Effect of traffic volume on American black bears in central Florida, USA

J. Walter McCown[1,5], Paul Kubilis[2], Thomas H. Eason[3], and Brian K. Scheick[4]

[1]*Florida Fish and Wildlife Conservation Commission, 1105 Southwest Williston Road, Gainesville, FL 32601, USA*
[2]*Florida Fish and Wildlife Conservation Commission, PO Box 110339, Gainesville, FL 32611, USA*
[3]*Florida Fish and Wildlife Conservation Commission, 620 South Meridian Street, Tallahassee, FL 32399, USA*
[4]*Florida Fish and Wildlife Conservation Commission, 1526 Kelvin Avenue, Deltona, FL 32738, USA*

Abstract: Of American black bears (*Ursus americanus*) killed by vehicles in Florida from 1976 to 2003, 45% were from the population in central Florida centered in Ocala National Forest (ONF). This area contains 8 of the state's 15 most severe roadkill areas. More bears were killed along State Road 40 (SR-40), which bisects this population, than along any other road in the state. Interest in widening this road provided an opportunity to document bear movements and the frequency with which they crossed SR-40 when average annual daily traffic (AADT) volume was at each of two levels: 5,100 vehicles per day (vpd) in ONF and 15,700 vpd in the adjacent community of Lynne. We analyzed the locations of 86 radiocollared bears (33 F:40 M in ONF and 13 F in Lynne) and monitored them 1–3 times/week from May 1999 through May 2003. Forty-eight bears crossed SR-40 a minimum of 388 times. ONF female bears were 2.9 times more likely than Lynne females to cross SR-40, but this rate was only marginally significant. ONF male bears were 4.3 times more likely to cross SR-40 than ONF females and 12.3 times more likely to cross than were Lynne females. We documented the mortality of 7 radiocollared bears by vehicles, 4 males in ONF and 3 females in Lynne. There were no deaths of ONF females due to vehicular collisions, but female bears in Lynne died from vehicle collisions at near the rate of ONF male bears. We recommend that a minimum of 6 crossing structures be incorporated along this highway to reduce the effect of highway expansion on the Ocala population of Florida black bears.

Key words: American black bear, Florida, highway crossings, Ocala National Forest, telemetry, *Ursus americanus*

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From 1990 to 2003, the human population in Florida increased 30% to an estimated 17 million people (US Census Bureau 2005). Habitat fragmentation resulting from anthropogenic sources has contributed significantly to reducing the range of black bears (*Ursus americanus*) in Florida. Large-scale conversions of habitat to residential, commercial, and agricultural uses and a well-developed transportation grid have created several isolated bear populations in Florida (Dixon et al. 2007; Fig. 1). Of all vehicle-caused bear mortalities in Florida from 1976 to 2003, 45% were from the Ocala black bear population (Florida Fish and Wildlife Conservation Commission [FWC], unpublished data), an area that contains 8 of the state's 15 most severe roadkill areas (Gilbert et al. 2001). In addition to directly affecting bears through mortality, highways can profoundly affect bear populations by causing the loss of approximately 2.6–5.6 ha of habitat/km of highway (Wooding and Maddrey 1994) and causing bears to avoid adjacent habitat due to noise and disturbance (Kasworm and Manley 1990, Orlando 2003, Waller and Servheen 2005). Habitat fragmentation associated with a high-volume and high-speed roadway can alter the distribution of home ranges (Brody and Pelton 1989, Proctor et al. 2002), alter movements, and prevent bears from using seasonally important nutritional resources (Brandenburg 1996). These effects can be regional or local in scope.

Because bears use their habitat on local to landscape levels, occur in relatively low densities, and have low productivity, highways can threaten population persistence and genetic interchange.

[5]Walter.McCown@myFWC.com

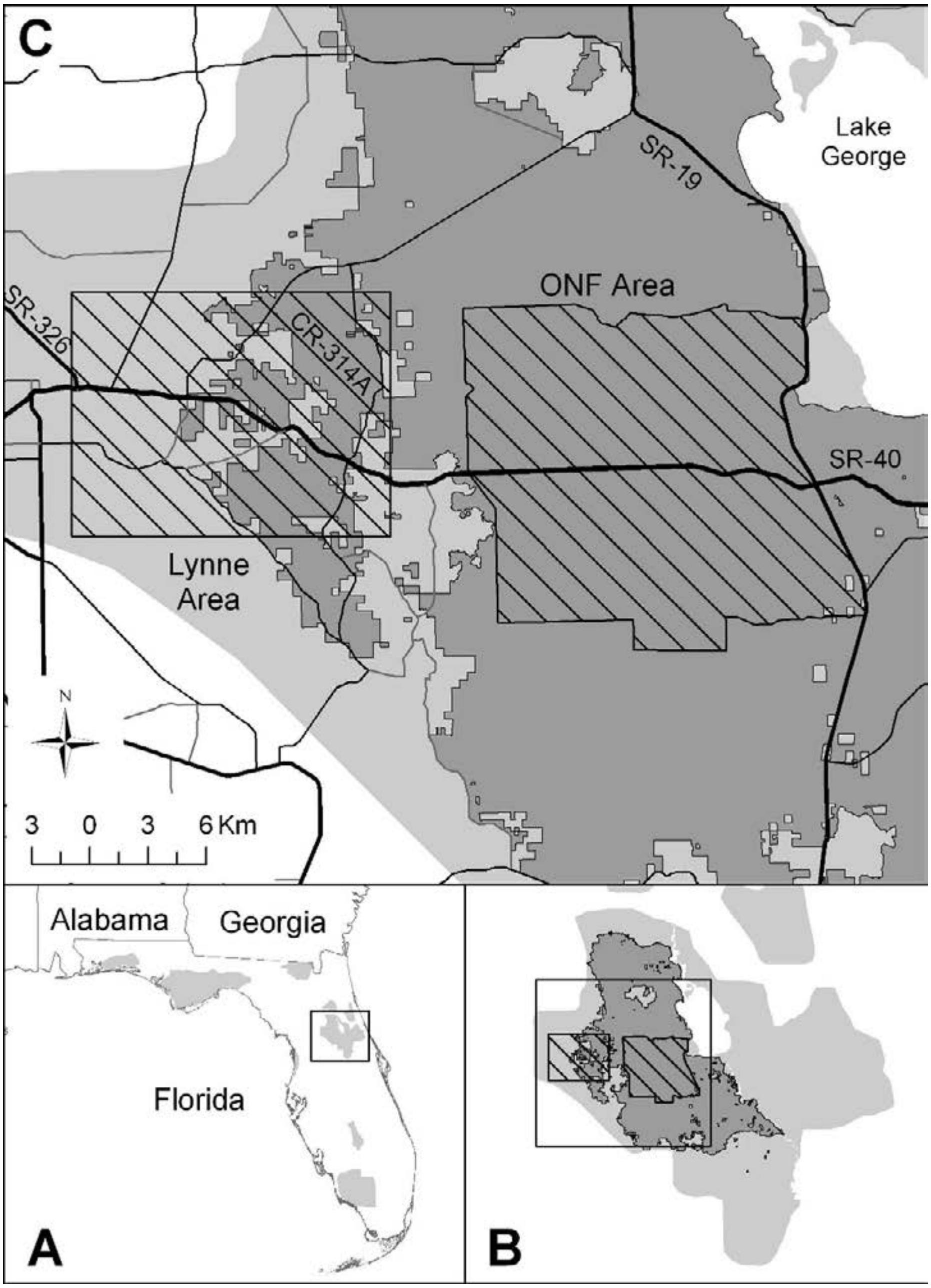

Fig. 1. The estimated breeding range of the black bear in Florida indicated by light shading (A) with study areas (hatched) in Ocala National Forest (dark shading) (B) and detail of study areas with major roads (C).

Recent evidence suggests that habitat fragmentation has significantly limited genetic interchange between most bear populations in Florida (Dixon et al. 2007). The degree to which highways contribute to habitat fragmentation may depend on traffic volume. Beringer et al. (1990) suggested that a traffic volume of 10,000 vehicles/day restricted, but did not totally impede, road crossings by bears in North Carolina. Brandenburg (1996) found that bears were much more likely to cross secondary roads than primary roads, and were much more likely to cross primary roads during periods of low traffic.

We sampled a portion of the bear population in Ocala National Forest and an adjacent community most likely to interact with SR-40, documenting the effects of low and moderate traffic volumes, gender, and distance from highways on the rate of highway crossings by these bears.

Study area

Our study areas in central Florida (approximately 29°11′N, 81°51′W) were located in the Ocala National Forest (ONF) and in the adjacent unincorporated community of Lynne (Fig. 1). The ONF study area encompassed approximately 287 km^2 of nearly contiguous bear habitat in the center of the forest. Managed forests of sand pine (*Pinus clausa*) with a dense understory containing several species of scrub oaks (*Quercus* spp.) growing on relic sea dunes composed the majority of forested lands; elevations ranged from 15 to 53 m above sea level. The ONF study area was bisected by SR-40, a major east–west highway in central Florida. Mean annual traffic along SR-40 in ONF during standard highway monitoring was 5,100 vehicles/day (Florida Department of Transportation [FDOT] 2003).

The Lynne study area was located approximately 9 km west of the contiguous western boundary of ONF and encompassed approximately 207 km^2 of small parcels of slash pine (*P. elliottii*) flatwoods managed by the US Forest Service as well as privately owned forests managed for commercial timber harvest; elevations ranged from 0 to 12 m (Fig. 1). Habitat in Lynne was highly dissected by a network of state and county roads as well by residential, industrial, and commercial development. Mean traffic along SR-40 through Lynne ranged from 14,700–16,700 vehicles/day (FDOT 2003).

Methods

Trapping

We captured bears using Aldrich foot snares (Johnson and Pelton 1980) with a modified anchor (Scheick et al. 2009). We trapped intermittently from mid-May to mid-December each year (1999–2003), concentrating our trapping efforts along the SR-40 corridor to focus on bears likely to interact with SR-40. Bears were immobilized with an injection of a 1:1 mixture of tiletamine hydrochloride and zolazepam hydrochloride (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) administered at 3.0–3.5 mg/kg of estimated bear weight via a carbon dioxide (CO_2) powered dart gun or blowpipe. We applied ophthalmic ointment to the eyes of immobilized bears and monitored vital signs (heart rate, respiration, rectal temperature) during immobilization. We extracted the first premolar for cementum annuli aging (Matson's Laboratories, Incorporated, Milltown, Montana, USA) and fitted bears with radiocollars (Telonics, Mesa, Arizona, USA) possessing a mortality switch and breakaway leather connectors. We selected individuals to be fitted with collars based on whether bears were of adequate size to prevent collar injury due to growth and maintaining as balanced a sex ratio as possible. We used the Kruskal-Wallis test to analyze distances of initial capture sites from SR-40 for all bears used in crossing analysis to detect whether any differences could have potentially biased our comparisons of bear subgroups. Bears in Lynne were captured as part of a separate biomedical investigation on demodetic mange that is passed from female to offspring, so no males were collared in Lynne.

Radiotelemetry

We obtained the daytime (0800–1900) locations of radiocollared bears 1–3 times/week from June 1999 to May 2003. Locations were estimated from the ground by triangulating compass bearings of the loudest signal (Springer 1979) from more than 2 positions using Locate II (Nams 1989). We estimated locations from the air by flying directly over the loudest signal and plotting that location onto a US Geological Survey topographic map. We estimated telemetry error by comparing estimated locations against the known locations of test collars, dropped collars, and winter dens. Bears were considered for crossing analysis only if they had at least 10 telemetry locations, were radiocollared a minimum of 30 days, and had no consecutive telemetry locations more than 30 days apart.

Crossings of SR-40 by radiocollared bears

We defined road crossings by radiocollared bears as all instances in which consecutive telemetry locations fell on opposite sides of SR-40. Because animals were not monitored continuously, this method of documentation provided a minimum frequency of crossings by radiocollared individuals (road crossing could have occurred without our detecting them). We evaluated air and ground locations for potential misclassification of crossings when the locations were within their respective mean telemetry error distance from SR-40. This was done by plotting 3 consecutive locations from the same animal where the accuracy of the middle point was in question. When the previous and subsequent points were on opposite sides of the road and beyond the mean telemetry error distance from SR-40, the timing of the crossing may have been in error but the crossing was correctly identified. However, a crossing may have been erroneously identified when the location close to SR-40 was incorrectly plotted on the opposite side of the highway from the other 2 locations (indicating 2 falsely defined crossings) or when the middle point was incorrectly plotted on the same side as the other 2 locations (indicating 2 possible unidentified crossings). Because our telemetry schedule documented only the minimum crossing frequency, falsely defined crossings were considered the more important error type.

We also used telemetry points to model the probability of a road crossing. We used mixed-effects logistic regression (Agresti 1990, Littell et al. 1996) as implemented in PROC NLMIXED (SAS V 9.1.3; SAS Institute, Cary, North Carolina, USA) to model the probability that consecutive locations of an individual bear would be on opposite sides of SR-40 among 3 groups of bears (GRP) defined by gender and locale (ONF males, ONF females, and Lynne females), and whether a bear was struck and killed by a vehicle (HBV) on SR-40. We assumed that crossings were less likely when bears were located further from SR-40 and when time between locations was shorter. Thus, we considered the perpendicular distance of the first of the 2 consecutive locations from SR-40, days elapsed between each 2 consecutive locations, and the interaction between these 2 effects as potential predictors in our models. Distances from bear locations to SR-40 were measured using the NEAREST FEATURE v.3.6c extension in ArcView 3.2 (ESRI, Redlands, California, USA). Because each bear contributed at least 10 locations to the analysis dataset (at least 9 pairs of consecutive locations), we modeled 'bear' as a random effect in each of the fixed effect models to account for any tendencies of individual bears to have higher or lower crossing rates. We used the small-sample version of the Akaike information criterion (AIC_c; Burnham and Anderson 1998) to evaluate the strength of evidence for models containing all combinations of grouping and continuous fixed effects as well as an intercept-only (null) model. Because we viewed the clustering of observations within 'bear' as a structural feature of our study design, and because the 'bear' random effect covariance exceeded its standard error by at least a factor of 3 in each of the mixed effect models considered, we restricted models for potential selection AIC_c to those that included the 'bear' random effect (Burnham and Anderson 1998). To compare crossing probabilities among bear groups, odds ratios with 95% confidence intervals were estimated and the Wald chi-square test was used to determine if they differed significantly from 1 (α = 0.05).

Traffic volume was monitored by FDOT each year using standardized methods independent of this study. Equipment was set at locations of their choosing and run continuously for 48 hours. Raw traffic counts were corrected for season using a standard seasonal factor based on monitoring sites throughout the state (R. Frase, FDOT, Tallahassee, Florida, USA, personal communication, 2008). Raw traffic data for each location in our study areas were provided at 15 minute increments and a corrected annual average daily traffic volume for each highway segment was provided (FDOT 2003).

Mortality

We documented mortality events by ground checking all mortality signals and reports of HBV bears. Necropsies were performed on dead bears to verify the cause of death. Kaplan-Meier (KM) survival curves (Kalbfleisch and Prentice 1980) that considered only HBV mortalities were estimated for each bear in each group (ONF females, ONF males, Lynne females). To determine if mortality rates due to vehicular collision differed among the 3 groups, the KM survival curves were compared using the log-rank test (Kalbfleisch and Prentice 1980).

Results

We fitted 95 adults (36 F, 46 M in ONF; 13 F in Lynne) with radiocollars. Mean distance from initial capture sites to SR-40 for bears used in crossing analysis was 2,324 m (ONF M was 2,443 m; ONF F was 2,794 m; Lynne F was 1,945 m). The mean distance of initial capture sites from SR-40 for Lynne females was marginally lower than that of ONF females (χ^2 = 5.14, 2 df, P = 0.0767). There was no other difference detected. The mean monitoring

Table 1. Road crossings and bears hit by a vehicle (HBV) by radiocollared American black bears in Lynne and Ocala National Forest (ONF) Florida, May 1999–May 2003.

	n	Bears crossing road	Total crossings	Range	Median	HBV
F Lynne	13	4	22	1–13	4	3
F ONF	33	15	115	1–30	7	0
M ONF	40	29	251	1–44	6	4

period for bears used in crossing analyses was 417 days for ONF males, 540 days for ONF females, and 323 days for Lynne females. Mean error was 251 m (SE = 270.3, $n = 25$) for aerial locations and 100 m (SE = 100.2, $n = 284$) for ground-based locations. We estimated that 26 defined crossings (6.7%) may have resulted from telemetry error. Conversely, our data set included 49 locations (17 aerial and 32 ground) not associated with a defined road crossing but which were within aerial or ground error-polygon distances of SR-40. Thus, additional crossings may have occurred that we failed to detect. However, all 32 of these ground locations were estimated using at least 1 bearing obtained directly from the highway shoulder, suggesting that field personnel had good vantage points to accurately determine which side of SR-40 the bear was on.

Eighty-six bears (33 F, 40 M in ONF; 13 F in Lynne) met our criteria for analysis. We documented a minimum of 388 crossings of SR-40 among 48 bears (15 F, 29 M in ONF; 4 F in Lynne). Of these 388, 137 were by females and 251 by males. Fifteen ONF females made 115 crossings and 4 Lynne females made 22 crossings. Four males in ONF and 3 females in Lynne were struck and killed by vehicles (Table 1). Vehicular collisions caused 7 of 12 (58%) mortalities of collared bears and were the leading cause of death. Of bears that we documented crossed SR-40 at least once, no ONF females, 4 ONF males, and 3 Lynne females were killed by vehicles.

The 2 models with the most support (Table 2) included the GRP + HBV (no interaction) or GRP grouping effects, and both distance (D) and time (T) effects with interaction (D + T + DT). All other models considered, including an intercept-only model, had effectively zero support for selection by Akaike weight. The model that grouped bears by both gender–locale (GRP) and vehicular interaction status (HBV) had slightly higher Akaike weight (36.7%) than the model that grouped bears only by gender–locale (23.4%). Akaike-weight support was

Table 2. Small-sample Akaike information criterion (AIC_c) based selection of models used to evaluate the association of various predictors with the probability of bears crossing SR-40. Each logistic regression model considered in the model selection exercise included an intercept and a bear subject-type random effect (each counted as 1 parameter). Models were considered with all possible combinations of grouping fixed effects (GRP or HBV) and continuous fixed effects (D or T), with or without interaction among the grouping effects, among the continuous effects, and between the grouping and continuous effects. Models that included interactions between grouping effects and continuous effects are indicated by an x **and those without interactions between grouping effects and continuous effects are indicated by a** +.

Fixed effects in model						
Grouping[a]		Continuous[b]	Total parameters[c]	AIC_c	ΔAIC_c	AIC_c weight
GRP + HBV	+	D[d] + T[e] + DT[f]	1i + 6f + 1r	2,257.9	0.0	0.367
GRP	+	D + T + DT	1i + 5f + 1r	2,258.8	0.9	0.234
GRP + HBV	+	D + T	1i + 5f + 1r	2,259.4	1.5	0.173
GRP	+	D + T	1i + 4f + 1r	2,260.2	2.3	0.116
GRP + HBV + GH	+	D + T + DT	1i + 8f + 1r	2,261.4	3.5	0.064
GRP + HBV + GH	+	D + T	1i + 7f + 1r	2,262.8	4.9	0.032
GRP	x	D + T + DT	1i + 11f + 1r	2,265.5	7.6	0.008
GRP	x	D + T	1i + 8f + 1r	2,266.0	8.1	0.006
GRP + HBV + GH	x	D + T	1i + 17f + 1r	2,271.1	13.2	0.000
HBV	+	D + T + DT	1i + 4f + 1r	2,275.7	17.8	0.000

[a]GRP = 2-parameter fixed effect defining, with the intercept, 3 groups of bears: ONF, M; ONF, F; and Lynne, F; HBV = 1-parameter fixed effect defining, with the intercept, 2 groups of bears: those hit by cars during the study and those not; GH = 2-parameter fixed effect representing interaction between GRP and HBV.

[b]D = 1-parameter continuous fixed effect representing distance of the first location in any consecutive pair of bear locations from SR-40; T = 1-parameter continuous fixed effect representing time between any pair of consecutive bear locations; DT = 1-parameter continuous fixed effect representing D and T interaction.

[c]Parameter types include the intercept (i), fixed effects (f), and the bear random effect variance (r).

Table 3. Comparison between bear groups of the odds ratios (OR) of predicted probabilities that a crossing of SR-40 will occur within 7 days. Data from radiocollared American black bears in Ocala National Forest (ONF) and Lynne, Florida, May 1999–May 2003.

Comparison	Odds ratio	95% CI	*P* (OR = 1)[a]
ONF M versus ONF F	4.26	1.88–9.63	0.0007
ONF F versus Lynne F	2.88	0.80–10.34	0.1035
ONF M versus Lynne F	12.26	3.63–41.45	0.0001
HBV[b] versus not HBV	2.42	0.80–7.35	0.1181
ONF HBV versus Lynne HBV	5.94	1.83–19.34	0.0036

[a] *P* (OR = 1): Probability that the odds ratio differed from 1, not significant if 95% CI brackets 1.

[b] HBV = hit (and killed) by motor vehicle.

double for these 2 models (60.1%) as for 2 similar models (28.9%) that excluded the interaction between distance and time effects (D + T).

The 2 models with greatest AIC_c support both indicated that bear subgroup membership was associated with the likelihood of observing a crossing of SR-40. These 2 models also indicated that both distance from SR-40 prior to crossing and time between consecutive locations were associated with the probability of observing a crossing, and that the influence of distance and time did not depend on bear subgroup membership. Thus in all bear subgroups, as the distance of a location from SR-40 increased, the likelihood that the next location would be on the opposite side of SR-40 decreased, although this tendency lessened in strength as the time between consecutive locations increased. As time between locations increased, the probability of observing a crossing increased, although this tendency lessened as the distance from SR-40 decreased.

There was effectively no support for models that did not distinguish bear subgroups or distinguished them only by whether they had been hit by a vehicle (HBV). Models with HBV group effects and continuously varying effects with or without interaction each resulted in a ΔAIC_c above 17 with an AIC_c weight of 0.000 (Table 2). There was also no support for models that included distance from SR-40 or time between consecutive locations by themselves, or for models that included interactions between grouping effects and distance or time effects, or interactions between the gender–locale grouping effect (GRP) and the HBV grouping effect (ΔAIC_c above 19 with weights of 0.000).

Differences between bear subgroups expressed as odds ratios (Table 3) were estimated using the first model (Table 2). These odds ratios are adjusted for the influence of first location distance from SR-40 and time elapsed between first and second locations, thus also accounting for differences among bear subgroups in mean initial release distance from SR-40.

Accounting for distance from the highway and elapsed time between locations, the odds of observing a crossing of SR-40 by an ONF male bear was 4.3 times greater than the odds of observing a crossing by an ONF female (Table 3). ONF females were 2.9 times more likely to be observed crossing the highway than Lynne females, although the *P* value for this odds ratio was 0.1035 (Table 3). ONF males were 12.3 times more likely to be observed crossing the highway than Lynne female bears.

The odds of observing a crossing by a bear that was subsequently killed by a motor vehicle was 2.4 times greater than for a bear that avoided this fate ($P = 0.1181$). Although we found the evidence persuasive that female bears in Lynne crossed at slightly lower rates than females in ONF and 12 times less than males in ONF, they were killed by vehicles at a greater rate than females in ONF and at a similar rate as ONF males. When only vehicular collisions were considered as mortality, the average annual mortality rate due to vehicular collision of Lynne females (0.23) was greater ($P = 0.0085$) than that of ONF females (0.00) and similar to that of ONF males (0.19).

Discussion

As expected, male bears crossed SR-40 much more often than did females because the larger home ranges of male bears mean they typically travel more and cross roads more often than females (Pelton 1982). We expected females in ONF, where traffic volume was much lower, to cross SR-40 more frequently than females in Lynne. Although female crossing rates in Lynne were marginally lower than in ONF, Lynne females were killed by vehicles more often than ONF females. Twenty-three percent of all collared Lynne females and 75% of those documented to have crossed SR-40 were killed by vehicular collision. No collared ONF females were struck by vehicles. The annual mortality rate of Lynne females due solely to vehicular collisions (0.23) was similar to the maximum sustainable annual mortality rate from all sources for black bear populations of similar demographic and reproductive characteristics (Bunnell and Tait 1980).

The lack of a strong difference in the crossing rates between ONF and Lynne females may be due to the low number of collared bears in Lynne and the highly variable crossing rates in both study areas. However, other factors, such as behavioral plasticity and habitat fragmentation, may have affected observed crossing rates but were not tested.

Bears that live close to humans often shift activity to a more nocturnal pattern in response to persistent human disturbance (Ayers et al. 1986). Bears may use behavioral adaptations to adjust for traffic as well, allowing them to cross roads during periods of low traffic. Grizzly bears (*U. arctos*) were more likely to cross a busy highway in Montana at night when traffic volume was <100 vehicles/hour (Waller and Servheen 2005). Similarly, Lynne bears may be more active at night than ONF bears and thus may be more likely to cross the highway during periods when traffic is lower (A. Neils, University of Florida, Gainesville, Florida, USA, unpublished data, 2007).

Because Lynne bears lived in fragmented habitat near humans, it is likely that they encountered humans and perhaps human foods more often than ONF bears. Although FWC received no complaints about marked bears, it is possible that some movements were in response to anthropogenic food sources and may have contributed to the deaths of 3 Lynne females killed illegally. Bears in Lynne may have adjusted their activity to minimize human disturbance, including avoiding traffic. However, that 3 HBV mortalities occurred despite only 22 documented crossings compared with no HBV mortalities of ONF females despite 115 crossings suggested to us that the behavioral adjustments by Lynne bears were inadequate.

The apparent correlation between high traffic volume and HBV incidents in the Lynne study area illustrates only one harmful effect that habitat fragmentation has upon bears in this region. Although bears normally avoid roadways with high traffic volume (Brody and Pelton 1989, Beringer et al. 1990), bears inhabiting severely fragmented habitat may be compelled to traverse busy roadways to seek mates, locate den sites, and obtain nutritional resources for themselves and their offspring. The increased risks to populations of wide-ranging carnivores inhabiting fragmented habitats and experiencing frequent human interactions (Woodroffe and Ginsberg 1998) is a problem facing most bear populations in Florida and is aptly demonstrated in Lynne.

Management implications

Female bears in Lynne exhibit natal philopatry (Moyer 2006) and have low reproductive potential and low cub survival (Garrison 2004). These characteristics make bears unlikely to persist in extensively fragmented habitats that perpetuate limited immigration and high levels of mortality. The planned expansion of SR-40 to 4 lanes through Lynne will significantly increase highway capacity (and therefore traffic volume), which will increase the risks to bears and contribute to further fragmentation of the remaining bear habitat. Because the estimated annual mortality in Lynne (37.6%; McCown et al. 2004) already occurs at an unsustainable level (Bunnell and Tait 1980), increased bear mortality and habitat fragmentation could isolate Lynne from the rest of ONF and imperil the existence of these bears.

We recommend that the FDOT consider the impacts to bears during the design process for the widening of SR-40. The construction of a series of crossing structures in this area would reduce risks to bears, mitigate additional mortality, and reduce the potential for genetic isolation. These structures should be designed and used with appropriate fencing to encourage bear use and strategically placed at existing bridge sites, at sites identified as having a history of bear–vehicle collisions (Gilbert et al. 2001), and at locations where pedestrian trails intersect the road.

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Literature cited

AGRESTI, A. 1990. Categorical data analysis. John Wiley and Sons, Inc., New York, New York, USA.

Ayres, L.A., L.S. Chow, and D.M. Graber. 1986. Black bear activity patterns and human induced modifications in Sequoia National Park. International Conference on Bear Research and Management 6:151–154.

Beringer, J.J., S.G. Siebert, and M.R. Pelton. 1990. Incidence of road crossing by black bears on Pisgah National Forest, North Carolina. International Conference on Bear Research and Management 8:85–92.

Brandenburg, D.M. 1996. Effects of roads on behavior and survival of black bears in coastal North Carolina. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Brody, A.J., and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17:5–10.

Bunnell, F.G., and D.E.N. Tait. 1980. Bears in models and in reality-implications to management. International Conference on Bear Research and Management 4:15–24.

Burnham, K.P., and D.R. Anderson. 1998. Model selection and multi-model inference: a practical information-theoretic approach. Springer-Verlog, New York, New York, USA.

Dixon, J.D., M.K. Oli, M.C. Wooten, T.H. Eason, J.W. McCown, and M.W. Cunningham. 2007. Genetic consequences of habitat fragmentation and loss: the case of the Florida black bear (*Ursus americanus floridanus*). Conservation Genetics 8:455–464.

Florida Department of Transportation. 2003. 2003 Florida traffic information digital video disc. Florida Department of Transportation, Tallahassee, Florida, USA.

Garrison, E.P. 2004. Reproductive ecology, cub survival, and den ecology of the Florida black bear. Thesis, University of Florida, Gainesville, Florida, USA.

Gilbert, T., R. Kautz, T. Eason, R. Kawula, and C. Morea. 2001. Prioritization of statewide black bear roadkill problem areas in Florida. Pages 574–579 in G.L. Evink, L. Coryell, L. Terwilliger, C. McCraken, K. Yondora, A. Peppers, and D. Zeigler, editors. A time for action: Proceedings of the International Conference on Ecology and Transportation. North Carolina State University, Keystone, Colorado, USA.

Johnson, K.G., and M.R. Pelton. 1980. Prebaiting and snaring techniques for black bears. Wildlife Society Bulletin 8:46–54.

Kalbfleisch, J.D., and R.L. Prentice. 1980. The statistical analysis of failure time data. John Wiley and Sons, New York, New York, USA.

Kasworm, W.F., and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79–84.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for mixed models. SAS Institute Inc., Cary, North Carolina, USA.

McCown, W., P. Kubilis, T. Eason, and B. Scheick. 2004. Black bear movements and habitat use relative to roads in Ocala National Forest. Final Report. Florida Department of Transportation Contract BD-016. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida, USA.

Moyer, M.A., J.W. McCown, T.H. Eason, and M.K. Oli. 2006. Does genetic relatedness influence space use pattern? A test on Florida black bears. Journal of Mammalogy 87:255–261.

Nams, V.O. 1989. Locate II—a program to triangulate radiotelemetry bearings and calculate error ellipses. http://www.nsac.ns.ca?envsci/staff/nams/Locate.html, accessed 1 July 2000.

Orlando, M.A. 2003. The ecology and behavior of an isolated black bear population in west central Florida. Thesis, University of Kentucky, Lexington, Kentucky, USA.

Pelton, M.R. 1982. Black bear. Pages 504–514 in J.A. Chapman and G.A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Proctor, M.F., B.N. McLellan, and C. Strobeck. 2002. Population fragmentation of grizzly bears in southeastern British Columbia, Canada. Ursus 13:153–160.

Scheick, B.K., M.W. Cunningham, J.W. McCown, and M.A. Orlando. 2009. Anchor modification for a foothold snare to capture American black bears. Ursus 20:47–49.

Springer, J.T. 1979. Some sources of bias and sampling error in radio triangulation. Journal of Wildlife Management 43:926–935.

US Census Bureau. 2005. Population estimates. US Census Bureau Population Division, Washington, DC, USA. www.census.gov/popest/estimates.php, accessed 1 October 2005.

Waller, J.S., and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69:985–1000.

Wooding, J.B., and R.C. Maddrey. 1994. Impacts of roads on black bears. Eastern Black Bear Workshop 12:124–129.

Woodroffe, R., and J.R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science 280:2126–2128.

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