Population viability of black bears on the Bruce Peninsula, Ontario

Eric J. Howe\textsuperscript{1}, Martyn Obbard\textsuperscript{2} and James A. Schaefer\textsuperscript{3}
\textsuperscript{1}Watershed Ecosystems Graduate Program, Trent University,\
\textsuperscript{2}Wildlife Research and Development Section, Ontario Ministry of Natural Resources\
\textsuperscript{3}Biology Department, Trent University

Abstract

The black bear population inhabiting the Bruce Peninsula, Ontario is isolated and presents a potential conservation concern. We conducted population viability analysis using a stochastic life table to investigate the potential consequences of habitat reduction, demographic and environmental stochasticity, and human-induced mortality. Estimates of vital rates were derived from a long-term study in a similar Ontario ecosystem. A slightly positive deterministic growth rate ($r = 0.00324$) was predicted for the closed population. Deterministic growth was most sensitive to changes in adult female survival. Initial population size was varied according to the range of densities of black bears in Ontario and modeled for three areas of suitable habitat on the Peninsula. Results indicate that when all non-developed natural habitat is occupied, the Peninsula can support a viable population of bears, even at low density (0.2 bears/km\textsuperscript{2}), if protected from human-induced mortality. If bears are, or become confined to the northernmost township (containing Bruce Peninsula National Park (BNP) remains, only a high-density (0.6 bears/km\textsuperscript{2}) population will be viable. When only BNP remains the habitat area, is insufficient to ensure persistence, even at high density and no human-caused mortality. Simulations indicate that current rates of harvest could threaten persistence. This threat is accentuated with diminishing area and initial population size. Non-natural mortality and habitat reduction may pose threats to the long-term conservation of this population.

Introduction

Populations of large carnivores are vulnerable to extirpation in areas of high human population density (Woodroffe, 2000). For bears, the key threats are habitat loss and direct, human-caused mortality (Servheen, 1989). In 1987, bears occupied 85\% of their historical range in Canada, but have been largely extirpated where the landscape is dominated by agriculture and human habitation (Kolenosky and Strathearn, 1987).

The population of black bears (\textit{Ursus americanus}) that inhabits Bruce Peninsula National Park (BNP) and the surrounding Upper Bruce Ecosystem in southwestern Ontario, appears to be genetically distinct from neighbouring populations (Obbard & Strobeck, unpublished). This suggests that the population is geographi-
cally isolated, and not subject to immigration and emigration. Annual reported harvests, 1987-98, have varied between zero and twenty one animals, and additional mortality may occur from unreported harvest, nuisance kills, and road-kill.

As part of an Ecological Integrity Monitoring Program in the Upper Bruce Ecosystem area, BPNP and Fathom Five National Marine Park have identified the black bear as a prime indicator species (Sutton, 1999). Quantifying risk to this species, therefore, is fundamental to ensuring the ecological integrity of the BPNP and surrounding area. Despite protected status, black bears have been extirpated from Canadian National Parks (Rivard et al. 2000). Concern for the Bruce Peninsula population has lead to a cooperative agreement between Parks and Heritage Canada and the Ontario Ministry of Natural Resources. In addition to an ongoing study on population dynamics and habitat use, this report on population viability analysis (PVA) represents part of this cooperative effort.

PVA is the application of Monte Carlo modeling techniques to estimate the risk of extinction within a specified time frame, given the population's size. The methodology for estimating a minimum viable population size (MVP) is the same, except an acceptable level of risk is defined a priori, and the size necessary to achieve that level of risk is output. PVA employs species or population-specific data on birth and death rates, and may be used to produce probabilistic results by incorporating uncertainty in population projections. Popular outputs of PVA models are risk of extinction and probability of decline (Akcakaya and Sjorgren-Gulve, 2000; Beissinger and Westphal, 1998). Sensitivity of models to changes in vital rates can pinpoint different stressors that may result in decline or extinction (Kelly and Durrant, 2000). Natural populations may be buffeted by demographic, environmental, or genetic stochasticity (Shaffer 1981). Demographic stochasticity refers to uncertainty and randomness in mean demographic rates as experienced by individuals (Lacy, 1993; Lande, 1993). Environmental stochasticity describes the effects of temporal (usually annual) variation in demographic rates due to climate and other extrinsic factors (Lacy, 1993; Lande, 1993), sometimes including rare catastrophes (Coulson et al. 2001; Lande, 1993). Genetic uncertainty refers to the potential to experience depressed survival or recruitment rates due to inbreeding and genetic drift (Shaffer, 1981; Lacy, 1993). Many researchers contend that genetic effects are less likely to lead to extinction than demographic processes (Beissinger and Westphal, 1998; Boyce, 1992; Lande, 1988).

The criticisms of PVA are manifold. As a management tool, PVA has been criticized based on inadequate or imprecise data, and overly-simplistic model structures and assumptions (Mann and Plummer, 1999; Beissinger and Westphal, 1998; Taylor, 1995; Caughley, 1994); these criticisms have included lack of habitat variation, constancy in vital rates, and the assumptions of closed populations and a stable age distribution. Some researchers have contended that model predictions are unreliable when populations are projected for long periods since confidence intervals around population size expand over time (Coulson et al. 2001; Beissinger
and Westphal, 1998). On the other hand, for long-lived species, there may be lag before extinction, such that even a 100-year time frame underestimates long-term risks of extinction (Armbuster et al, 1999). Numerical models are also difficult to validate in natural systems (Oreskes et al, 1994). Nevertheless, PVA is likely the best tool for conservation biologists for providing quantitative measures of extinction risk (Brook et al, 2000; Wilson, 2000). They are most useful when population stressors and management options can be built in, allowing for comparative assessment of results (Akcakaya and Sjorgren-Gulve, 2000; Beissinger and Westphal, 1998), and when new data can be incorporated, adaptive management (Boyce, 1992).

Appropriate models should avoid unsupported assumptions regarding density dependence, and should be linked to habitat when possible. Short-term fluctuations in black bear populations are generally attributed to the effect of annual variation in food availability on recruitment (Kolenosky, 1990; Elowe and Dodge, 1989; Rogers, 1987; Jonkel and Cowan, 1971) rather than any mechanism of density feedback. Mechanisms of density-dependent population regulation in black bears are not well understood, and have yet to be empirically demonstrated (Garshelis, 1994). There is evidence that black bears avoid major roads (Mattson, 1990) and that black bears will venture up to 200 m from escape cover into agricultural lands while foraging (Jonker et al, 1998). This behaviour could affect how bears utilize the habitats on the Bruce Peninsula.

**Methods**

We used the population model RiskMan, a stochastic life-table model specifically adapted to model species which exhibit multi-annual reproduction and extended parental care, such as bears. RiskMan can simulate the effects of demographic and environmental stochasticity (Taylor et al, 1998).

Estimates of the parameters for stochastic population projections were derived from a long term study near North Bay, Ontario (Kolenosky, 1990; Yodzis and Kolenosky, 1986), although but it was necessary to augment these observations from studies elsewhere (Table 1). Estimates of vital rates used to model this population (table 1) are within ranges of estimates for black bears reported in the literature (Garshelis, 1994; Beck, 1991; Rogers, 1987). Lacking a reliable estimate of the population’s size, we varied initial population size to reflect the range of habitat and bear density on the Peninsula.

To estimate the area of available habitat on the Bruce Peninsula, GIS coverages from Landsat TM imagery depicting landcover types and road networks on the Bruce Peninsula were obtained. Spectral signatures were classified into landcover types by the OMNR’s Provincial Mapping Office, and regrouped according to the codes provided into a more general map of significant forest types. Agricultural, urban, open water, and bare soil/rock cover types were excluded from estimates of available habitat area. Buffers were created around major roads and within agri-
Table 1. Model parameters used to simulate population dynamics of black bears on the Bruce Peninsula, and the source publications from which parameters were obtained. When two sources appear, the first is the source for the mean, and the second is the source for the annual variance.

<table>
<thead>
<tr>
<th>Parameter Definition</th>
<th>Estimated Mean</th>
<th>Estimated Annual Variance</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of First Reproduction</td>
<td>5</td>
<td>N/A</td>
<td>Kolenosky, 1990</td>
</tr>
<tr>
<td>Maximum Lifespan and Breeding Age</td>
<td>20</td>
<td>N/A</td>
<td>Yodzis and Kolenosky, 1986</td>
</tr>
<tr>
<td>Individual Cub Survival</td>
<td>0.833</td>
<td>0.051</td>
<td>Kolenosky, 1990; Taylor et al, 1987a</td>
</tr>
<tr>
<td>Whole Litter Cub Survival</td>
<td>0.90</td>
<td>N/A</td>
<td>Calculated from Kolenosky (1990)</td>
</tr>
<tr>
<td>Yearling Survival</td>
<td>0.720</td>
<td>0.096</td>
<td>Yodzis and Kolenosky, 1986; Taylor et al. 1971</td>
</tr>
<tr>
<td>Survival of Prime Age Classes (age 2-15)</td>
<td>0.889</td>
<td>0.185</td>
<td>Yodzis and Kolenosky, 1986</td>
</tr>
<tr>
<td>Survival of Older Age Classes (age 16-20)</td>
<td>0.604</td>
<td>0.185</td>
<td>Yodzis and Kolenosky, 1986</td>
</tr>
<tr>
<td>Litter Size</td>
<td>1.870</td>
<td>.114</td>
<td>Kolenosky, 1990; Jonkel and Cowan, 1971</td>
</tr>
<tr>
<td>Proportion of Available Females that Produce Litters</td>
<td>0.764</td>
<td>0.188</td>
<td>Kolenosky, 1990</td>
</tr>
<tr>
<td>Proportion of Male Cubs</td>
<td>0.50</td>
<td>0.0845</td>
<td>Kolenosky, 1990; Rogers, 1987</td>
</tr>
<tr>
<td>Resulting Deterministic Growth Rate</td>
<td>0.36%</td>
<td>N/A</td>
<td>RiskMan software</td>
</tr>
<tr>
<td>Initial Population Size</td>
<td>Variable</td>
<td>10% of mean</td>
<td>Habitat Modeling</td>
</tr>
</tbody>
</table>

cultural areas in ArcView GIS, to estimate the area of available habitat assuming that bears avoid areas within 100m of major roads, but use agricultural areas within 200m of escape cover.

Initial population sizes modeled were based on estimates of available habitat area on the entire peninsula, and in two political sub-units thereof: 1) St. Edmund's Township, the northernmost township on the peninsula, which is dominated by forested habitat, and contains Bruce Peninsula National Park, and 2) Bruce Peninsula National Park itself. Population sizes based on available habitat within political sub-units of the peninsula could reflect avoidance by bears of southern portions of the peninsula, where human impacts on the landscape are more severe, or future range contraction to those areas due to habitat loss. All estimates of available habitat area were multiplied by three observed densities of bears in Ontario (Obbard, 1999) to yield nine estimates of the potential current size of the popula-
tion. Estimated habitat areas, densities, and initial population sizes appear in table 2. Except for the highest and lowest values, all of our estimates of are within the range of reported estimates (Sutton, 1999) of the size for our study population.

Table 2. Potential sizes of the black bear population on the Bruce Peninsula, based on GIS analysis of available habitat on the peninsula and in two political subunits thereof, and reported (Obbald, 1999) densities of black bears in Ontario.

<table>
<thead>
<tr>
<th>Range Assumption</th>
<th>Density Assumption</th>
<th>Range Area (square km)</th>
<th>Density (bears/square km)</th>
<th>Estimated Population Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce Peninsula</td>
<td>High</td>
<td>1100</td>
<td>0.60</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>1100</td>
<td>0.40</td>
<td>440</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>1100</td>
<td>0.20</td>
<td>220</td>
</tr>
<tr>
<td>St. Edmund’s Township</td>
<td>High</td>
<td>220</td>
<td>0.60</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>220</td>
<td>0.40</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>220</td>
<td>0.20</td>
<td>44</td>
</tr>
<tr>
<td>BPNP</td>
<td>High</td>
<td>138</td>
<td>0.60</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>138</td>
<td>0.40</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>138</td>
<td>0.20</td>
<td>28</td>
</tr>
</tbody>
</table>

We estimated probability of persistence for a non-harvested population based on one thousand runs of the model for each of these initial population sizes. Sensitivity analysis was performed by independently varying each model parameter proportionally to its estimated annual variance, and plotting the change in deterministic growth rate with change in the parameters.

Simulations of harvest were also performed. We ran the model under conditions that 1) harvest is nonselective, affecting all bears older than one equally; 2) only trophy bears are harvested, and 3) trophy bears are selectively harvested, but all other bears older than one are vulnerable, and harvested when trophy bears are rare. Males older than seven and females older than twelve were considered “trophy bears”. We modeled harvest rates of five, ten, fifteen and twenty bears per year under each of the above assumptions, starting from different population sizes.

**Results**

The deterministic exponential growth rate (r) as calculated by RiskMan using the parameters in table one was 0.0036, or 0.36%. This would result in an increase in population size of 43% over one hundred years, assuming no stochasticity or density feedback.

Deterministic growth rate was most sensitive to changes in the survival rate of the prime age class of females. Altering this parameter within one standard deviation of the mean can lead to change in probability of persistence from zero (extinction of all populations), to 1.0 (no extinctions). The model was, to a lesser extent, sensitive to changes in yearling survival, and proportion of females producing litters, and relatively insensitive to all other parameters.
Preliminary results for a non-harvested population subject to environmental and demographic stochasticity indicate that if the area currently occupied remains available, the entire Bruce Peninsula can support a viable population of bears, even at low density (0.2 bears/km²). Assuming the population range becomes limited to St. Edmund’s Township, only a high-density (0.6 / km²) population will be viable for 100 years. Population sizes for medium (0.4 / km²) and low-density bear populations in this Northern portion have risks of extinction near or above five percent. Assuming only habitat within BPNP remains available, the current reserve size is insufficient to ensure the persistence of this population, even at high density (Figure 1).

![Graph](image)

Figure 1. The relationship between initial population size and extinction risk for a non-harvested population under demographic and environmental stochasticity.

Results of harvest simulations are currently being analyzed, however, the following general trends are apparent. The age and sex distribution of the harvest has implications for its sustainability. Non-selective harvest has more dire consequences than harvests selective for, or restricted to, trophy bears. If the range of the population is restricted to St. Edmund’s Township, or the size of the population is below our estimate based on medium (0.4 bears/km²) density on the entire peninsula, long-term persistence probabilities are low under even conservative harvest regimes. Harvest simulations consistently show that harvests of more than ten bears per year are not sustainable, and that any harvest strategy that allows adult females to contribute significantly or variably to the kill is likely to lead to high extinction risk. This is consistent with high sensitivity of the model to survival of prime age classes of females.
Discussion

The assumptions and limitations of PVA are well-documented. Our analysis has avoided the assumption of a stable age distribution (Yodzis and Kolenosky, 1986), and the assumption of a closed population is satisfied by the geographic isolation of the Bruce Peninsula population. However, results are still subject to the limitations of PVA (Coulson et al. 2001; Mann and Plummer, 1999; Beissinger and Westphal, 1998; Taylor, 1995; Caughley, 1994; Oreskes et al., 1994), so absolute estimates of extinction risk need to be interpreted with caution. Modeling the effects of stochasticity on population size can be a poor predictor of extinction in large carnivores in protected areas, since their persistence may depend more on interactions with humans at reserve edges (Woodroffe and Ginsberg, 1998). The distribution of population extinction times resulting from stochastic population simulations tends to be negatively skewed, so probability of persistence over a specific time interval may underestimate the true risk of extinction (Ludwig, 1999). Therefore, predictions of high extinction risk assuming range contraction to Bruce Peninsula National Park and no harvest are likely underestimates, due to skewed times to extinction, and effects of humans on bears that reside only partly within the Park. Management to prevent fragmentation and reduction of the currently available habitat is necessary to ensure viability of the Bruce Peninsula population, even if protected from sport harvest.

In our model, harvest mortality was assumed to be additive to natural mortality. While it has been suggested that recruitment in black bear populations responds positively to removals of adult males (LeCount, 1982), the assumption that harvest mortality is compensatory may not be consistent with the precautionary principle, especially in light of our meager understanding of regulation of black bear populations (Taylor, 1994). Results suggesting that harvest could propel or hasten the population to extinction are perhaps not surprising. Yodzis and Kolenosky (1986), cited increased immigration by sub-adult males, not improved recruitment, as the stabilizing factor in their heavily-hunted population. Horino and Miura (2000) cite harvest as a potential cause of extinction of an isolated population of Asiatic black bears. Powell et al (1996) observed that when survival rates of protected black bears and adjacent, harvested bears were combined, the mean survival rate resulted in overall population decline. High sensitivity to adult female survival is typical of long-lived species with low growth rates (Kelly and Durant, 2000; Caswell et al. 1999; Taylor et al. 1987b).

Black bears have been identified as an effective indicator species in the Upper Bruce Ecosystem (Sutton, 1999). The potential for the black bear population to go extinct at a high probability in the absence of human-induced mortality if confined to the boundaries of Bruce Peninsula National Park should raise concerns over the capacity of the current reserve to protect the ecological integrity of this ecosystem.
References


Classified Image (of the Bruce Peninsula). Inventory, Monitoring and
Assessment Section. Provincial Mapping Office, Ontario Ministry of Natural
Resources. Toronto.
Lande, R. 1993. Risks of population extinction from demographic and environ-
mental stochasticity and random catastrophes. *American Naturalist* 142:911-
927.
241(4872):1455-60
284:36-37.
Mattson, D.J. 1990. Human impacts on bear habitat use. *International Confer-
ence on Bear Research and Management* 8:33-56.
Obbard, M.E. 1999. Validation of bait stations surveys using DNA fingerprint-
ing of hair samples. *Ursus* 11 (published abstract).
samples from the Bruce Peninsula. *Cited in Federal/Provincial Agreement
between Parks Canada-Bruce Peninsula National Park and Ontario Ministry
of Natural Resources Wildlife and Natural Heritage Science Section. 1998.
Oreskes, N; Shrader-Frechette, K. and K. Belitz. Verification, validation, and
confirmation of numerical models in the earth sciences. *Science* 263(4):641-
646.
Powell, R.A; Zimmerman, J.W; Seaman, D.E. and J.F. Gilliam. 1996. Demo-
graphic analyses of a hunted black bear population with access to a refuge.
Rivard, D.H; Poitevin, J; Plasse, D; Carleton, M. and D.J. Currie. Changing
species richness and composition in Canadian National Parks. *Conservation
Biology* 14(4):1099-1109.
Rogers, L.L. 1987. Effects of food supply and kinship on social behavior,
movements, and population growth of black bears in northeastern Minnesota.
*International Conference on Bear Research and Management*. Monograph
Series Number 2. 1-16.
Sutton, Scott. 1999. *A study of black bear population dynamics and habitat
usage within the greater ecosystem of Bruce Peninsula National Park* 1999
Field Season Report. Tobermory. ON.
Taylor, B.L. 1995. The reliability of using population viability analysis for risk


