.4**	100.9
Pelican/Clear #1	2.0	2.0	0.0	2.0	2.0	0.0	0.5	0.5	0.0	97.8	97.8	0.0	108.4	106.0	106.0

Table A4. *1998 Baseline and 2016 percentages per subunit of open motorized access route density (OMARD), total motorized access route density (TMARD), and secure habitat for 40 Bear Management Unit subunits in the Grizzly Bear Recovery Zone, Greater Yellowstone Ecosystem.*

Bear management subunit	OMARD (% > 1 mile / mile^2)						TMARD (% > 2 miles / mile^2)			% Secure habitat			Area (miles^2) (excluding lakes)		
	Season 1 (Mar 1 – Jul 15)			Season 2 (Jul 16 – Nov 30)									Subunit	Secure habitat	
	1998	2016	% chg	1998	2016	% chg	1998	2016	% chg	1998	2016	% chg		1998	2016
Pelican/Clear #2	5.4	5.4	0.0	5.4	5.4	0.0	0.4	0.4	0.0	94.1	94.1	0.0	251.6	236.7	236.7
Plateau #1	22.0	16.9	-5.2	22.2	19.0	-3.3	12.9	10.3	-2.7	68.8	70.6	1.8	286.3	197.0	202.1
Plateau #2	8.5	8.5	0.0	8.5	8.5	0.0	3.5	3.2	-0.2	88.7	88.8	0.1	419.9	372.3	372.7
Shoshone #1	1.5	1.5	0.0	1.5	1.5	0.0	1.1	1.0	-0.1	98.5	98.5	0.1	122.2	120.3	120.4
Shoshone #2	1.3	1.1	-0.2	1.3	1.1	-0.2	0.7	0.6	-0.2	98.8	99.0	0.1	132.4	130.9	131.0
Shoshone #3	3.9	2.8	-1.1	3.8	2.8	-1.1	2.1	1.5	-0.6	97.0	97.8	0.8	140.7	136.5	137.6
Shoshone #4	4.5	4.4	0.0	5.3	5.2	0.0	2.9	2.7	-0.2	94.9	94.9	0.0	188.8	179.1	179.1
South Absaroka #1	0.6	0.6	0.0	0.6	0.6	0.0	0.1	0.1	0.0	99.2	99.2	0.0	163.2	161.9	161.9
South Absaroka #2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.9	99.9	0.0	190.6	190.3	190.3
South Absaroka #3	2.4	2.4	0.0	2.4	2.4	0.0	2.7	2.7	0.0	96.8	96.8	0.0	348.3	337.1	337.2
Thorofare #1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	273.4	273.4	273.4
Thorofare #2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	180.1	180.1	180.1
Two Ocean/Lake #1	3.5	3.6	0.2	3.5	3.6	0.2	0.3	0.5	0.2	96.3	96.3	0.0	371.9	358.3	358.2
Two Ocean/Lake #2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	124.9	124.9	124.9
Washburn #1	16.1	16.1	0.0	16.1	16.1	0.0	4.2	4.2	0.0	83.0	83.0	0.0	178.3	147.9	147.9
Washburn #2	7.4	7.4	0.0	7.4	7.4	0.0	1.1	1.1	0.0	92.0	92.0	0.0	144.1	132.6	132.6
GBRZ mean or total area	12.3	9.8	-2.5	12.7	10.9	-1.8	6.7	5.4	-1.3	85.6	87.0	1.4	9,025	7,724	7,854

**As of 2016, three subunits (Gallatin #3, Henrys Lake #2, and Madison #2) have secure habitat baselines established at thresholds to be achieved with full implementation of the 2006 Gallatin National Forest Travel Management Plan. New baseline thresholds raise the bar for these 3 subunits and supersede 1998 baseline values for secure habitat. Desired future Condition (DFC) of the Travel Plan has not yet been achieved for Gallatin #3 and Henrys Lake #2. Future conditions will open an additional 7.4 km of ATV route in Gallatin #3 (reducing secure to 70.7%), and decommission almost 2 km of gated motorized route in Henrys Lake #2 (increasing secure to 67.5%).*

Travel Plan Baselines (supersede 1998 thresholds)

Bear management subunit	% Secure habitat	Area (mile^2) Secure habitat
Gallatin #3	70.7	153.9
Henrys Lake # 2	51.7	72.5
Madison #2	67.5	100.9

Monitoring Secure Habitat outside the GBRZ

The 2006 Forest Plan Amendment requires the monitoring and reporting of changes in the percent secure habitat on national forests outside the GBRZ every 2 years in areas determined to be biologically suitable and socially acceptable for grizzly bear occupancy. Current secure habitat levels outside the GBRZ are reported and tracked per Bear Analysis Unit (BAU) against an established baseline. Prior to 2012 the baseline was predicated on a 2003 transportation data layer (USDA 2006, p.45, 56). However, this 2003 baseline layer was incomplete because several national forests had not yet completed a digital inventory of motorized trails and lacked a comprehensive inventory of motorized status for system and non-system routes. With passage of the 2005 Travel Management Rule (TMR, USDA 2005), motorized access was limited to a managed system of roads and trails (except in designated areas), and each national forest was responsible for generating maps available to the public that clearly identify authorized corridors for motorized travel. In 2012, the 2003 transportation baseline was replaced with a more recent and complete 2008 layer that more accurately captured unauthorized, non-system routes. However, the lack of a comprehensive inventory of user-created routes, combined with their continuing proliferation in some parts of the ecosystem, makes producing a definitive inventory a challenge. Table A6 represents the best estimates available for current and baseline values of percent secure habitat per Bear Analysis Unit (BAU) outside the GBRZ.

Changes in secure habitat outside the GBRZ (2015–2016)

Several changes in motorized routes yielded changes in secure habitat on Forest Service lands outside the GBRZ (Table A6). Below is a listed of changes to motorized routes and secure habitat that have occurred outside the GBRZ since last reported in 2014:

Boulder BAU: Secure habitat was diminished by 0.2 % inside the Boulder BAU on the Yellowstone Ranger District of the Custer-Gallatin National Forest due to motorized changes incurred in 2015. Changes included the construction of 3.8 km of new ATV route near Black Butte that had been previously decommissioned and the spatial realignment of 10.1 km of existing ATV routes in the north portion of the BAU.

Bozeman BAU: Motorized route construction conducted inside the Bozeman BAU in 2015 resulted in a 0.1% reduction in secure habitat. This loss in secure habitat was the result of 3.8 km of new ATV routes in the Moser Creek/Lick Creek area on the Yellowstone Ranger District of the Custer-Gallatin NF.

Crazy Mountains BAU: Estimates of secure habitat increased by 0.3% inside the Crazy Mountain BAU due to a 2015 correction in the Motorized Access Database. A number of tiny floater route features (artificial remnants of the editing process) erroneously caused small artificial buffers of non-secure habitat that did not reflect ground conditions. When corrected, the estimate for secure habitat in this BAU changed from 67.6% to 67.9%.

Dead Horse BAU: Approximately 7 km of new motorized route was constructed in 2016 inside the Dead Horse BAU on the Palisades Ranger District of the Caribou-Targhee National Forest. New construction included 2.2 km of the Nelson/Blacktail ATV route and 4.8 km of the new Burns/Trout Creek motorcycle trail. This new construction yielded a 0.4% reduction in secure habitat inside the Dead Horse BAU.

Gallatin BAU: For the same reasons provided for the Crazy Mountains BAU, estimates of secure habitat for the Gallatin BAU increased by 0.1% in 2015 with the removal of floater features in the Motorized Access Database that artificially inflated the calculated estimate of non-secure habitat. This change in secure habitat was due to a database correction and was not tied to any changes on the ground.

Gros Ventre BAU: Approximately 1.8 km of motorized route was decommissioned in the Soda Lake area on the Jackson Ranger District of the Bridger-Teton NF. This reduction in motorized access did not yield any measurable effect in secure habitat for the Gros Ventre BAU.

Palisades BAU: Approximately 3.5 km of the South Grove Creek ATV route on the Teton Basin Ranger District of the Caribou-Targhee National Forest was reconfigured to prevent resource damage. This had no measurable effect on secure habitat inside the Palisades BAU.

Stillwater BAU: A correction to the Motorized Access Database yielded a 0.2% reduction in the estimated percent secure habitat of the Stillwater BAU located on the Custer-Gallatin NF. The database correction restored approximately 3.8 km of motorized routes near Iron Mountain that were erroneously deleted during Travel Plan edits. This reduction in secure habitat is not tied to any physical change on the ground.

Gallatin BAU - As part of the Gallatin National Forest Travel Plan implementation in 2015, 2 km of new motorized trails were constructed in the Gallatin BAU including a small connector segment of Trail 166B (0.6 km), and the upper portion of the Buck Ridge ATV Trail (1.4 km).

Table A6. Percent secure habitat in Bear Analysis Units (BAUs) outside the Grizzly Bear Recovery Zone for the 5 national forests in the GYE. Levels of secure habitat in 2014 and 2016 are compared against 2008 baseline.

Bear Analysis Unit (BAU)	Percent secure habitat				BAU area [a] (miles^2)
	2008 (baseline)	2014	2016	Change (2008–2016)	
Beaverhead-Deerlodge National Forest					
Baldy Mountain	46.2	55.0	55.0	8.8	96.9
Bear Creek	60.7	62.6	62.6	1.9	36.4
Beaver Creek	48.5	57.3	57.3	8.8	478.9
Garfield	64.8	71.6	71.6	6.8	182.0
Gravelies	60.6	58.5	58.5	-2.1	384.4
Madison Range	99.2	99.4	99.4	0.2	89.2
Pintler Mountains	59.2	57.6	57.6	-1.6	410.3
Pioneer Mountains	52.9	55.1	55.1	2.2	912.2
Snowcrest Range	70.9	74.8	74.8	3.9	357.2
Sourdough	40.1	46.9	46.9	6.8	111.2
Starlight	40.0	34.8	34.8	-5.2	79.0
Tobacco Roots North	52.7	53.4	53.4	0.7	106.7
Tobacco Roots South	46.9	47.5	47.5	0.6	186.3
Mean secure or total area	57.1	59.6	59.6	2.4	3,431
Bridger-Teton National Forest					
Fremont	88.0	88.2	88.2	0.2	440.0
Green River	65.7	65.7	65.7	0.0	527.9
Gros Ventre	63.7	63.9	63.9	0.2	507.7
Hoback Range	58.9	58.9	58.9	0.0	292.9
Snake River	64.0	64.2	64.2	0.2	348.9
Mean secure or total area	68.1	68.2	68.2	0.1	2,117
Caribou-Targhee National Forest					
Centennials	50.9	50.9	50.9	0.0	199.1
Crooked Creek	59.4	59.5	59.5	0.1	403.0
Dead Horse Ridge	50.8	50.6	50.2	-0.6	364.8
Island Park	36.7	36.7	36.7	0.0	333.9
Lemhi Mountains	70.0	70.0	70.0	0.0	143.1
Palisades Reservoir	59.8	59.8	59.8	0.0	472.5
Teton	64.8	75.8	75.8	11.0	209.5
Mean secure or total area	56.1	57.6	57.6	1.5	2,126
Custer-Gallatin National Forest					
Boulder	64.8	69.9	69.7	4.9	277.9
Bozeman	45.6	59.4	59.3	13.7	270.5
Bridger	28.3	38.4	38.4	10.1	236.3
Cooke City	99.6	99.6	99.6	0.0	68.7
Crazy	57.2	67.6	66.9	9.7	254.8
Gallatin	52.3	59.5	59.6	7.3	415.0
Mill Creek	82.3	83.8	83.8	1.5	312.2
Pryor Mountains	38.8	38.8	38.8	0.0	121.8
Quake	85.0	92.1	92.1	7.1	66.2
Rock Creek	83.8	83.8	83.8	0.0	237.2

Table A6. Percent secure habitat in Bear Analysis Units (BAUs) outside the Grizzly Bear Recovery Zone for the 5 national forests in the GYE. Levels of secure habitat in 2014 and 2016 are compared against 2008 baseline.

Bear Analysis Unit (BAU)	Percent secure habitat				BAU area [a] (miles^2)
	2008 (baseline)	2014	2016	Change (2008–2016)	
Stillwater	85.3	85.7	85.5	0.2	404.7
Mean secure or total area	65.7	70.8	70.7	5.0	2,023
Shoshone National Forest					
Carter	77.6	77.9	77.9	0.3	261.1
Clarks Fork	70.1	70.1	70.1	0.0	160.5
East Fork	73.2	73.2	73.2	0.0	251.0
Fitzpatrick	98.4	98.4	98.4	0.0	317.8
North Fork	78.0	78.0	78.0	0.0	143.2
Warm Springs	30.6	29.4	29.4	-1.2	183.0
Wood River	84.7	85.3	85.3	0.6	228.5
Mean secure or total Area	73.2	73.2	73.2	0.0	1,545

[a] Lakes greater than 1 mi^2 are excluded from secure habitat calculations and from total BAU area counts.

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Appendix B

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

2016 Annual Report

Natural Resource Report NPS/GRYN/NRR—2017/1453

ON THIS PAGE
Salt Range, Bridger Teton National Forest, Wyoming
Photograph by NPS/ERIN SHANAHAN

ON THE COVER
Southern Madison Range of the Lee Metcalf Wilderness in Montana
Photograph by NPS/ERIN SHANAHAN

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

2016 Annual Report

Natural Resource Report NPS/GRYN/NRR—2017/1453

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May 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available from the Greater Yellowstone Network website and the Natural Resource Publications Management website. To receive this report in a format that is optimized to be accessible using screen readers for the visually or cognitively impaired, please email irma@nps.gov.

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Abstract

Whitebark pine (*Pinus albicaulis*) occurs at high elevations and in subalpine communities in the Pacific Northwest and northern Rocky Mountains. It is a key component in the upper ranges of these ecosystems where it plays a variety of ecological roles, including regulating snowpack and providing high-energy food sources to birds and mammals. As a stone pine species, it produces cones with wingless seeds and relies primarily on birds for seed dispersal.

In mixed and dominant stands, whitebark pine occurs in over two million acres within the five national forests and two national parks that make up the Greater Yellowstone Ecosystem (GYE). Currently, whitebark pine is impacted by multiple ecological disturbances. White pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), wildfires, and climate change all pose significant threats to the persistence of healthy whitebark pine populations on the landscape. Substantial declines in whitebark pine populations have been documented throughout its range. In 2004, an interagency whitebark pine long-term monitoring program was established. The objectives of the whitebark pine monitoring program are to detect and monitor changes in the health and status of whitebark pine populations across the GYE due to infection by white pine blister rust, attack by mountain pine beetle, and damage by other environmental and anthropogenic agents. This report is a summary of data collected in 2016 on Panel 1 of the four total sample panels (Panels 1 through 4), and marks the thirteenth year of monitoring. In addition, 2016 commenced the fourth time-step in our repeat data collection series.

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List of Acronyms

BLM	Bureau of Land Management
CI	confidence interval
DBH	diameter at breast height
GRYN	Greater Yellowstone Inventory & Monitoring Network
GYCC	Greater Yellowstone Coordinating Committee
GYCCWPS	Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee
GYE	Greater Yellowstone Ecosystem
GYWPMWG	Greater Yellowstone Whitebark Pine Monitoring Working Group
IGBST	Interagency Grizzly Bear Study Team
MSU	Montana State University
NPS	National Park Service
RZ	Recovery Zone (grizzly bear)
SE	standard error
USFS	United States Forest Service
USGS	United States Geological Survey

Introduction

Whitebark pine (*Pinus albicaulis*) is a foundation and keystone species in upper subalpine environments of the northern Rocky Mountains that strongly influences the biodiversity and productivity of high-elevation ecosystems (Tomback et al. 2001; Ellison et al. 2005). Throughout its historical range, whitebark pine has decreased significantly as a major component of high-elevation forests. As a result, it is critical to understand the challenges to whitebark pine—not only at the tree and stand level, but also how these factors influence the distribution of whitebark pine across the Greater Yellowstone Ecosystem (GYE).

This annual report summarizes data collected in 2016 as part of the long-term Interagency Whitebark Pine Monitoring Program for the GYE.

Interagency Whitebark Pine Monitoring Program

Under the auspices of the Greater Yellowstone Coordinating Committee (GYCC), the National Park Service (NPS) Inventory and Monitoring Program, and several other agencies, a collaborative, long-term monitoring program was started to track and document the health and status of whitebark pine across the GYE. This alliance resulted in the formation of the Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG, hereafter, the working group), which consists of representatives from the U.S. Forest Service (USFS), NPS, U.S. Geological Survey (USGS), and Montana State University (MSU).

Between 2004 and 2007, the working group developed a protocol for monitoring the health and status of the whitebark pine population in the GYE. After rigorous peer review, the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* was approved in 2007, and later updated in 2011 (GYWPMWG 2011). The complete protocol is available at http://science.nature.nps.gov/im/units/gryn/monitor/whitebark_pine.cfm.

Monitoring Objectives

Generally, the objectives of the whitebark pine monitoring program are to detect and monitor changes in the health and status of the whitebark pine population across the GYE due to infection by white pine blister rust (*Cronartium ribicola*, blister rust), attack by mountain pine beetle (*Dendroctonus ponderosae*), and the impacts of other environmental and anthropogenic agents.

Specifically, the interagency whitebark pine monitoring protocol (GYWPMWG 2011) addresses the following four objectives:

Objective 1 - Estimate the proportion of live whitebark pine trees (>1.4 m tall) infected with blister rust, and estimate the rate at which infection of trees is changing over time.

Objective 2 –Within transects having infected trees, determine the relative severity of infection of blister rust in whitebark pine trees >1.4 m tall (as indicated by canker location) and assess how severity is transitioning over time.

Objective 3 - Estimate survival of individual whitebark pine trees >1.4 m tall, explicitly taking into account the effects of blister rust infection rates and severity, mountain pine beetle activity, and fire.

Objective 4 - Document the recruitment of understory whitebark pine ≤1.4 m tall into the reproductive population and assess the multiple factors that influence regeneration and recruitment success over time.

Study Area

The Greater Yellowstone Ecosystem (GYE) study area includes five national forests and three national parks (throughout the rest of this report the John D. Rockefeller Jr. Memorial Parkway is included with Grand Teton National Park; Figure 1). The target population is all whitebark pine trees in the GYE. The sample frame includes stands of whitebark pine approximately 2.0 hectares or greater within and outside of the grizzly bear recovery zone (RZ). We mapped a total of 10,770 whitebark pine polygons (stands). The RZ contained 2,362 polygons, and 8,408 polygons were located outside of the RZ. Stands within the RZ were derived from the cumulative effects model for grizzly bears. Outside the RZ, the sample frame includes whitebark stands mapped by each of the five separate national forests (Dixon 1997; L. Landenburger, USGS Grizzly Bear GIS Database Coordinator, pers. comm., 2012). Areas that burned after 1970 were excluded from the sample frame.

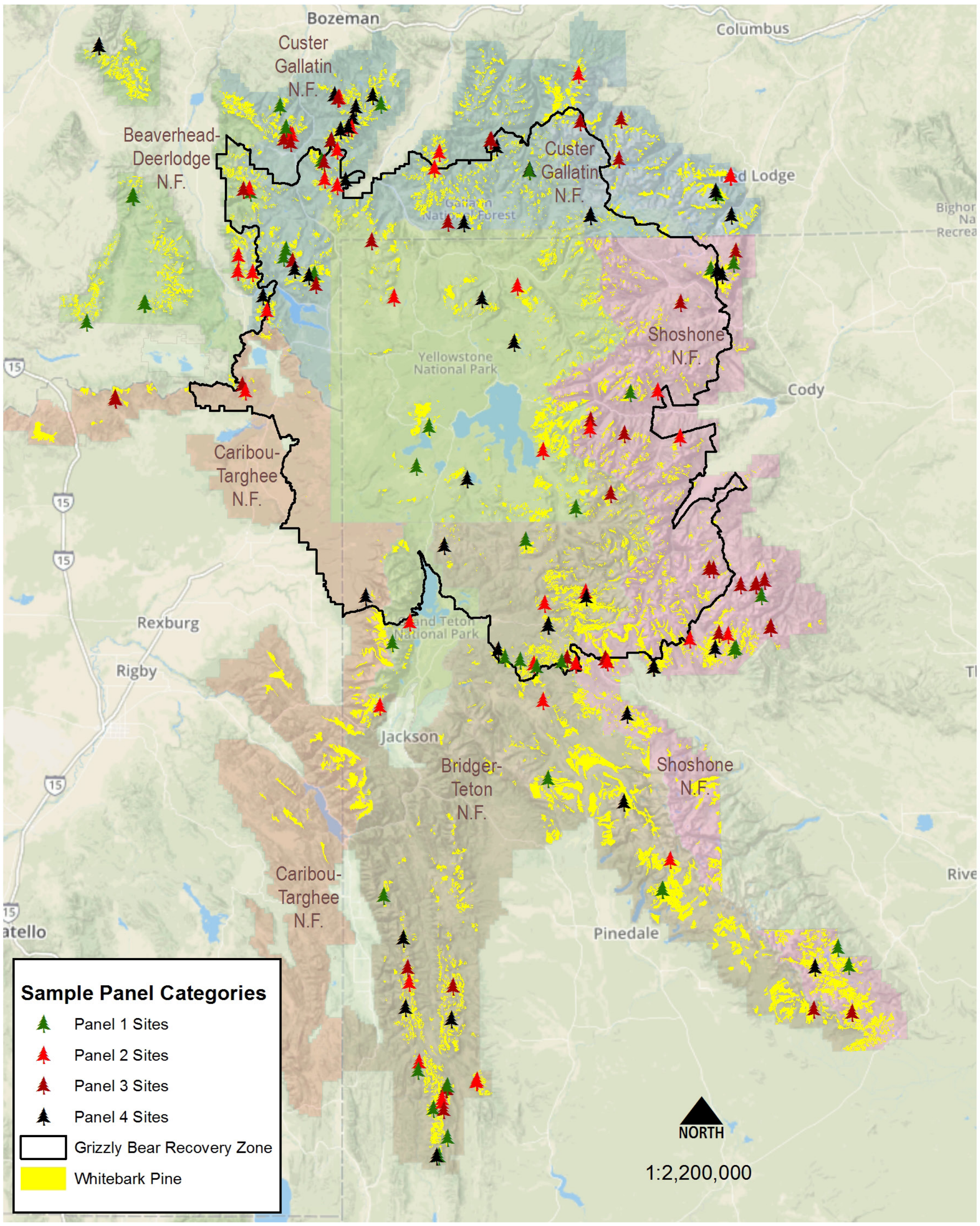

Figure 1. Location of whitebark pine survey transects within the Greater Yellowstone Ecosystem (all shaded regions).

Methods

Details of the sampling design and field methodology can be found in the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (GYWPMWG 2011) and in the 2007 and 2011 annual reports (GYWPMWG 2008, 2012). The basic approach is a two-stage cluster design in which stands of whitebark pine are the primary units, and 10 × 50 m transects within stands are the secondary units. Initial establishment of permanent transects took place between 2004 and 2007; during this period, 176 permanent transects in 150 whitebark pine stands were established and all individual whitebark pine trees >1.4 m tall were permanently marked in order to estimate changes in blister rust infection and survival rates over an extended period. The sample of 176 transects is a probabilistic sample that provides statistical inference to the GYE.

In 2008, individual transects were randomly assigned to one of four panels; each panel consists of approximately 44 transects. This is the number of transects that can be realistically visited in a given field season by a two-person field crew. Sampling every four years is sufficient to detect change in blister rust infection (GYWPMWG 2011); however, sites in each panel were surveyed every other year from 2008 through 2013 to incorporate the dynamic nature of the recent mountain pine beetle epidemic. These extra surveys focused on mountain pine beetle indicators (Figure 2). Both surveys record tree status as live, dead, or recently dead. In 2016, we completed a third full resurvey of all Panel 1 transects.

Time-Step Assignment

In order to evaluate step-trends in blister rust infection, infection severity and transition, and overall mortality, every four-year visit period is classified as a time-step (T#) interval. Time-step 1 (T1) consists of the 176 transects established in the period from 2004 to 2007 and is considered the baseline. Time-step 2 (T2) Panels (1 through 4) were revisited between 2008 and 2011. Time-step 3 (T3) was initiated in 2012 and was completed in 2015 following successful revisits to all four panels. Revisits to Panel 1 transects in 2016 initiated time-step 4 (T4), which will be completed after all panels are resurveyed in their scheduled revisit cycle by end of the 2019 field season (Figure 2).

Full Survey

White Pine Blister Rust Status

During a full survey visit, the presence or absence of blister rust infection is recorded for all live trees in the transect. A tree is considered infected if either aecia or cankers are present. For a canker to be conclusively identified as resulting from blister rust, at least three of five ancillary indicators need to be present (GYWPMWG 2011). Ancillary indicators of blister rust included flagging, rodent chewing, oozing sap, roughened bark, and swelling (Hoff 1992). To document the severity of infection, the location of a blister rust canker is recorded as occurring in the canopy and/or on the bole of an infected tree. While canopy cankers can affect the reproductive output of an infected tree, bole infections are considered more imminently lethal to the overall health of an infected tree.

Survey Schedule		Time-Step 1 (baseline)	Time-Step 2				Time 3				Time 4				Continued Monitoring 2020 Forward
Sample Panel	Transects per Panel	2004 thru 2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
1	43	Initial Surveys for all 176 transects	br & mortality		mortality only		br & mortality				br & mortality				
2	45			br & mortality		mortality only		br & mortality				br & mortality			
3	44		mortality only		br & mortality		mortality only		br & mortality				br & mortality		
4	44			mortality only		br & mortality		mortality only		br & mortality				br & mortality	

Figure 2. Panel sampling revisit schedule that includes full surveys for blister rust (br) and mortality, and mortality only surveys. This table shows the designated time series for each time-step assignment (Time 1: 2004–2007, Time 2: 2008–2011, Time 3: 2012–2015, Time 4: 2016–2019).

Mortality Status and Mountain Pine Beetle Presence

During a full survey visit, observers record any change in life status for each tagged tree that was alive at the previous transect visit. For both live and dead trees, signs of mountain pine beetle infestation, such as pitch tubes and frass, are documented. Pitch tubes are small, popcorn-shaped resin masses produced by a tree as a means to stave off a mountain pine beetle attack. Frass or boring dust is created during a mountain pine beetle attack and can be found in bark crevices and around the base of an infested tree. For dead trees only, a section of bark is removed to identify and record the presence of J-shaped galleries. These J-shaped galleries indicate that adult mountain pine beetle and their larvae occupied the tree (GYWPMWG 2011).

Recruitment and Understory Individuals

Transect surveys provide three indices of whitebark pine recruitment: the number of trees ≤1.4 m tall, the number of trees that grow to >1.4 m tall, and the number of live tagged trees, regardless of height, that show signs of reproductive activity. During a full survey visit, all whitebark pine trees ≤1.4 m tall on a transect are counted and observed for blister rust infection. Once a tree has reached a height >1.4 m, it is permanently tagged and assessed in a manner consistent with all other live, marked trees in the sample frame. In addition, three nested circular plots at the beginning, center, and end of the transect (1/300th acre for each circle), are evaluated for the occurrence and infection status of whitebark pine ≤1.4 m tall and overall tree species composition (GYWPMWG 2012). Finally, all live, tagged trees are assessed for indication of past or present reproduction as shown by the presence of cones or cone scars.

Data Management

Prior to analysis, all data are subjected to rigorous quality assurance and quality control (QA/QC) procedures as outlined in the protocol (GYWPMWG 2011). Due to minor retroactive updates to the master database as part of ongoing quality controls, there may be an insignificant amount of variability (typically <1% difference) when comparing data reported in previous years. All computational analyses and corresponding charts and graphs were produced using Microsoft Excel and the statistical computing language R (R Development Core Team 2011).

Crewmembers examining mature whitebark pine cones in the Southern Madison Range of the Lee Metcalf Wilderness in Montana. Photograph by NPS/ERIN SHANAHAN.

Results

Time-Step Considerations for Whitebark Pine Health and Status

Status and trend assessments are more meaningful after accumulating many years of comparable data (Witwicki 2012). For the Interagency Whitebark Pine Monitoring Program, more intensive evaluation of monitoring data is scheduled at four-year intervals after all 176 transects are resurveyed. Comparisons between years based on a single panel revisit are misleading, because each panel is composed of an entirely different set of transects. Data summaries from transects surveyed in 2016 (Panel 1) do not reflect the entire sample of transects, and therefore, do not represent the estimated status or long-term trend of the overall GYE population of whitebark pine. The reader is cautioned not to draw wide-reaching conclusions from the summary of data collected in 2016.

Monitored Transects

In 2016, all 43 transects assigned to Panel 1 were resurveyed between June and September by a two-person NPS crew. This is the third revisit to all Panel 1 transects for full survey data collection (blister rust and mortality). It also marks the first panel revisit in Time 4 in our time-step series (Figure 2).

White Pine Blister Rust Infection—Panel 1

A total of 860 live tagged trees in 38 transects from Panel 1 were examined for blister rust infection in 2016 (five transects no longer have live, tagged trees). This number includes the 40 new trees added during the 2016 survey. Results from a Wilcoxon Signed-Rank test comparing the proportion of infected trees on Panel 1 in 2012 to the proportion of trees infected on Panel 1 in 2016 (n = 34 stands for both time periods) suggests a slight, but nonsignificant increase (6%) in the proportion of trees infected between the two time periods (V = 97.5, P value = 0.1373).

Infection Transition

Of the 809 live trees that were surveyed in Panel 1 transects in 2012 and again in 2016, approximately 69% (558) had no evidence of blister rust infection, 18% (144) were infected in both years, 8% (67) transitioned from no evidence of infection to infected, and 5% (40) went from infected to uninfected (Table 1). A transition from infected to uninfected could be the result of factors such as observer error, an earlier-documented infection based on indicators that upon resurvey no longer meet the established standards of three indicators in the same location, or infected branches that self-pruned.

Table 1. Blister rust infection transition among live, tagged trees on Panel 1 transects in 2012 and again in 2016.

Transition	Number of Live Trees (n = 809)
Remained Uninfected	558
Remained Infected	144
Uninfected to Infected	67
Infected to Uninfected	40

Mortality—Panel 1

In 2016, we observed 69 newly dead tagged trees from Panel 1. Of the 69 dead trees, 91% (63 trees) were >10 cm in diameter at breast height (DBH). Approximately 21% (13 trees) of those >10 cm DBH trees died with only evidence of mountain pine beetle infestation. The remaining 79% (50 trees) of the >10 cm size class died with signs of blister rust, mountain pine beetle, and/or wildfire, or with signs of other factors, such as wind damage, animal damage, or from unknown causes (Figure 3). A total of 24 of the dead trees had previously been identified as cone producing while alive. Five Panel 1 transects no longer have live, tagged trees.

Recruitment and Understory Individuals

While transects are experiencing varying degrees of mortality, they are also experiencing varying degrees of recruitment. Once a whitebark pine tree within the transect boundary becomes greater than 1.4 m tall, it is permanently tagged and included in the live tree sample. In 2016, we tagged a total of 40 new trees. In addition, 2,422 understory whitebark pine trees (≤1.4 m tall) were counted on Panel 1 transects. This equates to approximately 56 small trees per transect.

In 2016, 129 recruitment plots (three per transect) were completed. Analysis of overall recruitment change (step-trend) will be conducted at the end of T4 (2019), which will be the first possible comparison interval.

Currently, we estimate that there are 942 live, reproducing, tagged trees across the four panels. This is likely a conservative estimate because we may not always observe a tree when it exhibits signs of reproduction, due to the panel revisit schedule. The majority of the reproducing trees have a DBH between 10 cm and 30 cm (79%), although our monitoring detected trees ≤2.5 cm DBH with evidence of reproduction.

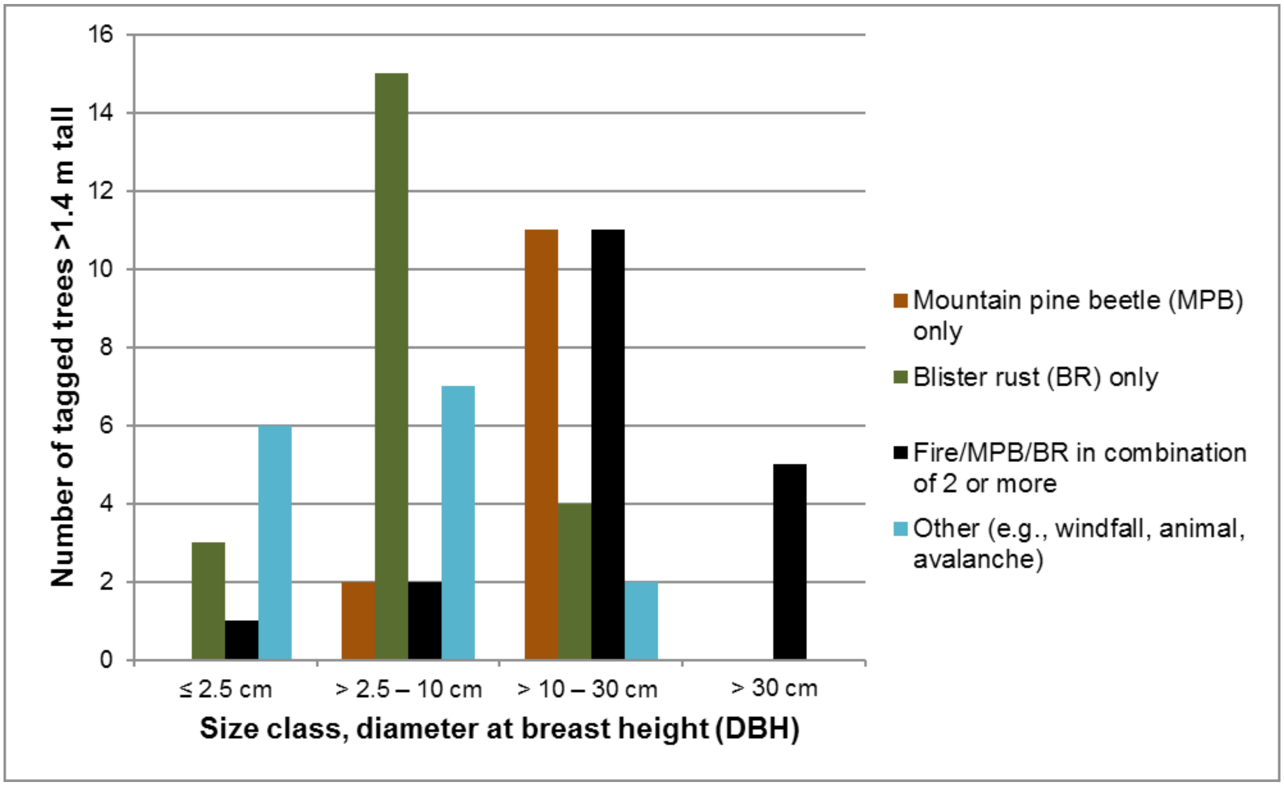

Figure 3. Size class and mortality influencing agents observed for 69 dead tagged trees in Panel 1 in 2016. Fire was not the sole cause of mortality for any of the trees this year.

Discussion

Blister rust infection is ubiquitous, but infection levels vary across the Greater Yellowstone Ecosystem (GYE). Based on monitoring data collected from 2012 to 2015, estimated rates of infection among whitebark pine ranged from 14% to 26% (Shanahan et al. 2017; Figure 4). Preliminary analysis suggests a slight increase (6%) in the proportion of trees infected

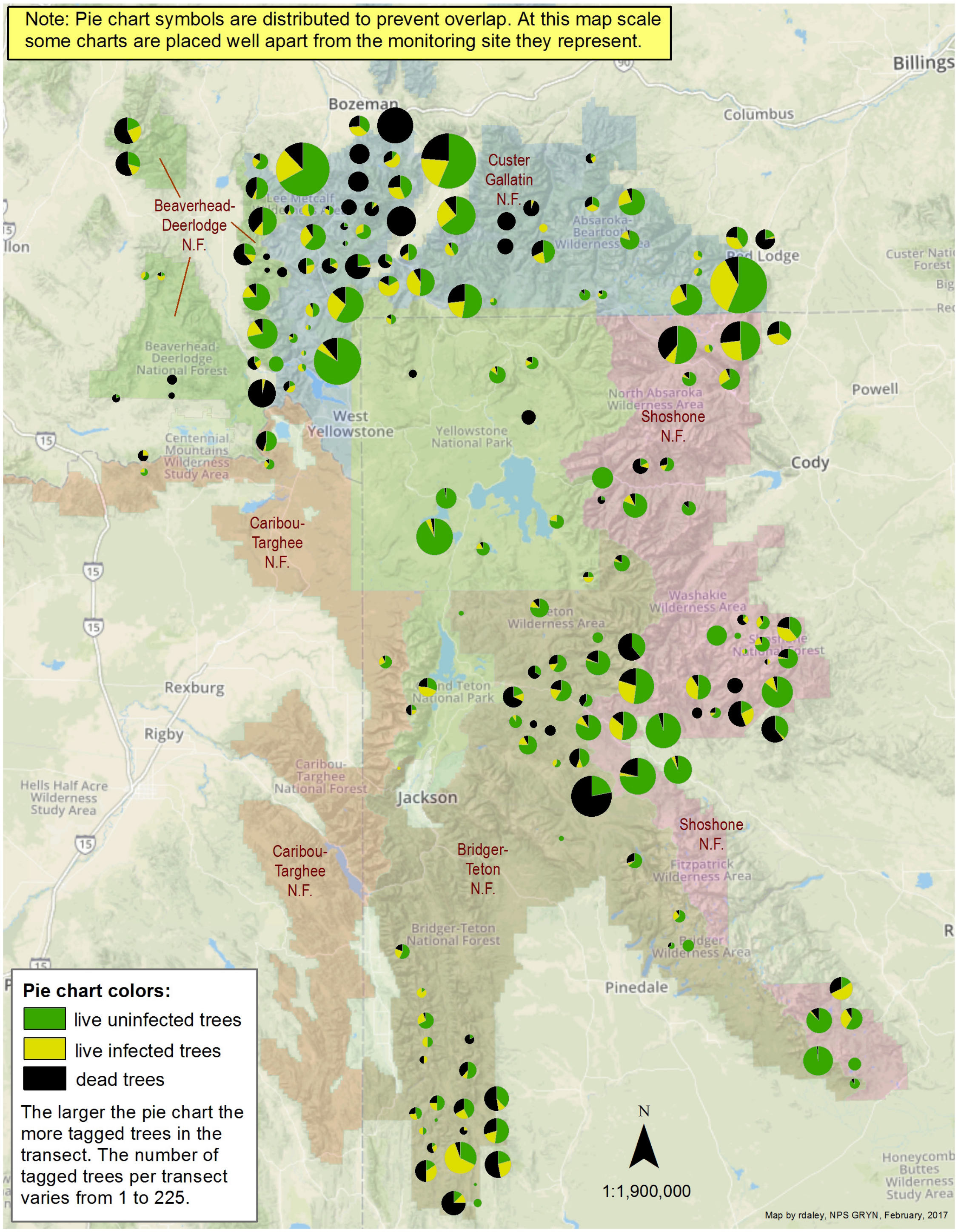

Figure 4. Infection and mortality status of whitebark pine trees surveyed from 2013 to 2016 in the Greater Yellowstone Ecosystem (all shaded regions). Infected trees range from those with a single canker on a branch to those with a bole canker.

with blister rust on Panel 1 transects between the 2012 and 2016 survey periods, although this was not statistically significant. We will continue to investigate the nuances related to changes in the proportion and severity of infection with more detailed analysis in subsequent step-trend reports.

Mortality attributable to mountain pine beetle attack continues to decrease in the GYE. Similar to blister rust, impacts from mountain pine beetle are widespread and variable across the GYE. Of the 176 established transects, 128 had recorded evidence of mountain pine beetle infestation, while 48 had no observed evidence of mountain pine beetle by the end of 2016 (Figure 5). There was an increase of only one transect with evidence of mountain pine beetle since 2015.

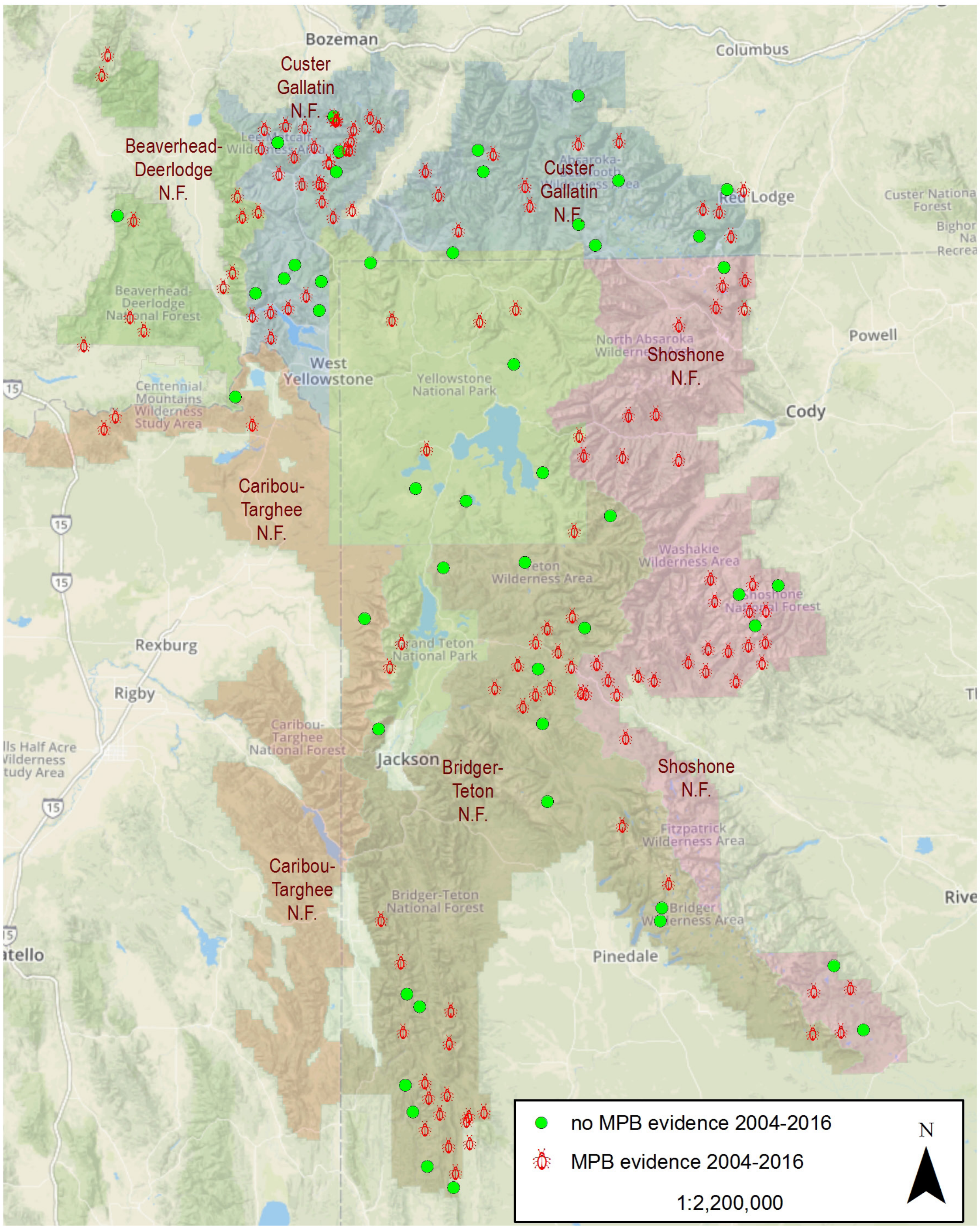

Figure 5. Location of transects throughout the Greater Yellowstone Ecosystem (all shaded regions) with and without evidence of mountain pine beetle infestation as of 2016.

Though wildland fire continues to affect forests throughout the GYE, only three of the 69 dead tagged trees were recorded as affected by fire at the 2016 revisit. Since 2008, approximately 254 tagged trees on 17 transects have experienced damage by wildland fire. The majority of these burns have been stand-replacing fires (Figure 6).

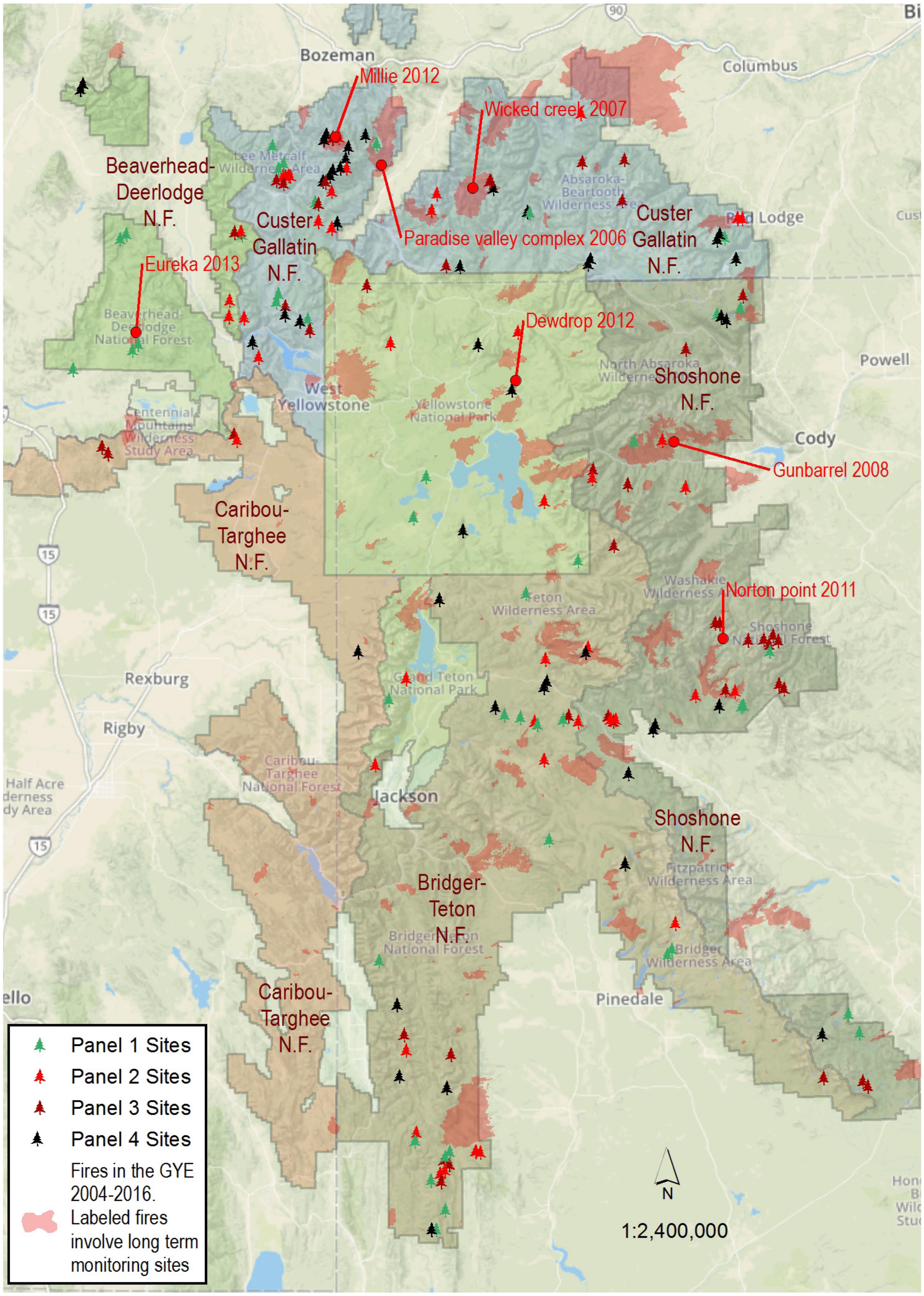

Figure 6. Location of wildland fires in relation to whitebark pine transects throughout the Greater Yellowstone Ecosystem as of 2016.

In addition to the regular whitebark pine monitoring in 2016, we contributed to other whitebark pine-related projects. We surveyed 117 rapid assessment transects and revisited one permanent transect on Bureau of Land Management Lands (BLM) in five areas of Wyoming. A total of 1,778 five-needle pine trees (whitebark pine and limber pine) were examined in this effort. We also provided training for BLM foresters from Montana and Wyoming on the methods outlined by the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* and on rapid assessment techniques for data collection on five-needle pine health. NPS crews also assisted in identifying pika (*Ochotona princeps*) populations in the GYE. Like whitebark pine, pika inhabit high elevation areas throughout the GYE. Whitebark pine crews traveling to whitebark pine transects took the opportunity to record pika locations and to record habitat metrics as well. This information is provided to the Craighead Institute as part of its pika research effort.

In 2017, we will revisit Panel 2 transects for the third time and revisit BLM permanently established transects. We will continue to collaborate with other research efforts that are taking place in the ecosystem as well as participate as a member of the Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee.

This long-term monitoring program provides critical information that will help determine the likelihood of whitebark pine persisting as a functional and vital part of the Greater Yellowstone Ecosystem. Data from this program are currently being used to inform managers, guide management strategies and restoration planning, support other whitebark pine research, and substantiate conservation efforts throughout the GYE. Our first step-trend report of data collected through 2011 was completed in 2014 (Shanahan et al. 2014). We have completed a second step-trend report for data collected through 2015. This and all other reports and studies related to the whitebark pine long-term monitoring program are available on the Greater Yellowstone Network website (https://science.nature.nps.gov/im/units/gryn/monitor/whitebark_pine.cfm). The interagency protocol has also been a valuable resource for other entities embarking on five-needle pine monitoring and has helped inform the Greater Yellowstone Coordinating Committee's Whitebark Pine Strategy for the Greater Yellowstone Area (GYCCWPS 2011).

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 101/138527, 136/138527, May 2017

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Appendix C

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Natural Resource Stewardship and Science

Status of Whitebark Pine in the Greater Yellowstone Ecosystem

A Step-Trend Analysis with Comparisons from 2004 to 2015

Natural Resource Report NPS/GRYN/NRR—2017/1445

ON THE COVER
Ramshorn Peak in the southern end of the Absaroka Mountain Range on the Shoshone National Forest”
Photograph by NPS/ERIN SHANAHAN

Status of Whitebark Pine in the Greater Yellowstone Ecosystem

A Step-Trend Analysis with Comparisons from 2004 to 2015

Natural Resource Report NPS/GRYN/NRR—2017/1445

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May 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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NPS 101/138263, 136/138263, May 2017

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Executive Summary

Background and Objectives

Whitebark pine (*Pinus albicaulis*) is a foundation and keystone species in upper subalpine environments of the northern Rocky Mountains that strongly influences the biodiversity and productivity of high-elevation ecosystems (Tomback et al. 2001). Throughout its historical range, whitebark pine has decreased significantly as a major component of high-elevation forests. As a result, it is critical to understand the challenges to whitebark pine—not only at the tree and at the stand level, but also as these factors influence the distribution of whitebark pine across the Greater Yellowstone Ecosystem (GYE).

In 2003, the National Park Service (NPS) Greater Yellowstone Inventory and Monitoring Network identified whitebark pine as one of twelve significant natural resource indicators or vital signs. This designation initiated a long-term, collaborative monitoring program of whitebark pine in the GYE. The objectives of the monitoring program are to

1. assess trends in the proportion of live whitebark pine trees (>1.4 m tall) infected with white pine blister rust (*Cronartium ribicola*; blister rust)
2. document blister rust infection severity by the occurrence and location on the tree of new and persisting infections and assess how infection severity is changing over time
3. assess trends in mortality of whitebark pine trees and describe contributing factors of mortality
4. document the recruitment of understory whitebark pine into the reproductive population and assess the multiple factors that influence regeneration and recruitment success overtime

In this report we summarize the past 12 years (2004–2015) of whitebark pine status and trend monitoring in the GYE divided into three time-steps: Time-Step 1 (2004–2007; herein referred to as Time 1), Time-Step 2 (2008–2011; herein referred to as Time 2), and Time-Step 3 (2012–2015; herein referred to as Time 3).

Summary of Results

Objective 1: Blister Rust Infection Proportions

The proportion of live whitebark pine trees infected with blister rust in the GYE in Time 1 was estimated at 0.21 (0.03 SE). In Time 2 the estimation was 0.22 (0.02 SE). In Time 3, we estimated the proportion of live trees infected with blister rust to be 0.20 (0.03 SE). We detected no significant change in the proportion of trees infected in the GYE among the three time-steps.

Objective 2: Blister Rust Infection Severity

At the end of Time 3, we found that 25% (942 trees) of live, tagged trees (3,716) were infected with blister rust. Trees with only canopy cankers represented 37% (343) of the total number of trees infected with blister rust, whereas trees with bole cankers comprised 63% (599) of the infected sample. A bole infection is more consequential than a canopy canker, as it compromises not only the overall longevity of the tree, but its functional capacity for reproductive output as well (Kendall and Arno 1990; Campbell and Antos 2000; McDonald and Hoff 2001; Schwandt and Kegley 2004).

In addition, we chronicled when a change or transition in infection location (canopy or bole) occurred in infected trees among time-steps. We found that 60% (237) of trees recorded with canopy cankers in Time 1 transitioned to bole cankers by Time 3. For this Time 1 to Time 3 comparison, revisits were separated by 4 to 11 years, depending on the transect and its assigned panel revisit schedule. For Time 2 to Time 3, which had a more consistent revisit interval of 4 years for all transects on all panels, only 12% (98) of canopy cankers transitioned to bole cankers. Additionally, once an infection was identified as occurring in the bole of a tree, the likelihood of that same tree exhibiting only a canopy canker at a subsequent visit (bole ➜ canopy 'transition'), was low. This information demonstrates the value of long-term monitoring to evaluate the implications of the severity of blister rust infection through time.

Objective 3: Whitebark Pine Mortality

We estimate the proportion of whitebark pine >1.4 m tall in the GYE that have died between 2008 and 2015 to be 0.26 (0.03 SE). The peak of mortality occurred from 2008 to 2011 when mountain pine beetle populations were at epidemic levels (Shanahan et al. 2014). Approximately 60% (902) of the dead tagged trees had signs of mountain pine beetle activity and the majority of these were >10 cm DBH. Wildland fire has also had an impact on whitebark pine. Fourteen of the transects have been burned and 249 tagged trees died, with signs of fire.

Objective 4: Whitebark Pine Recruitment

Reproducing trees made up approximately 26% (963) of the total live, tagged cohort of trees (3,716) at the end of Time 3. Of these, 43% (411) were infected with blister rust and

16% (154) had sign of mountain pine beetle. In Time 3, the average density of small trees ≤1.4 m tall was 51 understory trees per 500 m^2 (Time 1 = 37, Time 2 = 53). Raw counts of these understory individuals ranged from 0 to 521 small trees per transect. In addition, 447 trees were added to the tagged tree cohort by the end of 2015. These newly tagged trees reached a height of >1.4 m tall and were therefore added to the sample.

Throughout the past decade in the GYE, monitoring has helped document demographic shifts in whitebark pine forests in response to insect, pathogen, wildland fire, and other disturbance events. Blister rust infection is ubiquitous but variable across the region. And while we have documented mortality of whitebark pine, we have also recorded considerable recruitment. We provide this second step-trend report to characterize the current status and trends in the health of whitebark pine in the GYE.

Acknowledgments

The generous support and collaboration of the numerous agencies that comprise the Greater Yellowstone Whitebark Pine Monitoring Working Group have made this endeavor possible. We thank both current and past members of the group for their continued assistance, encouragement, and logistical backing. This report would not have come to fruition without the enduring character of the numerous field technicians who participated in data collection over the duration of the Interagency Whitebark Pine Monitoring Program for the Greater Yellowstone Ecosystem. It is to these dedicated and hardy individuals that we owe the success of this project.

We thank Dr. Kathryn Irvine and Siri Wilmoth for their guidance and assistance with the statistical analysis in this trend report.

We greatly appreciate the rigorous evaluations provided by numerous reviewers throughout the preparation of this report.

Funding for the Interagency Whitebark Pine Monitoring Program has been provided by the National Park Service Inventory and Monitoring Program, the U.S. Forest Service, the Bureau of Land Management, the Greater Yellowstone Coordinating Committee, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey.

This report was produced in coordination with the Greater Yellowstone Whitebark Pine Monitoring Working Group, with representatives from the National Park Service, U.S. Forest Service, U.S. Geological Survey, Bureau of Land Management, and Montana State University.

Introduction

Whitebark pine (*Pinus albicaulis*) forests are biologically significant components of high elevation regions in the United States northern Rocky Mountains. From an ecological perspective, whitebark pine is a keystone species that creates microhabitats for other vegetation (Keane and Arno 1993) and is an important food source for a variety of wildlife (Tomback et al. 2001). In some locations, it also traps winter snow, which helps to regulate hydrologic processes in the spring and summer (Arno and Hoff 1990; Weaver 2001). Whitebark pine is located primarily above 2400 m. It is found on over 800,000 ha in Yellowstone and Grand Teton National Parks and five surrounding national forests that are collectively identified as the Greater Yellowstone Ecosystem (GYE; Tomback et al. 1993; Shanahan et al. 2014). In addition to its ecological importance, whitebark pine is one of the most socially relevant and iconic tree species inhabiting high mountain ranges in the GYE. It is considered a symbol of a primitive America, a legacy of public land stewardship, and an ambassador for the conservation of subalpine environments (Tomback et al. 2001).

Currently, the long-term persistence of whitebark pine in the GYE is uncertain. Studies show a decline in the abundance of whitebark pine across the western United States as anthropogenic warming alters forest disease agents, drought duration, and fire regimes (Westerling et al. 2011; MacFarlane et al. 2013; Chang et al. 2014; Buotte et al. 2016). Recent estimates from aerial surveys (2009) documented greater than 80% mortality of overstory whitebark pine throughout the GYE (MacFarlane et al. 2013). While ground-based surveys implemented by the National Park Service's Greater Yellowstone Inventory and Monitoring Program (monitoring program) found similar estimates of mortality in the larger size class of trees that typically comprise the overstory population of whitebark pine, mortality rates across the range of size classes were estimated to be between 18% and 36%. Across the range of size classes, primary mortality factors include exotic white pine blister rust (blister rust; *Cronartium ribicola*), native mountain pine beetle (*Dendroctonus ponderosae*), and wildland fire (Shanahan et al. 2014).

Introduced in 1910, blister rust has resulted in severe declines in whitebark pine populations throughout their range (Kendall and Arno 1990; Keane and Arno 1993; Tomback and Achuff 2010). The life cycle of blister rust is complex. It requires high relative humidity and mild temperatures in the late summer for the production of basidiospores (reproductive cells) and the successful spread of infecting spores from intermediary host species (*Ribes* spp, *Castilleja* spp., and *Pedicularis* spp.) to whitebark pine (Van Arsdel et al. 1956; Hoff and Hagle 1990; McDonald et al. 2006). Whitebark pine stands in the moister environment of Glacier National Park, Montana, have been devastated by blister rust (Kendall and Arno 1990), whereas the impacts of blister rust in the GYE have been limited by an overall drier and colder environment (Campbell and Antos 2000; Koteen 2002; Larson 2011). Blister rust infection or cankers can cause the death of upper canopy cone-bearing branches, thus negatively impacting seed-production; cankers found on the lower portions of the bole will eventually kill an infected tree (Smith and Hoffman 2000; Koteen 2002; Newcomb 2003).

Mountain pine beetle life cycles have been linked to weather and climate (Raffa et al. 2008; Logan et al. 2010; Raffa et al. 2013), with populations typically held in check by low winter temperatures (Amman 1973). However, mountain pine beetle populations can exponentially increase in response to longer warm season temperatures by producing multiple broods in a single year (Logan et al. 2010). Previous periods of warming in the 1930s, 1970s, and 1980s resulted in epidemic mountain pine beetle levels, with populations declining to endemic levels following the return to cooler temperatures (both winter and summer) and the depletion of host resources (Logan et al. 2010). Many conifers have defenses that serve to protect them against bark beetle attacks (Raffa and Berryman 1983; Shrimpton 1978; Boone et al. 2011), yet these mechanisms can be compromised under high temperatures and seasonal drought stress (Berg et al. 2006; Raffa et al. 2008; Bentz et al. 2010; Preisler et al. 2012). It is possible for a healthy tree to pitch out (reject by producing extra pitch) the first invaders, but trees subjected to a range of physiological stresses (drought, defoliation, age) may have reduced defensive abilities, which enable attacking mountain pine beetles to overcome protective thresholds (Raffa et al. 2005; Raffa et al. 2008).

Wildland fire is yet another contributor to whitebark pine mortality in the GYE. As climatic changes augment drought severity across the western United States, the probability of wildland fire is expected to increase (Westerling et al. 2011). While wildland fire has historically been an important component for the maintenance of whitebark pine forests (Arno 1986), but predicted warming trends may increase the frequency and severity of fire events to the detriment of high elevation whitebark stands (Keane et al. 2016). In addition to the loss of genetically valuable individuals (Keane et al.

2016), remaining populations may be reduced to densities that preclude natural re-establishment.

This long-term monitoring program provides a unique opportunity to investigate the biotic and abiotic interactions that affect whitebark pine health through time. The first step-trend analysis (Shanahan et al. 2014) documented status and trends in whitebark pine health between the initial establishment period, 2004 to 2007 (Time 1), and the first revisit survey period, 2008 to 2011 (Time 2). This second step-trend analysis summarizes trends across the three periods 2004–2007, 2008–2011, and 2012–2015 (Time 3). It is imperative that we continue to improve our understanding of whitebark pine response to a changing climate. As the whitebark pine monitoring program moves forward, our ability to document persistent and emerging patterns in whitebark pine health continually expands. This science-based knowledge increases our capacity to provide relevant and contemporary health parameters to land managers who are responsible for the protection and conservation of whitebark pine in the GYE. In addition, information gleaned from this monitoring program can be extrapolated to other areas that support whitebark pine populations.

Report Objectives

Thus far, we have completed three time-steps following the objectives outlined in the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* (GYWPMWG 2011). The intent of this trend report is to

1. Describe the estimated proportion of live whitebark pine trees (>1.4 m tall) infected with blister rust across the three time-steps and assess changes in blister rust infection over time.
2. Document blister rust infection severity by the occurrence and location of new and persisting infection by the end of 2015 and evaluate the rate at which infection transitioned from canopy to bole cankers between the three time-steps.
3. Determine mortality of whitebark pine trees within Time 2, Time 3, and cumulatively from 2008 to 2015, and describe contributing factors of mortality
4. Document the recruitment of understory whitebark pine into the reproductive population.

Methods

In this section we briefly describe the methods used in the whitebark pine long-term monitoring program. For a more in-depth explanation of these processes, refer to the interagency whitebark pine monitoring protocol (GYWPMWG 2011).

Stand and Transect Selection

We define whitebark pine stands as a contiguous area of forest with whitebark pine as the dominant or co-dominant component. We identified stands from photo interpretation of vegetation habitat (Dixon 1997) and stand composition cover maps (GYWPMWG 2011). We selected stands randomly from a sample frame of approximately 10,770 mapped whitebark pine stands ≥2.0 ha in the Greater Yellowstone Ecosystem (GYE) (Dixon 1997; Landenburger et al. 2008; Figure 1). Stands were divided into four panels with differing revisit schedules (described in more detail in *Revisit Schedule*, below). We used a probabilistic, two-stage cluster design,

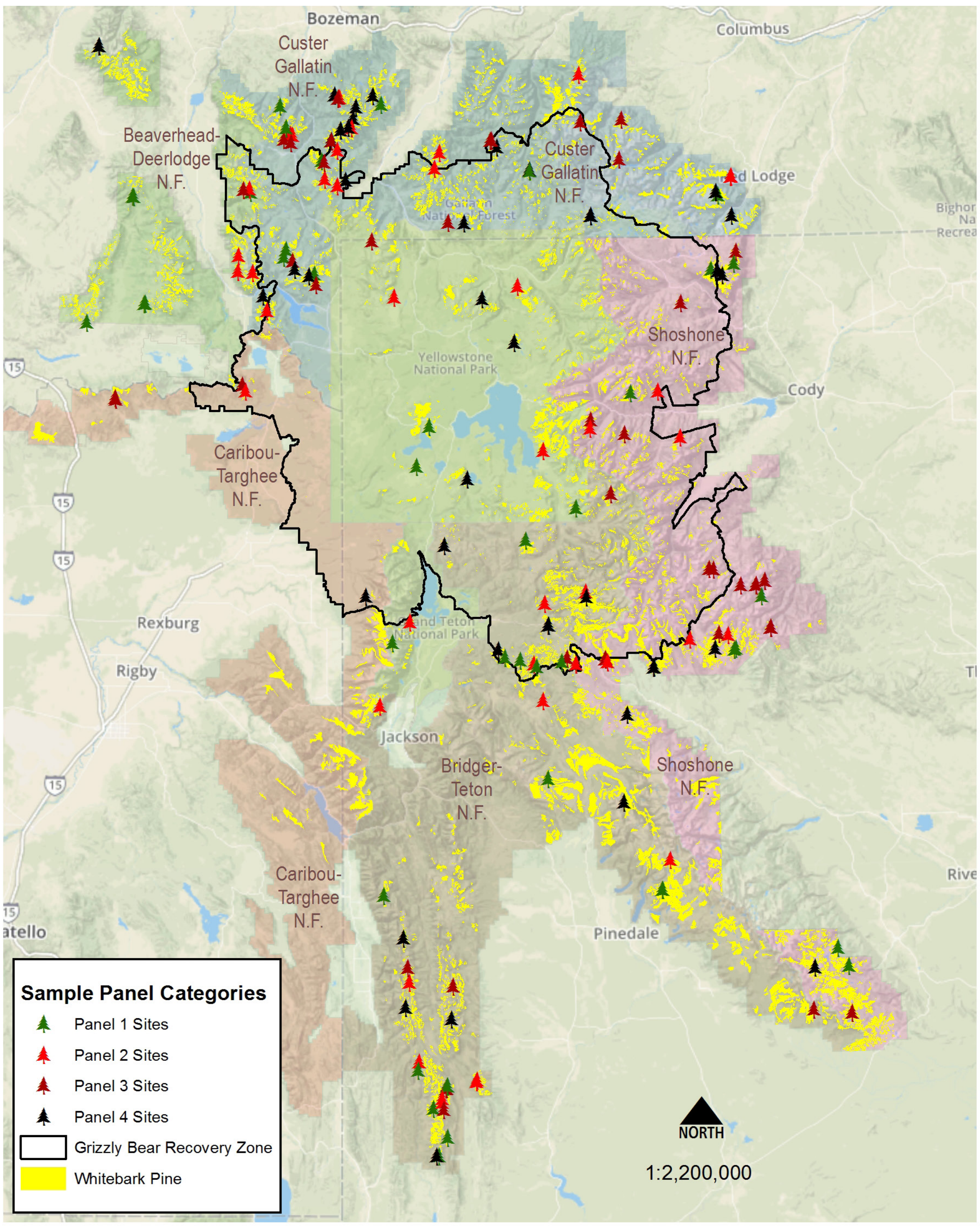


Figure 1. Interagency Whitebark Pine Monitoring Program study area in the Greater Yellowstone Ecosystem (all shaded regions).

where whitebark pine stands were the primary sample units and 10 × 50 m transects were the secondary sample units within selected stands (Lohr 2010). One or two transects were randomly placed within the delineated boundary of a stand (stands that had two transects installed were used to evaluate within stand variation). If a minimum of one live whitebark pine tree >1.4 m tall was observed, a transect was established and permanently monumented in order to facilitate relocation of the transect for future revisits.

Transect Establishment and Metrics

From 2004 to 2007 (Time 1), 176 permanent transects in 150 whitebark pine stands were established. All live, whitebark pine trees >1.4 m tall located within transect boundaries were marked with a numbered aluminum tag. A total of 4,768 individual trees >1.4 m tall were permanently tagged. We documented multiple attributes for every tagged tree (Table 1).

Tree status: If a tree had all brown needles or was devoid of needles, it was classified as dead in the year that this condition was observed (any year from 2008 to 2015).

Cones: We added the presence or absence value (Y/N) of cone production as an additional metric in 2007. Then in 2013, we began tracking reproduction and the number of cones produced per tree using a binning system (0, 1–5, 6–10, >10). This information could be used to assess how blister rust infection in the canopy or bole of an infected tree affects overall cone production and/or to evaluate the amount of potential seed source available for future regeneration.

Blister rust cankers: We examined trees for blister rust infection and recorded the location of blister rust infections (canopy or bole) for each tagged tree. A canopy canker was defined as any infection occurring within the canopy of a tree ≥5 cm distal from the main bole of the tree. A bole canker was an infection on the main trunk of the tree or within 5 cm of the bole along peripheral branches.

Tree health codes: While the monitoring program does not assign cause of death to a given tree, we do report observed indicators that are associated with tree mortality.

Understory counts: Trees ≤1.4 m tall that occurred within the boundaries of the belt transect were tallied and evaluated for the presence/absence of blister rust.

We noted additional information at transects, including UTM coordinates of beginning, center, and end points of the belt transect (Figure 2), elevation, habitat type (from Steele et al. 1983), and cover type (from Mattson and Despain 1985).

Revisit Schedule

After 2007, stands were randomly assigned to one of four panels, each consisting of 44 transects. Revisits to each stand

Table 1. Whitebark pine tree attributes documented during surveys in the Greater Yellowstone Ecosystem.

Attribute	Description
clump membership	number and letter
DBH	measured at 1.4 m above the ground
height	height bins 1= ≤5 m, 2 = >5 m to ≤10 m, 3 = >10 m
tree status	live = green needles still present recently dead = red or brown needles remaining on tree (only measured during subsequent revisit surveys) dead = tree is completely denuded of needles (only measured during subsequent revisit surveys)
cone count bins	initiated in 2007 as Y/N cone count bins initiated 2013 = 0, 1–5, 6–10, >10 S = cone scar(s) but no visible current-year cones
blister rust cankers	number and location in the canopy of the tree = upper third, middle third, or lower third number and location on the bole of the tree = upper third, middle third, or lower third
number of blister rust indicators	flagging, rodent chewing, swelling, roughened bark, and oozing sap
upper tree canopy volume	percentage of canopy in the upper one third of the foliage that is alive
mountain pine beetle indicators	pitch tubes, frass, or J-shaped galleries
tree health codes	can have multiple per tree such as dead top, fading crown, fire, etc.
understory counts	tally of understory trees (≤1.4 m tall); evidence of blister rust = present, absent, unknown

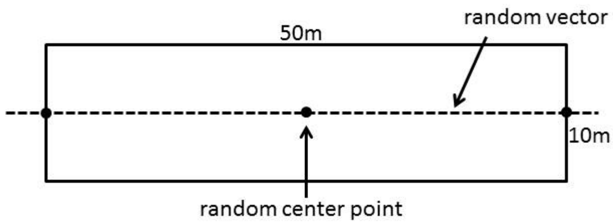


Figure 2. Belt transect layout for whitebark pine monitoring in the Greater Yellowstone Ecosystem. Permanent markers were placed at the two end points and the center point.

Survey Schedule		Time 1	Time 2				Time 3				Continued Monitoring 2016 Forward
Sample Panel	Transects per Panel	2004 thru 2007	2008	2009	2010	2011	2012	2013	2014	2015	
1	43	initial surveys for all 176 transects	br & mort		mort only		br & mort				
2	45			br & mort		mort only		br & mort			
3	44		mort only		br & mort		mort only		br & mort		
4	44			mort only		br & mort		mort only		br & mort	

Figure 3. Panel sampling revisit schedule (br = blister rust, mort = mortality) for monitoring whitebark pine in the Greater Yellowstone Ecosystem. All transects were visited every two years for mortality and every four years for blister rust status. Starting in 2014, after the mortality of live, tagged trees sharply declined, monitoring was restored to a four-year interval schedule documenting changes in blister rust and mortality.

in a panel were planned on a rotating, two- or four-year schedule (Figure 3). Following initial blister rust infection, it takes approximately four years to visually detect infection (McDonald and Hoff 2001). Therefore, field crews evaluated trees for blister rust infection every four years. Over the course of the mountain pine beetle outbreak (2008–2013), all transects were surveyed every two years to document mortality.

Tagged trees included in our investigation had two to five observations between 2004 and 2015. After Time 1, we tagged any whitebark pine tree within the boundary of a transect that attained a height of >1.4 m tall, recorded all attributes of the tree, and added it to the tagged tree cohort for long-term monitoring.

Data Management and Statistical Analyses

We trained field observers to carry and use a detailed data recording guide to help ensure legible, valid entries and maximize the quality of recorded values. Network personnel entered data from field data sheets into a Microsoft Access database on a regular basis throughout the field season using a customized data entry form that included a cascading system of data validation controls. We subjected data to rigorous quality assurance and quality control (QA/QC) procedures as outlined in the protocol (GYWPMWG 2011). Due to minor retroactive updates to the master database as part of ongoing quality controls, there may have been an insignificant amount of variability (typically <1% difference) when comparing data reported in previous years.

All analyses and corresponding figures used Microsoft Excel and the statistical computing language R (R Development Core Team 2015) specific to each objective. We have presented some of the results described in this trend report as preliminary findings in past versions of the Interagency Whitebark Pine Monitoring Program (monitoring program) annual reports (e.g., GYWPMWG 2015). This document provides results for the full 12 years of data collection and analysis in order to present a complete assessment of changes over time across the sample frame.

Objective 1

Describe the estimated proportion of live whitebark pine trees (>1.4 m tall) infected with blister rust across the three time-steps and assess change in the estimate over time.

We estimated the proportion of trees infected with blister rust in the sampled portion of 10,770 whitebark pine stands identified in the GYE. We used a combined ratio estimator on the live, tagged trees at the end of each time-step. A combined ratio estimator is appropriate for estimating a proportion from data collected using a stratified (e.g., Grizzly Bear Recovery Zone and administrative unit) two-stage cluster sample (Lohr 2010). The probabilistic sampling design allows inferences to the entire sampled population of mapped whitebark in the GYE. In addition, we evaluated three scenarios using a subset of sampled stands to investigate the potential infection rates given the inclusion and/or exclusion of known dead and newly tagged trees (Table 3 in Results provides a more detailed description).

To investigate the evidence of a change in the proportion of stands infected with blister rust, a nonparametric Wilcoxon Signed Rank test was used (wilcox.test in R). In stands that had two established belt transects (26 stands had two belt transects established in order to investigate within-stand variation), we calculated the overall average proportion for the stand to account for the potential lack of independence of belt transects nested within stands. We excluded stands that had transects without any live, tagged trees (due to complete mortality of all originally tagged trees), which explains the decrease in stand number with each consecutive time-step.

Objective 2

Document blister rust infection and severity by location on the tree of new and persisting infection at the end of 2015 and evaluate the rate at which infection transitioned from canopy to bole cankers.

We recorded infection status (uninfected or infected) for each live, tagged tree. In addition to tracking status, we documented whether blister rust cankers occurred in the canopy or on the bole. We reported canker locations in two categories: branch only or bole (bole includes those trees that have blister rust infection occurring in both the branch and bole). We compared changes in canker position between Time1, Time 2, and Time 3 in order to assess changes in infection severity. From one time-step to the next, infection status can remain static (uninfected ➔ uninfected or infected ➔ infected), or change (uninfected ➔ infected or infected ➔ uninfected). Due to the random panel assignment following initial surveys in the transect establishment period (Time 1), resurvey for individual trees varied by time-step. For the Time 1 to Time 2 comparison, the interval for individual tree resurvey was anywhere from 1 to 7 years. For the Time 1 to Time 3 comparison, the resurvey interval varied from 4 to 11 years. For the Time 2 to Time 3 comparison, all trees analyzed were resurveyed on a 4-year interval. The number of trees used in the analysis for each time-step follows:

- 3,795 trees tagged in Time 1 that were still alive in Time 2
- 3,270 trees tagged in Time 1 that were located and still alive in Time 3
- 3,554 trees tagged in Time 1 or Time 2 that were still alive in Time 3

We will present a more thorough investigation of canker transition in a future report that models infection transition as it relates to DBH, time, and a DBH-time interaction.

Objective 3

Determine cumulative mortality rates of whitebark pine trees from 2008 to 2015, with factors influencing mortality.

To determine whitebark pine mortality, we resurveyed all belt transects to identify which of the permanently tagged trees >1.4 m tall were still alive. We compared the total number of live, tagged trees to the total number of dead, tagged trees, both cumulatively and at the end of each time-step. We identified all potential mortality-influencing conditions, including blister rust, mountain pine beetle, fire, and others. In addition, we evaluated the change in distribution of DBH size classes in whitebark pine populations as a result of mortality.

We used a combined ratio estimator to calculate the proportion of mortality for overall mortality across the GYE at the end of 2015 and between Time 2 and Time 3. Strata with low sample sizes were combined so that there were at least two transects within each stratum (e.g., sites within an Administrative Unit inside or outside of the Grizzly Bear Recovery Zone were aggregated by Administrative Unit if a stratum had only one transect).

Objective 4

Document the recruitment of understory whitebark pine into the reproductive population and assess the multiple factors that influence regeneration and recruitment success overtime.

To investigate the proportion of live, reproducing tagged trees, we divided the total number of positively identified live, cone-bearing trees by the total number of live trees remaining in the tagged tree sample at the end of each revisit time-step. To approximate the average density of recruitment trees per stand, we summed trees ≤1.4 m tall by stand (within the 500 m^2 transect area) and divided by the total number of stands. Some stands were precluded from the ≤1.4 m tall survey due to lingering snow cover. Where there were two belt transects per stand (26 cases), we averaged the count of small trees over the two belt transects for one stand total. We did not report the average small tree count for Time 1; these data were unreliable because the trees were originally counted regardless of partial snow cover in this time period.

Whitebark pine survey crew in 2016 with the Madison Range, Custer Gallatin National Forest, in the background. Photo NPS/ERIN SHANAHAN

Results

The following results are based on data collected by the monitoring program in Time 1, Time 2, and Time 3. Comparisons between time-steps are dependent upon the objective being addressed.

Objective 1: Blister Rust Infection Proportions

We estimated the proportion of live trees infected with white pine blister rust in the Greater Yellowstone Ecosystem (GYE) (Table 2):

- Infected proportion in Time 1 was 0.21 (0.03 SE)
- Infected proportion in Time 2 was 0.21 (0.02 SE)
- Infected proportion in Time 3 was 0.19 (0.03 SE)

There was no significant change in the proportion of trees infected in the GYE between the three time-steps. We conclude that the overall proportion of whitebark pine trees infected with blister rust at the end of Time 3 (2015) remains in the range of 0.13 to 0.25 (SE 0.03) in the GYE (Table 2 and Figure 4).

Fifty-two percent (72) of stands exhibited a decrease in the proportion of trees infected from Time 2 to Time 3, 25% (34) of stands showed an increase, and 23% (32) remained unchanged. Overall, we estimated a 7% decrease in the mean percentage of trees infected with blister rust within a stand from Time 2 to Time 3 (n = 138, Wilcoxon Signed Rank Test). Figure 5 reflects the changes in the proportion of trees infected with blister rust at the stand level.

Table 2. Design-based ratio estimates for the proportion of trees infected with blister rust in the Greater Yellowstone Ecosystem. Transects without any live, tagged trees are excluded from this analysis; therefore, the number of transects decreased with each consecutive time-step.

					Combined ratio estimates		
Time-Step	No. of transects	No. of stands	No. of live trees	Proportion of transects infected	Proportion of live trees infected	Standard Error (SE) for proportion of live trees infected	Confidence Interval (CI) for proportion of live trees infected
2004–2007 [T1]	176	150	4746	0.81	0.21	0.03	[0.14, 0.27]
2008–2011 [T2]	172	146	4210	0.84	0.21	0.02	[0.16, 0.26]
2012–2015 [T3]	162	138	3689	0.79	0.19	0.03	[0.13, 0.25]

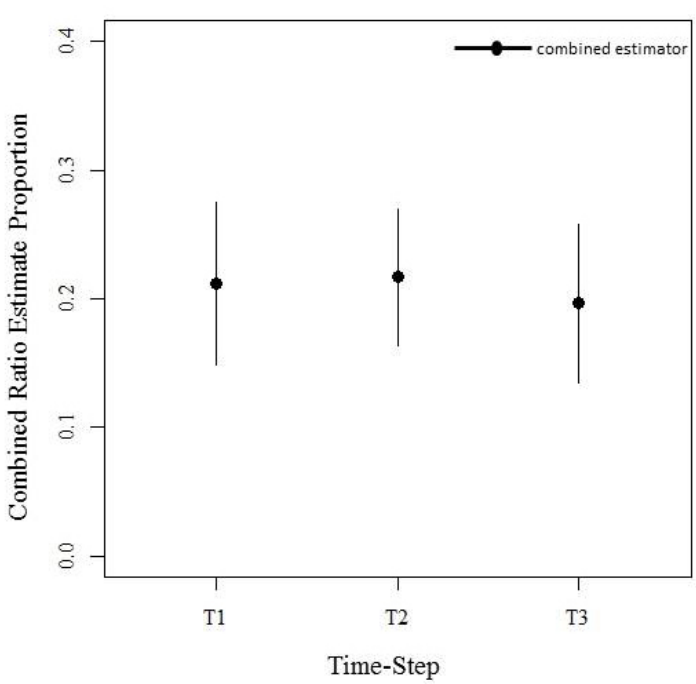


Figure 4. Trends in the proportion of trees infected with blister rust in the Greater Yellowstone Ecosystem, based on combined ratio estimates for each of three time-steps. T1 = 2004–2007, T2 = 2008–-2011, T3 = 2012–2015.

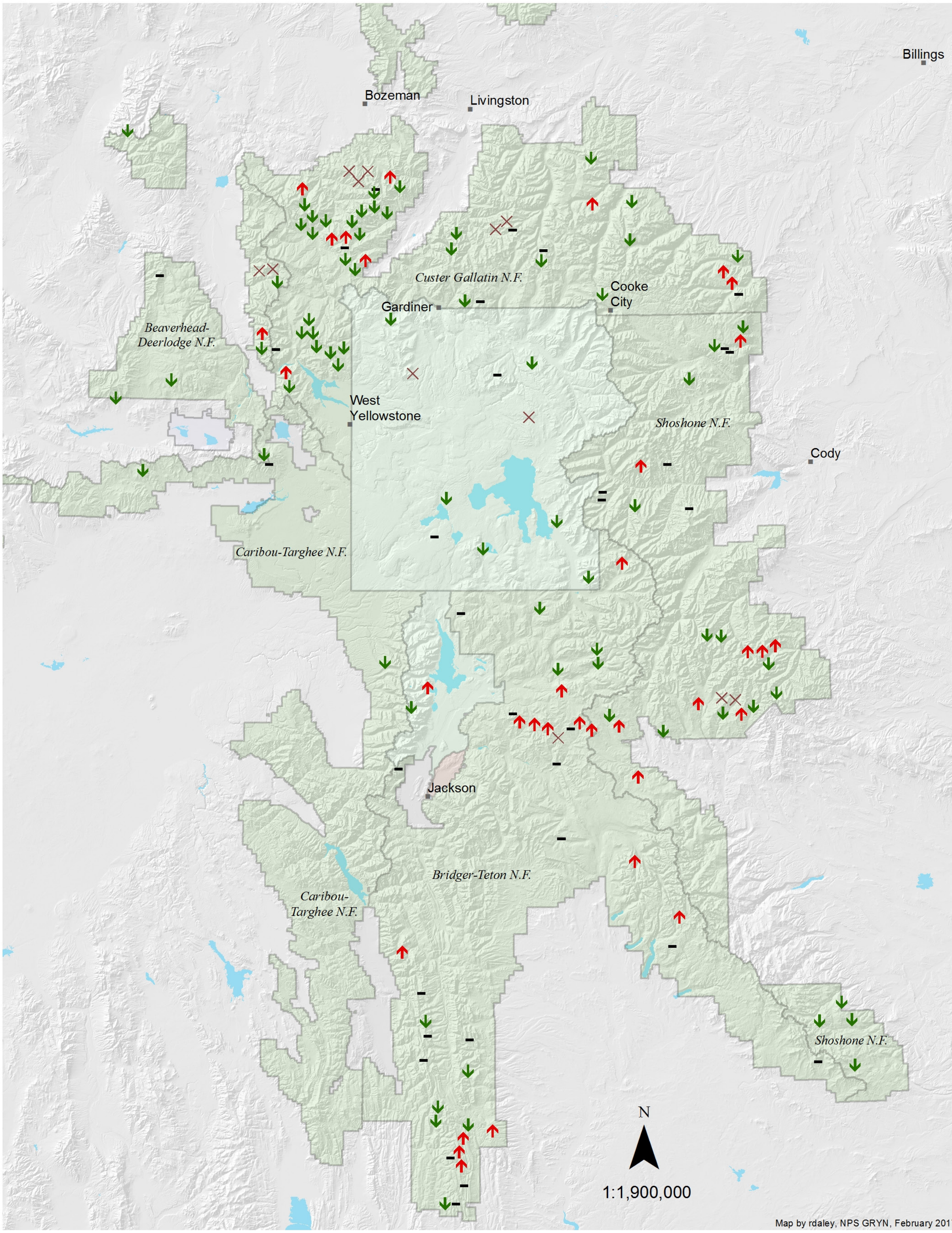


Figure 5. Change in the proportion of whitebark pine trees infected with blister rust within each of the stands with remaining live, tagged trees between Time 2 and Time 3 in the Greater Yellowstone Ecosystem. Twenty-five percent of stands (34 total stands) had increased infection (↑) , 52% of stands (72 total stands) had a decrease in infection (↓), and 23% of stands (32 total stands) "-" had no change in infection.

Whitebark pine forests have experienced many dynamic changes over the past decade. To properly represent these changes, we calculated the combined ratio estimator using three additional data subset scenarios. Each scenario corresponds to an alternative outcome had mortality not occurred at such a substantial degree (Subset 3, 4) and/or new trees not been added to the sample (Subset 2, 3) between 2008 and 2015 (Table 3). We recognized that all four of these scenarios may have influenced our reported overall estimate for blister rust infection in the GYE, and we therefore undertook further analysis to investigate this potential bias. Data Subset 1 reflects the current, on-the-ground conditions of the monitoring transects, where dead trees have been removed from the sample and newly tagged trees have been added to the sample.

We found no significant difference in the proportion of trees infected with blister rust using a combined ratio estimator under four different scenarios that included or excluded known tagged dead or newly tagged trees (Table 4). All estimates were within 4% of each other and fell well within the current 14% to 26% estimated infection rate within the GYE (excluding the standard error).

Objective 2: Blister Rust Infection Severity

At the end of Time 3, we found that 25% (942 trees) of the live, tagged trees (3,716) were infected with blister rust. This included eight newly tagged trees documented with blister rust infections. In addition, we documented whether blister rust cankers occurred in the canopy or on the bole. A bole infection is considered more consequential than a canopy canker as it compromises not only the overall longevity of the tree, but its functional capacity for reproductive output as well (Kendall and Arno 1990; Campbell and Antos 2000; McDonald and Hoff 2001; Schwandt and Kegley 2004). Trees with infections only in the canopy made up approximately 37% (343 trees) of the total number of trees infected with blister rust at the end of Time 3. Trees with bole cankers comprised 63% (599 trees; this included trees with combination bole and canopy cankers) of the infected sample. Of the documented reproducing trees (963), 43% (411) were infected with blister rust.

Infection Status and Transition—Time 1 to Time 3 and Time 2 to Time 3

Long-term monitoring tracks infection status and severity (i.e., location on the tree) through time for all live, tagged whitebark pine trees. Among the possible changes in infections status, only the change from Uninfected ➜ Infected declined substantially during Time 2 ➜ Time 3 (Table 5). It should be noted that the Time 1 to Time 3 comparison does not take into account any infection status change that may have occurred within Time 2.

In addition to the overall proportion of infection, we chronicled if and when infection location changed or transitioned in the canopy and bole of infected trees between time-steps. As with infection status, infection location can stay the same (canopy ➜ canopy or bole ➜ bole) or transition (canopy ➜ bole or bole ➜ canopy) over the time-step period. Again, we assigned trees infected with both canopy and bole cankers to the bole canker category for this analysis. Not surprisingly, we found that over a longer time interval of four to eleven years, as expressed in the Time 1 to Time 3 comparison, 60% of canopy cankers transitioned to the bole (Table 6). In addition, we found that once an infection occurs in the bole, the likelihood of it transitioning back to a canopy canker is low (Table 6).

Table 3. Description of data inclusions and exclusions for each of the four data subset scenarios used to calculate the proportion of whitebark pine trees infected with blister rust in the Greater Yellowstone Ecosystem.

Ratio estimator data subset scenarios	Dead tagged trees in Time 2 and Time 3	Newly tagged trees in Time 2 and Time 3
Subset 1*	Excluded	Included
Subset 2	Excluded	Excluded
Subset 3	Included	Excluded
Subset 4	Included	Included

*Subset 1 was used to calculate and report on the current status of blister rust in the Greater Yellowstone Ecosystem.

Table 4. Estimated proportion of whitebark pine trees infected with blister rust in the Greater Yellowstone Ecosystem in Time 2 and Time 3 using a combined ratio estimator for the four possible data subset scenarios.

Time	Subset	Estimate	SE
Time 2	*Subset 1**	0.22	0.03
	Subset 2	0.23	0.03
	Subset 3	0.24	0.03
	Subset 4	0.22	0.03
Time 3	*Subset 1**	0.20	0.03
	Subset 2	0.22	0.03
	Subset 3	0.22	0.03
	Subset 4	0.20	0.03

*Subset 1 was used to calculate and report on the current status of blister rust in the Greater Yellowstone Ecosystem.

Table 5. Infection status and change in infection status between time-steps for tagged whitebark pine trees in the Greater Yellowstone Ecosystem. "n" represents the number of tagged trees that remained alive between the time-step comparisons. Due to the random panel assignment following transect establishment in Time 1, resurvey for individual trees varied by time-step. The interval for individual tree resurvey was anywhere from one to four years for the Time 1 to Time 2 comparison, five to twelve years for the Time 1 to Time 3 comparison, and four years for the Time 2 to Time 3 comparison.

Infection status	Time 1 → Time2 (n = 3,795)	Time 1 → Time3 (n = 3,270)	Time 2 → Time3 (n = 3,554)
Uninfected → Uninfected	64% (2,418)	66% (2,169)	69% (2,435)
Uninfected → Infected	11% (423)	10% (343)	4% (150)
Infected → Infected	21% (780)	18% (574)	22% (784)
Infected → Uninfected	6% (174)	6% (184)	5% (185)

Table 6. Infection location and change in infection location between time steps. "n" represents the number of tagged trees that remained alive and infected between the time-step comparisons. Due to the random panel assignment following transect establishment in Time 1, resurvey for individual trees varied by time-step. The interval for individual tree resurvey was anywhere from one to four years for the Time 1 to Time 2 comparison, five to twelve years for the Time 1 to Time 3 comparison, and four years for the Time 2 to Time 3 comparison

Infection location	Time 1 → Time2 (n = 613)	Time 1 → Time3 (n = 574)	Time 2 → Time3 (n = 784)
Canopy → Canopy	36% (245)	27% (157)	30% (237)
Canopy → Bole	32% (235)	60% (237)	12% (98)
Bole → Bole	30% (280)	28% (163)	53% (416)
Bole → Canopy	2% (20)	9% (17)	4% (33)

Objective 3: Whitebark Pine Mortality

We estimated the proportion of dead whitebark pine trees across all size classes to be 0.26 in the GYE (0.03 SE) by the end of Time 3, using a combined ratio estimator. Documented mortality of trees decreased in Time 3 to a rate of 0.09 (0.02 SE) compared to the 0.17 (0.03 SE) mortality recorded during Time 2 (Figure 6). These estimates were derived from the total number of live, tagged trees starting at the beginning of each time-step.

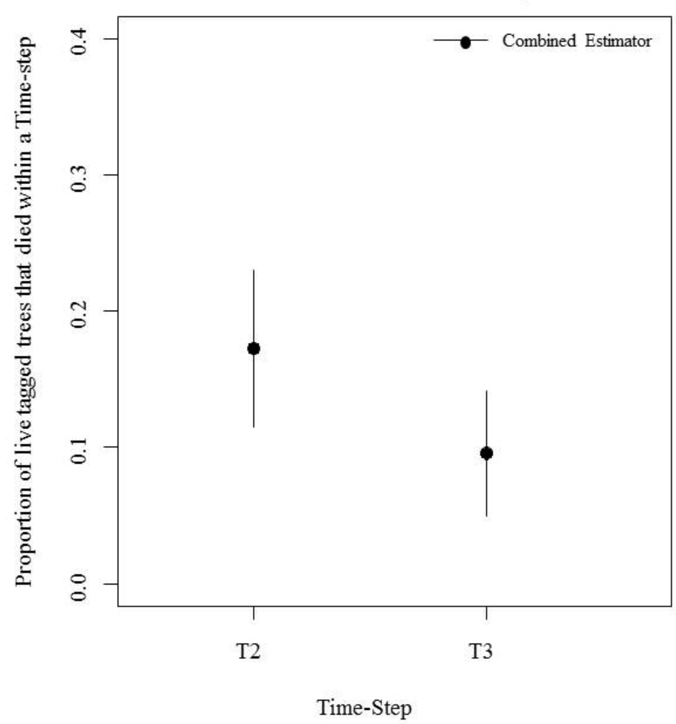


Figure 6. Estimated mortality of whitebark pine trees greater than 1.4 m tall in the Greater Yellowstone Ecosystem, using a combined ratio estimator comparing Time 2 and Time 3. The total number of live trees was different at the beginning of each time-step (T2≈ 4,700, T3≈ 4,000); therefore, these estimates are distinct for each four-year period, rather than cumulative.

By the end of Time 3, 29% (1,502) of the tagged trees had died; 99% of the dead trees were from the original live, tagged trees cohort in Time 1. Approximately 32% (481) of the dead trees showed evidence of mountain pine beetle infestation only. The majority (902) of trees killed with evidence of mountain pine beetle were within the >10 to 30 cm DBH size class. Blister rust was the only associated factor for 14% (203) of the dead trees. Dead trees with sign of blister rust varied in size class but were predominantly in the >2.5 cm to 10 cm size class range. A total of 8% (121) of dead trees were documented with only fire scars. The remaining 46% (697) of trees died with evidence of a combination of factors, such as fire, mountain pine beetle, or blister rust, or with other factors such as structural or animal damage (Figure 7).

Live, Tagged Tree Distribution History

With the mortality following the mountain pine beetle outbreak and other factors, we documented a shift in the size class distribution for the live, tagged tree cohort to smaller DBH trees (Figure 8; Shanahan et al. 2016).

We have observed a shift to smaller size classes of trees among the three time-steps (Table 7). The mean tree DBH has decreased from 13.22 cm in Time 1 to 9.09 cm in Time 3 (Table 7; Shanahan et al. 2016).

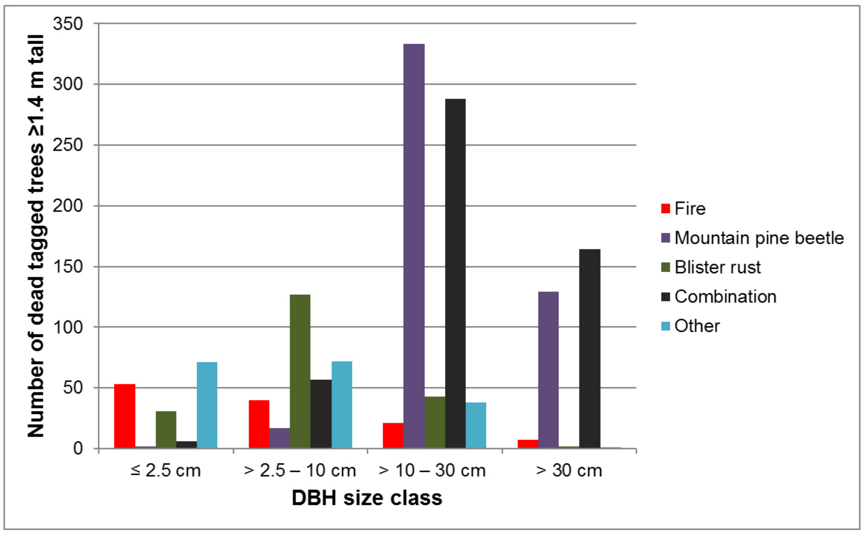


Figure 7. Cumulative mortality of tagged whitebark pine trees in the Greater Yellowstone Ecosystem from 2008 through the end of Time 3 (2015) by DBH size class and by indicators: fire, mountain pine beetle, blister rust, or other (i.e., wind throw, animal damage). The "combination" category refers to the simultaneous occurrence on a given dead tree of two or more of the three main indicators: mountain pine beetle, blister rust, and fire.

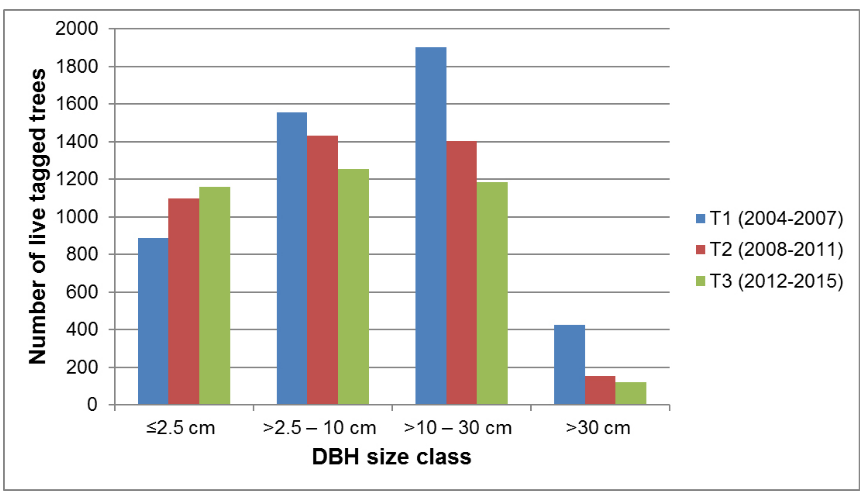


Figure 8. Size class distribution for live, tagged trees over the course of the 12-year whitebark pine monitoring program in the Greater Yellowstone Ecosystem.

Table 7. Summary statistics for Diameter at Breast Height (DBH; cm) values for all live, tagged whitebark pine trees monitored in the Greater Yellowstone Ecosystem for each time-step.

Time-Step	Min	1st Quartile	Median	Mean	3rd Quartile	Max
T1	1	4	10	13.22	19.5	126.5
T2	1	3	8	10.77	15.5	95
T3	1	2	6.5	9.09	13	95

Objective 4: Whitebark Pine Recruitment

We assessed recruitment by tracking the number of new whitebark pine trees added to the tagged tree sample, the number of cone-producing trees, and by recording seedlings and saplings in the understory. In Time 3, an additional 160 trees were tagged that grew to >1.4 m tall since Time 2. This brought the total count of newly tagged trees added since initial transect establishment to 447 (including the 287 trees that were added in Time 2).

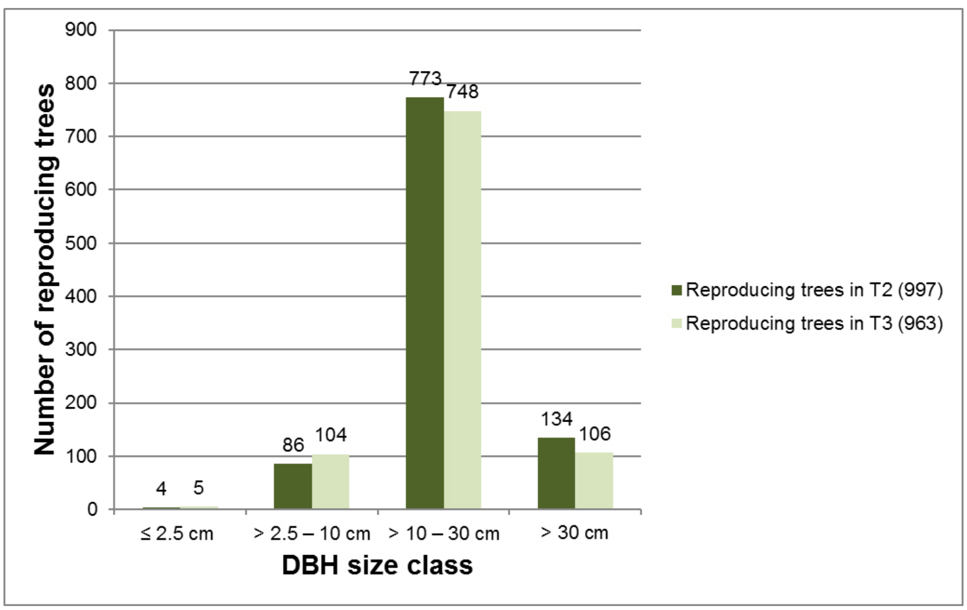
Cone-Producing Trees

Known reproducing trees made up approximately 26% (963 trees) of the total live, tagged trees at the end of Time 3 (Figure 9). In Time 2, 997 trees were recorded as reproducing. We report this as a conservative estimate because we recognize that due to the panel revisit schedule, this metric may not be observed if the panel that a tree is assigned is not visited while a tree is exhibiting signs of reproduction. Although we documented reproduction across all four size classes, the smaller-DBH trees usually did not produce as many cones. These typically younger trees tended to have fewer canopy branches and less overall canopy volume compared to their larger-DBH counterparts. A total of 74% (2,753) had no observable signs of cone scars, cones, or conelets. Of the reproducing trees, 43% (411) had blister rust infections with 54% (220) of these infections located on the bole. One hundred and fifty-four (16%) reproducing trees had sign of mountain pine beetle.

Understory Seedlings and Saplings

Differentiating between whitebark pine and limber pine (Pinus flexilis) seedlings or saplings is problematic given the absence of cones or cone scars. Therefore, understory summaries in this report may include individuals of both species when they are sympatric in a stand. In Time 3, the density of trees ≤1.4 m tall averaged 51 understory trees per 500 m^2, which was similar to the density reported for Time 2, of 53 per 500 m^2. Raw counts of these understory individuals ranged from 0 to 521 small trees per belt transect (Figure 10). We documented <1% (80) of these small trees as having some level of blister rust infection.

Figure 9. Number of live, reproducing, tagged whitebark pine trees in the Greater Yellowstone Ecosystem in Time 2 (997) compared to the number in Time 3 (963), differentiated by DBH size class.



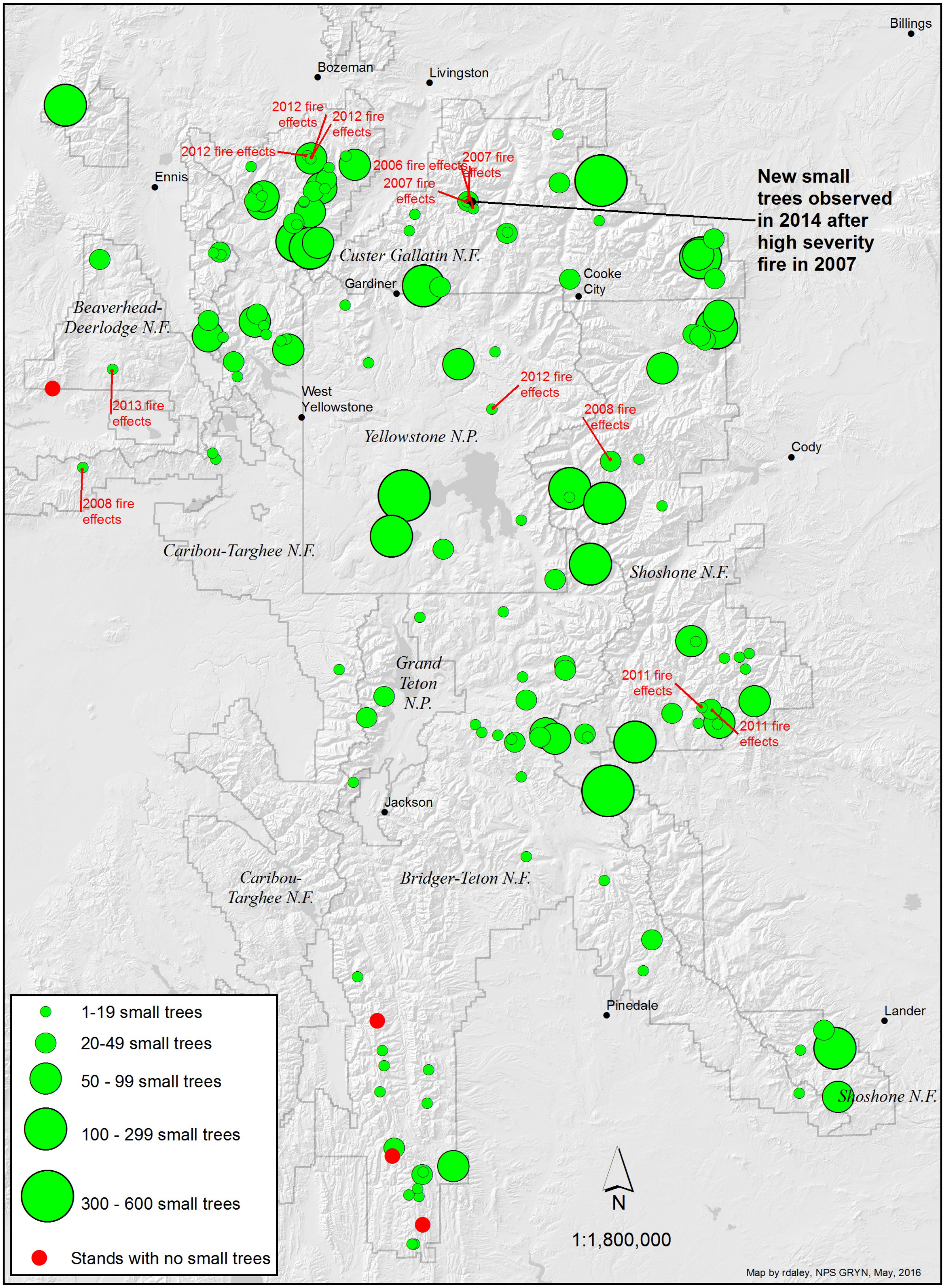


Figure 10. Average count of whitebark pine trees (per 500 m^2) less than 1.4 m tall in stands monitored from 2004 through 2015 in the Greater Yellowstone Ecosystem.

Discussion

Blister Rust Infection Proportions

The estimated proportion of whitebark pine trees infected with blister rust in the Greater Yellowstone Ecosystem (GYE) was similar across all three time-steps (2004–2007, 2008–2011, 2012–2015). The overall percentage of whitebark pine trees >1.4 m tall that were infected with blister rust in the GYE continues to range between 14% and 26%. While variation (increases and decreases) in blister rust infection occurred across the monitoring transects and resulted in shifts in the proportion of trees infected for the majority (77%) of stands, we detected no significant difference in the overall blister rust infection rate among the time-steps. We recognized that the mortality that occurred over the course of the three time-steps had the potential to impact our reported estimate of the proportion of trees infected with blister rust in the GYE. To address this concern, we calculated estimates for three alternative scenarios of exclusion and inclusion, described in Table 3, in addition to the estimate conveyed in this report. Results from these three scenarios demonstrate that the death of 29% (1,502) of the originally tagged trees did not affect the rate of infection in the GYE, nor did the addition of 447, predominantly uninfected new trees. The greatest difference between any of the scenarios presented in Tables 3 and 4 was no greater than 4% and not statistically significant. Trees with or without blister rust showed evidence of mountain pine beetle (Shanahan et al. 2016) and fire in relatively equal numbers.

Blister Rust Infection Severity

While we did not observe a discernable change in the proportion of trees infected with blister rust in the GYE, we documented infection transitioning from canopy to bole. This kind of transition may be a potentially more informative indicator of individual tree health and the overall population trajectory with regard to the impacts of blister rust infection. By the end of Time 2, 58% (698 of 1,203) of infected tagged trees were infected in the bole (Shanahan et al. 2014), compared to approximately 63% (599 of 942) of bole infected trees at the end of Time 3. Over the 12-year monitoring period, 60% (237) of the trees that remained alive and infected transitioned from a less lethal (canopy) form of infection to one considered more detrimental (bole) to the health status of the tree. Cones are produced on the outer branches in the upper canopy of whitebark pine; portions of a branch that are distal to an active canker are often precluded from vital nutrients necessary to sustain normal tree function, healthy foliage, and cone production (Maloney et al. 2012). As a result, death of infected upper branches can occur and negatively impact cone production. Maintaining our long-term monitoring program and adhering to the panel revisit schedule will allow us to investigate the dynamic nature of infection transition. Continued evaluation of this metric is a more informative indicator of individual tree health. It will also enable us to better predict the overall whitebark pine population trajectory as it relates to the persistent impacts of blister rust infection.

Whitebark Pine Mortality

Mortality of whitebark pine occurred across all DBH size classes. By the end of Time 3, we estimated the proportion of whitebark pine >1.4 m tall in the GYE that had died since Time 1 to be 0.26 (0.03 SE). While mortality of tagged trees continued in Time 3, it occurred at a reduced rate of 9%, compared to the mortality of tagged trees documented in Time 2 (17%; Figure 6). While we continued to record dead trees with signs of mountain pine beetle in Time 3, we suspect that many of these trees were likely attacked during Time 2 but not recorded as dead until two years later when they were revisited according to their panel schedule (Figures 3 and 7). Very few new or active mountain pine beetle attacks were observed on the monitoring transects during Time 3. Blister rust was the sole attribute in 14% of the total number of dead, tagged trees by the end of Time 3.

Along with mountain pine beetle and blister rust, whitebark pine stands have also been affected by wildland fires across the ecosystem. Fire-influenced mortality increased two-fold during Time 3, from a total of 6 burned stands in Time 2 to 14 in Time 3. The majority of these fire events were stand replacing, where all trees within the fire perimeter were killed. A cumulative total of 254 dead, tagged trees were documented as fire affected. Under projected climate change conditions, wildland fire events are predicted to increase in the GYE (Westerling et al. 2011). Consequently, we expect an increase in the number of stands affected by fire into the future.

Over the course of the monitoring program, a distinct shift in the size class distribution of live, tagged trees was evident (Figure 8 and Table 7). The initially tagged sample had almost equal numbers of trees ≤10 cm DBH and trees >10 cm DBH. The ensuing mortality since establishment resulted in a shift to smaller size classes (≤10 cm DBH) and potentially fewer cone-bearing trees in the GYE (Figure 9). Given that blister rust is thought to be more detrimental to smaller trees (Tomback et al. 1995), this finding suggests that, in the coming decades, blister rust may become the most probable cause of whitebark pine mortality in the GYE (Shanahan et al. 2016).

Whitebark Pine Recruitment

Although approximately 29% (1,502) of the tagged trees have died, we observed reproducing trees, regeneration in the understory, and recruitment on the majority of monitoring transects. We documented 26% (963) of the live, tagged trees as cone producing. Regeneration varies dramatically across the 176 belt transects. Counts of whitebark pine trees ≤1.4 m tall ranged from 0 to 521 trees per 500 m^2 belt transect (Figure 10). Our estimates suggest that there were 51 five-needle pines ≤1.4 m tall per 0.04 ha. In addition, by the end of Time 3, we tagged an additional 447 new trees within the belt transects that had grown into the >1.4 m tall height category.

Interactions between Factors Influencing Mortality

In addition to our annual and trend reports, we recently published a study (Shanahan et al. 2016) that analyzed the associations between observed mortality in relation to tree-level variables, including duration and location of blister rust, mountain pine beetle, tree size, potential interactions between tree size, blister rust, and mountain pine beetle, and water availability. In this study, tree and disease variables were linked to stand level estimates of water availability, calculated with gridded climate data and a water balance model that accounts for sub grid cell variations in slope, aspect and soil water holding capacity. Our findings describe how warming temperatures from 2006 to 2008 that likely released temperature constraints on beetle development (Shanahan et al. 2016) contributed to the mountain pine beetle outbreak that caused extensive mortality described in this study. We demonstrated that larger DBH whitebark pine were preferentially attacked and subsequently killed by mountain pine beetle, which resulted in a regionwide shift to smaller DBH trees (Figure 8 of this trend report; Shanahan et al. 2016). When infected with blister rust, these smaller DBH trees experience higher mortality than their larger infected cohorts do. We found no evidence for an interactive effect between blister rust and mountain pine beetle on whitebark pine mortality (see Shanahan et al. 2016, page 9, Figure 3). This interactive effect had been previously suggested by other studies of whitebark pine in the GYE (Bockino and Tinker 2012; Dooley and Six 2015). We also observed that greater water availability positively influenced survival in trees attacked by mountain pine beetle (see Shanahan et al. 2016, page 11, Figure 4), improving the tree's ability to pitch out beetles by strengthening its resin response. These conclusions suggest that preferential planting in locations that have higher water availability and lower relative humidity (less conducive to the spread of blister rust) may confer a survival advantage in the face of a warmer and drier future. With continued monitoring, we expand our understanding of whitebark pine survival and mortality as it relates to pathogens, insect outbreaks, and climatic effects. This information improves our overall understanding of the biophysical influences on whitebark pine with the purpose of advancing conservation efforts in the GYE.

Conclusions

Throughout the past decade in the GYE, monitoring has helped document shifts in whitebark pine forests as they have been impacted by insect, pathogen, wildland fire, and other events. Blister rust infection is ubiquitous but spatially variable in the ecosystem and infection proportions are variable across the region (Figure 11). The proportion of whitebark pine trees >1.4 m tall that died across the GYE at the end of Time 3 was 0.26 (0.03 SE). It is important to note that estimates presented here reflect data collected from ground-based monitoring efforts that assess mortality status across all size (height and DBH) classes as opposed to other studies that report higher estimates of mortality based on aerial and remote sensing detection that focus exclusively on canopy occupying trees (Logan et al. 2010; McFarlane et al. 2013).

Mortality of overstory cohorts in many stands throughout the GYE has prompted considerable interest and emphasized the need for investigating the growth of the whitebark pine understory. An effort to track this metric was piloted over the course of Time 3. As we initiate the fourth time-step, we will begin collecting data to accurately assess recruitment of small trees into the >1.4 m height category using nested plots within the 10 × 50 m permanent transects.

The monitoring program continues to impart meaningful information to the broader regional assessment of trends in the health and status of whitebark pine. The monitoring program acts as an important resource for a variety of organizations embarking on five-needle pine monitoring. It has provided contemporary data both regionally and on a landscape level where other populations of whitebark pine persist. Data from the program have been used by multiple organizations and private entities:

- local US Forest Service and Bureau of Land Management districts have used the data to assess the "wilderness character" of surrounding public land
- the U.S. Geological Survey Interagency Grizzly Bear Study Team have included the data as part of their food synthesis report (Interagency Grizzly Bear Study Team 2013)
- the program provides science-based data to the U.S. Fish and Wildlife Service in their listing consideration for whitebark pine under the Endangered Species Act, including annual updates to population health (USFWS 2011)
- the data are used for baseline infection status and other health metrics for the Whitebark Pine Strategy for the GYE (GYCCWPS 2011)
- the program fulfills numerous data requests for other investigations on whitebark pine health, many of which have been related to climate change (Chang et al. 2014; Buermeyer et al. 2016; Hansen et al. 2016)

We provide this second step-trend report to improve understanding of the state of whitebark pine in the GYE. Many aspects of whitebark pine health are highly variable across the range of its distribution in the GYE. Through sustained implementation of the monitoring program, we will continue efforts to document and quantify whitebark pine forest dynamics as they arise under periodic upsurges in insect, pathogen, fire episodes, and other climatic events in the GYE. Since its inception, this monitoring program perseveres as one of the only sustained long-term efforts conducted in the GYE with the singular purpose to track the health and status of this prominent keystone species.

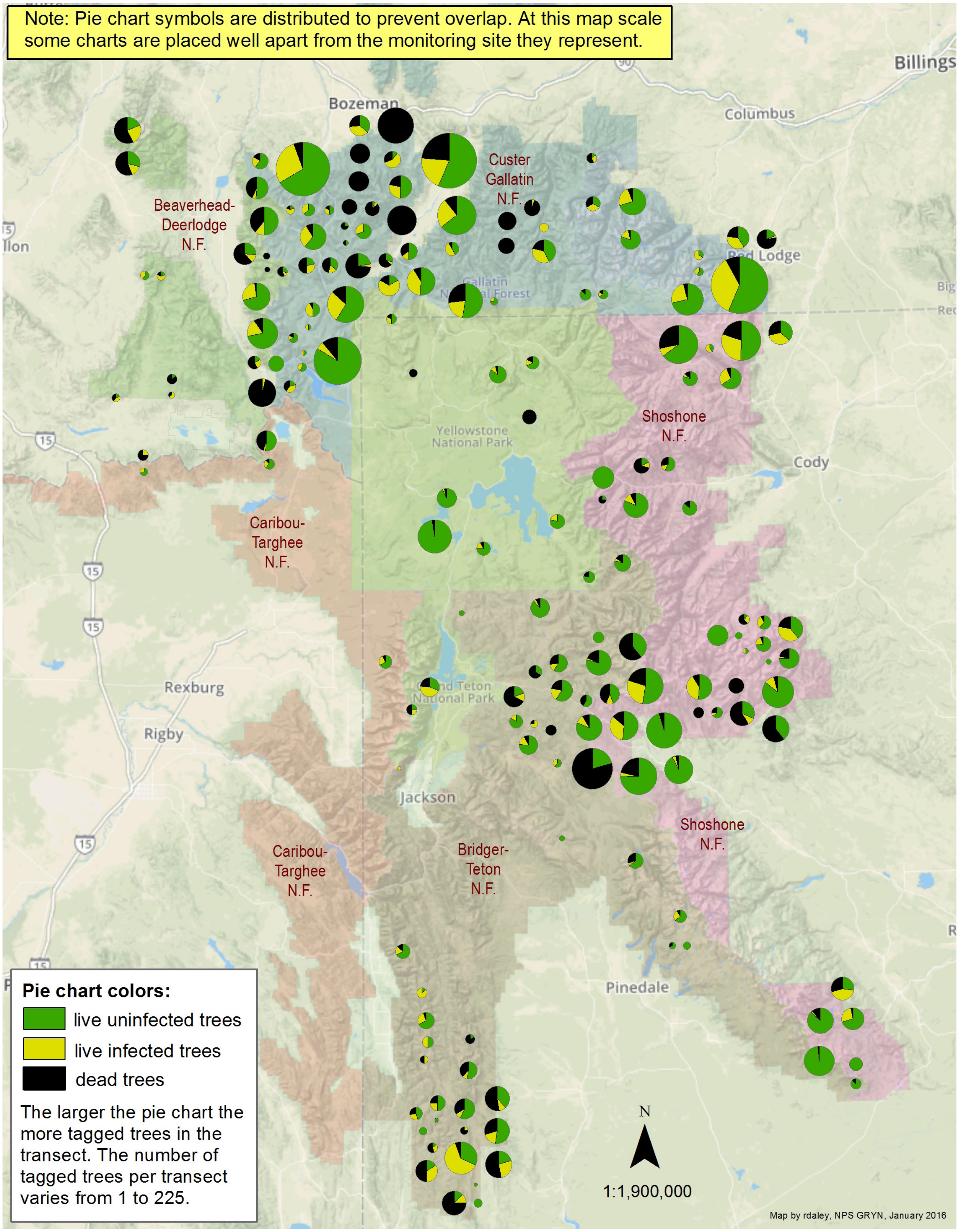


Figure 11. Distribution of blister rust-infected whitebark pine trees in sampled transects in the Greater Yellowstone Ecosystem at the end of 2015.

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 101/138263, 136/138263, May 2017

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Appendix D

2016 Wyoming Bear Wise Wyoming Project Update

Introduction

The Bear Wise Community Program is a proactive initiative that seeks to minimize human-bear (American black bear and grizzly bear) conflicts, minimize management-related bear mortalities associated with preventable conflicts, and to safeguard human communities in northwest Wyoming. The overall objective of Bear Wise is to promote individual and community ownership of ever-increasing human-bear conflict issues, moving toward creating a social conscience regarding responsible attractant management and behavior in bear habitat. This project seeks to raise awareness and proactively influence local waste management infrastructures with the specific intent of preventing conflicts from recurring. Strategies used to meet the campaign's objectives are: 1) minimize accessibility of unnatural attractants to bears in developed areas; 2) use public outreach and education campaigns to reduce knowledge gaps about bears and the causes of conflicts; and 3) implement bear-resistant waste management systems and promote bear-resistant waste management infrastructure.

This report provides a summary of program accomplishments in 2016. Past accomplishments are reported in the 2006–2015 annual reports of the Interagency Grizzly Bear Study Team (IGBST) and in the 2011–2015 Annual Job Completion Reports of the Wyoming Game and Fish Department (WGFD or Department).

Background

In 2004, a subcommittee of the IGBST conducted an analysis of causes and spatial distribution of grizzly bear mortalities and conflicts in the Greater Yellowstone Area (GYA) for the period of 1994–2003. The analysis identified that the majority of known, human-caused grizzly bear mortalities occurred due to agency management actions in response to conflicts (34%); self defense killings, primarily by big game hunters (20%); and vandal killings (11%). The report made 33 recommendations to reduce human-grizzly bear conflicts and mortalities with focus on 3 actions that could be positively influenced by agency resources and personnel: 1) reduce conflicts at developed sites; 2) reduce self-defense killings; and 3) reduce malicious killings (Servheen et al. 2004).

To address action number 1, the committee recommended that a demonstration area be established to focus proactive, innovative, and enhanced management strategies where developed site conflicts and agency management actions resulting in relocation or removal of grizzly bears had historically been high. Spatial examination of conflicts identified the Wapiti area in northwest Wyoming as having one of the highest concentrations of black bear and grizzly bear conflicts in the GYA. The North Fork of the Shoshone River west of Cody was then chosen as the first area composed primarily of private land to have a multi-agency-public approach to reducing conflicts at developed sites.

In 2005, the Department began implementation of the Bear Wise Community Program. Although the program's efforts were focused primarily in the Wapiti area, the Department initiated a smaller scale project in Teton County to address the increasing number of black and grizzly bear conflicts in the Jackson area. For the last 11 years, the Bear Wise Community Programs in Northwest Wyoming have deployed a multi-faceted education and outreach campaign in an effort to minimize human-bear conflicts and promote proper attractant management. Although a wide array of challenges remain and vary between communities, many accomplishments have been made and progress is expected to continue as Bear Wise efforts gain momentum. In an effort to broaden the scope of the program, this work was rebranded as the Bear Wise Wyoming Program.

Wapiti Project Update

The Wapiti Bear Wise Community Program continues to use radio, television and print media, mass mailings, and the use of signage on private and public land to convey the educational messages surrounding human-bear conflict prevention. Conflict prevention information is also disseminated through public workshops and presentations and by contact with local community groups, governments, the public school system, and various youth organizations. To compliment educational initiatives, the program uses an extensive outreach campaign that assists the community in obtaining and using bear-resistant products and implementing other practical methods of attractant management. Ongoing efforts and new accomplishments for 2016 are as follows.

The Carcass Management Program continues to provide a domestic livestock carcass removal service for livestock producers located in occupied grizzly bear habitat within Park County, Wyoming. The program has been traditionally funded by the Park County Predator Management District and Wyoming Animal Damage Management Board. In addition to those donors, the program received contributions from Park County Commissioners, Wyoming Outdoorsmen, and the Memorial Bear Fund. The program provides livestock producers and owners with an alternative to the use of on-site carcass dumps, which are a significant bear attractant and indirectly contribute to numerous human-bear conflicts. Since June 2008, 852 domestic livestock carcasses have been removed from private lands.

Recommendations concerning the proper storage of garbage and other attractants are provided to the Park County Planning and Zoning Commission for new developments within the greater Cody area. The Coordinator reviews proposed developments on a case-by-case basis, attends monthly meetings, and contacts applicants directly to discuss conflict prevention measures. To date, these comments have been adopted as either formal recommendations or as a condition of approval for 21 new developments within Park County.

This year, with grants from the Wyoming Outdoorsmen, Bow Hunters of Wyoming, and Yellowstone Country Bear Hunters Association, the Department was able to purchase 100 cans of bear spray for distribution to sportsmen. The bear spray was handed out at the Cody Wyoming Game and Fish Check Station and all cans were distributed in under an hour. Sportsmen where asked to voluntarily fill out a short survey to gather a better understanding how the Bear Wise program can better meet constituent needs.

Dusty Lasseter of the Wyoming Game and Fish Department hands out surveys to evaluate the Bear Wise program and bear awareness in the community during the bear spray giveaway.

- The Wyoming Game and Fish partnership with the North Fork Bear Wise Group (NFBWG) continues to grow. The group is comprised of 6 local Wapiti citizens that meet monthly to articulate community needs and assist in the development of educational and outreach initiatives. The group met once a month for 6 month (during active bear season) and were instrumental in developing ideas on how to reduce human-bear conflicts.

- Educational materials for identification of black bears and grizzly bears were distributed to individuals and to local sporting goods stores in the Cody, Pinedale, and Lander areas and mailed to black bear hunters who registered bait sites with the Department in areas surrounding the GYA.

- Numerous informational presentations were given that focused on human-bear conflict prevention to audiences including the Park, Fremont, Hot Springs, and Big Horn County public school systems, homeowners associations, Boy Scouts, 4-H members, DANO, Paint Rock Hunter Management Program, guest ranches, and college students. Frequent one-on-one contacts were made during the 2016 conflict season in areas where the occurrence of human-bear conflicts has historically been high.

- A “Working Safely in Bear Country” workshop was conducted for the Park County Weed and Pest District, Bureau of Land Management, Rocky Mountain Power, and Bighorn Forest Service employees.

- A booth containing information on bear identification, attractant storage, hunting and recreating safely in bear country, and the proper use of bear spray was staffed at the Lander Winter Fair, Cody Arbor Day, Cody RV Show, Dubois Museum Days, Powell Outdoor Safety Day, and Wyoming Outdoorsmen Banquet.

- By using the bear trailer, booths, workshops, and giving 50 presentations upon request, the Bear Wise program directly reached approximately 4,200 people in Northwest Wyoming. The level of interaction differed from person to person, this contributed to greater bear awareness and lessened conflicts.

- The Department gave two interpretative hikes up the Elk Fork River on the Shoshone National Forest to discuss the ecology, management and conservation of the Yellowstone grizzly bear for the annual Cody Chambers sponsored Spring Into Yellowstone. These tours were approximately 5 hours and considerable bear sign was identified on the tour.

- A public service announcement (PSA) was recorded by WGFD personnel on “Staying Safe in Bear Country” and broadcast over the radio in the spring and fall of 2016 on the Bighorn Basin Radio Network.

- In the Cody Region, Large Carnivore Section personnel erected 19 temporary electric fences around bee apiaries to reduce conflicts. There were also several electric fences temporarily placed around apple orchards to deter bears.

Walking the perimeter of an electric fence around a bee apiary, approximately 15 miles outside of the grizzly bear Demographic Monitoring Area.

- In the spring, Large Carnivore Section personnel held 13 “Living in Large Carnivore Country” workshops across Wyoming. The objective of these workshops is to reach out to the public and give them the opportunity to learn how to live with bears, mountain lions, and wolves. In 2016 we gave presentations and hands-on demonstrations to 267 attendees.

- A seasonal mailing containing human-bear conflict prevention information and the availability of conflict prevention resources was delivered to residents in targeted areas west of Cody.

The Bear Aware display at the Fremont County Library.

- A traveling Bear Aware educational display was developed and produced for use in public libraries across northwest Wyoming. The display focuses on the prevention of human-bear conflicts and features graphics, an interactive touch screen monitor, short video segments, a grizzly bear hide and skull, and educational materials that are available for check out. The display was featured at the Fremont County Library in Dubois for 5 months

- The Wyoming Department of Transportation donated 20 used paint barrels. These paint barrels are 55 gallons and with a locking lid can be used to secure attractants like livestock feed. These barrels will be given to landowners next year in order to give them the means to securely store attractants.

- Yellowstone Country Bear Hunters Association (YCBHA) received a grant to purchase 8 bear-resistant food storage boxes for campsites in occupied bear habitat. These food storage boxes were put on Game and Fish commission managed lands to prevent human-bear conflicts and provide campers with the means to securely store foods and other attractants. Department personnel volunteered time in-kind to properly place the food storage boxes.

Members of the Yellowstone Country Bear Hunters Association and Wyoming Game and Fish Department personnel installing bear-resistant food storage boxes outside of Dubois, Wyoming.

- All hunters that successfully drew an elk, deer, or antelope license were also provided with information about staying safe while hunting in bear country. The conflict prevention material was approximately 100,000 pieces that went out to hunters.

Pinedale Area Update

In 2011, a Bear Wise Community effort was initiated targeting residential areas north of Pinedale, where the occurrence of human-bear conflict has increased in recent years. Accomplishments for the Pinedale area in 2016 are as follows:

- The Department hosted multiple educational presentations, for example: a “Living in Lion, Bear, and Wolf Country” workshop in Pinedale. Approximately 35 people attended the workshop. Bear safety presentations were given to the Boy Scouts of America at “Camp Newfork”. Hunting in Bear Country presentations were given to hunter safety classes throughout the Region.
- A bear safety presentation was given to cowboys and sheepherders of 2 different grazing associations in the Region.
- A bear safety presentation was given to staff members of the Sublette County Chamber of Commerce and Sublette County Visitor’s Center.
- A bear safety presentation was given to the Pinedale and Big Piney Ranger Districts of the U.S. Forest Service and the Pinedale office of the Bureau of Land Management.

Bear spray education in Pinedale, Wyoming.

- A bear safety presentation was given to Sublette County Weed and pest workers and volunteers.

- The Department hosted a bear safety booth at Pinedale's Rendezvous Days Celebration, contacting hundreds of participants over a 3-day period. Pinedale's Rendezvous Days attracts approximately 10,000 people over the 4-day event and Department employees contacted an estimated 1,000 constituents.

- The Department participated in the first annual "Wind River Mountain Festival" in Pinedale. Over 2,000 people attended the festival. There was great interest in bear safety information presented throughout the festival.

- A bear safety presentation was given to Tronox employees in Green River.

- A large carnivore safety presentation was given to Tip Top Search and Rescue volunteers in Pinedale.

Objectives for 2017 include continued expansion of the program into the other areas of the state where human-bear conflicts continue to be a chronic issue and the continuation of current educational and outreach efforts in the Cody area with specific focus on areas that have not adopted proper attractant management methods. The Department is also working to assist the U.S. Forest Service with providing bear-proof storage and meatpoles at targeted areas in the Region.

The Wapiti and Pinedale area Bear Wise Community programs face the ongoing challenges of: 1) the absence of ordinances, regulations, or laws prohibiting the feeding of bears; 2) limited educational opportunities and contact with portions of the community due to a large number of summer-only residents and the lack of organized community groups and; 3) decreased public tolerance for grizzly bears due to record numbers of human-bear conflicts and continued federal legal protection. The future success of the Bear Wise program lies in continued community interest and individual participation in proper attractant management.

Jackson Hole Project Update

The Bear Wise Jackson Hole program continues educational and outreach initiatives in an effort to minimize human-bear conflicts within the community of Jackson and surrounding areas. In 2016, the program's public outreach and educational efforts included the use of signage; public workshops and presentations; distribution of informational pamphlets; promoting awareness about bear spray; carcass and fruit tree management; and using our bear education trailer.

- A bear education trailer was purchased in August 2010 with funding contributions from the Department, Grand Teton National Park, Bridger Teton National Forest, and Jackson Hole Wildlife Foundation. Two bear mounts (1 grizzly bear, 1 black bear) have been placed in the trailer along with other educational materials. The bear mounts were donated to the Department through a partnership with the U.S. Taxidermist Association and the Center for Wildlife Information. The trailer was displayed and staffed at various events and locations including Teton National Park, Jackson Elk Fest, Fourth of July Parade, and the National Elk Refuge Visitor Center.

- Public service announcements were broadcast on 4 local radio stations in Jackson for a total of 6 weeks throughout the spring, summer, and fall of 2016. The announcements focused on storing attractants so they are unavailable to bears and hunting safely in bear country.

- Numerous educational talks were presented to various groups including homeowner's associations, guest ranches, youth camps, Jackson residents, tourists, school groups, and Teton County employees.

- Door flyers with detailed information about attractant storage and bear conflict avoidance were distributed in Teton County residential areas where high levels of human-bear conflicts were occurring.

- A considerable amount of time was spent removing ungulate and livestock carcasses from residential areas and ranches in the Jackson Region.

- Worked with the residents at a north Jackson sub-division and a property management company to pick apples from 70 crab apple trees that were a significant bear attractant.

- Refrigerator magnets featuring tips about proper attractant management were distributed to Teton Village homeowners, Aspens Property Management, and Jackson Hole Mountain Resort lodging.

- Numerous personal contacts were made with private residents in Teton County. This has proven to be a useful way to establish working relationships with residents and maintain an exchange of information about bear activity in the area.

- A booth containing information on bear identification, attractant storage, hunting and recreating safely in bear country, and the proper use of bear spray was staffed at the Jackson Hole Antler Auction and Kids Fishing Day.

- Assisted hunting outfitters with the installation and maintenance of electric fence systems around their field camps located in the Bridger-Teton National Forest.

- Assisted Teton County Transfer Station staff with the installation and maintenance of an electric fence enclosure around their dead animal pit.

- Assisted an apiary owner with the installation and maintenance of an electric fence around his bee hives.

"Red Shirts in the Classroom" – talking with Jackson, Wyoming students about bear awareness.

- Assisted the Fish Division with the installation of 2 electric fences around their field camps at Brooks Lake.

- Signage detailing information on hunting safely in bear country, bear identification, recent bear activity, and proper attractant storage were placed at U.S. Forest Service trailheads and in private residential areas throughout Teton County.

- Consultations were conducted at multiple businesses and residences where recommendations were made regarding sanitation infrastructure and compliance with the Bear Conflict Mitigation and Prevention LDR.

- Bear Aware educational materials were distributed to campground hosts in the Caribou-Targhee National Forest, hunters, and numerous residents in Teton County.

- Several radio and newspaper interviews were conducted regarding conflict prevention in the Jackson area.

- Educational black bear-grizzly bear identification materials were distributed to black bear hunters who registered bait sites with the WGFD in the Jackson region.

- Worked with a Jackson sanitation company and the Jackson Hole Wildlife foundation on placing new bear-resistant garbage cans at Teton Village homes.

Objectives for the Bear Wise Jackson Hole program in 2017 will be focused on supporting Teton County and local waste management companies with projects that will help disseminate information and achieve compliance with the recently adopted Teton County Bear Conflict Mitigation and Prevention Land Development Regulations (LDR). In addition, more work will be done to identify areas within the city limits of Jackson and Star Valley communities where better attractant management and sanitation infrastructure is needed.

The recent implementation of the Teton County Bear Conflict Mitigation and Prevention LDR has greatly reduced the amount of available attractants on the landscape and is a tremendous step forward for the Bear Wise Jackson Hole program. The new challenges faced by the Department will be achieving full compliance with this regulation, even in years with low conflict when it may appear that conflict issues are resolved. The Bear Wise Jackson Hole Program will convey the importance of compliance and strive to maintain public support for the LDR through public outreach and education projects. In order for the Jackson program to be successful, the program must continually identify information and education needs within the community while being adaptive to changing situations across different geographic areas. This will require the Department to coordinate with other government agencies and local non-government organizations working across multiple jurisdictions to develop a uniform and consistent message. If this level of coordination is achieved, the Department will be more effective in gaining support and building enthusiasm for Bear Wise Jackson Hole, directing resources to priority areas, and reaching all demographics.

Additional Information and Education Efforts

In addition to the standard duties by WGFD's Large Carnivore Section through the Bear Wise Wyoming Program, multiple avenues of outreach and education occur throughout Wyoming and the world-wide-web**.**

In working with Departmental personnel in Cheyenne, there has been a great deal of effort to update and incorporate messages regarding grizzly bear ecology, management, and safety into the Department website. The grizzly bear management web page continues to be maintained and updated on a regular basis to provide timely information to the public regarding grizzly bear management activities conducted by the Department. Web page content includes various interagency annual reports and updates and links to other grizzly bear recovery web sites. Beginning May 2016, weekly updates of ongoing management activities related to depredations, research, trapping and monitoring, and information and education were posted to the department's website. A total of 17 weekly updates were posted from June 4, 2016 through October 7, 2016. A monthly update of the activities of the Large Carnivore Section is posted on the webpage, as well as various reports and publications pertinent to grizzly bear ecology and management in Wyoming. In addition, personnel issued multiple educational news releases throughout the year informing readers and listeners of bear safety, behavior, conflict avoidance, food storage, and natural food availability. For information specific to the Department's grizzly bear management program; including links to publications, reports, updates, and plan visit: https://wgfd.wyo.gov/web2011/wildlife-1000674.aspx

As per Wyoming Statute, grizzly bear relocation from one county to another must be announced through local media and to the local sheriff of the county into which the bear was relocated. Each announcement is posted in a timely fashion to the web page. In 2016, 14 notifications were distributed and posted on the website.

Hunter Education is a vital component toward the mission of the Department. Every hunter education class in Wyoming is required to discuss how to hunt safely in bear country. To assist instructors, the Department has provided inert bear spray canisters for demonstration purposes and DVDs titled "Staying Safe in Bear Country, A Behavioral Based Approach to Reducing Risk". A section on bear safety is included in the student manual. Approximately 5,000 students are certified each year.

Publications

For information specific to the Wyoming Game and Fish Department's grizzly bear management program; including links to publications, reports, updates, and plans visit:

https://wgfd.wyo.gov/web2011/wildlife-1000674.aspx

Links to other publications, annual reports, and peer reviewed literature for grizzly bears in the Greater Yellowstone Ecosystem are provided on the U.S. Geological Survey website: http://www.nrmsc.usgs.gov/products/IGBST.

For additional information about the Wyoming Bear Wise Program contact:

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Appendix E

Project Update: Grizzly Bear Response to Elk Hunting in Grand Teton National Park

(*Michael R. Ebinger, Mark A. Haroldson, and Frank T. van Manen; U.S. Geological Survey, Interagency Grizzly Bear Study Team; and Steve L. Cain, Katharine R. Wilmot, and David D. Gustine; National Park Service, Grand Teton National Park*)

Introduction

Although population growth of grizzly bears (*Ursus arctos*) in the Greater Yellowstone Ecosystem (GYE) has slowed from 4–7% during the 1980s and 1990s to 0–2% during the last decade, expansion of occupied range has continued throughout the last decade. Successful population recovery has coincided with increases in human populations on the periphery of the ecosystem and human visitation to national parks. One particular challenge is the availability of ungulate gut piles and carcasses during fall hunting seasons, a time when bears' caloric demand and intake is greatest (hyperphagia). Areas that exhibit traditional and concentrated ungulate hunter success may become seasonal "ecocenters" for bears. Supporting this concept, Haroldson et al. (2004) found that grizzly bears were 2.4–2.7 and 2.3–4.4 times more likely to be outside Yellowstone National Park's northern and southern boundaries, respectively, following the opening of the September elk season, thus increasing the risk of human-bear conflicts and grizzly bear mortality. Gunther et al. (2004) found that grizzly bears killed in defense of human life or property (n = 32) represented the greatest source of human-caused mortality during 1992–2000, including 27 from ungulate hunters.

Under its 1950 establishing legislation, GRTE is authorized to conduct a joint elk reduction program (ERP), when necessary, with the State of Wyoming for conservation of the Jackson elk herd, a significant portion of which travels though GRTE during annual fall migrations to wintering areas on the National Elk Refuge (NER) and 3 nearby state feed grounds. Because the GRTE hunting season is open later than those on adjacent lands, the 'ecocenter' effect of a highly attractive grizzly bear food source may exacerbate the potential for bear-hunter conflicts. Clearly, the fall elk hunting in conjunction with increasing grizzly bear numbers creates a unique and substantial challenge for wildlife managers at GRTE.

Several GRTE provisions for mitigating hunter-grizzly bear conflicts are already in place, including requiring hunters to carry bear spray, providing hunt camps with game storage facilities, prohibiting artificial elk calls, and providing hunters with a bear safety education packet. In response to the recent human-bear conflicts, GRTE proposed additional measures and revisions to the ERP for 2013. These revisions are currently based on a limited set of regulatory tools, involving changes in hunter densities (e.g., hunters/day, access), closure of areas to hunting (e.g., Snake River bottoms), and changes in hunting regulations to reduce wounding loss (e.g., ammunition limits). However, even with these changes, GRTE managers expect conflicts between elk hunters and grizzly bears to increase. Therefore, park managers are seeking new, science-based information to help reduce conflict potential.

The overall goal of this study is gain a thorough understanding of grizzly bear responses to the ERP in GRTE. Our specific objectives are to determine: 1) changes in grizzly bear density and distribution relative to the timing and location of the GRTE elk hunting season, 2) spatial and temporal distribution of elk remains, 3) grizzly bear detection and use of elk remains, and 4) the relative risk of human-bear encounters.

Field Data Collection

Data collection in 2016 focused on the time period of the ERP. In Hunt Area 79, we recorded 155 GPS locations for a total of 10 bear-days from 3 bears during the open elk harvest season (#399 = 2 days;

#506 = 7 days; #747 = 1 day). In Hunt Area 75, we recorded no GPS locations from grizzly bears during the open season.

We set up hair-snare corrals at 24 sites around ungulate carcasses (road kill, hunter harvest, natural mortality) during the 2016 elk harvest season. We collected 147 bear hair samples during from 16 of the 24 hair-snare corrals and 5 opportunistic samples from vegetation while backtracking bear tracks in the snow. Hair samples are awaiting genetic analysis for individual identification and results are expected by fall 2017.

We visited 22 clusters of grizzly bear GPS locations that were not associated with known hair snares during the elk harvest season. We discovered evidence of hunter-harvested elk remains at 7 of those clusters (6 female and 1 bull elk) and all were on national forest lands outside the ERP hunt boundaries. We found a single bison carcass. Thirteen of the 22 clusters showed evidence of nearby bear daybeds, and 2 clusters had no discernable bear sign.

With the cooperation of hunters participating in the ERP, we successfully downloaded 55 hunter GPS tracks during the 2016 ERP season. These data will be analyzed in conjunction with grizzly bear movement data, once GPS collars have dropped from bears and their store-on-board GPS and activity data have been downloaded. A final report for this project is planned for the end of 2017.

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