Portable Electric Fencing for Bear Deterrence and Conservation

Article *in* Human-Wildlife Interactions · December 2018

DOI: 10.26077/h9sw-qg28

4 authors, including:

Tom S Smith
Brigham Young University - Provo Main Campus
44 PUBLICATIONS **908** CITATIONS

SEE PROFILE

John Gookin
National Outdoor Leadership School (NOLS), Lander, WY, United …
34 PUBLICATIONS **661** CITATIONS

SEE PROFILE

Bryan Hopkins
Brigham Young University - Provo Main Campus
88 PUBLICATIONS **1,455** CITATIONS

SEE PROFILE

Human–Wildlife Interactions 12(3):309–321, Winter 2018 • digitalcommons.usu.edu/hwi

Portable electric fencing for bear deterrence and conservation

Tom S. Smith, Plant and Wildlife Sciences, Brigham Young University, 5050 LSB, Provo, UT 84602, USA *tom_smith@byu.edu*
John Gookin, National Outdoor Leadership School, 284 Lincoln Street, Lander, WY 82520, USA
Bryan G. Hopkins, Plant and Wildlife Sciences, Brigham Young University, 5050 LSB, Provo, UT 84602, USA
Samantha Henrie Thompson, Department of Geography, University of Washington, Smith Hall 408, Seattle, WA 98195, USA

Abstract: Although bear-inflicted (*Ursus* spp.) human fatalities are rare in North America, human injuries, property damage, and bear mortalities occur wherever bears and humans commingle. We investigated the efficacy of portable electric fencing systems for bear deterrence under a variety of environmental conditions in the lab and field. Our results showed that the bear deterrent systems we evaluated were effective in protecting humans, their food, and property from bears >99% of the time. Herein, we discuss the benefits of using electric fencing, reasons why fences sometimes fail, and provide guidance regarding the most effective implementation of the systems we evaluated. Lastly, we also explore why this deterrent is not yet in widespread use. We encourage the use of electric fencing in bear country for protecting humans, their camping gear and food, and ultimately to promote bear conservation.

Key words: bear deterrents, bear–human interactions, black bears, deterrents, electric fencing, grizzly bears, polar bears, *Ursus americanus*, *U. arctos*, *U, maritimus*

Although bear-inflicted (*Ursus* spp.) fatalities are rare in North America, human injuries, property damage, and bear mortalities occur wherever bears and humans commingle (Herrero 2002, Gunther 2015). While appropriate human behavior is a critical element for reducing the risk of human–bear conflict, it may not be possible to eliminate all risk (Herrero 2002).

However, technological advances in recent years have not only provided new tools for bear deterrence, but also resulted in improvements in preexisting ones. Chief among these improvements is the advent of lightweight, portable electric fencing. Our conversations with resource managers, recreationists, and workers in bear country have made clear that electric fencing is an often misunderstood, and hence underutilized, deterrent (T. Smith, Brigham Young University, unpublished data).

Electric fencing as a deterrent

Electric fencing has been widely used to exclude a variety of animal species from areas of concern for many years. Examples include coyotes (*Canis latrans*; Gates et al. 1978), polar bears (*U. maritimus*; Davies and Rockwell 1986), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), domestic cattle (*Bos taurus;* Karhu and Anderson 2006), and black bears (*U. americanus*; Storer et al. 1938).

In response to chronic human–bear conflicts, the U.S. National Park Service (NPS) has deployed electric fencing to protect facilities and campers from bears in a variety of locations. At the Katmai National Park's Brooks Camp Campground in Alaska, USA, the NPS encircled the area with electric fencing in 1995. This fencing essentially eliminated all incursions into the area and property damage (M. Wagner, Brooks Camp manager, personal communication). Similarly, Parks Canada installed an electric fence around the Lake Louise campground in Banff National Park, Alberta, Canada, in 2001, thus eliminating bear–camper conflicts that had been an ongoing concern in the area for decades. The NPS promotes the use of electric fences in areas where bears are present (NPS 2008). Others have produced a variety of guides for electric fence use in bear country (Thompson et al. 2009, Masterson 2015). In spite of the well-documented effectiveness of electric fencing for deterring bears, it is not as widely used as one might expect, and for a variety of reasons.

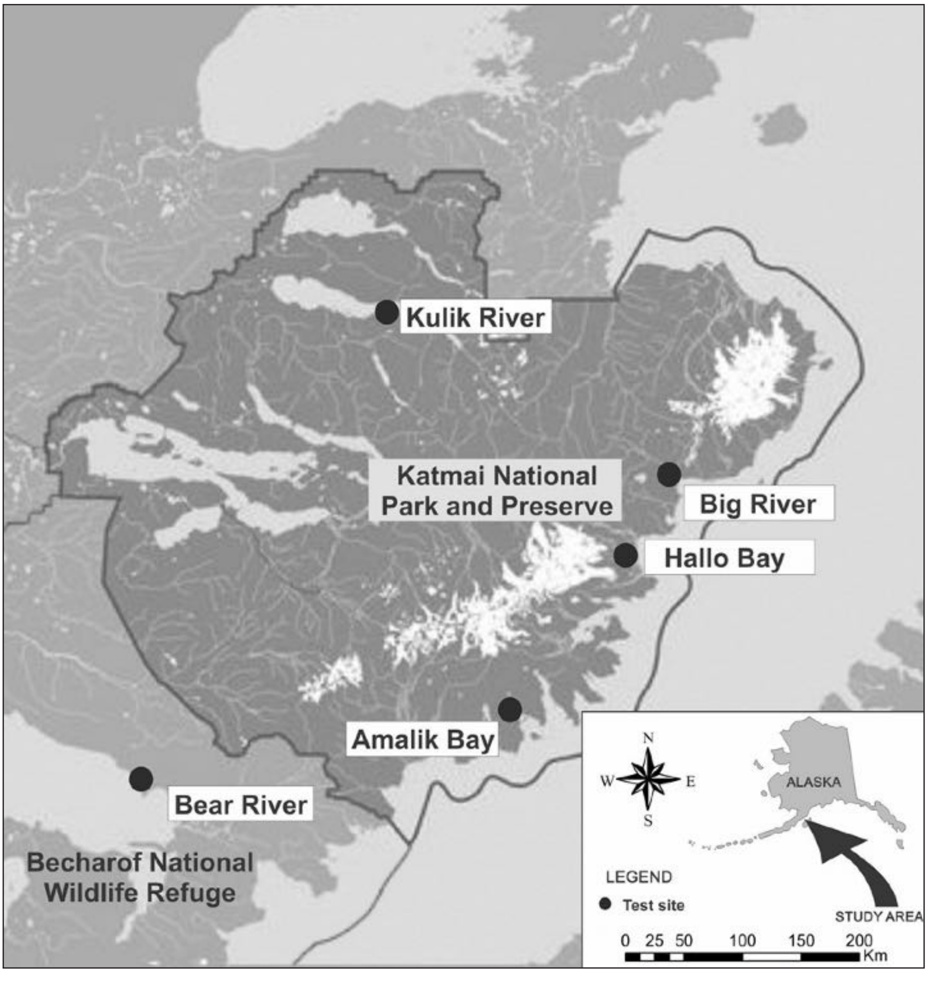

Figure 1. Locations where portable electric fences were used to deter brown bears (*Ursus arctos horribilis*) from accessing backpacker food on the Alaska Peninsula, USA.

Why aren't fences used?

A lack of confidence in the ability of electric fencing to repel bears; unfamiliarity with electric fence systems; misconceptions regarding their weight, cost, and ease of deployment; and a preference for firearms are among the many reasons why electric fencing has been slow to be widely adopted for bear deterrence. A similar reluctance to use proven technology is partly responsible for hikers not carrying bear spray (Smith et al. 2008). Nonetheless, recent technological advances now offer economical, lightweight, easily deployed electric fencing that can provide a measure of added security in bear country.

Newer, lightweight technology

Electric fence chargers, also known as energizers, have traditionally been heavy (>10 kg), steel-encased units that were marginally portable and required heavy, deep cycle batteries (~ 20 kg) for power. Additionally, fence wire was stiff, metal wire that was unweildy and cumbersome to install, requiring heavy (3.4 kg; 2 m) steel posts for support. This is still the state-of-the-art for permanent electric fence installations that are used around livestock paddocks, outfitter camps, apiaries, and the like. Today, however, energizers created specifically for protecting campers and gear from bears are small (2 x 9 x 17 cm), lightweight (215 g), run for several days on 2 AA batteries, and produce an electrical shock capable of deterring curious bears (e.g., the Sureguard™ portable energizer). These compact energizers are ideal for use by outdoor enthusiasts and those working in bear country. Fence wire technology has advanced as well, with polywire (polyethylene interwoven with at least 6 strands of stainless steel wire) replacing the heavier steel wire. Additionally, polywire, as opposed to steel fence wire, is very lightweight (55 g; 10 m), flexible, and hence easily deployable.

Increased fence efficacy

Previous work has indicated that the 2 most important variables influencing electric fence efficacy are soil particle size and soil moisture content (Friedman 2004). We conducted laboratory experiments that evaluated the role of soil particle size and moisture content on the efficacy of electric fences. Our hypothesis was that both soil particle size and soil moisture content influence electrical conductivity (EC) such that smaller particles and increasing water content increase EC. We also expected that water would have a more profound influence on overall soil EC than would soil particle size. In the field, we documented bear responses to electric fencing with both captive brown/grizzly bears (*U. arctos horribilis*, hereafter grizzly bears), and wild, free-ranging brown and black bears. In this paper, we report on research conducted in the lab and field to evaluate the efficacy of electric fencing, identify common problems, and promote broader use.

Study areas

We conducted lab tests at the Brigham Young University Life Sciences Greenhouse Complex in Provo, Utah, USA (1,400 m above sea level; 40.2338° N, 111.6585° W). We conducted electric fence-protected food cache tests with captive grizzlies at the Grizzly and Wolf Discovery Center (GWDC) located in West Yellowstone, Montana, USA. We tested the ability of electric fencing to protect field camps from grizzly bears on the Alaska Peninsula, in both Katmai National Park (KNP) and Becharof National Wildlife Refuge (BNWR). These areas provided many opportunities for testing electric fences, as they support some of the highest densities of grizzly bears in the world (Sellers et al. 1999).

Within KNP, we tested electric fences around seasonal field camps at Hallo Bay, Amalik Bay, Big River, and Kulik River areas (Figure 1). Within BNWR, we tested electric fences on Bear Creek, near its confluence at Becharof Lake (Figure 1). From 1996 to 2016, we outfitted National Outdoor Leadership School (NOLS) expeditions with 55 energizers (6 x 8 x 17 cm; 410 g) and electric fences in a mesh configuration that enclosed a 4-m^2 area where all food was stored overnight. The NOLS trips were scattered throughout the Greater Yellowstone Ecosystem, primarily in the Wind River and Absaroka Ranges (Figure 2), in high-density black and grizzly bear populations with a significant history of human–bear conflicts.

Methods

Laboratory tests

We evaluated the effects of soil particle size and moisture content with regard to their ability to conduct electricity. Soil is comprised of unconsolidated blends of organic matter and minerals, including: clay (<0.002 mm), silt (0.002–0.05 mm), sand (0.05–2 mm), and rock (>2 mm). A variety of soil types were evaluated in this study, including the following types with their associated cation exchange capacity (CEC, $cmol_c\ kg^{-1}$): 1) organic matter (EC = 289), 2) bentonite clay (EC = 154), 3) loam texture soil (EC = 23), 4) sandy loam texture soil (EC = 14), 5) sand (EC = 3), 6) gravel (EC <1), and 7) river rock (EC <1). We selected this range of soil types (fine organic matter to large river rock) because all soil types in North America fall within this range of materials and are some combination thereof. The CEC is the universally accepted metric for determining water-holding capacity in soil, with higher values equal to higher holding capacities. Particle sizes in organic matter are somewhat variable with ranges from very long to very short chain molecules, but overall it has a very high surface area and, thus, is very reactive in terms of water-holding capacity.

Our organic matter soil type was composed of a bark/leaf mulch material that would be similar to the "duff" layer often found in the soil's O horizon, or uppermost soil layer commonly found in forested regions. We used bentonite clay, which was nearly pure clay (97% clay, 2% silt, and 1% sand), the type used commercially to line ponds and in well drilling operations. We made our loam (9% clay, 42% silt, and 49% sand) and sandy loam (19% clay, 26% silt, and 55% sand) soils with materials used from topsoil removed from building sites

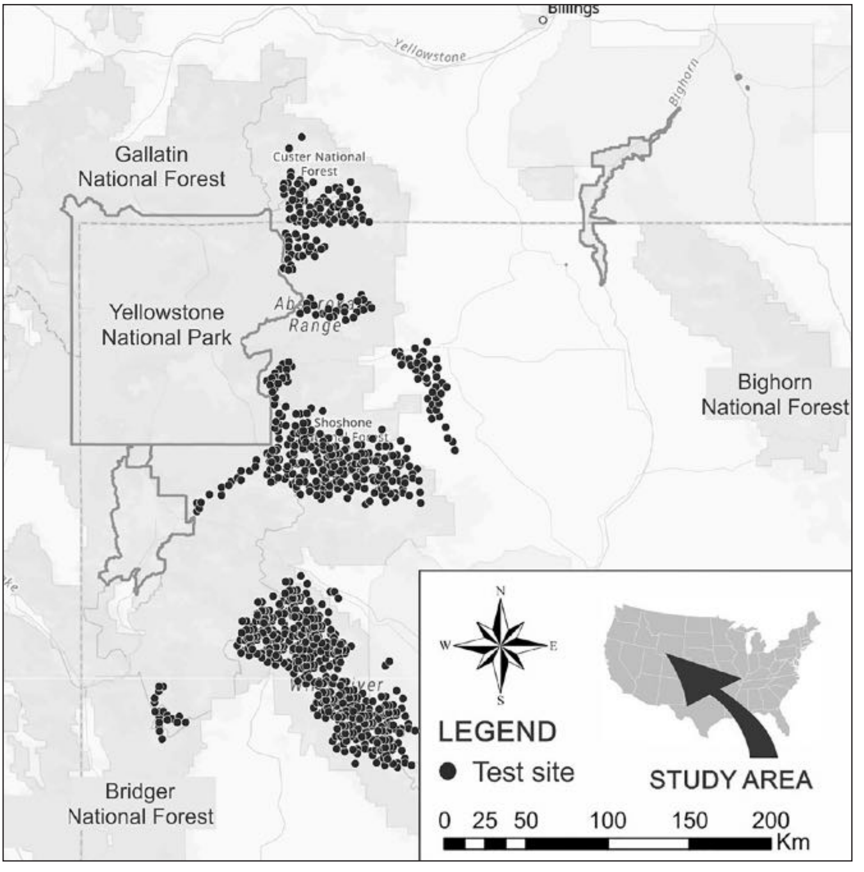

Figure 2. Distribution of electric fences deployed at camps in the Greater Yellow Ecosystem and Wind River Range, USA, for the National Outdoor Leadership School program.

at the Brigham Young University campus in Provo, Utah, USA. We obtained pre-sieved and washed gravel (2–20 mm) and river rock (20–100 mm) from a local quarry (both with <1% clay, silt, and sand).

We prepared 7 plastic tub containers (30 x 60 x 40 cm) by drilling an array of 1.3-cm diameter holes in the bottom to allow for water drainage. We placed galvanized metal hardware cloth (1.3-cm mesh) on the bottom of each tub as an electrical grounding plane. Soldered to each mesh was a 12-gauge braided and insulated wire, which extended upwards and out of each container. We filled each tub with an equal weight (22 kg) of one of the oven-dried (0% moisture), homogeneous soil mediums.

We connected a small, battery operated (2 D-cell batteries) energizer (Sureguard®, Lismore, New South Wales, Australia), identical to those used in the NOLS field trials, to each wire attached to the grounding plane (wire mesh) at the bottom of the tub. This energizer produces an electrical output of 0.1 joules (J), 7 kV, weighs 350 g empty and 600 g with batteries installed. Batteries power this unit continuously for approximately 160 hours under normal (0–35°C) use conditions.

To determine electrical conductance through each substrate, we welded a 20 x 40 x 0.6-cm steel plate to a 2 x 5-cm steel rod to which we attached a joule-kV meter. We connected the meter to both the welded steel rod and the positive lead of the energizer, and connected the negative lead to the wire soldered to the galvanized mesh at the bottom of each substrate-filled tub. The steel plate's surface area approximated that of an average grizzly bear paw (based on our measurements of fresh tracks on a variety of soil types). We placed the steel plate on the surface of each substrate and measured the amount of electricity as it passed from the energizer through the

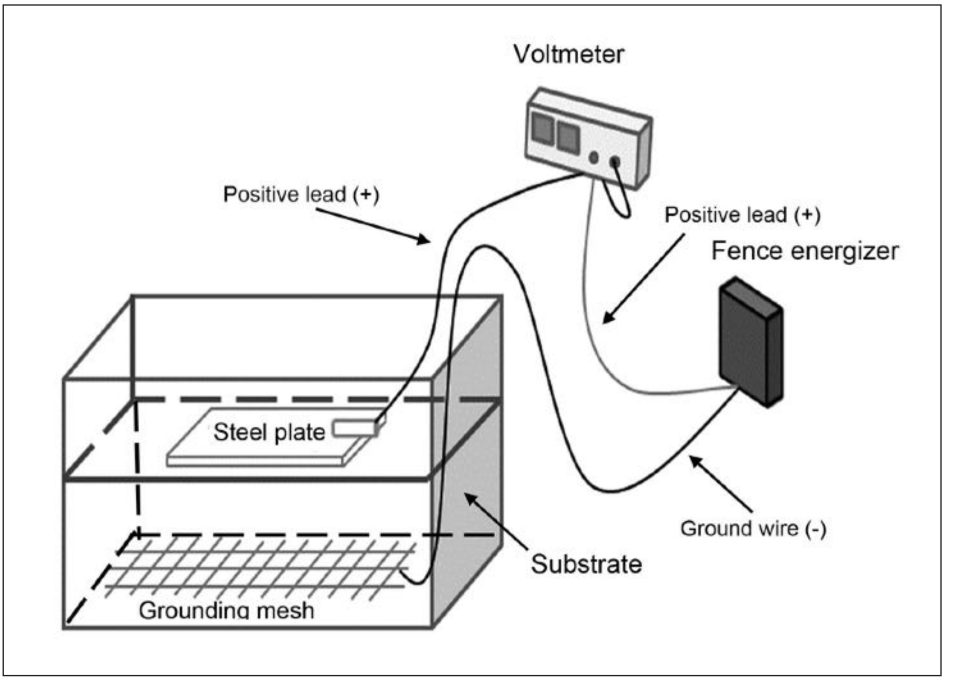

Figure 3. Soil conductivity testing apparatus. Plastic tubs had holes for drainage, wire mesh for conducting electricity through substrate, and a heavy steel plate to simulate the surface area of an average bear's (*Ursus* spp.) foot when stepping onto the soil.

substrate and to the grounding mesh (Figure 3). We recorded conductivity, as measured in joules and kilovolts, for each medium using a TruTest® (Auckland, New Zealand) electrical performance meter (EPM).

For reference, 1 joule of energy is the amount needed to generate 1 watt of power for 1 second. The amount of electrons that passes with each pulse of a fence energizer is measured in joules. Prior to adding water, we measured each oven-dried soil substrate's EC and recorded this as its dry value. To determine the EC of each substrate at varying soil moisture levels, we completely saturated each substrate with tap water (saturated state), and measured subsequent EC at 0, 4, 24, 72, 144, 288, 432, 576, and 720 hours post-saturation. The purpose of our lab tests was to explore the relationship between EC, soil particle size, and moisture, so whether we used distilled water (low EC) or tap water (higher EC) did not matter because resulting EC values were relative to one another and provided the insights we sought.

We organized the laboratory component of this study in a completely randomized design. We replicated conductivity measurements 6 times per substrate for each post-saturation period. We analyzed conductivity data with an analysis of variance with means separated by the Tukey-Kramer test. Significance was set at $P < 0.05$.

Field trials

In all of our tests, we used an energizer grounded by a stake or rod driven into the soil. Therefore, our 2-wire, 3-wire, and mesh net fences were hot, and a bear needed to touch only 1 wire to receive a powerful shock. In situations where an adequate ground is not available (e.g., snow, solid rock, etc.), persons alternate fence wires between hot and ground. In such instances, a bear must touch 2 wires, a hot and a ground, to be shocked. We did not deploy and test those systems for this research. Additionally, we tested 2-wire, 3-wire, and mesh net fences as all 3 are commonly deployed configurations. Electrified mesh net fences not only keep bears away from food, but also meso-carnivores such as raccoons (*Procyon lotor*), foxes (*Vulpes* spp.), and skunks (*Mephitis mephitis*) that can easily slip under a fence wire and chew through nylon sacks containing food.

Alaska Peninsula – Katmai National Park and Becharof National Wildlife Refuge. Between the

Figure 4. Double-stranded electric fence deployed around a field camp on the Alaska Peninsula, Alaska, USA, designed to deter bears (*Ursus* spp.; *photo by J. Gookin*).

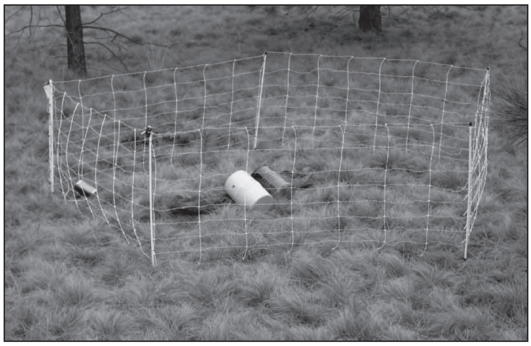

Figure 5. Electric mesh used to protect food from bears (*Ursus* spp.), Greater Yellowstone Ecosystem, USA (*photo by J. Gookin*).

Table 1. Specifications of electric fence energizers used in Alaska and the Greater Yellowstone Ecosystem, USA.

Energizer make/model	Cost (USD[a])	Weight (g)	Power source	Output (kV)
Fi-Shock SS2D	$60	1,080 g	2 D-cell batteries	7.5
Sureguard bear electric fence model #120	$200	730 g	2 D-cell batteries	7.5
Sureguard model #M2	$215	204 g	2 AA batteries	7.0

[a]2016 prices listed.

years of 1994 and 2006, we installed electrified perimeter fences around 5 field camps in Alaska (Figures 1 and 4), for a total of 383 user nights of ongoing bear research activities. Although individual camps varied in size, most encompassed an average of 200–400 m^2. We placed all camp gear, including food and tents, within these electrified, 2-wire fence perimeters. Additionally, all food preparation and consumption occurred within the perimeter. We secured all foods in bear-resistant food containers (e.g., 208-L steel barrels with locking lids in semi-permanent research camps, or the smaller, 10-L bear-resistant food containers used by hikers in backcountry areas) as an added precaution so that bears would not receive a food reward if a fence failed.

Energizers used for these fences included the Fi-Shock SS2D® (operated with 2 D-cell batteries), Fi-Shock ESP2M® solar energizer (operated with solar powered batteries), and Zareba Yellowjacket® battery-operated fence energizer (operated with 4 D-cell batteries). We surrounded field camps with 2 strands of polywire suspended on fiberglass fence posts, or tensioned through non-conductive nylon cordage tied to trees or shrubs (Figure 4). We positioned fence wires approximately 46 cm and 76 cm above ground level and trimmed all vegetation from the fence line to eliminate voltage loss. We grounded energizers with either a copper-coated steel grounding rod (1.5 m) at semi-permanent research camps or an aluminum tent peg (20 cm) for short-term overnight camps. A fence power tester (voltmeter) showed that an aluminum tent peg, used as a grounding rod around a short-term overnight camp, was just as effective as the much larger 1.8-m rod.

Our camp enclosures ranged from 5 x 5 m to 20 x 20 m, with their size ultimately determined by the number of tents and gear within. We measured the strength of charge in fences with a Zareba digital electric fence tester (Zareba model DEFT), a unit which measures the voltage (kV) of each pulse (1 pulse sec^{-1}) of the energizer. We did not install any access gates around camps. Rather, personnel cleared the fence (76 cm in height) by stepping onto objects placed on either side (logs and/or stones). We present the specifications for energizers used in this research (Table 1).

Grizzly and Wolf Discovery Center, West Yellowstone, Montana. The Interagency Grizzly

Bear Committee (IGBC) required successful deterrence trials for specific energizers and fence configurations prior to approval for their use in the wild. At the GWDC, we experimented with 2-wire, 3-wire, and mesh net electric fence systems. Bears at the GWDC were rotated off display (e.g., viewing paddocks) every 90 minutes, thus providing a bear-free opportunity for researchers to erect fences for testing.

We placed approximately 100 kg of food, an amount typically carried by NOLS groups on expeditions (including freeze-dried meals, granola, candy bars, etc.), within nylon stuff sacks or plastic coolers within each electrified enclosure. To encourage bears to test our fences, we applied peanut butter to the ground just outside fences and extended a line of it underneath toward the food cache. In 2002, the electric fence surrounding the food cache was comprised of 3 strands of polywire, or 1.3-cm-wide polytape (both containing multiple strands of highly conductive stainless steel wire), supported on fiberglass fence posts affixed with non-conductive insulators. We used the Zareba Yellowjacket® energizer for these tests. This multi-power source energizer (i.e., can be powered with 110 volts alternating current [AC], 6 volts direct current [DC] wall charger, or 6 volts DC from batteries), is rated for a maximum output of 0.28 J, but produces only half that when powered by 4 D-cell batteries.

We experimented with the height of 2 fence wires to determine wire-height for optimal bear deterrence. To do this, we raised or lowered fence wires ± 30 cm from starting points of 30 cm and 60 cm to determine optimal placement for a 2-wire system. We tested mesh fences with captive bears at the GWDC in 2003 (Figure 5). These fences were comprised of polywire formed into a mesh net (10 x 15-cm cells). We used the same protocols for testing stranded and tape polywire fences with mesh net fences.

NOLS Field Camps, Greater Yellowstone Ecosystem, Wyoming. We evaluated the ability of electric fences to protect food caches from bears at NOLS from 2002 to 2014. A typical NOLS wilderness expedition lasts 30 days (a range of 14–135 days). Rather than surrounding tents with electric fences, as was done in our Alaska trials, we placed all camp food in a central cache (food stored in nylon stuff sacks piled together) and surrounded this cache with an electrified mesh (Figure 5).

The area within food caches protected by electric mesh nets was approximately 9 m^2. Each NOLS expedition included 10–15 people who received food supplies every 10 days (~10 kg of food per person/resupply). Therefore, at any given time, as much as 150 kg of food was in caches protected with an electrified mesh. Expeditions typically moved every 1–2 days, at which time campers erected electrified food caches. One user-night corresponded to each night a group of campers used the fence to protect food. Each NOLS group deploying a mesh net fence kept a journal of fence voltages (as determined with a fence tester) and other relevant notes, such as soil type, moisture, and results of fence deployment.

Results

Laboratory tests

Soil type and moisture content influenced EC (Figure 6; Table 2). Our meter was not sensitive enough to provide accurate values for EC in joules, so we have reported only kV values. All substrates exhibited similar EC when completely dry ($\bar{x}$ = 4.22 ± 0.14 kV). However, once substrates were fully water-saturated, conductivity increased sharply for all substrates, with a range of increase from 60% (river rock) to 127% (clay).

Organic matter had the highest conductivity of all substrates throughout the trial after saturation, with the exception of the clay being higher immediately once saturated (Figure 6, Table 2). As organic matter dried, conductivity trended downward, but the loss was minimal and not statistically significant throughout the trial period. Clay exhibited conductivity declines similar to organic matter until 288 hours post-saturation, at which time conductivity decreased rapidly with an EC lower than the organic matter soil. The conductivity of clay steadily and significantly decreased from 1 measurement to the next after the first 72 hours.

Loam presented a similar pattern, although its EC was less than that of clay at all times past 288 hours post-saturation. Its slope was a significantly steeper decline than that of clay. Sandy loam soil was also initially similar in conductivity to the other substrates but became less conductive than loam at 432 hours post-

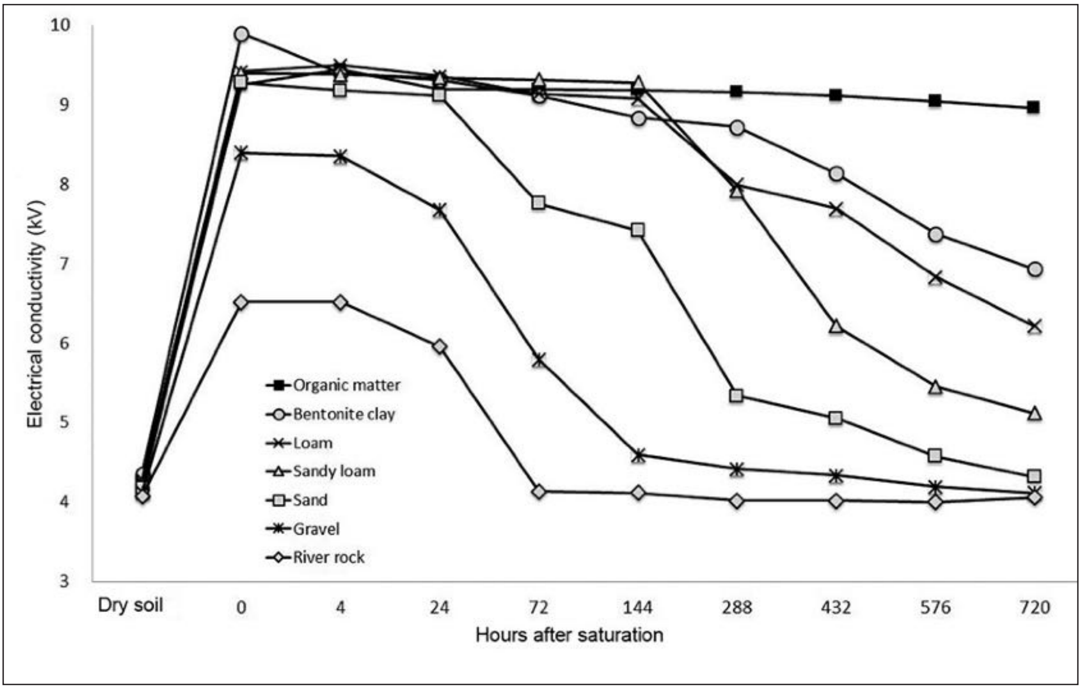

Figure 6. Electrical conductivity for various soil substrates as determined in laboratory trials performed at Brigham Young University, Provo, Utah, USA. Fence voltages in the field will test lower, but 1.5 kV deterred bears (*Ursus* spp.) in field trials.

saturation. Loam's slope had a significantly steeper decline than that of organic matter. Although initially similar to the other substrates, its EC decreased markedly after the first 24 hours post-saturation with an even steeper rate of loss.

Following the first 24 hours, the conductivity of sand was lower than the finer textured soils and organic matter, yet greater than rock materials until it reached its dry state, with conductivity equal to rock materials. Although showing an initial increase in conductivity, rock substrates never matched the conductivity of the other materials and decreased markedly after the first 24 hours. River rock achieved a conductivity equal to its dry state within 72 hours after saturation. Gravel was slightly more conductive than river rock but matched river rock by 576 hours post-saturation.

In general, as substrates dried down, EC decreased, with organic matter the least affected by drying (Figure 6; Table 2). The interaction between substrate and drying time is evident with all non-rock substrates being approximately equal. However, 432 hours post-saturation, the greatest variation in substrate EC occurred with declines in organic matter > clay > loam > sandy loam > sand > gravel > river rock. Not surprisingly, this order follows the order of the CEC and associated water holding capacity. By the end of the trial, sand, gravel, and river rock had all reached conductivity levels equivalent as to when they were oven dry prior to wetting. All other substrates reflected a similar trend. Based on slopes (Figure 6) and common knowledge of how soil materials dry over time, we expect that each of these materials would eventually reach complete dryness, and associated conductivity, although the time taken would be long, most notably for the organic matter soil.

Field trials

Alaska Peninsula, Katmai National Park and Becharof National Wildlife Refuge. Coastal grizzly bears contacted fences a minimum of 25 occasions. In all instances, fences kept bears from entering camps. Often times, even when in tents, we knew when bears contacted fences due to a sudden outburst of huffing, snorting, and paw swatting of vegetation. In all cases, bears left the area immediately after being shocked. On one occasion, a fence was knocked down when a cub's feet got entangled in the lower wire and

Table 2. Electrical conductivity through various soil substrates beginning with dry conditions followed by saturation and then dry down. Values (across soils and time) sharing the same letter(s) are not statistically different from one another. Conducted at Brigham Young University, Provo, Utah, USA.

Soil type	Dry soil		Hours post-saturation																	
			0		4		24		72		144		288		432		576		720	
Organic matter	4.28	tuv	9.26	bcd	9.44	abc	9.20	bcde	9.20	bcde	9.18	bcde	9.16	bcde	9.12	bdce	9.04	bcde	8.96	cde
Clay	4.36	tuv	9.90	a	9.40	abc	9.32	bcd	9.12	bcde	8.84	def	8.72	ef	8.14	gh	7.38	jk	6.94	kl
Loam	4.28	tuv	9.42	abc	9.50	ab	9.36	bcd	9.14	bcde	9.08	bcde	8.00	gh	7.70	hij	6.84	l	6.22	mn
Sandy loam	4.24	tuv	9.40	abc	9.38	abc	9.34	bcd	9.32	bcd	9.28	bcd	7.92	ghi	6.22	mn	5.46	opq	5.12	qr
Sand	4.18	tuv	9.28	bcd	9.18	bcde	9.12	bcde	7.76	hij	7.42	ijk	5.34	pq	5.06	qrs	4.58	stu	4.32	tuv
Gravel	4.12	tuv	8.40	fg	8.36	fg	7.68	hij	5.80	nop	4.60	rst	4.42	tuv	4.34	tuv	4.20	tuv	4.12	tuv
River rock	4.08	tuv	6.52	lm	6.52	lm	5.96	no	4.14	tuv	4.12	tuv	4.02	v	4.02	v	4.00	v	4.06	uv

dragged that wire along with the rest of the fencing, about 10 m, as the cub fled the area. We were not in the camp at the time, but were approaching and observed the incident. While the cub rendered the fence inoperable, no gear was damaged as it fled the area. In none of our tests did fences fail to work properly.

Grizzly and Wolf Discovery Center, West Yellowstone, Montana. When released into viewing areas with electrified fences surrounding food caches, bears initially approached and closely examined fence wires. Bears cautiously edged their noses close to each wire (<3 cm), as if to determine whether or not wires were electrified (see YouTube® video of NOLS bear fence test: https://www.youtube.com/watch?v=Sv2G-aRDvyY). Bears avoided touching fence wires and did not attempt to breach fences to gain access to food. When we used peanut butter as an enticement, bears fed upon it but did not touch fence wires to obtain peanut butter that extended under electrified fences into the enclosure. In all trials, we did not observe a fence failure.

We raised and lowered fence wires (± 30 cm from starting points of 30 cm and 60 cm) to determine optimal placement for a 2-wire system. Even when we lowered the top wire to 30 cm, a height we expected bears to simply step over, bears attempted to go under rather than over the fence. When we positioned the lowest wire at 30 cm, bears were unable to reach >60 cm into the enclosure before they contacted the lowest wire and were shocked. Our tests indicated that an upper wire placement of approximately 70 cm was optimal. Given time, bears attempted to dig under the lower wire to gain access to food. However, in our wilderness trials, bears did not attempt to dig under our fencing to gain access to food caches, as has been reported elsewhere (Storer et al. 1938).

NOLS Field Camps, Greater Yellowstone Ecosystem, Wyoming. Electric fencing (electrified mesh nets; Figure 5) successfully protected food supplies from depredation for 5,638 user nights. However, on 2 occasions, bears breached fences to obtain food. In the first instance, a juvenile black bear acquired a small amount of food from within the electrified cache. Subsequent investigation revealed that a broken solder joint within the energizer disabled it. In the second instance of failure, a fence surrounded the food cache but the energizer had not been activated.

On this occasion, a NOLS student saw a young black bear snatch a nylon stuff sack filled with food from the cache. Fortunately, when pursued by the student, the bear dropped the bag and all food was recovered.

Aside from these 2 failures, we had fences knocked down by other wildlife species on 10 occasions, but no food was taken. Because food did not appear to be the reason for the fence knockdown, we concluded that animals had most likely stumbled into these fences in the dark. Consequently, to enhance visibility, we attached blinking LED lights, each powered by a single 1.5 VDC AA battery, to the top of fence posts to alert wildlife. Since adding LEDs to food caches, only 2 additional fence knockdowns occurred, both during nights when the LEDs were off (Gookin 2013). Thus, there were no failures at the NOLS camps due to bears breaching a functioning electric fence.

Discussion

Our lab work demonstrated that soil type and moisture strongly influenced the strength of charge electric fencing can deliver to curious bears. However, we found that soil moisture had a much more pronounced effect on soil EC than did soil particle size (Figure 6; Table 2). It is important to note, however, that the voltages we recorded in laboratory trials are not indicative of voltages one might expect to measure on fences deployed in the field. This is due largely to our experimental setup (Figure 3), which was not intended to fully imitate that of actual fence installations.

Our field data showed that fences in the field occasionally carried voltages as low as 1.5 kV. However, we found these effective in repelling curious bears. To optimize the voltage carried on fences, we recommend situating fences on sites with at least some small mineral particles and/or organic matter present, as these types were the most conductive. As noted, moisture content played a significant role in soil EC, so moist sites should always be preferable to drier ones. However, normal moisture levels in soil should be adequate because wildlands soils do not approach oven dry conditions. Substrate trials made clear that when options exist, electric fences should be placed on the finest-grained substrate available, such as clays and organic matter. However, even the coarsest substrates have the potential to conduct adequate electricity, but wetness plays an increasingly important role as particle size increases. The worst-case scenario for camp placement would be to set it up on dry rock where conductivity is lowest.

We recommend that persons carry a lightweight fence tester (i.e., voltmeter) to determine the charge on the fence and to verify its proper operation. Affordable lightweight models include the Zareba Model #A5LVT-Z, which costs about $12 USD and weighs 72 g. Low test voltages may be due to poor substrates (e.g., gravel, sand, or river rock), dry conditions, weak batteries, vegetation touching and grounding the fence (i.e., grasses, shrubs, or trees), or a malfunctioning energizer.

We also recommend testing an energizer prior to use in the field because they occasionally fail, most often due to broken solder joints that can be repaired by resoldering. Additionally, we found that a metallic tent peg was an adequate ground in all of our encampment enclosures. This alleviates the need to carry the heavy grounding intended for livestock applications. One can also dispense with fence posts as long as non-conductive material (e.g., zip ties, parachute cord, etc.) is used to suspend fence strands from trees or shrubs. Our electric fence gear that protected a 20 x 20-m area weighed <750 g (1.7 lbs), making it lightweight and easily packable.

It is often stated that only the highest output energizers should be considered suitable for bear deterrence, given both their large body size and thick hair, which protects them from electrical shock, and that the voltage carried in fence wires should exceed 5 kV (http://www.adfg.alaska.gov/index.cfm?adfg=livingwithbears.bearfences). Indeed, recommendations for high voltage fences (e.g., >5 kV) may be warranted when protecting highly attractive objects, such as game meat, apiaries, or garbage. However, in the case of campsites and other non-food situations, our field experience suggests that much lower voltages effectively protected them. In many instances, our fences carried approximately 2 kV, with some voltages as low as 1.5 kV, yet they effectively repelled curious bears in our trials. Importantly, in the case of campsite protection, our observation is that bears do not push through fencing, nor lean up against them, but rather, cautiously approach and test wires with their noses or bite them, both resulting in powerful shocks to their muzzle. Clearly alarmed when shocked, bears abruptly backed away, or fled the area. A shocked and startled bear would often huff, jaw pop, or swat vegetation. Not surprisingly, we did not observe a bear approach any of our fences a second time after having been shocked.

At the GWDC, bears were accustomed to electric fences, and their lack of testing them was likely due to their prior experience. Additionally, these captive bears were well fed and likely less motivated to push past the fence than wild bears. Still, with strong enticements (e.g., peanut butter extending under the electric fence), GWDC bears did not successfully obtain food within any of these electrified mesh-protected food caches, although they could reach in up to 60 cm when the lowest fence wire was set at 30 cm above the ground. This suggests that while fences can keep bears out of electrified enclosures, they can, and will, extend paws underneath and grab what they can. On 1 occasion in Katmai, a bear reached under a fence and snagged a tent with its claws, then dragged it toward the fence before the startled person within began shouting at it.

In Katmai and Becharof, we erected 2-stranded fences around campsites in as little as 30 minutes, depending on the camp's size and the availability of trees and shrubs that we could use for suspending wires, rather than having to use posts. In some areas where trees and shrubs were abundant, we routed fence wires through non-conductive plastic zip strips or nylon cordage, thereby saving both time and weight. When camping in open areas, we used lightweight fiberglass posts to support fence wires. Because fiberglass is a non-conductive material, we did not need to position insulators on posts to hold wires in place. Rather, we secured fence polywires around posts with a clove hitch knot to hold them securely in place, thereby eliminating the need for insulators (Figure 4). In treeless settings, we anchored fiberglass posts with nylon cordage and stakes to keep fence wires taut. Although somewhat frail appearing (Figure 4), the main purpose of a 2-wire perimeter fence is simply to present bears with a hot wire by which to get shocked.

We often tied a piece of red plastic survey flagging to the top fence wire, midway between 2 posts, to draw bears' attention and curiosity. On several occasions, we observed bears drawn to this flagging, biting down on it, then receiving a powerful shock. Our campsites were not visible from a distance, so bears that approached them were not attracted to the area by fence flagging. However, flagging served to focus their attention once close, and resulted in them getting shocked in the mouth, a powerful deterrent.

Bears that tested our fences and were shocked did not linger nor return. It is possible that this form of aversive conditioning teaches curious bears to avoid all campsites, fenced or not, which may be an added benefit to both bears and people. In our Alaska Peninsula trials, no gear or food was lost to bears, and this has important implications for persons working or recreating in bear country. Kayaks, inflatable rafts, tents, food, and other gear sometimes unavoidably left unattended can be protected from curious bears with these highly portable and easily deployed fence systems. In addition, solo campers can protect their belongings and themselves by using a fence.

Our use of electric mesh nets around food caches for 5,638 user nights with no loss of food, save 1 instance, strongly underscores the effectiveness of this deterrent. Reasons for mesh net failures included dead batteries, energizer malfunction (i.e., broken internal wiring or on/off switches), improper grounding, inadequately cleared weeds (an electrically shorted-out fence), and persons failing to turn the fence on at night. Protecting energizers from excessive jarring and moisture will minimize the chances of failure. In the electric fence failures we have seen beyond this study, operator error was the most common cause. Persons failed to properly ground energizers, fence wires touched grass, shrubs, or trees, or the batteries were not fully charged. Additionally, few persons we interviewed used fence voltage testers to ensure a properly operating fence, even though testers are inexpensive and lightweight. We highly encourage persons to carry voltage testers, make sure their batteries are fresh, carry spares for longer trips, and that they familiarize themselves with the proper installation and use of electric fences before entering bear country.

We tested 2-wire, 3-wire, and mesh net fences in these trials and found that all 3 fences worked effectively to protect food and gear from bears. There are advantages to each, however. The 2-wire system is the lightest, requires less setup time, and has been very effective at thwarting curious bears. The 3-wire system, while heavier and more cumbersome to set up, provides a bit more security with smaller openings below and between wires and is more suited to longer-term encampments. The mesh net system is heaviest, yet prevents meso-carnivores, such as skunks (*Mephitis* spp.) and raccoons (*Procyon lotor*), from accessing nylon sacks with food. Clearly, if campers are carrying a bear-resistant food container (BRFC), no fence is needed to protect it. However, the food required to supply the typical NOLS outing exceeds the capacity of most bear canisters, requiring persons to carry 2 containers. To avoid the extra weight and cumbersome task of hauling 2 BRFCs, NOLS devised the electric mesh net approach where food is stored in nylon sacks. This arrangement, though highly effective for bear deterrence as shown by this work, is not permitted in national parks, in which case food must be in a BRFC. Beyond those costs (Table 1), additional fence components (i.e., polywire, voltage tester, insulators) can be obtained for approximately $30 USD. Mesh nets are around $100 USD and can be obtained on the internet.

A recent analysis of bear conflicts in Alaska by Smith and Herrero (2018) revealed that 9% of incidents (55 of 605) involved bears and persons in tents. In many cases, persons first became aware of the bear when their tents collapsed upon them. Among persons involved in these incidents (n = 123), injuries ranged from none (n = 108), injured but unspecified extent (n = 3), slight (n = 7), moderate (n = 1), and severe (n = 2) to fatalities (n = 2). It is conceivable that had electric fences been in place, tents, gear, and people would have been spared bear-inflicted damage and injury. Similarly, gear was destroyed by bears in many other incidents not involving tent camps, including kayaks, inflatable rafts, research weather ports (rubberized tents), and other personal items. Again, it seems likely that had fencing been in place, these losses may have been prevented along with interrupted research, recreation, and work.

To the best of our knowledge, electric fencing is not prohibited from use on any federal lands, including parks, refuges, and wilderness areas. The NPS, for example, has produced a brochure that demonstrates the use of electric fencing, presumably within parklands (NPS 2008). While electric fencing can deliver powerful shocks, they are non-injurious to wildlife and people, and thus they should not be feared as a potentially harmful deterrent. While we strongly encourage their use in backcountry settings, we do not encourage front-country use where hapless persons may shock themselves.

Management implications

Astronomer Carl Sagan was credited with saying "the absence of evidence is not the evidence of absence." In these field trials, we did not station trail cameras to document how many times bears tried, and failed, to enter fenced enclosures, but rather opportunistically observed and recorded them. With 2 failures out of >5,000 user nights in bear habitat, we conclude that mesh net fences are effective barriers for keeping food, property, and people safe from bears and other would-be food cache raiders. On the Alaska Peninsula, where grizzly bear densities are among the highest in the world (Sellers et al. 1999), no fence failures, in spite of a number of documented attempts, underscores the value of this tool for protecting people, their gear, and bears from trouble.

Acknowledgments

We are grateful to the Grizzly and Wolf Discovery Center for having provided access to their captive bears for testing. We thank NOLS, the National Park Service, Katmai National Park, Becharof National Wildlife Refuge, Brigham Young University, and the U.S. Geological Survey for their support of this work. Additionally, we are grateful to B. Roundy and R. Larsen of Brigham Young University for their assistance with statistics, and for anonymous reviewers and A. Clark, HWI associate editor, who substantially improved this manuscript.

Literature cited

Davies, J. C., and R. F. Rockwell. 1986. An electric fence to deter polar bear. Wildlife Society Bulletin 14:406–409.

Friedman, S. P. 2004. Soil properties influencing apparent electrical conductivity: a review. Computers and Electronics in Agriculture 46:45–70.

Gates, N. L., J. E. Rich, D. D. Godtel, and C. V. Hulet. 1978. Development and evaluation of anti-coyote electric fencing. Journal of Range Management 31:151–153.

Gookin, J. 2013. Electric fences for short-term food storage in grizzly bear habitat (poster). Proceedings of the 22nd International Conference on Bear Research and Management, Provo, Utah, USA.

Gunther, K. 2015. Risk, frequency, and trends in grizzly bear attacks in Yellowstone National Park. Yellowstone Science 23:62–65

Herrero, S. 2002. Bear attacks: their causes and avoidance. Lyons and Burford, New York, New York, USA.

Karhu, R. R., and S. H. Anderson. 2006. The effect of high-tensile electric fence designs on big-game and livestock movements. Wildlife Society Bulletin 34:293–299.

Masterson, L. J. 2015. Living with bears handbook. Expanded second edition. Pixy Jack Press, Masonville, Colorado, USA.

National Park Service. 2008. Electric fences in bear country. Harpers Ferry NPS publication, Washington D.C., USA, <http://www.nps.gov/kefj/learn/management/upload/Electric%20Fences%20in%20Bear%20Country%20s.pdf>. Accessed September 1, 2015.

Sellers, R. A., S. D. Miller, T. S. Smith, and R. Potts. 1999. Population dynamics of a naturally regulated brown bear population on the coast of Katmai National Park and Preserve. Final report, NPS/AR/NRTR-99/36. U.S. National Park Service, Anchorage, Alaska, USA.

Smith, T. S., S. Herrero, T. D. DeBruyn, and J. M. Wilder. 2008. Efficacy of bear deterrent spray in Alaska. Journal of Wildlife Management 72:640–645.

Smith, T. S., and S. Herrero. 2018. Human–bear conflict in Alaska: 1880–2015. Wildlife Society Bulletin. In press.

Storer, T. I., G. H. Vansell, and B. D. Moses. 1938. Protection of mountain apiaries from bears by use of electric fence. Journal of Wildlife Management 2:172–178.

Thompson, S., J. Jonkel, and P. Sowka. 2009. Living with predators resource guide: practical electric fencing resource guide: controlling predators. Living with Wildlife Foundation, Condon, Montana, USA, <http://www.gsseser.com/RMAteachers/electric_fence_2009.pdf>. Accessed September 2, 2015.

Associate Editor: Alan Clark

Tom S. Smith is an associate professor in the Wildlife and Wildlands Conservation Program at Brigham Young University and has been working on issues of human–bear conflict for the past 26 years. His research focus has been mainly on North American bear species (black, brown, and polar), but he also studies human–sloth bear conflict in India.

John Gookin (retired) served as the curriculum & research manager at the National Outdoor Leadership School. He has expertise in bear safety, bear deterrence, and continues camping and working in bear country.

Bryan G. Hopkins is a Certified Professional Soil Scientist and a professor in the Department of Plant and Wildlife Sciences at Brigham Young University. His research is focused on biophysical soil chemistry.

Samantha Henrie Thompson graduated with a B.S. degree in wildlife and wildlands conservation at Brigham Young University and is presently pursuing an M.S. degree in GIS with an emphasis on sustainability at the University of Washington.