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Black bear exclusion fences to protect mobile apiaries

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Abstract: Demand for commercial bee (*Apis mellifera*) services recently has increased, resulting in greater use of mobile apiaries for crop pollination. When commercial apiaries are moved into areas occupied by black bears (*Ursus americanus*), conflicts between beekeepers and bears sometimes occur. Commercial pollination often involves moving apiaries among agricultural fields, and, thus, permanent fencing is not a viable option for reducing damage by bears. In 2010, we tested the effectiveness of 4 temporary electric fence designs for excluding black bears from bait sites in northern Michigan. We determined the effectiveness of each fence design by observing bear behavior obtained from 24-hour video surveillance. From >433 minutes of bear–fence interactions (BFI), we recorded 168 BFIs in 73 visits by an estimated 15 bears. The only fence design deemed 100% effective at excluding bears consisted of 3 polytape strands charged with 5,000 V and spaced 0.58, 0.39, and 0.23 m from the ground, respectively. Proper fence construction and maintenance are critical elements of effectiveness, and we provide guidance on each. Our results demonstrate that low-cost temporary fencing can be an effective tool for excluding bears from localized sites, such as apiaries.

Key words: *Apis mellifera*, black bears, electric fencing, honey bees, human–wildlife conflict, pollination services, *Ursus americanus*

Crop pollination by honey bees (*Apis mellifera*) is critical to the agriculture industry (Morse and Calderone 2000, U.S. Environmental Protection Agency 2008, U. S. Fish and Wildlife Service 2009). Global declines in feral honey bee populations have resulted in demand for commercial pollination services (vanEngelsdorp and Meixner 2010). Commercial pollination services typically involve placing pallets of beehives in proximity to the areas requiring pollination. As such, the bee colonies tend to occupy relatively small areas that should be easy to protect with fencing. Efficacy of pollination depends on the stability and social structure of bee colonies (vanEngelsdorp and Meixner 2010), and, although numerous publications on using electrical fencing to protect bees have been produced by state and federal agencies, few have experimentally quantified differences in bear (*Ursus americanus*) behaviors around different fence designs (Storer et al. 1938, Huygens and Hayashi 1999, Creel 2007).

In many parts of the United States, black bears are a nuisance to beekeepers because bears are attracted to bee colonies as a food source (Maehr 1984, Caron and Bowman 2004, Maryland Department of Natural Resources 2004). Once a bear locates a source of food, it is likely to return (Hygnstrom and Craven 1996, Masterson 2006). A single bear encounter with an unprotected apiary can result in hive damage and colony loss, often imposing considerable negative economic consequences for the beekeeper (Maehr and Brady 1982, Jonker et al. 1998) and creating a problem that can last throughout the pollination season (Clark et al. 2005). State and federal wildlife management agencies have recommended the use of electric fencing as an option for protecting bee colonies from black bears, and electrified permanent fencing has proven effective (Washington Department of Fish and Wildlife 2007). However, permanent fencing is not a viable option for a mobile commercial bee industry (Burgett et al. 2010). Additionally, profit margins for commercial apiarists can be low, thereby restricting the ability to invest in protection devices.

One area of concern is the northwestern Lower Peninsula of Michigan where pollinator crops, particularly cherries (*Prunus* spp.), are important to the local economy (Michigan Land Use Institute 2009). According to the U.S. Department of Agriculture (USDA) Farm

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Service Agency, Michigan is a leader in the production of several major crops, many of which require pollination by commercial bees (Morse and Calderone 2000, Burgett et al. 2010). The northwestern Lower Peninsula alone (including Antrim, Benzie, Grand Traverse, Kalkaska, Leelanau, and Wexford counties) contributes nearly 25% to the annual fruit yield and nearly 60% to the annual cherry yield of Michigan (Michigan Land Use Institute 2009). The potential for apiarist–bear conflict is a wildlife management concern (Michigan Department of Natural Resources 2009). Although different techniques have been tested, electric fencing appears to be the most effective way to exclude bears from apiaries (Meadows et al. 1998, Caron and Bowman 2004, Clark et al. 2005). However, fencing often is not totally effective likely because of poor fence design, setup, and maintenance (Huygens and Hayashi 1999).

Few studies testing the effectiveness of electric fences for excluding black bears have used video surveillance to support their conclusions (e.g., USDA Forest Service 2007), and, to date, information on bear behavior around electric fences is lacking (McKillop and Sibly 1988). Understanding bear behavior could prove useful for improving fence design. The goal of this project was to quantify black bear behavior in proximity to portable fences and to use that information to identify an effective, temporary fence design for use by beekeepers. Our criteria for effectiveness included relative ease of installation and removal, low cost, and ability to exclude bears. We provide quantitative evidence in support of using temporary electrical fencing to exclude bears from small-scale attractants and offer insights into proper construction and maintenance techniques.

Study area

Our study occurred during July and August (overlapping a portion of the commercial bee season) of 2010 in the northeastern Lower Peninsula of Michigan, an area that supports high numbers of bear (D. Etter, Michigan Department of Natural Resources, personal communication). We identified 12 potential sites for fence testing in Alpena County, Michigan, on property owned by Beaver Lake Hunt Club (BLHC). Beaver Lake Hunt Club encompasses 17 km^2 of northern hardwood forest and forested wetlands (*Acer, Betula, Tilia, Prunus*, *Pinus*, *Thuja,* and *Abies* spp.), ranges in elevation from 231.6 to 304.8 m, receives

Table 1. Pre-baiting, nights prior to bear detection at pre-baiting sites, and total nights of baiting used to test the efficacy of temporary electrical fences for excluding black bears from bait sites, Beaver Lake Hunt Club, Lachine, Michigan, 2010.

Site number	Began baiting	Bears detected	Nights baited prior to bear detection	Total nights baited (includes fence testing)	Fence designs tested	Number of nights tested
1	June 24	June 29	3	15	A [a]	3
2	July 21	- [a]	- [a]	10	- [a]	- [a]
3	July 12	July 16	4	9	C	2
4	July 26	July 29	3	8	D	3
5	August 3	August 6	3	8	B	3
6	June 17	June 21	2	17	A and B	5 (A), 1 (B)
7	July 28	July 31 or August 2[b]	3	8	D	2
8	July 21	July 24	3	8	C	2
9	July 18	July 24	4	6	C	2

[a] Fence designs are shown in Figure 1. There were no bears detected at site 2.
[b] No camera on site, but bear activity was evident. For example, a wide pathway led to the bait area, the vegetated ground where the bait had been placed had been worked over thoroughly; all bait was gone and a swath of bare earth remained.

between 52 and 94 cm of precipitation annually (National Oceanic and Atmospheric Administration 2013), and borders other privately-owned hunt club properties. Hunt club properties are actively managed for popular game species, primarily white-tailed deer (*Odocoileus virginianus*). Management includes planting food plots and manipulating vegetation to provide cover and mast-producing trees.

Methods

We selected sites for fence testing in consultation with BLHC staff and members who identified areas of high bear activity and favorable summer habitat (e.g., forested wetlands). We started pre-baiting potential test sites on June 17, 2010 (Table 1). We used 4.4 to 13.2 L of bait per day to attract bears to these sites; the amount used on any given day depended on how much bait remained from the day before. Specific bait items included combinations of bread, cookies, trail mix, Circus Peanuts (Spangler Candy Company, Bryan, Ohio), cinnamon-chocolate chips, vanilla icing, blueberry pie filling, honey, bacon, sardines, and fryer grease. Our objectives with pre-baiting were to: (1) document bear use of potential test sites and (2) to reward bears that visited the sites to encourage their return.

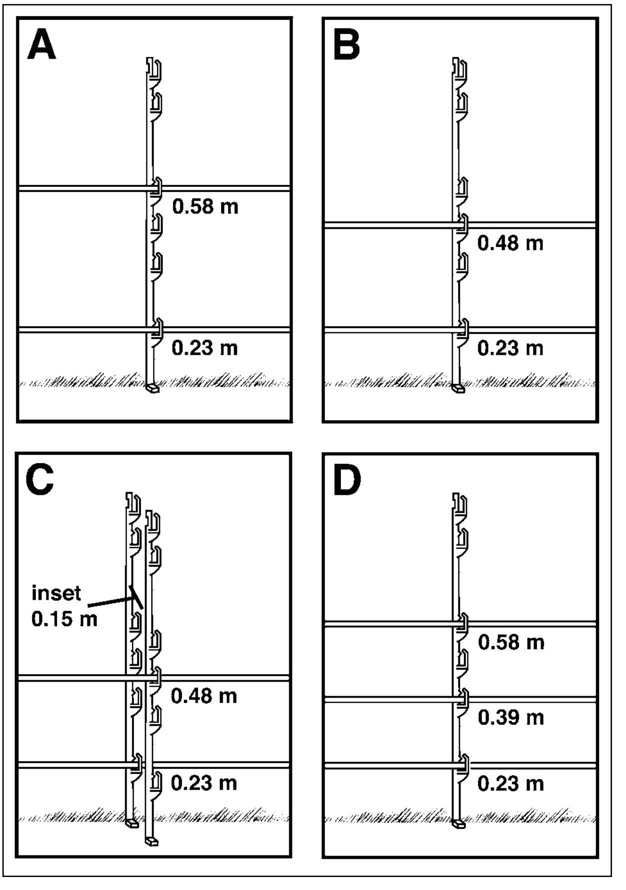

Figure 1. Fence designs that were tested for excluding black bears in the Beaver Lake Hunt Club, Lachine, Michigan, June to August 2010. All fence designs used the same wire type: 1.3-cm white polytape.

At each potential test site, we used a motion-triggered, infrared, digital trail camera (Cuddeback® Excite 2.0 Megapixel Digital Trail Camera, Non Typical Inc., Green Bay, Wis.) to determine the presence of bears at the bait. These cameras were placed in trees at a height of 0.9 to 1.2 m, a distance from the bait of 1.8 m to 2.7 m, and were angled slightly downward. If a bear was detected at the bait during the pre-baiting period, the site was considered active and used to test a fence design. If no bears appeared at the site after 10 days of pre-baiting (with periodic refreshing of the bait), we considered the site inactive, and it was removed from the candidate sites for fence testing. During fence testing, the same baiting mix and regime were used to encourage bear interactions with the fence.

We evaluated 4 fence designs, each based on a different polytape configuration (Figure 1). Each fence cost approximately $150 to $200 and all were comprised of the same components: white electric polytape, 1.3-cm-wide; fiberglass corner fence rods, 1.8-m-long and 0.04-m-diameter; plastic step-in fence posts, 1.1-m-long; a portable, battery-powered 0.25 Joule fence energizer (Kencove Farm and Fence Supplies, Blairsville, Penn.); galvanized grounding rod, 1.2-m-long and 1.3-cm-diameter; 1.3-cm-diameter brass grounding rod clamps; and double-insulated electric wire rated at 20,000 V to connect the energizer to the fence and grounding rods (Figure 2). We used a 12 V, deep-cycle marine battery to power the fence energizer, and we maintained approximately 5,000 V through the polytape, consistent with Hygnstrom (1994), Hygnstrom and Craven (1996), and Montana Fish, Wildlife, and Parks

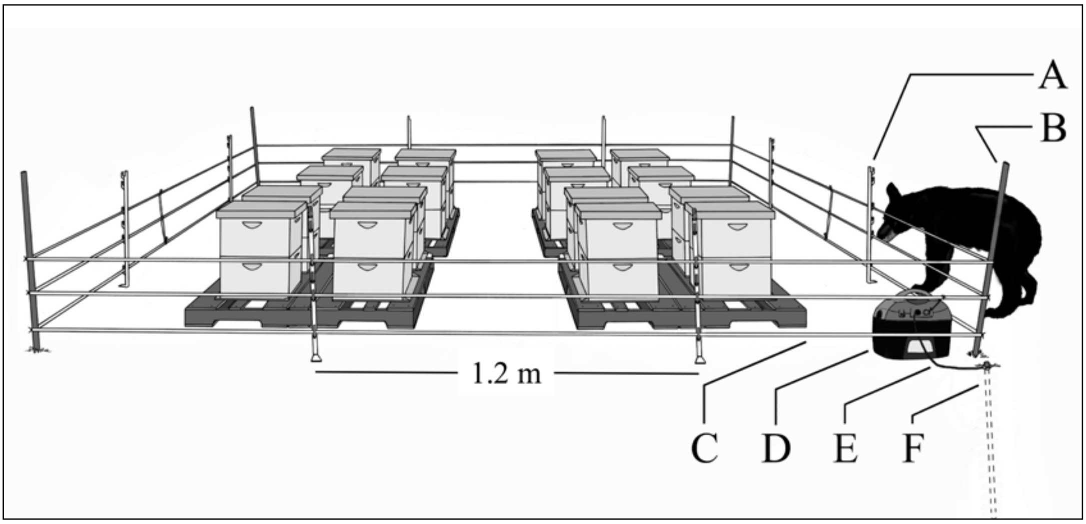

Figure 2. Most effective fence design for excluding black bears from bait sites in the Beaver Lake Hunt Club, Lachine, Michigan, June to August 2010. Fence materials include: step-in post (A), fiberglass rod (B), polytape (C), fence energizer (D), double-insulated wire (E), and grounding rod with clamp (F).

(2010). A battery-powered 0.25-Joule fence energizer can charge 2.4 km of wire if properly grounded. The construction of portable electric fences was relatively intuitive (Figure 2); it took approximately 1 hour for 1 person to set up a fence.

Bear-fence interactions (BFIs) were recorded using a high-resolution, motion-sensing, anti-vibration digital video recorder system (Model: GV-LX4C2V; GeoVision, Neihu District, Taipei 114, Taiwan). The weatherproof, infrared security cameras (Model: KPC139D; AVTECH Corporation, Nankang, Taipei 115, Taiwan) captured video in color during the day, black-and-white at night, and were capable of recording in complete darkness (0 lux). Each camera (3 at each site) was attached to a wooden base, secured at a height of 2.4 to 3.1 m in a tree (diameter at breast height approximately ≥15 cm) with cords and cable ties, and aimed directly at the bait from a distance that ensured that the entirety of the fence could be viewed through each camera.

We randomly assigned the order of fence designs for testing. The first test site was randomly selected, and subsequent test sites were located farthest from the previous test site. Separating the sites by farthest distance increased the likelihood of different bears visiting the fences; however, distances were too short to ensure that unique bears visited different fence testing sites. To estimate the number of unique bears interacting with our experiment, we developed individual identification techniques based on a variety of morphometric measurements, markings (e.g., ear tags, branding), and behaviors (Otto 2012). We recorded a variety of data on each BFI (Table 2) from the video recordings, along with several physical characteristics of each bear that aided in individual identification (Otto 2012).

We defined a BFI as an event when a bear came within 3 m of the fence and showed interest in either the fence or the bait. A bear showed interest in the fence or bait by directly approaching it with a clear line of sight and with ears and nose concentrated on the test site. A bear visit is defined as any time a bear was detected by the video cameras at a test site. Bears often circled fences repeatedly, sometimes approaching within 3 m of the fence multiple times as they moved. As a result, a bear could accrue multiple BFIs in 1 visit; it was also possible for a bear to accrue no BFIs during a visit. In this way, BFIs were tallied and linked to individual bears (Table 2). Our goal was to document ≥10 BFIs with a minimum of 3 unique bears per test site before moving to a different site and fence design. However, if 3 nights passed with fewer than 10 BFIs from 3 bears, we moved testing to another site.

Results

Pre-baiting occurred at 9 testing sites (Table

Table 2. Bear activity and fence performance, per fence design, during fence testing at the Beaver Lake Hunt Club, Lachine, Michigan, 2010.

	Fence design			
Metric	A	B	C	D
Bear visits	24	12	22	15
Detection nights[a]	7 of 8	4 of 4	5 of 6	4 of 5
Bear–fence interactions (BFIs)	52	30	48	38
Total duration of BFIs (min.)	246	30	86	70
Unique bears	4	6	4	3
Average visits/bear	6	2	6	5
Average BFIs/bear	13	5	12	13
Break plane or touch fence (count (%)[b]	11 (21)	5 (17)	17 (35)	6 (16)
Breach without bait access[b]	0	2	0	1
Breach with bait access	3	0	3	0
BFIs with breach (%)	6	7	6	3
Fence effectiveness (%)[c]	94	100	94	100

[a] Number of nights in which a bear was detected by cameras at the fence.
[b] Breaking the plane of the fence is defined as an event when a bear extends any part of its body through the vertical plane of the fence. A breach is defined as a bear breaking the plane of the fence by extending the entirety of at least 1 leg through the vertical plane of the fence
[c] 100 = breach with bait access/BFIs * 100

1); distances among testing sites ranged from 0.7 to 6.0 km (= 2.47 km). Sites were pre-baited for 3.1 ± 0.2 nights (± SE) before a bear was detected. Bears were observed at 8 sites (Table 1). Once bears were detected at a site, baiting continued until a fence was established and testing was complete at the site. Baiting (i.e., pre-baiting and then baiting during fence testing) occurred for 9.9 ± 1.2 nights on average at each testing site (Table 1). Variation in total baiting nights among sites was caused by 2 factors: (1) the fence was being tested on another site and hence was not available for immediate deployment; and (2) because pre-baiting occurred simultaneously at multiple sites, fence deployment had to be staggered, once bears were detected.

Seventy-three bear visits were recorded (Table 2). Total bear visits ranged from 12 to 24 per fence design and each fence design received comparable bear attention. Conservatively, we estimated that 3 to 6 individual bears interacted with each fence design (Table 2). On average, bear fence interactions lasted <5 minutes (Table 2). Total duration of BFIs for Design A (246 minutes) exceeded that of any other fence design (Table 2). Design A failed to exclude bears from the bait, and, hence, the time spent consuming bait inflated the BFI total and average. Individual bears visited fences multiple times (range 2.0 to 6.0), and we recorded multiple BFIs from each bear (range 5.0 to 13.0; Table 2).

The proportion of BFIs that resulted in a bear either breaching or touching the fence was 0.21, 0.17, 0.35, and 0.16, for Designs A, B, C, and D, respectively. This suggested that fence designs A, B, and D received comparable bear attention during testing and that design C received approximately twice the attention (Figure 3). Breach events occurred on all fence designs, but the proportion of BFIs that resulted in a breach varied among designs (Table 2). Design D had the lowest proportion (2.6%) of BFIs that resulted in a breach. All breach events that occurred for Designs A and C resulted in bait access, while none of the breach events that occurred for Designs B and D resulted in bait access. Fence Design B had 2 breach events without bait access. During one of these breaches, a large bear entered the fence between the top and bottom polytape strands. It received a shock on its back left leg, along the inner thigh. The bear responded by turning and leaping to avoid colliding with a step-in post. Because the top polytape strand was over its back as it had entered the fence, the strand pulled free from the corner post as the bear fled. Although this breach event did not result in bait access, fence damage occurred, making the bait vulnerable to future bear visits. The other breach events did not result in fence damage; both bears attempted to step over the top polytape strand and received a shock on the upper inside of a front leg (a desirable location for bears to feel the shock). Designs B and D were considered 100% effective, because bears did not access the bait during the breach events.

Discussion

The goal of our project was to identify a portable, inexpensive electric fence that was 100% effective at excluding black bears from a relatively small area (i.e., ~13.4 m^2). We intentionally tested fence designs that some

Figure 3. Example of field set-up for testing fences (design C is pictured) for excluding black bears from bait sites in the Beaver Lake Hunt Club, Lachine, Michigan, June to August 2010.

may view as sub-optimum to keep costs and assembly or disassembly times low. We found that two of the designs we tested (Designs B and D) were 100% effective at preventing bait access. Gates et al. (1978), Reidy et al. (2008), Tolhurst et al. (2008), and Honda et al. (2009) evaluated electric fence effectiveness for different species (i.e., coyotes (*Canis latrans*), feral swine (*Sus scrofa*), badgers (*Meles meles*), raccoon dogs (*Nyctereutes procyonoides*), and masked palm civets (*Paguma larvata*)), using the same criterion for evaluation (i.e., access to attractant). All agreed that a properly designed and maintained fence is an important tool for the prevention of damage caused by wildlife. Reidy et al. (2008) observed that juvenile swine successfully breached fencing more frequently because of their small size. We made a similar observation; small bears (≤ 0.5 m at the shoulder) successfully breached fences more frequently than larger bears. Given that each fence design received a comparable amount of bear attention, that all designs were breached, but only 2 designs kept bears away from the bait, and that Design D allowed the fewest breach events per BFI where no fence damage occurred, we designated Design D as the preferred fence design for excluding black bears from bait.

Behavioral differences were also apparent between young bears (birth year) and large, presumably older bears. After receiving a shock from the fence, birth-year cubs often attempted to breach the fence again just moments after the initial shock. Large bears (≥0.7 m at the shoulder), alternatively, were rarely seen again at the fences after receiving a shock. Our results suggest that electrical fencing may prove useful in conditioning older bears to avoid localized areas, provided that the motivation to seek a reward (i.e., the bait) does not override the risk associated with receiving a shock. Bears likely exhibit varying motivations for challenging a fence based on the urgency to acquire the perceived reward. Older bears may possess a more extensive cognitive map of various food sources within their environment and hence more readily abandon a protected reward. The size of older bears also allows them to travel greater distances more efficiently. Yet when natural food is scarce, as would occur in years of low mast production, it is likely that bears of any age would challenge electric fences more frequently and with greater vigor, particularly in areas of relatively high bear density (Garshelis 1989, Hygnstrom 1994).

We observed 3 breach events of our fences that did not result in bait access. Two of those breaches may not have occurred if a fourth tier of polytape was installed above the top-most strand on Designs B and D (Figure 1). This observation is consistent with Masterson (2006), who recommended a minimum of 4 tiers of wire for effectively excluding black bears. Additionally, other studies have documented that portable electric fencing effectively excludes bears (*U. americanus* or *U. thibetanus*) if the fences contained 4 tiers of wire, where the top strand was situated between 0.91 and 1.02 m above the ground. (e.g., Storer et al. 1938, Huygens and Hayashi 1999, Creel 2007).

Bear behaviors observed most frequently during this study were consistent with those of other studies (e.g., Storer et al. 1938, Huygens and Hayashi 1999, Creel 2007). Prior to a BFI, bears cautiously approached the fence, circling from a distance presumably to investigate the fence and the test site while remaining vigilant of their surroundings (e.g., nose up and sniffing the air, looking around). During a BFI, bears appeared to remain cautious and inquisitive, circling frequently, and sniffing the fence and fence energizer. If they received a shock from the fence, most bears ran away. After a BFI, some bears continued circling the test site, while others moved beyond the view of the cameras, presumably having left the area. Though bears were occasionally observed digging around the fence, no bear focused consistently in a single location or dug down beyond approximately 2.5 cm.

Creel (2007) found that once a bear accessed bait, it returned more frequently to test sites, compared to bears that had not accessed bait; this is an example of cognitive mapping ability that is supported by numerous accounts (e.g., Beckmann et al. 2004, Clark et al. 2005, Masterson 2006, Leigh 2007, Washington Department of Fish and Wildlife 2007). This bear behavior provides incentive to install fencing proactively as a means to prevent initial access to the reward and, thereby, decreasing the longer-term risk of bear damage. Creel (2007) also found that a bear could access bait once it gets through a fence and be deterred by the same electric fence on subsequent visits.

Standard wooden pallets (approximately 1.0 m x 1.2 m) often are used as platforms for mobile beehives and it is common for beekeepers to move entire pallets into croplands (R. Hoopingarner, Michigan Beekeepers Association, personal communication). We recommend placing beehives away from riparian areas, positioning hives >0.6 m from the electric fence, and removing trees and debris that bears potentially could topple onto the fence. Additionally, herbaceous vegetation should be kept away from the polytape to reduce the chances of an electrical short developing along the fence. Beekeepers frequently live or work out-of-state while their bees perform services for landowners. In these cases, arrangements must be made to ensure that electric fences receive regular maintenance. Maintenance checks should ensure adequate voltage through the polytape (measure voltage at the point farthest away from the energizer), a check on battery charge, and an overall assessment of the fence structure (polytape free of debris, fence posts securely in place, tight and clean connections between the fence and the energizer).

The fences tested in this study might also be useful against other nuisance mammals if the number of polytape strands is increased and the distance between each strand is decreased. Although few North American mammals are known to seek beehives as a source of food, bears and striped skunks (*Mephitis mephitis*) are known pests (Hygnstrom and Craven 1996), while raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), and mice (Suborder Myomorpha) may also be of nuisance to apiarists (Caron 2000). Mice are an issue primarily during winter (Morland 1938, Caron 2000). Although no skunks were seen visiting our test sites, raccoons, opossums, and mice were frequently observed breaching exclusion fences by moving underneath the lowest fence tier.

Management implications

Human–bear conflict is an on-going concern for wildlife managers. These conflicts can negatively affect the views of stakeholders toward wildlife management agencies. We caution that fencing is only 1 methodology that managers should consider. Public education on removing and properly managing bear attractants (e.g., garbage, bird feed), managed hunts, hazing, and, as an absolute last resort, relocation of problem bears will all help minimize human–bear conflict in localized areas. For beekeepers in particular, bear damage can be extremely expensive, and, for those who have experienced damage, attitudes toward bears are likely negative. Our results suggest that properly designed, erected, and maintained portable electric fences effectively deter bear access to an attractant. Even the least effective design deterred bear access to bait during 86% of all bear visits.

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