Grizzly Bear Nutrition and Ecology Studies in Yellowstone National Park

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This grizzly bear is digging for pocket gophers and their food caches. GPS collars, hair snares, isotope analysis, and DNA are being used to gain insights into the nutritional ecology of bears.

The chance to see a wild grizzly bear is often the first or second reason people give for visiting Yellowstone National Park. Public interest in bears is closely coupled with a desire to perpetuate this wild symbol of the American West. Grizzly bears have long been described as a wilderness species requiring large tracts of undisturbed habitat. However, in today's world, most grizzly bears live in close proximity to humans (Schwartz et al. 2003). Even in Yellowstone National Park, the impacts of humans can affect the long-term survival of bears (Gunther et al. 2002). As a consequence, the park has long supported grizzly bear research in an effort to understand these impacts. Most people are familiar with what happened when the park and the State of Montana closed open-pit garbage dumps in the late 1960s and early 1970s, when at least 229 bears died as a direct result of conflict with humans. However, many may not be as familiar with the ongoing changes in the park's plant and animal communities that have the potential to further alter the park's ability to support grizzly bears.

These changes include the decline in Yellowstone Lake cutthroat trout due to the unplanned introduction of the predaceous lake trout, the spread of whirling disease, and a long-term drought (Koel et al. 2004; McIntyre 1996). Cutthroat trout have been consumed for thousands of years by grizzly bears from mid-May to mid-August, when they spawn in the small streams that flow into Yellowstone Lake (Haroldson et al. 2005). Whitebark pine, one of the most important fall foods of the grizzly bear, is infected with an exotic fungus, white pine blister rust. The high-fat, energy-rich whitebark pine nuts are consumed during the fall when the crop is limited or during the entire year when the crop is abundant (Felicetti et al. 2003; Lanner and Gilbert 1994). Although blister rust has not killed a great number of trees to date, it has the potential to do so if climatic conditions change and weaken the trees' resistance. Whitebark pines, along with most conifers, are also facing an epidemic of mountain pine beetles. These tiny creatures, which are native to the ecosystem, burrow under the bark and feed voraciously on the trees' living cambium. Trees weakened by summer drought or old age are particularly susceptible. Mountain pine beetles have the potential to kill a significant portion of the mature whitebark pines in the park, although outbreaks have occurred previously. Reductions in the quantity or quality of such high-value foods decrease birth rates, growth rates, and the survival of bears (Mattson, Blanchard, and Knight 1992).

For more than 30 years, members of the Interagency Grizzly Bear Study Team (IGBST) have been investigating grizzly bear biology in the park. Much of the early work was gleaned by tracking radio-collared bears, examining scats and foraging sites, and observing bears in general. In recent years, the IGBST has used the newest research techniques and cooperated with outside specialists in chemistry, genetics, and nutrition to advance the understanding of grizzly bear ecology. The new research techniques used by the IGBST include highly accurate Global Positioning System (GPS) collars that pinpoint a bear's location many times a day, hair snares fashioned of barbed wire that collect small clumps of hair when bears rub against them, and DNA and nutritional analyses that determine the sex, identity, and diet of each bear that left a hair sample. Both DNA and nutritional analyses can be performed on very small samples, such as bone flakes, a drop of dried blood, or a few hairs. Even samples from museum specimens can be used to determine family lineages and diets of bears that died long ago.

One of the major outside collaborations has been with scientists from the Washington State University Bear Research, Education, and Conservation Program in Pullman, Washington. This program is the only facility in the world in which a significant number of captive grizzly bears are held for the purpose of developing new techniques or knowledge that will directly assist in understanding the needs of wild bears. The facility normally has 10–12 grizzly bears, ranging from newborn cubs weighing one and a half pounds to 20-year-old adults weighing more than 800 pounds. Undergraduate and graduate students majoring in the biological sciences have the unique opportunity to work with the captive bears on a daily basis and to conduct field studies as needed.

Quantifying Diets

One of the first studies jointly conducted by scientists of the IGBST and Washington State University examined how diets of grizzly bears changed either as the West was settled or park management changed (Jacoby et al. 1999). For historical studies, skins and skulls in museums, including the Smithsonian Institution, are valued treasures. However, techniques of scat analysis or direct observation that are used to quantify diets of living bears could not be used on these long-dead bears. The new technique we used to quantify the diets of both living and dead bears is called "stable isotope analysis." Isotopes are different forms of the same element, for example ^{14}N and ^{15}N. They are both nitrogen, but the far rarer form, ^{15}N, has one extra neutron, is non-radioactive, has been on Earth for billions of years, and is preferentially retained relative to ^{14}N when consumed by animals. Thus, bears that have eaten only plants will have less ^{15}N in their hair or bones than will bears that have eaten other animals. It is this ^{14}N-to-^{15}N ratio that allows us to quantify the proportion of plant and animal matter that a bear ate during the past few weeks, months, or lifetime. By feeding the captive bears at Washington State University various diets that included deer, trout, clover, grass, and other foods and analyzing the isotope ratios of both food and bear, we were able to calibrate this technique specifically for grizzly bears. After death, the ratio of rare-to-common isotopes remains the same in properly preserved bones or hair. This technique has also been used to examine how the diets of Egyptian pharaohs and their wives differed from those of commoners and slaves (guess who had the best diet and lived the longest) and to determine when and where corn was first domesticated and became an important part of the human diet.


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A grizzly bear rips open a log to feed on the ants inside.

In our studies, we wanted to know how the diets of bears that might be reintroduced into central Idaho would differ from those that lived there historically. We were able to find the skulls or hides of 10 grizzly bears that were killed in the Columbia River drainage prior to the crash in salmon populations associated with dams, over-harvesting, and other human causes. Locations where the bears were killed ranged from the banks of Puget Sound in Washington, the Cascade Mountains and Blue Mountains of Oregon, to the high

Table 1. Comparative data on grizzly bear diets at different times and places (Jacoby et al. 1999).

	Meat	Plants
Grizzly bear bones from 1,000-year-old packrat midden in Lamar Cave	32%	68%
19th century grizzlies killed in eastern MT and WY	32%	68%
1914–1918, Yellowstone garbage-fed grizzlies	85%	15%
Contemporary Yellowstone adult females and subadult grizzlies	40%	60%
Contemporary Yellowstone adult male grizzlies	80%	20%
Contemporary Yellowstone grizzlies preying on livestock outside the park	85%	15%
Contemporary Alaskan salmon-feeding grizzlies	72%[1]	28%
Contemporary Glacier NP and Denali NP grizzlies	3%	97%

[1]This meat category includes salmon plus terrestrial meat sources, such as moose.

Bitterroot Mountains of Idaho. Hair and bone analyses indicated that all 10 bears consumed salmon, and that salmon provided approximately 60% of their annual nourishment. This level of salmon consumption is identical to that of today's Alaskan bears, such as those in Katmai National Park, that continue to feed on abundant salmon (Hilderbrand, Jenkins, et al. 1999; Hilderbrand, Schwartz, et al. 1999). One can only be amazed at how markedly our natural systems have changed since the time when 16 million salmon returned to the Columbia River drainage and nourished grizzly bears throughout the region. Now, only in the headwaters of the Columbia River drainage, such as in Yellowstone, do grizzly bears exist, and none consume salmon.

We also investigated the historical diets of Yellowstone grizzly bears. The oldest grizzly bear bones that we found came from a 1,000-year-old packrat midden excavated from the Lamar Cave. Due to the efforts of this hard-working packrat that had a fetish for bones, we know that meat (everything from ants to trout and elk) provided 32% of the nourishment for those grizzly bears and 68% came from plants (everything from roots and leaves to berries and nuts) (Jacoby et al. 1999). That distribution of dietary meat to plants is identical to what we found for five grizzly bears killed from 1856 to 1888 in eastern Montana and Wyoming (Hilderbrand et al. 1996).

From 1914 to 1918 when many hotels were feeding kitchen scraps to attract grizzly bears for tourist entertainment and local towns had open-pit garbage dumps, the park's grizzly bears switched to 85% meat, 15% plants. After all such feeding ended by the early 1970s and bears were forced to return to natural foods, the diets of young bears of both sexes and adult females returned to the levels observed 1,000 years ago (~40% meat, 60% plants). Adult males have continued a more carnivorous life (~80% meat, 20% plants) (Jacoby et al. 1999). Large males can prey more efficiently on the park's elk and bison or claim the carcasses of animals that died from other causes. Bears that have been killed for preying on livestock outside the park had diets that were 85% meat, 15% plants. These levels of meat consumption are in contrast to those of grizzly bears in Glacier National Park and Denali National Park, where plant matter provides 97% of their nourishment (Table 1). Thus, for grizzly bears, the opportunity to consume meat differentiates the Yellowstone ecosystem from many other interior ecosystems where bears must feed primarily on plants. Cutthroat trout are one of those meat sources.

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A bear defends a bison carcass from other scavengers. Meat provides approximately 80% of adult male grizzly bears' annual nourishment in Yellowstone National Park.

Cutthroat Trout

One of the great wonders of Yellowstone Lake has been the native cutthroat trout. In recent years, cutthroat trout have spawned in at least 59 of the 124 streams flowing into Yellowstone Lake. The trout that weigh 1 to 1.5 lbs when spawning are easy prey for bears, otters, eagles, and dozens of other animals, as many of the streams are narrow and shallow. A study conducted in the late 1980s concluded that at least 44 grizzly bears fished for cutthroat trout, female bears made more use of this resource than did males, and 90% of the bears' diet during the spawning season was trout (Mattson and Reinhart 1995; Reinhart and Mattson 1990).

The conclusion that females were making more use of the trout than males suggests that trout may have been an important food for females with cubs. Grizzly bear mothers with new cubs benefit from good food resources when they emerge from their winter dens. Studies at the Washington State University Bear Center determined that grizzly bear milk has 4.5 times more fat and 17 times more protein than human milk. While each cub consumes about three-quarters of a pint per day of this very concentrated milk during hibernation, mothers must quadruple milk production to sustain the increased growth of cubs once they emerge from the winter den (Farley and Robbins 1995).

PHOTO COURTESY IGBST

Hair snares allow scientists to collect grizzly bear hair samples in a non-intrusive manner without trapping or handling the bears. The bear pictured here is investigating a scent lure inside a barbed-wire hair snare.

However, lake trout were discovered in Yellowstone Lake in 1994 and found in substantial numbers by 1995. Lake trout have probably been in the lake for more than 20 years, and illegal introductions may have occurred multiple times from the mid- to late 1980s through the 1990s (Munro, McMahon, and Ruzycki 2001). Adult lake trout are highly efficient predators of cutthroat trout (Donald and Alger 1993; Gerstung 1988). Each adult lake trout consumes 50 to 90 cutthroat trout annually (Schullery and Varley 1996). Lake trout have significantly reduced or eliminated native trout populations in other waters where they have been introduced. Lake trout could reduce the cutthroat trout population in Yellowstone Lake by as much as 90% (McIntyre 1996). Lake trout, unlike cutthroat trout that spawn in small streams in late spring and summer, spawn in the deeper water of the lake and are therefore not accessible to bears and other wildlife (Schullery and Varley 1996). In a follow-up study in the late 1990s after lake trout had become well established, 74 grizzly bears visited cutthroat trout spawning streams, but the sex ratio of those bears was dominated almost 2:1 by males (Haroldson et al. 2005).

To determine if female grizzly bears were still consuming fish, we needed to find non-intrusive ways to individually sex and identify each bear visiting cutthroat trout spawning streams and measure how many trout those specific bears consumed. This was not an easy task as grizzly bears are wary, often forage at night, and may feed at many locations separated by great distances. Thus, we could not visually count trout being consumed, nor could we depend on older techniques, such as scat analyses.

Food chains of most aquatic ecosystems, whether marine or freshwater, tend to accumulate heavy metals. While we often think of heavy metals in aquatic ecosystems as pollution, recent studies by U.S. Geological Survey scientists have found naturally occurring mercury in the Yellowstone Lake food web. That discovery turned out to be our answer to determining how many cutthroat trout each bear ate, even though we never saw many of the bears and never trapped any of them. Yellowstone Lake cutthroat trout have 508 parts per billion (ppb) mercury, whereas elk, bison, plant foliage, roots, and other grizzly bear foods have less than 6 ppb (Felicetti et al. 2004). For comparison, tuna, salmon, shrimp, and many other marine-derived human foods contain less than 200 ppb, although shark and swordfish typically contain 1,000 ppb. Fish

PHOTO COURTESY IGBST

Grizzly bear hair collected on barbed-wire hair snares can be used for both isotope and DNA analysis.

with more than 1,000 ppb cannot be sold in interstate commerce, and the FDA recommends that people limit their intake of such fish to one serving per week (ATSDR 1999).

From other studies investigating the consequences of mercury consumption, we knew that mercury tends to be deposited in hair as it grows. The questions that we needed to answer were 1) do grizzly bears eating mercury-laden fish also deposit mercury in their hair and 2) does the mercury content of the hair directly reflect the amount of trout that has been consumed? By feeding the captive grizzly bears held at Washington State University known amounts of trout taken from Yellowstone Lake, we found that mercury was deposited in their hair and that the amount of mercury in small hair samples was directly related to the number of trout that each bear had eaten.

But how were we going to collect hair samples from large numbers of wild grizzly bears without trapping them, which we wanted to avoid? For this, we were able to capitalize on information learned from the field of DNA analysis. Because bears are constantly rubbing against plants or ducking under fallen timber or low-hanging branches, they treat barbed wire as just another impediment. Barbed wire that is either wrapped on a rub tree or strung about two feet off the ground along a trail or stream will snag small clumps of hair as bears pass underneath. This very simple technique allowed us to collect large numbers of bear hair samples from all around Yellowstone Lake. By using the same DNA identification techniques routinely used by criminal investigators and our newly developed relationship between trout consumption and hair mercury content, we could identify each individual bear visiting a trout stream, determine its sex and whether it was a grizzly bear or an American black bear, and determine the amount of trout that it had consumed. We found that male grizzly bears consumed five times more cutthroat trout than did females. Of the bears that consumed the largest amounts of trout, 92% were males. Thus, this food resource had largely been taken over by male grizzly bears (Felicetti et al. 2004).

While a total count of cutthroat trout in Yellowstone Lake is impossible, all signs indicate that the cutthroat trout population has declined in recent decades. In addition to predation by lake trout, whirling disease and drought have contributed to a reduction in cutthroat numbers. For example, total numbers of spawning cutthroat trout counted at a weir on Clear Creek, a backcountry stream on the east shore of Yellowstone Lake, declined from more than 70,000 in the late 1970s, to a maximum of 14,000 per year between 1997 and 2000, to fewer than 1,000 in 2005 (Haroldson et al. 2005; Koel et al. 2004). Similarly, while in the late 1980s grizzly bears were consuming an estimated 21,000 cutthroat trout per year (1.6% of the spawning population), our studies using mercury analysis of hair showed that trout consumption by grizzly bears had dropped to only 2,200 by the late 1990s, or an average of fewer than 30 trout per bear living around Yellowstone Lake (Felicetti et al. 2004). Thus, the average grizzly bear was consuming fewer cutthroat trout than the average adult lake trout.

Beginning this fall (2006), we will initiate a four-year study to determine if female grizzly bears are still consuming cutthroat trout, and if not, why. We are also interested in determining how successful they've been in replacing this important spring food with alternative foods. We've hypothesized that when spawning cutthroat trout were in the hundreds of thousands, all bears were able to use this food, as it far exceeded what could be consumed. However, as the numbers declined below what was necessary to meet the needs of all bears, large males increasingly dominated and perhaps defended this food resource (Haroldson et al. 2005). In the new study, at least six grizzly bears and six black bears will be trapped each year around Yellowstone Lake in large culvert traps and fitted with GPS collars, spawning streams will be censused weekly for cutthroat trout, remote cameras will be mounted on the streams to record how bears are interacting with each other, and hair snares will be established on the streams to identify which species, sex, and individuals are feeding on trout, and ultimately how many trout are being consumed. This information will be used by park managers to evaluate and perhaps intensify the current lake trout control program. If cutthroat trout cannot be saved, plant matter is likely to become a much more important dietary component to the park's grizzly bears.

Whitebark Pine Nuts

Whitebark pine nuts are by far the most important plant food eaten by the park's grizzly bears. The pine nut story is particularly interesting, in that grizzly bears depend on small red squirrels to harvest the cones and bring them down to the ground where bears can feast. When pine nuts are abundant, bears tend to be in the high-elevation areas where whitebark pines grow and are, thus, far from human developments and conflict. In years of pine nut failure, grizzly bear mortality can

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Grizzly bears depend on red squirrels to harvest and cache whitebark pine cones.

be three times higher than in good pine nut years, as the bears are forced to forage more widely and closer to people (Mattson, Blanchard, and Knight 1992).

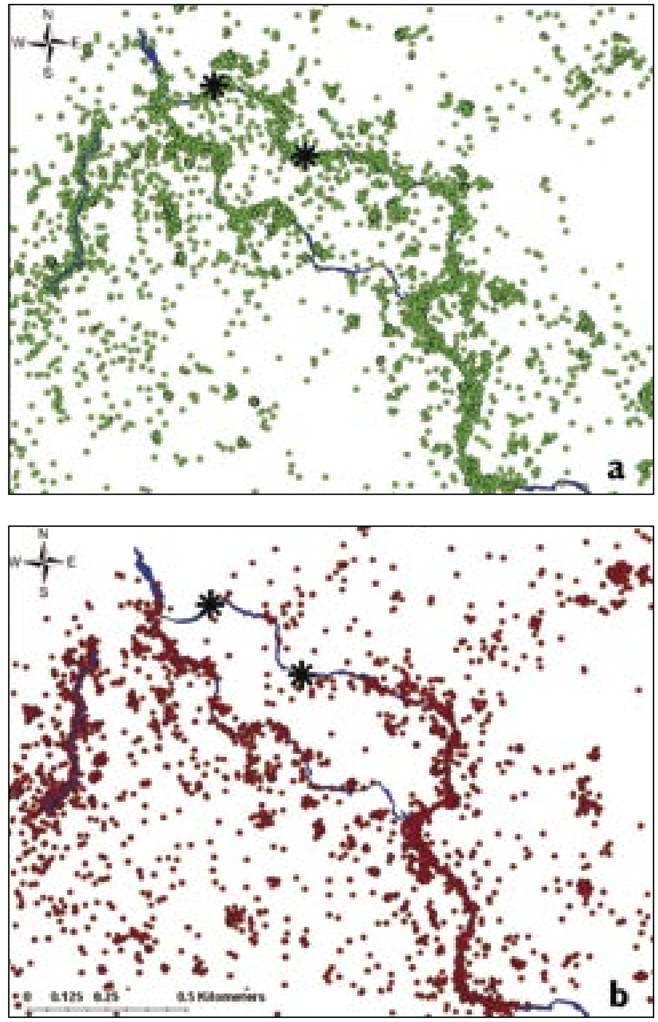
In addition, female bears that have fattened during the previous fall on good pine nut crops typically produce litters of three cubs compared to twins or singletons after falls of few nuts. The link between increased cub production and great pine nut years occurs because fatter females produce more cubs that are born earlier in the winter den and grow faster because mom produces more milk. The average (290-lb) adult female grizzly bear in Yellowstone can gain as much five pounds/day when feeding on pine nuts, which are 28% fat. The amount of fat accumulated in a single day of feeding on abundant pine nuts in the fall can meet the needs of a hibernating adult female for five days if she has cubs, or for nine days if she does not. Thus, the potential reduction of whitebark pine would likely be even more significant than the loss of trout, which are a spring and early summer food.

Whitebark pine nuts are by far the most important plant food eaten by the park's grizzly bears.

In a separate study (Felicetti et al. 2003), we wanted to quantify the nutritional value of pine nuts to the park's grizzly bears. Whitebark pine cone production varies dramatically between years. We needed to find some element that occurred in pine nuts that did not occur in the bears' other foods, was absorbed when nuts were consumed, and ultimately was deposited in the bears' hair in proportion to the amount of nuts consumed. Fortunately, whitebark pines concentrate a rare sulfur isotope (^{34}S) that occurs in the nuts' protein and is deposited in the bears' hair. When there were at least 40 cones produced per tree, pine nuts provided 97% of the annual nourishment for the park's grizzly bears. The breakpoint for good versus poor years was about 20 cones per tree.

Grizzly Bear–People Interactions

A quick survey of hunting magazines featuring stories of attacks on humans by bloodthirsty grizzly bears can make any of us paranoid at the thought of hiking in Yellowstone. In a study that we recently completed in a densely forested area of Alaska, we wanted to know how grizzly bears respond to fishermen and ecotourists (Rode 2005). Our experimental ecotourists were one to seven college students that we employed to hike through the forest each day to the banks of a small stream full of thousands of spawning sockeye salmon. Once there, they sat, observed, and recorded grizzly bear activity. Using the same techniques that we will apply in Yellowstone, we determined



COURTESY K. RODE, S. FARLEY, AND THE ALASKA DEPARTMENT OF FISH AND GAME

Figure 1. Comparison of the use of an Alaskan stream containing thousands of spawning sockeye salmon by five collared bears during (a) a control period with no human activity and (b) a 24-hour treatment period with students sitting at the locations marked with an asterisk. The small circles are the GPS locations where each bear was at a specific time.

that 33 grizzly bears visited that particular stream during the spawning season, 7 of which were captured and fitted with GPS radio collars. Because salmon provided 66% of the bears' annual nourishment, the students were sitting at the bears' dinner table. However, the bears vacated the portion of the stream where just one student was sitting (Figure 1). Even though bears were all around the students and could be heard catching fish in other portions of the stream, the students saw grizzly bears for less than 1 hour out of 288 hours of observation. From these studies, it was clear that the bears avoided humans and that even a single human can displace grizzly bears from high-value feeding sites.

In 1983, Yellowstone National Park began closing areas of high-density grizzly bear habitat for part or all of the period

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GPS collars allow scientists to pinpoint grizzly bear feeding sites.

when bears are not denning. Known as Bear Management Areas, these closures were intended to eliminate human entry and disturbance, prevent human–bear conflicts and habituation of bears to people near prime food sources, and provide places where bears can pursue natural behavioral patterns and social activities. Four areas around Yellowstone Lake where grizzly bears are known to forage for fish are closed during the trout spawning season. Over the years, the park has received challenges to these closures, with specific requests to open such areas to human entry. Given the reduced abundance of fish around Yellowstone Lake, we hypothesize that Yellowstone bears are far less likely than those observed in Alaska to voluntarily leave important, high-quality food resources due to the presence of people and therefore the potential for bear–human conflict is real.

To help understand the importance of the Bear Management Areas around Yellowstone Lake, the foraging patterns and travel routes of the bears fitted with GPS collars will be studied. The collars will be programmed to record each bear's location every 15 minutes. To understand how humans use the area, we will use the same technology by providing campers and hikers with hand-held GPS units to track their movements and activities after the seasonal closure. Although the humans will not be in the area when bears are eating fish, the study will help us understand how both bears and humans use these areas.

Summary

Biologists now understand many facets of the biology of the Yellowstone's grizzly bears. While we continue to examine home ranges, movements, births, deaths, and other typical wildlife parameters, our vocabularies have changed to include terms such as GPS collars, isotopes, isotope ratio mass spectrometry, DNA, polymerase chain reaction, and atomic absorption spectrometry. Many of these new techniques have allowed us to learn more about Yellowstone bears without the bears realizing that they were subjects in a scientific study. One museum curator commented that these new techniques have given life and meaning to their long-dead specimens, as he could now talk about their diets and family lineages. However, because the foods and therefore the well-being of the park's grizzly bears will always be changing, we must continue these studies for as long as Yellowstone National Park exists and grizzly bears roam its beautiful landscapes.

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DARIN WATKINS

COURTESY IGBST

Charles T. Robbins (left) is a professor in the Department of Natural Resource Sciences and the School of Biological Sciences at Washington State University in Pullman. He has spent more than 30 years studying the nutrition of wild animals. In the picture, he's shown with one of the captive grizzly bears held at the Washington State University Bear Research, Education, and Conservation Program. This particular bear (Mica) was hand-raised from six weeks of age for physiological measurements, including blood sampling, without the use of anesthetic drugs. **Chuck Schwartz** (right) works for the U.S. Geological Survey at the Northern Rocky Mountain Science Center in Bozeman, Montana. He is leader of the Interagency Grizzly Bear Study Team, an interdisciplinary group responsible for long-term research and monitoring of grizzly bears in the Greater Yellowstone Ecosystem. Chuck worked for the Alaska Department of Fish and Game for more than 20 years. He has worked on programs with grizzly bears in Alaska, Russia, Pakistan, and Japan. His research with large mammals has included moose as well as brown and black bears and focused on ecological issues of predator–prey dynamics, carrying capacity, and nutrition and physiology. Chuck holds a BS in Agriculture/Natural Resources from Ohio State University, and an MS and a PhD in Wildlife Biology from Colorado State University.

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CHUCK BARTLEBAUGH

Kerry A. Gunther (left foreground, with Mark Haroldson) is Yellowstone National Park's Bear Management Biologist. He oversees bear–human conflict resolution and bear research and monitoring throughout the park, and has worked in the park for 24 years. He has also worked in grizzly and black bear research and management for the U.S. Forest Service and the U.S. Fish and Wildlife Service. Kerry holds a BS in Biology with minor studies in Earth Sciences from Northland College in Wisconsin, and an MS in Fish and Wildlife Management from Montana State University. **Chris Servheen** (right foreground, with Tom Radandt) has been the Grizzly Bear Recovery Coordinator for the U.S. Fish and Wildlife Service (USFWS) for 25 years. He coordinates all the research and management on grizzly bears in the lower 48 states and works with biologists in Alberta and British Columbia. He holds a BA/BS in Zoology/Wildlife Biology from the University of Montana, an MS in Wildlife Biology from the University of Washington, and a PhD in Forestry/Wildlife Biology from the University of Montana.

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