American black bears and bee yard depredation at Okefenokee Swamp, Georgia

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Abstract: We studied American black bears (*Ursus americanus*), on the northwest periphery of Okefenokee Swamp in southeast Georgia, to assess landowner attitudes toward bears, estimate the extent of damage to commercial honey bee operations by bears, and evaluate methods to reduce bear depredations to apiaries. We collected 8,351 black bear radiolocations and identified 51 bee yards on our study area. Twenty-seven of 43 home ranges contained $\geq$1 bee yard, averaging 11.3 and 5.1 bee yards/home range of males (n = 7) and females (n = 20), respectively. From 1996 to 1998, we documented 7 instances of bears raiding bee yards within our study area and 6 instances in adjacent areas. All but 1 of the 13 raided yards were enclosed by electric fencing. In the 12 cases of damage to electrically fenced yards, however, the fences were not active because of depleted batteries. Based on compositional analysis, bear use of areas 800–1,400 m from bee yards was disproportionately greater than use 0–800 m from bee yards. Bears disproportionately used bay (red bay: *Persea borbonia*, loblolly bay: *Gordonia lasianthus*, and southern magnolia: *Magnolia virginia*), gum (water tupelo: *Nyssa aquatic* and black gum: *N. sylvatica*), and cypress (*Taxodium* spp.) and loblolly bay habitats, however, compared with slash pine (*Pinus elliottii*) or pine–oak (*Quercus* spp.), where bee yards usually were placed. The distribution of bear radiolocations likely reflected the use of those swamp and riparian areas, rather than avoidance of bee yards. Distances to streams from damaged bee yards ($\bar{x}$ = 1,750 m) were less than from undamaged yards ($\bar{x}$ = 4,442 m), and damaged bee yards were closer to unimproved roads ($\bar{x}$ = 134 m) than were undamaged bee yards ($\bar{x}$ = 802 m). Our analysis suggests that bee yard placement away from bear travel routes (such as streams and unimproved roads) can reduce bear depredation problems. Our results strongly indicate that working electric fences are effective deterrents to bear damage to bee yards, even in areas frequented by bears. A survey of beekeepers indicated that apiarists often relied on more expensive, less effective, and sometimes illegal methods to protect their bee yards from bears. Beekeepers within bear range should be urged to consider electric fencing, which can almost eliminate bear damage to their yards.

Key words: American black bear, apiary, bees, damage, electric fencing, Florida, Georgia, habitat, Okefenokee, *Ursus americanus*

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Beekeeping is an important industry the US. More than 82 million kg of honey was produced in 2003, worth >$255 million (National Agricultural Statistics Service 2004). Unfortunately, high quality bee range often coincides with black bear habitat; American black bears (*Ursus americanus*) are the most significant cause of damage to apiaries in North America (Huygens and Hayashi 1999). Damage is difficult to estimate, but losses to individual beekeepers can be economically devastating (Lord and Ambrose 1981, Maehr and Brady 1982, Jonker et al. 1998). It is, therefore, important to better understand bear behavior relative to bee yards so that effective management techniques can be developed to reduce losses to apiarists.

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Fig. 1. Study area location and landscape characteristics along the northwestern portion of Okefenokee National Wildlife Refuge, Georgia, 1995–99.

Electric fences have long been used to deter bears from bee yards (Storer et al. 1938) and are considered to be the most effective method to protect apiaries (Maehr 1984, Huygens and Hayashi 1999). Other measures, such as the use of aversive baits and on-site release of trapped nuisance bears, have been used with varying success (Colvin 1975, Wooldridge 1976, Brady and Maehr 1982). Evaluation of the effectiveness of electric fencing to deter bears has largely been anecdotal, although Huygens and Hayashi (1999) performed a more rigorous assessment of Asiatic black bear (*Ursus thibetanus*) depredation rates at fenced apiaries and crop fields in Japan. They documented bear activity near fences based on field sign but documented no depredations. Movement of American black bears near bee yards has not been intensively studied, however, nor has the frequency with which bears encounter bee yards and factors that may lead to those encounters.

Bears that raid properly fenced bee yards in Georgia are most commonly relocated; killing depredating bears generally is not permitted. Relocation is sometimes perceived by beekeepers as ineffective and, consequently, has generated negative attitudes about management agencies and black bears. Management agencies, on the other hand, want to address damage issues without compromising the status of the bear population. Our objectives were to assess local landowner attitudes toward bears, evaluate movement of bears relative to bee yards, estimate the extent of losses to bears in an area with a high density of apiaries, and evaluate methods to reduce bear depredations.

Study area

Our research was centered at 30°40′ north latitude and 82°30′ west longitude, adjacent to the northwest portion of Okefenokee National Wildlife Refuge (ONWR) in Charlton, Clinch, and Ware counties in southeast Georgia (Fig. 1). Private lands within the study area were predominately pine plantations, managed by Jefferson Smurfit and Container Corporation and by Rayonier Incorporated. Nearby human population centers were the cities of Waycross to the north and Folkston to the east of the study area.

Okefenokee Swamp lies within ONWR and is one of the largest freshwater wetlands in the United States. Water input primarily occurs through precipitation, but springs and stream runoff from higher lands to the northwest add to the volume (Duever 1982). Soils in this region, formed from marine sediments deposited during the Pleistocene and Holocene epochs, are typically acidic and poor in nutrients (Cohen et al. 1984, Loftin et al. 2000). The vertebrate diversity of this wetland system is greater than in any area of similar size in the southeastern US; this is a result of the dynamic and complex landscape mosaic (Meyers and Odum 1991, Wigley and Lancia 1998) and because many species reach the geographical limit of their ranges at or near the area (Laerm et al. 1980).

The climate in southern Georgia is subtropical, characterized by cool, dry winters and hot, wet summers (Howell 1984). The average annual temperature for the region is 20°C and ranges from an average minimum of 13°C to an average maximum of 27°C (Henry et al. 1994). Wetland habitats of Okefenokee Swamp are comprised of pure to mixed stands of bay (red bay: *Persea borbonia*, loblolly bay: *Gordonia lasianthus*, and southern magnolia: *Magnolia virginia*), gum (water tupelo: *Nyssa aquatic* and blackgum: *N. sylvatica*), and cypress (*Taxodium* spp.), shrub swamps, prairies, and open water. The drier upland areas on the remote islands and surrounding the swamp basin are made up of forested pinelands interspersed with smaller bayheads and cypress domes. The surrounding private lands are predominantly managed as industrial slash pine plantations on cutting rotations of about 25 years. Prescribed fire is frequent and the understory of those plantations is primarily comprised of saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), and bitter gallberry (*Ilex glabra*). Dense vegetation throughout both wetland and upland habitats affords bears nearly ubiquitous escape and resting cover. Blueberry (*Vaccinium* spp.) and huckleberries (*Gaylussacia* spp.) are primary spring foods for bears at Okefenokee, followed by sweet gallberry (*Ilex coriacea*), saw palmetto fruit, and grapes (*Vitis* spp.) in summer, and palmetto fruit, black gum, and acorns (*Quercus* spp.) in autumn (Dobey et al. 2005). Black gum and acorns are patchily distributed in wetland areas, whereas sweet gallberry, blueberry, huckleberry, grapes, and saw palmetto are widespread in upland areas.

In addition to wood products, honey is an important agricultural commodity of the region (National Agricultural Statistics Service 2004). Bee yards on our study area were located outside ONWR on private lands. Bee yard plots were designated and leased to beekeepers by corporate landowners on a yearly basis.

Methods

Capture and handling

We captured black bears with Aldrich spring-activated foot snares (Aldrich Animal Trap Company, Clallam Bay, Washington, USA) equipped with automobile hood springs (Johnson and Pelton 1980). Trapping took place from early June through late September 1995–98. Trap-sites were generally established to completely sample the area and avoid large gaps in the sampling grid. Traps were set near known bear travel routes and bear sign. We immobilized captured bears with a 2:1 mixture of ketamine hydrochloride (ketaset, Burns Veterinary Supply Incorporated, Farmers Branch, Texas, USA) and xylazine hydrochloride (rompun, Haver-Lockhart Incorporated, Shawnee, Kansas, USA). Immobilization drug was intramuscularly administered with a push pole at a dosage of 4.4 mg of ketamine hydrochloride and 2.2 mg of xylazine hydrochloride per kg of estimated body mass. We monitored body temperature, pulse, and respiration throughout each immobilization.

We tattooed a permanent identification number on the inside upper lip or inner thigh of each bear. Numbered ear tags, corresponding to individual tattoo identification numbers, were placed in both ears of each bear. Each female bear estimated to be >1 year of age and a select number of male bears received radiocollars (Telonics Incorporated, Mesa, Arizona, USA and Lotek Engineering Incorporated, Ontario, Canada). We equipped each collar with a 12.5-cm wide × 0.4-cm thick leather spacer that served as a breakaway device (Hellgren et al. 1988). We extracted a first upper premolar tooth for aging by cementum annuli analysis (Willey 1974). Tooth sectioning, staining, and age assignment were conducted by Matson Laboratories (Milltown, Montana, USA). At the conclusion of handling each bear, we administered yohimbine hydrochloride (Lloyd Laboratories, Shenandoah, Iowa, USA), an antagonist for xylazine hydrochloride, through the sublingual vein at a dosage of 0.2 mg/kg of body mass. All trapping and handling activities were in accordance with approved University of Tennessee Animal Care and Use Protocols (UT-ACUC #760).

Radiotelemetry

We estimated the location of radiocollared bears from the ground with a Model TR-4 receiver (Telonics Incorporated, Mesa, Arizona, USA) and a 5-element, vehicular roof-mounted antenna (Wildlife Materials, Carbondale, Illinois, USA). Aerial locations were collected from a Cessna 172 fixed-wing aircraft with a receiver and a toggle switch that enabled us to change reception between H-antennae (Telonics Incorporated) mounted to each wing strut.

Telemetry locations estimated from the ground were determined by triangulation using the loudest signal method (Springer 1979, Mech 1983). Bear locations were calculated from ≥ 3 azimuths that were between 45° and 135° apart and collected within 20 min. Ground telemetry data were plotted on 1:24,000 US Geological

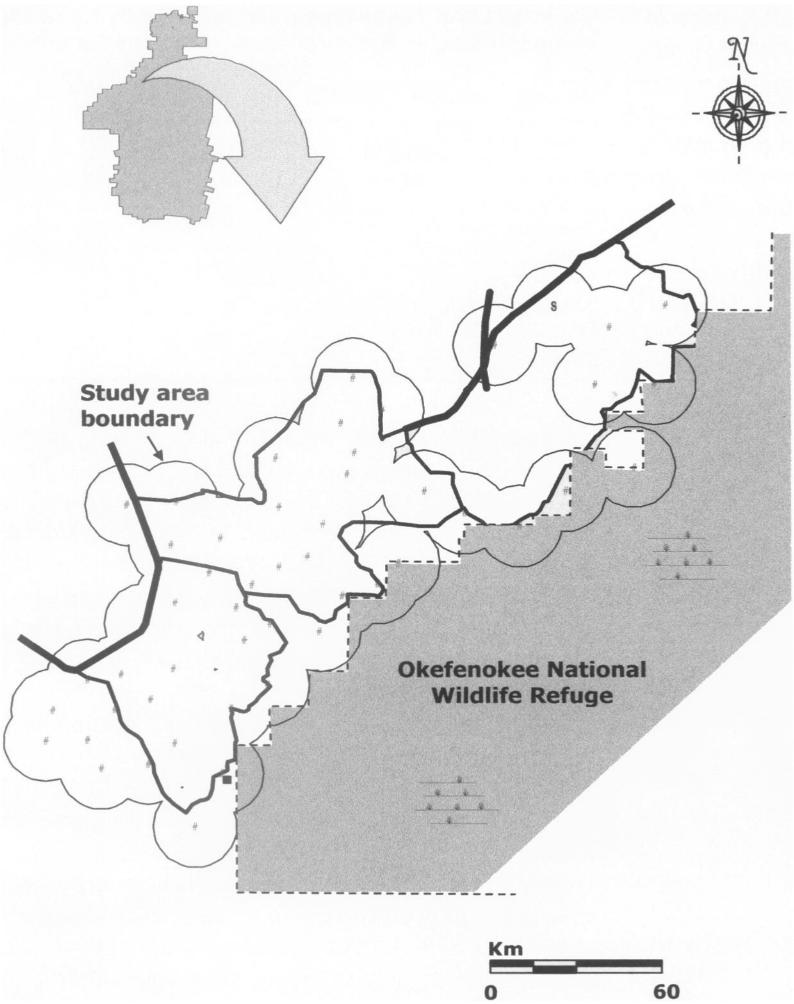

Fig. 2. Bee yard locations adjacent to the northwestern portion of Okefenokee National Wildlife Refuge, Georgia, 1995–99. Study area boundaries were delineated by buffering each bee yard with an arc with a radius equal to the average minimum distance between bee yards (1,611 m). The outside periphery of those arcs represent the study area boundary.

Survey (USGS) topographic maps at the time of collection and subsequently recorded as universal transverse Mercator (UTM) coordinates. Aerial locations were obtained by flying increasingly smaller circles over radiocollared bears until we presumed individuals to be directly under the aircraft. Locations were then recorded using a global positioning system (GPS; Magellan GPS Systems, Osborne Park, Australia). All GPS locations were recorded as UTM coordinates.

We estimated telemetry error by placing test collars in all habitat types that were used by bears. Test collars were located with ground and aerial telemetry using methods identical to those described above. Radio fixes were known by the recorder to be test collars but locations of those collars were not known. In addition to test collars, we also incorporated location data from dropped radiocollars and known den sites into our telemetry error analysis. In those cases, error was determined by calculating the distance between the actual location and the first recorded telemetry location when we presumed collar loss or den emergence occurred based on clustered sequential locations. Telemetry error was obtained by calculating the distance between the estimated location and the actual location, the latter determined with a GPS (Zimmerman and Powell 1995).

Spatial analysis

We used the 95% fixed kernel method (Worton 1989) to estimate overall home ranges of bears. All 95% fixed kernel estimates were calculated using the Animal Movement Extension (Hooge and Eichenlaub 1997) to ArcView® Geographic Information System (GIS, Environmental Systems Research Institute, Redlands, California, USA). Overall home ranges were calculated for all bears with ≥40 radiolocations (Seaman et al. 1999) that were monitored for ≥6 months during the active season (late Apr to Dec).

To determine whether bear movements were associated with bee yards, we identified all bee yards within the study area and determined UTM coordinates with a GPS. Bee yard locations were entered into ArcView® as a point coverage. Bear telemetry locations and home ranges were overlaid with the bee yard coverage.

We were interested in evaluating bear movements only in the portion of the study area where bee yards were present. Therefore, to restrict our analysis to areas near bee yards, we circumscribed each bee yard with a circle, the radius of which was equal to the average minimum distance between bee yards. Boundaries were defined by overlaying those circles around bee yards and connecting the outermost series of arcs using the BUFFER procedure in ArcView® GIS (Fig. 2). We created 8 distance categories consisting of a series of 200-m wide bands surrounding each bee yard, again using the BUFFER procedure. We then used compositional analysis (Aebischer et al. 1993) to determine whether some distance bands were disproportionately used by bears relative to availability within their respective home ranges (third-order selection, Johnson 1980). Compositional analysis uses multivariate analysis of variance to analyze use and availability data in which variables are represented as proportions. The technique determines statistical significance of differences and the rank order of differences between the variables.

Additionally, we established 7 cover types based on a digital map layer (30- × 30-m resolution; Florida Gap Analysis Project, Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, Florida, USA): gum–bay–cypress, loblolly bay, pine–oak, pine, swamp forest, shrub wetlands, and disturbed (Dobey et al. 2005; Table 1). Again, we restricted our analyses to the area near bee yards. The disturbed classification was represented by open water, bare soil, and urban or agricultural lands; those classifications were pooled because they comprised <3% of the total area for each site and received low use by bears. We also used compositional analysis to rank bear use of the 7 cover types in proximity to bee yards, again at the third-order level of selection.

Apiary depredation

In addition to UTM coordinates of bee yards, we recorded the owner, surrounding habitat, dimensions, number of beehives, arrangement of hives, and fence characteristics for all bee yards on the study area. Fence characteristics were described in detail, including type and height of fence, type of wire, and number of electrified strands. Road and stream coverages were developed from USGS digital line graphs. We determined the distances from bee yards to unimproved roads and streams with Arcview® GIS. We monitored bee yard damage during daily research activities and by notification from local apiary owners. We responded to all depredation reports within 24 hr of the reported incident. Fence voltage, damage to the fence, damage to hives, and how the bear gained access were recorded for each site. If possible, depredating bears were captured, radiocollared, and released as previously described.

Nuisance bears were defined as bears captured <100 m from a recently raided bee yard. Nuisance bears were captured and handled with the same techniques used to capture non-nuisance bears on our study area. After verifying normality and heterogeneity of variance assumptions, we used Student's *t* tests to compare characteristics of damaged and undamaged bee yards to identify factors that may have contributed to depredation. We also performed logistic regression to determine whether bear depredation was related to the physical characteristics of the bee yards themselves (Proc LOGISTIC, SAS Institute, Inc. 1997). We tested for differences in age class with analysis of variance (Proc GLM, SAS Institute, Inc. 1997) after verifying normality and equal variance of residuals assumptions. We monitored the movements of nuisance bears to determine whether new home ranges were established after on-site release or, if the bear was relocated, whether it returned to its previous home range.

Finally, we developed a survey of beekeepers in and around the study area to evaluate the extent of bee yard depredation. The survey contained short-answer and multiple-choice questions about the extent and type of damage the landowner might have experienced, control measures that had been used, and landowner attitudes toward bears. Names and addresses were obtained from local and state beekeeper associations in southern Georgia and northern Florida. The survey was mailed on 27 October 1997 and a reminder was mailed 2 weeks later. We mailed a second survey to non-respondents on 10 November 1997 and a final reminder on 15 December 1997. Results of those surveys were tabulated to estimate means and standard errors, and comparisons were made with Student's *t*-tests.

Table 1. Land cover types and availability used for compositional analysis for black bears on the northwest periphery of Okefenokee National Wildlife Refuge, Georgia 1995–99.

Cover type	Area (ha)	Percent
Black gum–bay–cypress	3,360	13.4
Loblolly bay	1,543	6.2
Pine–oak	2,656	10.6
Pine	11,258	45.0
Swamp forest	5,189	20.7
Shrub wetlands	556	2.2
Disturbed	476	1.9
Total	25,038	

Results

Spatial analyses

From June 1995 to September 1998, we captured 127 bears (76M:51F) 213 times. Annual captures ranged from 33 (1996) to 78 (1995). We obtained 8,351 radiolocations from 62 (16M:46F) bears from July 1995 to December 1999; aerial telemetry accounted for 84%

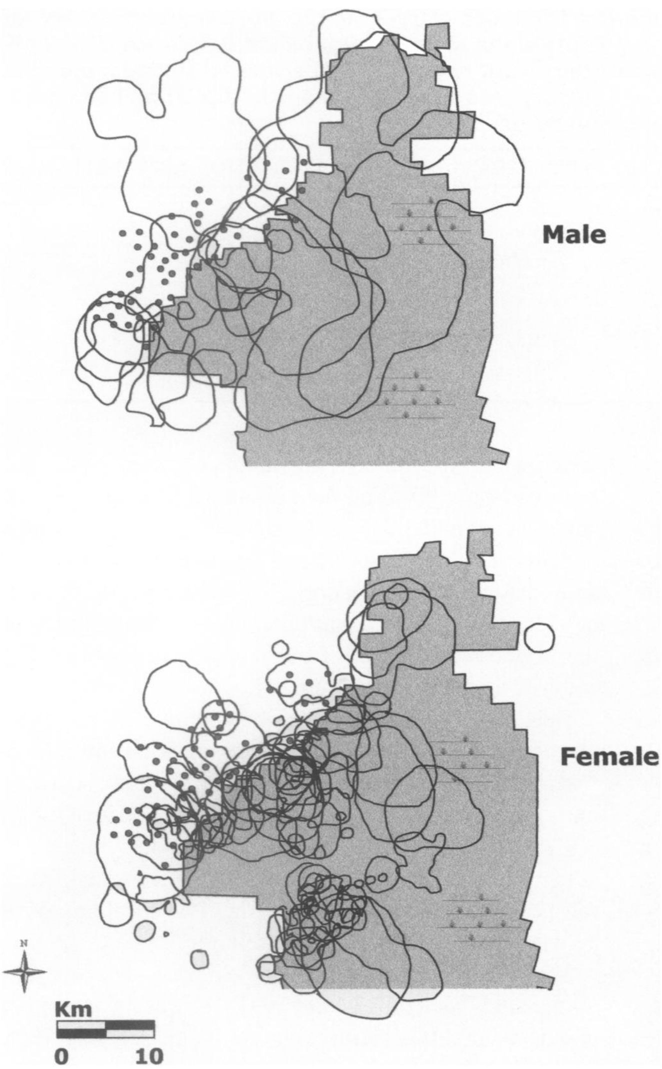

Fig. 3. Fixed kernel home ranges for 43 radiocollared male and female black bears in relation to bee yards (solid dots), northern Okefenokee National Wildlife Refuge, Georgia, 1995–99.

($n = 7{,}014$) of those locations. Forty-three bears met our sample size requirements for kernel home range estimation. Overall home range sizes averaged 364.9 km^2 ($n =$ 7, SE = 97.4) for males and 63.4 km^2 (n = 36, SE = 10.5) for females. Home-range overlap was extensive for all radiocollared bears on Okefenokee (Fig. 3).

We obtained 90 test locations (52 test collars, 26 dropped collars, and 12 den sites) from February 1996 to December 1999. Our mean errors and were 130.1 m ($n =$ 48, SE = 12.3) for aerial and 117.3 m (n = 42, SE = 10.6) for ground telemetry. Because mean error did not differ between those methods (t = 0.78, 88 df, P = 0.438), we pooled our test locations. Consequently, our overall mean error was 124.1 m ($n = 90$, SE = 8.2); 95% of all estimated locations were within 255 m of the true coordinates.

We identified and described 51 bee yards on our study area (Fig. 2). Those bee yards were an average of 1,611 m apart and, after we applied that distance as a buffer around each hive, our analysis area totaled 25,038 ha. Of the 43 bears whose home ranges we estimated, 27 (7M:20F) occupied home ranges that contained $\geq$1 bee yard, averaging 11.3 bee yards/home range (range = 2–18, SE = 2.4) for males and 5.1 bee yards/home range (range = 1–18, SE = 1.0) for females.

Compositional analysis indicated that bears within 1,600 m of bee yards selected areas more distant to bee yards. Generally, bears disproportionately used areas 800–1,400 m from bee yards more than areas 0–800 m from bee yards (Table 2). Black gum–bay–cypress and loblolly bay cover types were more likely to be used in the analysis area than were pine or pine–oak cover types (Table 3).

Apiary depredation

All bee yards on our study area were located in slash pine plantations and were enclosed with some form of electric fencing. Total fenced area ranged from 116 to 924 m^2 ($\bar{x} = 337.7$ m^2, SD = 164.7) and number of hives ranged from 14 to 76 ($\bar{x} = 28.0$, SD = 9.4) per bee yard. Electrical wire and barbed wire were most commonly used to construct electric fences, but electrical tape and electrified woven wire also were used. Fence height ranged from 58 to 127 cm ($\bar{x}$ = 88.1 cm, SD = 17.3). Power sources typically consisted of an automobile battery connected to a voltage-regulating fence charger (6 or 12 volts). Solar panels were used on-site to recharge batteries except in areas where the likelihood of theft was high.

Average distance from bee yards to nearest roads and streams was 710 m (range 7–8,915 m) and 2,119 m (range 10–8,687 m), respectively. Damaged bee yards were closer to roads ($\bar{x} = 134$ m) and streams ($\bar{x} = 1{,}750$ m) than undamaged bee yards ($\bar{x} = 802$ m, $t = 2.7$, 51 df, $P = 0.009$ and $\bar{x} = 4{,}442$ m, $t = 2.7$, 51 df, $P = 0.009$, respectively).

From 1996 to 1998, we documented 13 instances of bear damage to bee yards; 7 of the 51 bee yards on our study area were damaged, whereas 6 damaged yards were adjacent to our area. All but 1 of the 13 raided yards were enclosed with some form of electric fence. In

Table 2. Compositional analysis of distance categories from bee yards on the northwest periphery of Okefenokee National Wildlife Refuge, Georgia 1995–99. Triple signs signify a significant difference ($P < 0.05$) between corresponding categories on each axis, + means the category on the vertical axis was used more than the category on the horizontal axis; – means vertical category was used less than the horizontal category. Rank column reflects least (1) to greatest (8) disproportionate use.

Distance (m)	0–200	200–400	400–600	600–800	800–1,000	1,000–1200	1,200–1,400	1,400–1,600	1,600–1,611	Rank
0–200		–	–	–	—	–	—	–	+	1
200–400	+		–	–	—	–	—	–	+	2
400–600	+	+		+	–	—	—	–	+	4
600–800	+	+	–		—	—	—	–	+	3
800–1,000	+++	+++	+	+++		–	–	+	+++	7
1,000–1,200	+	+	+++	+++	–		—	+	+++	6
1,200–1,400	+++	+++	+++	+++	+	+++		+++	+++	8
1,400–1,600	+	+	+	+	–	–	—		+	5

12 instances when damage occurred to electrically fenced yards, the fence was not active because of depleted batteries. We recorded 1–8 destroyed hives/bear visit, and in no instances were all hives in a yard destroyed. Of the 13 depredation instances, 6 involved repeated bear visits on subsequent dates. Those 6 bee yards yielded 6 bear captures (4M:2F; Table 4) with an average time until capture of 4 days; we had previously captured and radiocollared 3 (2M:1F) of those 6 bears. Male and female nuisance bears averaged 2.3 (SE = 0.3) and 2.5 (SE = 0.5) years of age, whereas male and female non-nuisance bears with bee yards within their home ranges were older, averaging 6.8 (SE = 1.1) and 5.6 (SE = 0.5) years of age, respectively (F = 13.55; 1, 27 df; P = 0.001). Logistic regression revealed no relationships between bear damage to apiaries and fenced area, fence height, number of hives, or number of wire fence strands (Wald $\chi^2 < 2.54$, $P > 0.11$).

Nuisance bear movements

Bear 90, a 3-year-old male, was captured 12 April 1997 near Jesup, Georgia, 90 km northeast of our study area, where he raided an unfenced bee yard. We relocated bear 90 to an area about 16 km south of our study area. On 7 July, he was located on our study area and, on 11 July, he was located 16 km north of our study area near Waycross, Georgia. He continued north until he reached Highway 1 and established a home range in the northeastern corner of our study area, about 70 km south of his original capture site.

Bear 103, a 2-year-old male, was captured 26 May 1997 at a bee yard on the study area. Radiotracking subsequent to release indicated that he remained on the study area near other bee yards but did not cause additional damage.

Bear 84, a 2-year-old male, was captured 1 June 1997 at the same bee yard where bear 103 was captured. After release, his collar malfunctioned and no locations were collected; this bear was not recaptured.

We captured bear 85, a 2-year-old male, at a bee yard on the study area on 13 June 1997. He was recaptured at another raided bee yard on our study area 26 July 1998 and euthanized.

We captured bear 999, a 3-year-old female, on 4 December 1997 at a bee yard 30 km southeast of our study area. Bear 999 was initially captured as a cub with

Table 3. Compositional analysis of vegetation cover types near bee yards on the northwest periphery of Okefenokee National Wildlife Refuge, Georgia 1995–99. Triple signs signify a significant difference ($P < 0.05$) between corresponding categories on each axis, + means category on the vertical axis was used more and – means it was used less than the corresponding category on the horizontal axis. Rank reflects least (1) to greatest (7) disproportionate use.

Cover type	Black gum–bay–cypress	Loblolly bay	Pine–oak	Pine	Swamp forest	Shrub wetland	Disturbed	Rank
Black gum–bay–cypress		+	+++	+++	+++	+++	+++	7
Loblolly bay	–		+	+	+	+++	+++	6
Pine–oak	—	–		–	+	+	+++	4
Pine	—	–	+			+	+++	5
Swamp forest	—	–	–	–		+	+++	3
Shrub wetlands	—	—	–	–	–		+++	2
Disturbed	—	—	—	—	—	—		1

Table 4. Captured nuisance bears and their November 1998 status on the northwest periphery of Okefenokee National Wildlife Refuge, Georgia 1996–98.

Identification	Date captured	Mass (kg)	Sex	Age	Status
090	12 Apr 97	102	M	3	Active
103	26 May 97	66	M	2	Active
084	1 Jun 97	57	M	2	Active
085	13 Jun 97	66	M	2	Euthanized
999	4 Dec 97	75	F	3	Harvested
140	24 Jul 98	80	F	2	Active

her mother in 1993 by state officials in response to a nuisance complaint in Orange County, Florida. She and her mother were marked and relocated about 240 km north to Osceola National Forest, Florida; we subsequently captured her approximately 60 km north of that site in Florida. In December 1997, she was captured at another bee yard and we relocated her to Dixon Memorial Wildlife Management Area, about 20 km north of our study area. Bear 999 moved back to the northeast corner of our study area where she established a home range.

Finally, bear 140, a 2-year-old female, was captured at a bee yard on our study area on 24 July 1998. After her capture she remained in the area and maintained her home range; her nuisance activity apparently ceased.

Questionnaire survey

Beekeepers returned 58 of 84 surveys (70%). Each respondent maintained 0–3,000 hives ($\bar{x} = 599$) in 0–120 bee yards ($\bar{x} = 19$) in 1997. Of those bee yards, 13% were <1.6 km (1 mile) from the ONWR boundary, whereas 57% were >16.1 km (10 miles) from the boundary. Seventy-one percent of the respondents stated that bears raided their bee yards at least once from 1993 to 1997. Most damage occurred in spring (36%), followed by summer (31%), fall (22%), and winter (11%). Thirty-five percent of beekeepers who experienced damage considered the damage to be high, compared with 37% moderate, 21% less than moderate; 7% had no opinion. Estimates of monetary losses were $1,000–4,000. Most beekeepers (58%) felt that damage by bears increased from 1993 to 1997, and most of those (59%) felt this was because more bears were in the area. Respondents reported that bears damaged 0–32 ($\bar{x} = 6$) of their bee yards per year.

Seventy-four percent of the respondents reported that they attempted to prevent bear damage to bee yards. Chemicals (presumably poison, 22%) and trapping by management agencies (27%) were the 2 most common methods used by the respondents, but most deemed them ineffective. Electric fences were used by 14% of the respondents, and all who used them considered them at least somewhat effective. To prevent bear damage, beekeepers chose special permit harvesting of nuisance bears at bee yards (41%) followed by the use of electric fences (19%).

When asked about attitudes toward bears in the area, 43% thought bears were a nuisance whereas 47% enjoyed seeing bears but worried about bee yard damage. Most respondents (67%) felt bear damage was unacceptable, whereas 31% felt that bear damage was unwanted but recognized it as part of beekeeping in their area. Beekeepers with damage were >10 times more likely to say that bear populations had increased than beekeepers without damage ($t = 2.9$, 43 df, $P = 0.006$).

Discussion

Estimates of annual home range sizes of Okefenokee bears during this study were larger than those reported for most black bear populations in North America (Dobey et al. 2005). The abundance of black gum and palmetto fruit, dominant foods in the diet of Okefenokee bears (Dobey et al. 2005), fluctuated dramatically between years and often was patchily distributed on the area. As a result, home ranges on Okefenokee included relatively large areas as bears were forced to seek out those natural foods. That resulted in greater inclusion of bee yards within home ranges and increased opportunities for bears to encounter bee yards.

Although our compositional analysis suggest that bears were generally located away from bee yards, the analysis also revealed selection for swamp and riparian areas (black gum–bay–cypress and loblolly bay habitat). Those cover types were the primary interface between upland pine habitats and the swamp interior of ONWR (Dobey et al. 2005). Travel between upland pine and swamp forest habitats may have resulted in bears spending considerable amounts of time in swamp and riparian areas, where bee yards were not likely to be located. Similarly, riparian zones on Eglin Air Force Base in Florida were the primary habitat type used by bears (Stratman et al. 2001). We suspect that bears used areas away from bee yards because of cover preference rather than avoidance of bee yards.

Bee yards near streams and roads were more likely to be damaged by bears. Warren (1975) noted that bears used forested corridors as approaches to bee yards. Similar findings relating corridor use and bear damage were reported by Gunson (1973) and Merrill (1978). Although the swamp forest cover type, where streams occurred, was widely interspersed and accounted for only 12.3% of the study area, this vegetation association appears to provide important escape cover and relatively secure routes of travel through upland pine, where bee yards were located. Roads in our study area were unimproved with low vehicular traffic and, as such, were often used for travel by bears. Clearly, bee yards located in areas more likely to be frequented by bears were at greatest risk.

Of the 27 bears with annual home ranges encompassing bee yards, only 1 of 20 females but 2 of 7 males were known to have caused problems. Although many bears had access to bee yards and relatively few caused damage, the likelihood of damage was much greater for males. We consider the bear density on our study area to be moderate (0.12 bears/km^2, Dobey et al. 2005) and the bee yard density (0.16 bee yards/km^2) to be high. We noticed a bear trail along the fence of almost every bee yard on the study area, yet most bee yards were never damaged by bears. Presumably, bears were attracted to the yards but were prevented from entering by the electric fences. Bears may regularly check the operational status of these fences; indeed, all instances of bear depredation occurred only a few days after batteries that powered electric fences expired. Other researchers also found electric fences effective for deterring bear damage (Brady and Maehr 1982, McKillop and Sibly 1988, Huygens and Hayashi 1999).

Studies in Florida suggested that trapping and release of nuisance bears at bee yards prevented problem behavior (Brady and Maehr 1982, Wooding et al. 1988). Of the 6 nuisance bears that we radiocollared, however, 2 resumed nuisance activity, indicating that the release technique was not entirely effective. Several factors may affect the success of trap and release programs. First, we were never sure that the bear we captured was the bear that had caused the damage. Our average time before capture was 4 days, and we left traps set at bee yards for up to 7 days, leaving ample opportunity to capture non-nuisance bears. Also, there was a time lag between damage and acknowledgment of damage. Beekeepers on our study area checked their yards about every 3 days, and additional time elapsed before the bear was captured. If the animal we captured was the offending individual, such time lags may diminish the negative association of capture and release with the behavior we were attempting to prevent. Also, many damaged bee yards were not revisited by bears; those individuals could then raid other yards. Finally, we could never be sure that the lack of detectable nuisance behavior among bears was due to the aversion caused by capture or due to reactivation of the electric fencing. Because we never documented depredations of working electric fences, and found repeated nuisance behavior among some captured bears, we caution that the apparent aversion from capture may be at least partially due to fence reactivation.

Beekeepers that responded to our survey preferred to reduce the overall bear population with poisoning, trapping, or shooting, and most did not employ electric fences to deter bears. Those who used electric fences, however, deemed them somewhat effective. Indeed, on our study area where bear densities were higher than in areas further from ONWR, all bee yards were enclosed with electric fencing, suggesting that beekeepers more experienced with bears employ the fences. Survey respondents reported that they maintained an average of 19 bee yards and that bears damaged an average of 6 bee yards/year (32% annually). This contrasts with estimates from our study area, where only 7 of the 51 yards we monitored were damaged by bears during a 3-year period (5% annually). It is unclear whether the higher damage estimate was exaggerated by beekeepers (or perhaps a result of non-response bias) or whether survey respondents in areas with fewer bears were less effective in protecting their apiaries. Nevertheless, electric fencing is cost-effective for preventing bear damage; if it were otherwise, beekeepers within our study area would not have invested in the method so extensively or would have located bee yards elsewhere. The replacement cost of 1 hive (i.e., 2 hive bodies, frames and bees) is roughly equal to the cost of a solar fencer and charger (Mann Lake Ltd., Hackensack, Minnesota, USA and WoodsEnd Inc., Weston, Connecticut, USA) and, thus, electric fencing also would be cost effective for beekeepers in adjacent areas with lower bear densities.

Management implications

Human–bear conflicts can be critical determinants of black bear population dynamics in and adjacent to Okefenokee Swamp; where bears are not tolerated by humans, bears do not exist. Bear damage can be economically catastrophic to individual beekeepers, and their attitudes toward bears were generally negative. Our results suggest that working electric fences effectively deter bear damage to bee yards, even in areas frequented by bears, and are cost effective even in areas with few bears. Given proper deployment and maintenance, electric fencing should prevent almost all nuisance bear problems, at least in conditions similar to those in our study area. Additionally, the location of bee yards can affect nuisance activity; placing bee yards away from riparian corridors and, to some extent, unimproved roads may reduce problems with bears.

Most respondents to our survey did not employ electric fencing to prevent bear damage, yet most had experienced damage by bears. Clearly, managers must better inform beekeepers in southeastern Georgia and northern Florida about techniques (e.g., solar chargers, inexpensive fencing designs) that can almost eliminate bear damage to their yards. That might be accomplished with pamphlets or other publications, workshops, or by working with state Cooperative Extension Service officials. In instances when preventative methods have been employed but have failed, managers must consider alternatives, including euthanasia of trapped bears and the issuance of kill permits, to garner support among beekeepers for black bear conservation.

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