Age, Sex and Relocation Distance as Predictors of Return for Relocated Nuisance Black Bears Ursus americanus in Ontario, Canada

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Original article

Age, sex and relocation distance as predictors of return for relocated nuisance black bears *Ursus americanus* in Ontario, Canada

Lynn J. Landriault, Glen S. Brown, Josef Hamr & Frank F. Mallory

Relocation has been used as a management tool for nuisance black bears *Ursus americanus* for decades. Using tag recovery data from relocated nuisance bears in Ontario, Canada, we developed predictive models to assist managers in determining the efficacy of black bear relocation based on the sex and age of the animal, and a range of relocation distances. We considered relocation success in terms of nuisance recurrence rates and whether bears returned to within 20 km of the capture site. A minimum of 30% of relocated bears were subsequently involved in another nuisance event and adult females were the segment of the population most likely to re-offend (48%). Adult bears consistently exhibited higher return rates than juveniles (73 vs 29%), hence we modeled these two groups separately. Based on logistic regression models, the probability of return for animals 1-3 years of age increased with age, females were more likely to return than males, and return rates decreased with increasing relocation distance. For bears $\geq$4 years of age, these variables were poor predictors of return; the model had difficulty identifying bears that did not return. We used receiver-operating characteristic curves to estimate relocation distance thresholds for juvenile bears. The results suggest that 2- and 3-year-old male bears will not return to within 20 km of the capture area if relocated a minimum of 30 km and 64 km, respectively. Although relocation appears to be an effective strategy for the management of juvenile male bears, success rates were low for adults. Our findings can aid resource managers in making more informed decisions as to the potential effectiveness of relocation as a management tool.

Key words: age, American black bear, distance, homing, Ontario, relocation, Ursus americanus

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Throughout the range of the American black bear *Ursus americanus*, human-bear conflicts frequently arise, and relocation of offending bears has been a standard management response for decades (Linnell et al. 1997). Captured bears are relocated to remove the animal from the area, temporarily or permanently, and to discourage relocated individuals from further nuisance activity. Numerous factors affect return rates and future behaviour (Harger 1970, Rogers 1986b, Stiver 1991), such that the most ap-

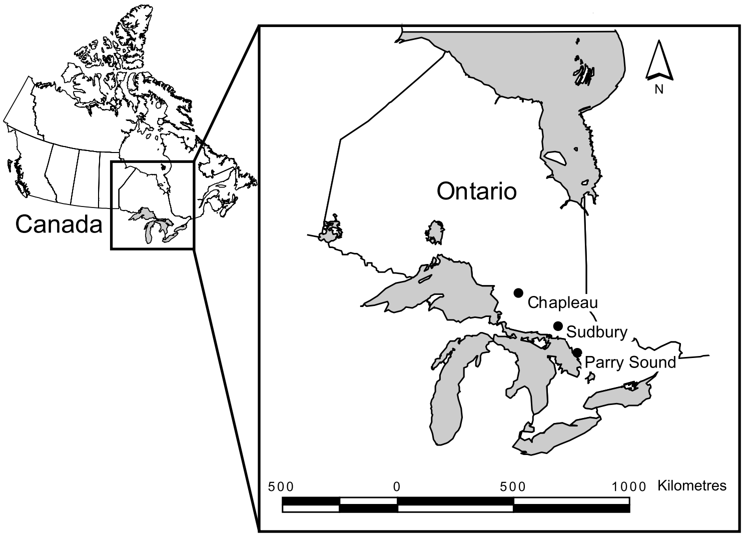

Figure 1. Location of the Chapleau, Sudbury and Parry Sound study areas in Ontario, Canada, from which data on the relocation and recovery of nuisance black bears were collected.

propriate management action may vary from one nuisance occurrence to another.

Most analyses of relocation data have focused on homing behaviour and several studies have demonstrated that a high proportion of relocated bears return to the capture area (Alt et al. 1977, Rutherglen & Herbison 1977, McArthur 1981, Rogers 1986b, Shull 1994), with adult bears being more likely to return than juveniles (Harger 1970, Rogers 1986b). It has been hypothesized that the differential post-relocation homing success displayed by adult animals is a consequence of increased navigational ability gained by experience and fidelity to established home ranges (Anderson et al. 1977, Rogers 1986a, Landriault et al. 2006). Given that female bears generally remain philopatric (Rogers 1987, Elowe & Dodge 1989, Schwartz & Franzmann 1992, Lee & Vaughan 2003) and maintain more stationary home ranges than their male counterparts (Kolenosky & Strathearn 1987), there may be a difference in return rates between the sexes, once the effect of age is accounted for. Although transfer distance has been observed to play a major role in relocation success (Harger 1970, McArthur 1981, Rogers 1984, Rogers 1986a), investigations have rarely considered the interaction between distance and the age or sex of relocated animals.

We employed predictive modeling as a tool to aid managers in determining the efficacy of black bear relocation. Using tag recovery data for relocated nuisance black bears from three study areas in Ontario, Canada, we investigated nuisance recurrence rates and evaluated the relative importance of sex, age and relocation distance on return rates. Furthermore, we sought to identify potential relocation distance thresholds that would minimize the probability of return.

Material and methods

Study areas

We obtained nuisance bear relocation and tag recovery data from the Ontario Ministry of Natural Resources (OMNR) for three jurisdictions in Ontario: Chapleau, Sudbury and Parry Sound (Fig. 1). Chapleau is a remote town located in north-central Ontario with a population of approximately 3,000 people (see Fig. 1). Immediately north of town lies the 7,000-km^2 Chapleau Crown Game Preserve. At the time of the study, hunting and trapping of wildlife was not permitted within the preserve. The Chapleau study area is located in the Boreal Forest (Rowe 1972), dominated by balsam fir *Abies balsamea*, black spruce *Picea mariana* and white birch *Betula papyrifera*. Jack pine *Pinus banksiana* is the dominant tree species on coarse mineral soils.

At the time of our study, the City of Sudbury (see Fig. 1) and surrounding communities had a population of about 162,000. Sudbury is on the northern edge of the Great Lakes-St. Lawrence Forest (Rowe 1972). Extensive disturbance from smelter operations in the early and mid 1900s greatly reduced the abundance of native flora near the city. Tree cover is dominated by hardy early successional species, such as trembling aspen *Populus tremuloides*, balsam poplar *P. balsamifera*, and white birch (Amiro & Courtin 1981). Jack pine occurs frequently on sand

Table 1. Time periods and sample sizes for nuisance black bear relocation data sets from the Chapleau, Sudbury and Parry Sound study areas in Ontario, Canada. Data did not include cubs or dependent yearlings and each bear was only included once.

			Number		
Area	Tagging years	Recovery years	Tagged and relocated	Aged and sexed	Complete relocations[a]
Chapleau	1982-1983	1982-1984	20	20	20
Sudbury	1994-1997	1994-1997	98	57	44[b]
Parry Sound	1983-1995	1983-1996	85	79	59
Total			203	156	123

[a] Complete relocation records included information on age, sex, capture location and release location.

[b] The number of complete relocations in this area did not include animals captured in 1997.

flats and other coarse textured soils. Farther from the city, forest cover is more representative of the Great Lakes-St. Lawrence Forest and includes northern red oak *Quercus rubra*, eastern white pine *Pinus strobus*, red pine *Pinus resinosa*, and red maple *Acer rubrum*.

Parry Sound is located on the shore of Georgian Bay of Lake Huron (see Fig. 1). Including small rural communities, the Parry Sound area contains roughly 18,000 permanent and 66,000 seasonal residents. Parry Sound is in the Great Lakes-St. Lawrence Forest (Rowe 1972), characterized by a mixture of sugar maple *Acer saccharum*, American beech *Fagus grandifolia*, basswood *Tilia americana*, yellow birch *Betula alleghaniensis*, eastern hemlock *Tsuga canadensis*, eastern white pine, red maple, northern red oak, and white ash *Fraxinus americana*. White spruce *Picea glauca* is common on sand flats.

Data collection and analysis

Each of the three OMNR jurisdictions provided data for bears that were involved in human-bear conflicts and subsequently captured, transported and released at new locations (i.e. relocated). The OMNR captured nuisance black bears in traps or by darting free-ranging bears with immobilization agents. They immobilized captured bears using a mixture of ketamine hydrochloride and xylazine hydrochloride. Capture personnel extracted a premolar from immobilized bears for age determination (Johnston et al. 1987). Bears were ear-tagged with a unique identification number and tags were recovered on a voluntary basis from animals harvested by hunters, killed in vehicle collisions or destroyed as nuisance animals. The spring bear hunt was open from mid-April to mid-June, whereas the fall hunt started at the beginning of September and ended in mid-October.

The nuisance bear data sets included information on age, sex, capture location, release location, recovery location, and associated dates. The years of data collection varied among jurisdictions and ranged from 1982 to 1997 (Table 1). We excluded cubs and dependent yearlings from all analyses, as their movements were dependent upon those of their mothers. For age class comparisons, we categorized bears <4 years of age as juveniles and those ≥ 4 years as adults (Kolenosky 1990, Stiver 1991). For bears that were captured multiple times, only data from the first capture was used unless otherwise stated. Of the records from the Sudbury area, 14 did not include the exact capture, release or recovery locations. For these records, we used the center of the recorded township for movement analysis. Townships in this part of Ontario were approximately 100 km^2 (10×10 km). All distance calculations presented are straight-line estimates. We calculated the time in days from release to tag recovery, and then investigated the relationship between relocation distance and time to tag recovery for adults and juveniles using Spearman's rank correlation coefficient (r_s).

Recurrence of nuisance behaviour

We used nuisance recurrence rate to refer to the proportion of bears involved in human-bear conflicts subsequent to the initial relocation. This included all relocated bears recaptured or killed because of nuisance behaviour, irrespective of where it occurred. We excluded all bears relocated <21 km from their capture site. We also excluded bears captured in the Sudbury District during 1997 because the database did not include recovery information after 1997. The resulting data set of 123 individual bears included 27 adult females, 23 adult males, 23 juvenile females and 50 juvenile males. We estimated minimum nuisance recurrence rates by age and sex categories, and then compared mean time to tag recovery for bears involved in nuisance recurrences to other recovery methods using an independent means t-test.

Post-relocation return

Extensive seasonal movements are frequently observed in both male and female black bears (Kolenosky & Strathearn 1987, Rogers 1987, Samson & Huot 1998), suggesting that the area bears are familiar with is substantially larger than their core home range. We identified a relocated bear as a returning animal if it was recovered ≤ 20 km from the capture site. We assumed that within a 20-km distance bears had returned to familiar territory, and were capable of returning to the capture site. In support of our chosen threshold distance, the average maximum distance between any two telemetry locations for 11 radio-collared bears in the Sudbury area was 20.70 km (SD = 9.13; L.J. Landriault, unpubl. data), and the average minimum convex polygon (MCP), including all locations for each animal, was 90.8 km^2 (SD = 51.2; Landriault 1998). Similar data were not available for the Chapleau and Parry Sound areas. However, based on the diversity of berry and hard mast crops, we would expect MCP home ranges to be larger in Chapleau and smaller in Parry Sound. Only bears that were recovered were included in our analysis of post-relocation return. We refer to the proportion of recovered bears that returned to within 20 km of the capture site as the return rate. We excluded from the analyses bears transferred < 21 km from their capture site. A bear was only identified as an animal that did not return to the capture area if it was recovered ≥ 20 days after release, to ensure the animal had sufficient time to return. We considered 20 days from relocation to recovery a sufficient period given the average relocation distances used in the three study areas (68-80 km). Radio-telemetry studies have shown that black bears home quickly and are capable of movement rates in excess of 10 km/day (Rogers 1986b, Landriault 1998).

We calculated the proportion of recovered bears that returned and then determined whether the return was affected by study area using logistic regression. We then developed logistic regression models to evaluate the relationships between post-relocation return and age, sex and relocation distance. We modeled all possible subsets of the three predictor variables, without interaction terms. We were interested in determining the shortest relocation distance that would be effective in removing bears from an area but wanted to include each individual bear only once. Therefore, for bears relocated multiple times, we included the record with the shortest distance from which they did not return. In cases where a bear returned after one relocation and not after the next (or *vice versa*), we used the record that was first chronologically. There were too few bears in the data set with multiple captures to consider prior nuisance behaviour or relocation experience as a factor in the models. A second data set was obtained from Sudbury OMNR and used for model validation only. The data included capture and recovery information for 26 individuals relocated from 2000 to 2002, comprised of five adult females, six adult males, seven juvenile females and eight juvenile males. The average relocation distance in the validation data set was 73 km (SD = 29.1, range: 21-150 km).

We used the information-theoretic approach described by Burnham & Anderson (2002) to guide model selection and inference based on the second-order Akaike's Information Criterion corrected for small sample sizes (AIC$_c$). We calculated the differences between the AIC$_c$ of each model and that of the best approximating model (Δ_i) and AIC$_c$ weights (w_i). AIC$_c$ weights present the relative evidence that model i is the best model among those being compared (Burnham & Anderson 2002). We used the sum of w_i to assess relative importance of variables as the number of models that included each variable were equal. A model is considered to be the best predictor when the AIC$_c$ weight is > 0.90 (Burnham & Anderson 2002). When none of the models was clearly the best predictor, we generated model-averaged estimates and associated unconditional standard errors (Burnham & Anderson 2002). The effect of our independent variables on post-relocation return is discussed in terms of odds ratios. Odds ratios were calculated by raising the base of the natural logarithm to the power of the value of model coefficients. We subsequently produced graphs illustrating the probability of a bear returning to the capture site based on age, sex and relocation distance using the following equation:

$$\text{Probability} = \frac{e^{\ln \text{odds}}}{1 + e^{\ln \text{odds}}},$$

where the ln odds is the natural logarithm of the odds of a bear returning to the capture area based on the selected logistic regression model.

We quantified predictive accuracy of the models using receiver-operating characteristic (ROC) curves. We then calculated the area under the curves (AUC) for the modeling and validation data sets. The ROC curve represents the relationship between sensitivity (i.e. proportion of animals expected to

Table 2. Age and sex composition of tagged and recovered relocated nuisance black bears from the Chapleau, Sudbury and Parry Sound study areas in Ontario, Canada. Data did not include cubs or dependent yearlings. AF = adult females; AM = adult males; JF = juvenile females; JM = juvenile males.

	Tagged bears				Recovered bears			
Area	AF	AM	JF	JM	AF	AM	JF	JM
Chapleau	4	10	2	4	3	7	0	2
Sudbury	14	8	16	19	9	2	2	9
Parry Sound	16	10	12	41	5	7	6	19
Total	34	28	30	64	17	16	8	30

return that did return) and 1 - specificity (i.e. proportion of animals expected to return that did not). AUC values can range from 0 to 1.0. A value of 0.5 describes a model with discrimination ability no better than random, whereas a value of 1.0 indicates a model with perfect discrimination ability (Pearce & Ferrier 2000). AUC values can also be interpreted as the probability that a model will correctly distinguish between two observations, one positive and the other negative (Pearce & Ferrier 2000). For models where relocation distance odds ratios were significantly different from 1, we used the modeling data set ROC curve to estimate relocation distance thresholds (Guénette & Villard 2005). We chose the threshold that yielded the maximum accuracy, that is, where the sum of sensitivity and specificity was maximized. We used SPSS software (SPSS Incorporated 2005) for all statistical analyses.

Results

The age and sex composition of captured nuisance bears varied among the study areas (Table 2). Of the bears captured in the Chapleau area, 50% were adult males, whereas adult males made up only 14 and 13% of captures in Sudbury and Parry Sound, respectively. The majority of bears captured in the Sudbury and Parry Sound areas were juveniles. However, the sex composition varied between the two areas with a roughly 1M:1F ratio in Sudbury and a 3M:1F ratio in Parry Sound.

Average relocation distances were 76 km (SD = 23.7, range: 30-125 km) for Chapleau, 70 km (SD = 13.2, range: 40-115 km) for Parry Sound and 80 km (SD = 53.7, range: 21-389 km) for Sudbury. Of the relocated bears, 51% (80/156) were recovered at least once. Hunter harvest accounted for 46% of recoveries followed by nuisance recaptures (27%), nuisance kills (19%), road-kills (7%) and sightings of marked bears (1%). Time to tag recovery ranged within 1-1,772 days ($\bar{x} = 215$, SD = 194.4) for juvenile bears and 5-812 days ($\bar{x} = 317$, SD = 416.2) for adults. Our data suggest a relationship between relocation distance and days to recovery for adults ($r_s = 0.290$, $P = 0.101$, $N = 33$), but not for juveniles ($r_s = -0.133$, $P = 0.426$, $N = 38$).

Recurrence of nuisance behaviour

A minimum of 30% (37/123) of relocated bears were subsequently involved in at least one other nuisance event. Adult females were frequently involved in nuisance recurrences (48%), whereas this behaviour was rare in juvenile males (18%). A minimum of 39% of adult males and 26% of juvenile females were involved in nuisance recurrences. Of relocated bears, 57% were involved in subsequent nuisance behaviour in the same year, i.e. prior to hibernation, and 81% within one year (365 days). The mean number of days to recovery for bears recaptured or killed for subsequent nuisance behaviour (165 days, SD = 180.4) was significantly less than the mean number of days to recovery observed for bears recovered as a result of harvest or vehicle collisions (330 days, SD = 374.4; ln transformation, $t = -2.516$, $df = 69$, $P = 0.012$). Time to recovery was longest for bears captured in July, irrespective of whether they were recovered as a result of repeat nuisance behaviour or harvested (the two primary recovery methods).

Post-relocation return

Relocated adult black bears consistently had much higher return rates than juveniles (73 vs 29%; Table 3), suggesting that factors affecting return rates differed between age classes. Therefore, we developed separate models for the two age classes but still included the continuous age variable within

Table 3. Proportion of recovered nuisance bears that returned to within 20 km of their capture area in the Chapleau, Sudbury and Parry Sound study areas in Ontario, Canada.

Area	Adults	Juveniles
Chapleau	7/10	0/2
Sudbury	9/11	4/11
Parry Sound	8/12	7/25

Table 4. Differences in Akaike's Information Criterion between the ith and top-ranked model (Δ_i) and Akaike's weights (w_i) for all models predicting the probability of return of relocated nuisance black bears in Ontario, Canada. All models include a constant.

Model	Juveniles (N=38) Δ_i	Juveniles (N=38) w_i	Adults (N=33) Δ_i	Adults (N=33) w_i
Age	0.364	0.199	0.000	0.402
Sex	3.288	0.046	2.002	0.148
Relocation distance	2.599	0.065	2.095	0.141
Age, sex	0.985	0.146	2.321	0.126
Age, relocation distance	0.198	0.217	2.601	0.109
Sex, relocation distance	2.006	0.088	4.470	0.043
Age, sex, relocation distance	0.000	0.239	5.114	0.031

the juvenile and adult models. Study area had no effect on whether a bear returned to the capture area (-2 log likelihood=96.028, likelihood ratio $\chi^2=2.384$, df=2, P=0.304), so we pooled data from the three areas. The resulting data set included 17 adult females, 16 adult males, eight juvenile females and 30 juvenile males.

Juveniles

Based on the sum of AIC$_c$ weights of the individual predictor variables (Table 4), it appears that age was the most important variable in predicting return in juvenile bears ($\sum w_i=0.8$), followed by relocation distance ($\sum w_i=0.6$) and sex ($\sum w_i=0.5$). No model was clearly the best predictor of the probability of post-relocation return for juvenile bears, and the largest AIC$_c$ weight (w_i) was only 0.239 (see Table 4). Therefore, we used a model-averaging approach. Based on model averaging, the odds of returning to the capture area were roughly four times greater for females than for males, and the odds of returning increased by approximately three times for each year of age (Table 5). Relocation distance had a negative effect on the probability of return for juvenile animals with the odds of return decreasing by 3% for every 1 km increase in relocation distance. The AUC value for the modeling data set was 0.822 (SE=0.080) and the AUC value for the Sudbury validation data set was 0.750 (SE=0.164), indicating that the averaged model correctly discriminated between returning and non-returning bears 75-82%

Table 5. Model-averaged coefficients (β), unconditional standard errors (SE) and odds ratios for models predicting the probability of return of relocated juvenile and adult nuisance black bears in Ontario, Canada. For Sex: female=1, male=0; the relocation distance is in km.

Model variable	Juveniles (N=38) β	Juveniles (N=38) SE	Juveniles (N=38) Odds ratio	Adults (N=33) β	Adults (N=33) SE	Adults (N=33) Odds ratio
Sex	1.479	0.962	4.388	0.405	0.798	1.499
Age	1.172	0.582	3.228	0.193	0.149	1.213
Relocation distance	-0.035	0.022	0.965	0.002	0.008	1.002
Constant	-1.760	2.152	0.172	0.016	1.049	1.016

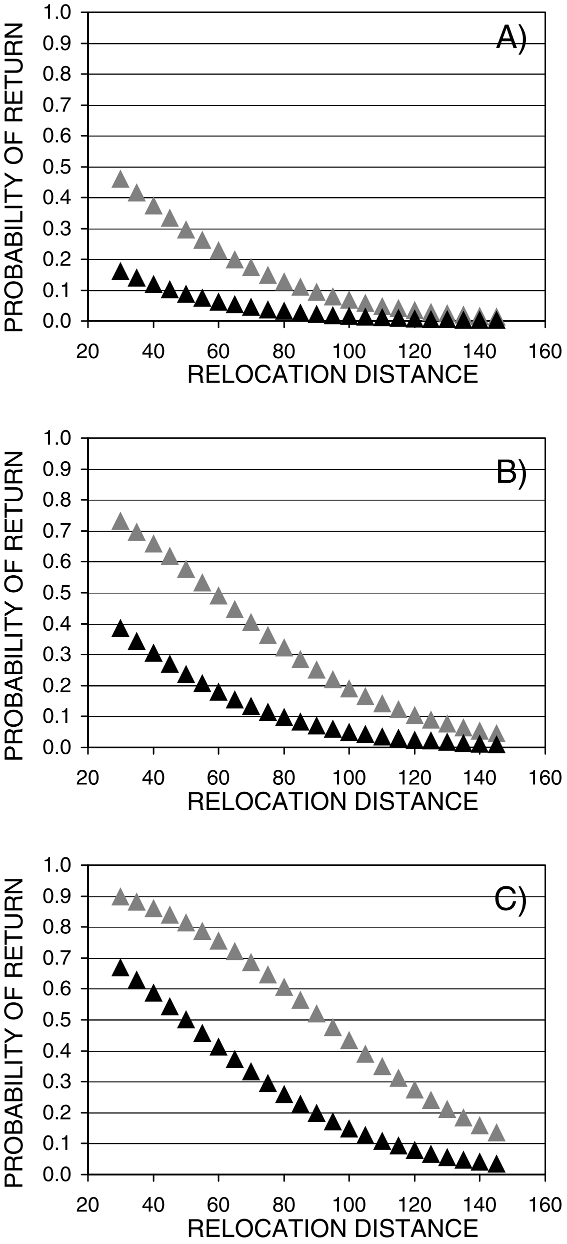

Figure 2. Effects of sex and distance on the post-relocation probability of return for 1-year-old (A), 2-year-old (B) and 3-year-old (C) nuisance black bears in Ontario, Canada. Black symbols represent male bears and gray symbols represent females. Distance is presented in kilometers. Estimates of return were based on recovery of tagged bears. Bears were identified as returning animals if they were recovered within 20 km of their capture site.

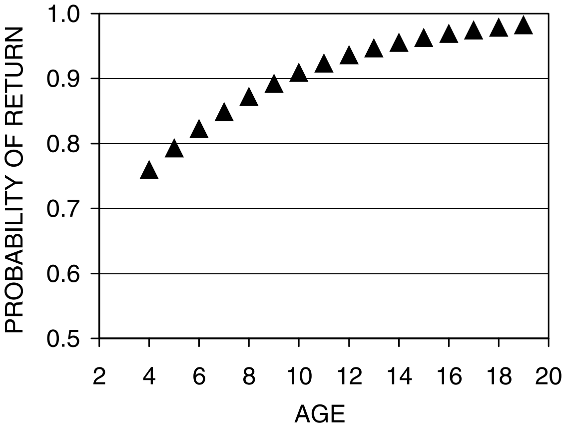

Figure 3. Effect of age on the post-relocation probability of return for relocated adult nuisance black bears in Ontario, Canada. Distance is presented in kilometers. Estimates of return were based on recovery of tagged bears. Bears were identified as returning animals if they were recovered within 20 km of the capture site.

of the time. The high standard error on the AUC value for the validation set is a reflection of the high variability around the coefficients of the independent variables in our averaged model (see Table 5). Our model achieved maximum accuracy when bears with a probability >38% were predicted to have returned to the capture area. Using Figure 2, we obtained a minimum recommended relocation distance (i.e. the relocation distance corresponding to a 38% probability). For male 2- and 3-year-old bears, this resulted in relocation distances of 30 km and 64 km, respectively. The threshold values were 73 km and 106 km for females of corresponding ages (see Fig. 2). Caution should be used in interpreting return probabilities and relocation distance thresholds for juvenile females, as the sample size was small relative to juvenile males (N = 8 and N = 30, respectively).

Adults

Similar to the results obtained for juvenile animals, age was the most important variable in predicting return in adult bears ($\sum w_i = 0.7$), with sex and relocation distance of equal value ($\sum w_i = 0.3$). Among the suite of models developed for adult bears, the single variable model with age as the predictor had the greatest explanatory power (see Table 4). However, the w_i value was relatively low (0.402), suggesting that other models were plausible. Therefore, we used a model-averaging approach (see Table 5). The coefficient for the relocation distance variable in the resulting model was 0.002, suggesting that distance had little effect on return. Although the coefficient for the sex variable was 0.405, the variability around the estimate was very high, suggesting that it also had limited utility in predicting return. The AUC value for the modeling data set was 0.757 (SE = 0.107) and the AUC value for the Sudbury validation data set was 0.500 (SE = 0.185). The low predictive ability of the averaged model was a result of low specificity, that is, difficulty in predicting adults that do not return. We set the relocation distance at the average value (80.7 km) and the categorical sex variable to 0.5 when developing the probability of return graph (Fig. 3).

Discussion

In most cases, black bear relocation would be considered successful if the animal was not involved in any subsequent human-bear conflicts, irrespective of whether the animal returned to the capture area. We estimated a minimum nuisance recurrence rate of 30% for relocated bears. Similarly, Stiver (1991) noted that 34% of relocated marked bears in Great Smoky Mountains National Park were subsequently involved in nuisance events. However, using mark and recovery data to estimate the proportion of animals involved in recurrences can be problematic, as resulting recurrence rates are absolute minimums. Unless they possess very distinctive markings, individuals can only be identified if recaptured or killed. In addition, it appears that bears living adjacent to urban areas are more likely to forage at night relative to their wildland conspecifics (Beckmann & Berger 2003), making it even harder to identify individuals.

The high nuisance recurrence rates we observed for adult bears may be linked to the high proportion of adults that returned to the capture area. These animals were likely returning to established home ranges where they were familiar with the location of wild and anthropogenic food sources, and had time to become habituated to human presence. Adult females were most likely to return and be involved in a nuisance recurrence. It appears that female bears require high carbohydrate and fat diets to reproduce successfully (Elowe & Dodge 1989), such that the availability of reliable and readily accessible high-energy human foods may provide a strong incentive for female bears to return to, and forage in, developed areas.

Our results corroborate existing evidence that younger bears are less likely to return after relocation than are older animals (Harger 1970, Rogers 1986b). This may be a result of poor navigational ability at a young age or the influence of age-related dispersal behaviour. Young males tend to disperse from their natal range (Rogers 1987, Elowe & Dodge 1989, Schwartz & Franzmann 1992, Lee & Vaughan 2003) and many relocated young males may simply not attempt to return to the capture area. Age also had a role in determining the effect of relocation distance on the probability of post-relocation return. Our data suggested that adult black bears of $\geq$4 years were likely to return, and that relocation distance, within the observed range (21-389 km), was not an impediment to homing. In contrast, the probability of return for juvenile bears decreased with increasing relocation distance, suggesting that distance was either acting as a deterrent, or younger animals were not capable of navigating over longer distances. Moreover, our results support the hypothesis that home-range fidelity affects the probability of return for relocated bears. As predicted, juvenile males had a lower probability of return than their more philopatric female counterparts.

Age, sex and relocation distance were good predictors of the probability of return for juvenile bears. However, these variables were of limited use in estimating the probability of return for adult animals. The difficulty our model had in predicting which adult bears did not return could simply be a result of the small sample of animals in this category. Unfortunately, the small sample size also precluded the addition of more independent variables. We speculate that season of capture and natural food availability could have influenced return rates. Male home ranges tend to be more stable during the mating season (Rogers 1987) and males often go on extensive foraging excursions at other times (Rogers 1987). This would suggest that males might show a stronger fidelity to an area, and hence be more likely to return after relocation, during the mating season. Natural food availability also affects bear movements. When food sources become scarce (within or among years), bears forage more widely and are more likely to encounter humans and human-based food sources (Rogers 1976, Alt et al. 1977, Shull 1994). We would speculate that in years when berry or nut crops fail, many adult animals may not return to the capture area because they were captured outside of their home range. Level of habituation and past experience could also have played a role in adult bear return, such that more habituated bears would be more likely to return and be recaptured. Unfortunately this type of information is rarely available for tagged animals.

Management implications

Relocation may be a useful management tool for the removal of juvenile animals involved in human-bear conflicts. Juvenile males generally make up the majority of nuisance bears (Harger 1970, Rutherglen & Herbison 1977, Rogers 1987, Stiver 1991, Schwartz & Franzmann 1992, Shull 1994) and are least likely to return to the capture area or be involved in subsequent nuisance events. Based on our analyses, we expect that 2- and 3-year-old male bears will not return to within 20 km of the capture area if relocated a minimum of 30 km and 64 km, respectively. We anticipate threshold distances to differ in areas with more extreme physiography or more significant anthropogenic barriers than those in our study areas. Although most juvenile male bears may not return to the capture area, it is worth noting that they are also unlikely to remain near the release area and often demonstrate extensive post-relocation movements (Harger 1970, Rogers 1984, Linnell et al. 1997, Landriault 1998).

Based on our analyses, relocation may be ineffective in managing adult animals involved in human-bear conflicts. A large proportion of adults returned to within 20 km of the capture area, and recurrence rates of nuisance behaviour were high. Based on our results, if 100 adult female bears were relocated, a minimum of 50 would be involved in a subsequent nuisance occurrence, and 40 would do so within one year. All of our study areas were adjacent to large forested areas, such that nuisance bears likely made up a small proportion of the black bears on the landscape. However, jurisdictions with a policy of destroying bears involved in more than one nuisance incident should take into consideration the number of adult females being destroyed and the potential effect on local bear populations. Given the low success rates for relocation of adult bears, we suggest that nuisance bear management strategies emphasize the management of anthropogenic food sources and take into consideration the efficacy and acceptability of alternative approaches (e.g. aversive conditioning) for managing persistent individuals.

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References

Alt, G.L., Matula, Jr., G.J., Alt, F.W. & Lindzey, J.S. 1977: Movements of translocated nuisance black bears of Northeastern Pennsylvania. - In: Transactions of the Northeast Fish and Wildlife Conference, Boston, Massachusetts, USA, 34: 119-126.

Amiro, B.D. & Courtin, G.M. 1981: Patterns of vegetation in the vicinity of an industrially disturbed ecosystem, Sudbury, Ontario. - Canadian Journal of Botany 59: 1623-1639.

Anderson, P.K., Heinsohn, G.E., Whitney, P.H. & Huang, J.P. 1977: *Mus musculus* and *Peromyscus maniculatus*: homing ability in relation to habitat utilization. - Canadian Journal of Zoology 55: 169-182.

Beckmann, J.P. & Berger, J. 2003: Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. - Journal of Zoology (London)261207212 < XMLFILE.

Burnham, K.P. & Anderson, D.R. 2002: Model selection and multimodel inference: a practical information-theoretic approach. 2nd edition. - Springer, New York, NY, USA, 488 pp.

Elowe, K.D. & Dodge, W.E. 1989: Factors affecting black bear reproductive success and cub survival. - Journal of Wildlife Management 53: 962-968.

Guénette, J-S. & Villard, M-A. 2005: Thresholds in forest bird response to habitat alterations as quantitative targets for conservation. - Conservation Biology 19: 1168-1180.

Harger, E.M. 1970: A study of homing behavior of black bears. - M.A. thesis, Northern Michigan University, Marquette, Michigan, USA, 81 pp.

Johnston, D.H., Joachim, D.G., Bachmann, P., Kardong, K.V., Stewart, R.E.A., Dix, L.M., Strickland, M.A. & Watt, I.D. 1987: Aging furbearers using tooth structure and biomarkers. - In: Novak, M., Baker, J.A., Obbard, M.E. & Malloch, B. (Eds); Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario, Canada, pp. 228-243.

Kolenosky, G.B. 1990: Reproductive biology of black bears in east-central Ontario. - In: Darling, L.M. & Archibald, W.R. (Eds); A Selection of Papers from the Eighth International Conference on Bear Research and Management, Victoria, British Columbia, Canada 8: 385-392.

Kolenosky, G.B. & Strathearn, S.M. 1987: Black bear. - In: Novak, M., Baker, J.A., Obbard, M.E. & Malloch, B. (Eds); Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario, Canada, pp. 443-454.

Landriault, L.J. 1998: Nuisance black bear (*Ursus americanus*) behavior in central Ontario. - M.Sc. thesis, Laurentian University, Sudbury, Ontario, Canada 95 pp.

Landriault, L.J., Hall, M.N., Hamr, J. & Mallory, F.F. 2006: Long-range homing by an adult female Black Bear, *Ursus americanus*. - Canadian Field-Naturalist 120: 57-60.

Lee, D.J. & Vaughan, M.R. 2003: Dispersal movements by subadult American black bears in Virginia. - Ursus 14: 162-170.

Linnell, J.D.C., Aanes, R., Swenson, J.E., Odden, J. & Smith, M.E. 1997: Translocation of carnivores as a method for managing problem animals: a review. - Biodiversity and Conservation 6: 1245-1257.

McArthur, K.L. 1981: Factors contributing to effectiveness of black bear transplants. - Journal of Wildlife Management 45: 102-110.

Pearce, J. & Ferrier, S. 2000: Evaluating the predictive performance of habitat models developed using logistic regression. - Ecological Modelling 133: 225-245.

Rogers, L. 1976: Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. - Transactions of the North American Wildlife Conference 41: 431-438.

Rogers, L.L. 1984: Homing by black bears and other large mammals. - In: Maehr, D.S. & Brady, J.R. (Eds); Proceedings of the Eastern Workshop on Black Bear Research and Management, Florida Game and Freshwater Fish Commission, Gainsville, Florida, USA, 7: 76-77.

Rogers, L.L. 1986a: Effects of translocation distance on frequency of return by adult black bears. - Wildlife Society Bulletin 14: 76-80.

Rogers, L.L. 1986b: Homing by radio-collared black bears, *Ursus americanus*, in Minnesota. - Canadian Field-Naturalist 100: 350-353.

Rogers, L.L. 1987: Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. - Wildlife Monographs 97, 72 pp.

Rowe, J.S. 1972: Forest regions of Canada. - Canadian Forestry Service Publication 1300, Ottawa, Ontario, Canada, 172 pp.

Rutherglen, R.A. & Herbison, B. 1977: Movements of nuisance black bears (*Ursus americanus*) in southeastern British Columbia. - Canadian Field-Naturalist 91: 419-422.

Samson, C. & Huot, J. 1998: Movements of female black bears in relation to landscape vegetation type in southern Quebec. - Journal of Wildlife Management 62: 718-727.

Schwartz, C.C. & Franzmann, A.W. 1992: Dispersal and survival of subadult black bears from the Kenai Peninsula, Alaska. - Journal of Wildlife Management 56: 426-431.

Shull, S.D. 1994: Management of nuisance black bears (*Ursus americanus*) in the interior highlands of Arkansas. - M.Sc. thesis, University of Arkansas, Fayetteville, Arizona, USA, 101 pp.

SPSS Incorporated 2005: Version 14.0. - SPSS Incorporated, Chicago, Illinois, USA.

Stiver, W.H. 1991: Population dynamics and movements of problem black bears in Great Smoky Mountains National Park. - M.Sc. thesis, University of Tennessee, Knoxville, Tennessee, USA, 134 pp.