Relationships among food availability, harvest, and human–bear conflict at landscape scales in Ontario, Canada

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Abstract: Managers of American black bears (Ursus americanus) must maintain populations to ensure viability and opportunities for sport harvest, and minimize human–bear conflict (HBC). Harvest is a cost-effective management tool in most jurisdictions, and intuitively it seems that with fewer bears, there should be fewer conflicts. Therefore, managers may attempt to achieve both objectives by manipulating the harvest. Further, because data describing harvest and HBC are frequently collected, managers sometimes infer changes in population status from trends in harvest and HBC. However, evidence that larger harvests reduce HBC is lacking, and changes in harvest metrics and the frequency of HBC may be independent of bear density. Understanding relationships among food availability, hunter effort, harvest, and HBC could help managers avoid making invalid inferences about population status from data describing harvest and HBC, and evaluate whether management actions are having intended results. We investigated relationships among food availability, HBC, and harvest at landscape scales in Ontario, Canada, 2004–2011. We hypothesized that HBC and harvest would be negatively correlated with food availability; that HBC would be negatively correlated with prior harvest; and that harvest would be positively correlated with number of hunters. We used Spearman rank correlation to test hypotheses. Human–bear conflict was negatively correlated with food availability across Ontario, and in the 2 administrative regions where food availability varied synchronously. Total harvest and the proportion of females in the harvest were negatively correlated with food availability across Ontario and in one region. Human–bear conflict was not correlated with prior harvests, providing no evidence that larger harvests reduced subsequent HBC. Given the variation in natural foods, harvest is unlikely to prevent elevated levels of HBC in years of food shortage unless it maintains bears at low densities—an objective that might conflict with maintaining viable populations and providing opportunities for sport harvest.

Key words: American black bear, food availability, harvest, human–bear conflict, Ontario, Ursus americanus

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During the late 1980s, American black bears (*Ursus americanus*) were managed for sustainable yield in most jurisdictions with healthy populations (Miller 1990), though populations in a few U.S. jurisdictions were still recovering from past over-harvest. Since then, minimizing conflicts with humans has become an increasingly important aspect of black bear management (Hristienko and McDonald 2007, Spencer et al. 2007). Most management agencies have initiated programs to educate the public about how to minimize human–bear conflict (HBC), but their effectiveness is difficult to measure because of multiple influences on the frequency of, and reporting rate for, human–bear interactions (Garshelis 1989, Gore et al. 2006, Spencer et al. 2007, Howe et al. 2010). Sport harvest can be a cost-effective means of removing animals from the population, so it is intuitive and convenient for managers to assume that harvest could be used to limit or reduce HBC by reducing bear density and distribution. However, evidence demonstrating the effectiveness of harvest management for reducing HBC is lacking (Garshelis 1989, Treves et al. 2010).

Wildlife managers frequently infer trends in bear populations from changes in harvest metrics (Garshelis 1991, Garshelis and Hristienko 2006, Hristienko and McDonald 2007), and typically evaluate the efficacy of education programs designed to prevent HBC from trends in the number of conflicts reported by the public (Schirokauer and Boyd 1998, Gore et al. 2006, Hristienko and McDonald 2007, Spencer et al. 2007). However, both harvest metrics and measures of HBC vary among years in response to changes in the availability of natural foods (Gilbert et al. 1978; Garshelis 1989; McDonald et al. 1994; Noyce and Garshelis 1997; Ryan et al. 2004, 2007; Howe et al. 2010). This variation obscures trends and may also confound tests for relationships among bear population size, hunting pressure, harvest, and HBC, which makes it difficult for managers to assess whether management actions are having the desired effect unless concurrent data on food availability are available to provide insights (Garshelis 1991, Gore et al. 2006, Garshelis and Noyce 2008, Treves et al. 2010). Knowledge of relationships among food availability, hunter effort, harvest, and HBC would enable us to explain fluctuations or trends in HBC and harvest metrics. This could help managers and other stakeholders avoid drawing incorrect inferences about trends in the bear population from HBC or harvest data, and facilitate evaluations of whether management actions are approaching or meeting identified long-term targets with regard to levels of HBC, sustainability of harvests, and population status.

During the 1990s, data describing HBC in Ontario, Canada, were not maintained in a standardized manner across the province, and food availability was measured over only a portion of black bear range (Poulin et al. 2003). Controversy surrounding the effects of the 1999 cancellation of the spring hunting season on the frequency of HBC spurred the Ontario Ministry of Natural Resources (OMNR) to appoint an independent Nuisance Bear Review Committee in 2002 (Howe et al. 2010). That committee recommended standardizing collection of data on HBC, and the expansion of food availability surveys to the entire province (Poulin et al. 2003). Both of these recommendations were implemented in 2004.

This study describes the first analysis of relationships among food availability, HBC, and harvest at landscape scales in Ontario. Our objectives were (1) to assess whether food availability varied synchronously over large areas; (2) to test for trends in harvest and measures of HBC; (3) to test for negative correlations between food availability and HBC; (4) to test for negative correlations between food availability and each of total harvest, hunter success rate, and the sex and age ratio of harvests; (5) to test for negative correlations between harvest and subsequent HBC; and (6) to test for positive correlations between hunter effort and harvest. An understanding of spatial synchrony in annual variation in food availability was necessary to assess the validity of pooling data over large areas to test for correlations at landscape scales. Similarly, trends in HBC and harvest were potentially relevant to the interpretation of results of other tests. Objective 3 and 4 address the hypothesis that when natural foods are scarce, black bears are more prone to HBC and more vulnerable to harvest as they seek out alternative foods. We expected that food shortages would affect the vulnerability of females to harvest more strongly than vulnerability of males because subadult females typically restrict their movements more than subadult males do (i.e., subadult males are vulnerable to harvest even when natural foods are abundant) and adult females must meet the energetic requirements of gestation and lactation. Objective 5 was intended to test the assumption (appealing from a management perspective) that harvesting liberally reduces HBC. Objective 6 tests whether harvest increased with hunting pressure.

Methods

Study area

The study area was Ontario, Canada. Most data describing food availability, HBC, and harvest were from contiguously forested Boreal and Great Lakes–St. Lawrence Forest Regions that are permanently occupied by black bears (Fig. 1); but we collected some data on food availability, and recorded occasional occurrences of HBC and harvest, in fragmented habitat used by a small number of bears. The OMNR divides the province into 3 administrative Regions: Northeast (NER), Northwest (NWR), and Southern (SR). Regions are further subdivided into administrative Districts (Fig. 1). From 2004 to 2011, NER and NWR were characterized by contiguous black bear habitat, low black bear harvest densities ($\bar{x}_{2004-2011} = 0.6/100 \text{ km}^2$), and low and stable human population densities (Natural Resources Canada 2006; Statistics Canada 2007, 2012). Most of Ontario’s human population lived in SR (Statistics Canada 2007, 2012). Human populations in SR increased from 2001 to 2006 and again from 2006 to 2011, with some of the largest increases occurring in areas with the highest bear densities (Statistics Canada 2007, 2012; Howe et al. 2013). Black bear harvest densities in SR ($\bar{x}_{2004-2011} = 2.6/100 \text{ km}^2$) were >4 times those in NER or NWR (Dix-Gibson 2012).

Data collection

Ontario Ministry of Natural Resources District staff measured food availability annually (2004–2011) by ranking production of fruit- and nut-producing species (or groups of species within a genus) on a 5-point scale by visual observation, similar to the approach of Noyce and Coy (1990). Different sets of species were monitored in each of 3 Forest Regions within the greater study area (Boreal Forests, and Great Lakes–St. Lawrence Forests east and west of the Great Lakes; Fig. 1; Table 1). We selected these species based on their prevalence in the respective Forest Region, and with reference to studies of black bear feeding habits in Ontario and similar habitat elsewhere (Rowe 1972, Obbard 1987, Rogers and Allen 1987, Noyce and Garshelis 1997, Romain et al. 2013; Table 1). All were native to Ontario, except feral domestic apples ($Malus pumila$) present in eastern and western Great Lakes–St. Lawrence Forests, and European mountain-ash ($Sorbus aucuparia$), which contributed to scores for mountain-ash ($Sorbus$ spp.) where present. Our Bear Food Index (BFI) was the average of rankings across all species used by bears in the respective Forest Region. When calculating the BFI, we first calculated the mean rank for each species across multiple observations within Districts and years (where available). We then calculated District-specific annual BFI values as the average rank across species, and finally we calculated regional and provincial BFI values as the mean BFI across Districts within those geographic areas.

Staff at many District offices ranked food availability at multiple locations within their District each year; in other cases, rankings reflected availability within entire Districts, as assessed by one or more observers. Food availability was not measured in all Districts in all years. The mean (SD) number of Districts that measured food availability annually in each Region was 6.5 (2.6) of a possible 9 Districts in NER, 4.0 (1.3) of 7 Districts in NWR, and 5.3 (1.6) of...
8 Districts in SR. The mean (SD) number of annual observations of the BFI across Districts was 34.5 (18.7) in NER, 7.0 (SD 3.1) in NWR, and 34.8 (SD 4.6) in SR. In the case of SR, 95% of observations were from the 5 primarily forested Districts with contiguous black bear populations, and 5% of observations were from the 3 Districts at the southeastern fringe of black bear range in Ontario.

During 2004, hunting seasons for black bear were open from 15 August to 15 October in NER and in 17 of 27 Wildlife Management Units in NWR, from 15 August to 31 October in 10 Wildlife Management Units in NWR, and from 1 September or the Tuesday following Labor Day through 30 November in SR. From 2005 to 2011, seasons ran from 15 August to 31 October in NER and NWR, and from 1 September or the Tuesday following Labor Day through 30 November in SR. During 2004, a postcard survey was mailed to resident hunters, which they were asked to voluntarily complete. During 2005, the survey was attached to the hunting license, and from 2006 to 2011 the survey was provided in the annual Hunting Regulations Summary. Hunters were required to complete and return the survey to OMNR by 15 December of the same year. A reminder was mailed to hunters who had not replied. During 2004, the reply rate for the postcard survey was 45% (Dix-Gibson 2012). Completion and submission of the postcard survey became mandatory in 2005; since then, the reply rate has varied between 60% and 70% (Dix-Gibson 2012). Information hunters were requested to provide included the Wildlife Management Unit in which they hunted; whether they hunted using bait; whether they killed a bear and if so, its sex; and whether they enclosed a premolar tooth for age determination. Total resident harvest and resident-hunter success rates were calculated by assuming returned surveys were representative of all licensed hunters. Non-residents of Ontario were required to report their black bear hunting activity and harvest on a Non-Resident Black Bear Hunting License Validation Certificate obtained either from an operator licensed to provide bear hunting services or from an OMNR office. Completion of these certificates was mandatory and reply rates were 100% (Dix-Gibson 2012).

During 2004, OMNR initiated standardized, province-wide recording of the number of reported occurrences of human–bear conflict (hereafter,
“occurrences”) via a toll-free reporting line available to the public 24 hours/day, 7 days/week. The number of traps set to capture bears at the site of occurrences was recorded beginning in 2005. Traps were set only when deemed necessary by OMNR staff to prevent property damage or if there was a risk to human safety after investigation by OMNR staff.

**Data analyses**

We assessed synchrony in the direction of change in BFI scores among years within Regions using Buonaccorsi’s average measure of agreement ($\bar{A}$), which is equivalent to the average proportion of time that pairs of series agree in their change in direction (Buonaccorsi et al. 2001). When assessing synchrony, we used data only from Districts that measured food availability in $\geq 5$ of the 8 years in our time series. Data from 7 of 9 Districts in NER, and 5 of 7 Districts in each of NWR and SR met this criterion. We assessed synchrony among Regions by calculating the simple measure of agreement ($A_{ij}$) between pairs of Regional BFI time series (Buonaccorsi et al. 2001). We deemed fluctuations in food availability synchronous where $\bar{A}$ or $A_{ij}$ was $>0.75$.

Because our sample sizes were small (i.e., 7 or 8 annual observations of each variable), and the BFI was a rank variable, we used Spearman rank correlation to test for trends and for relationships among food, HBC, and harvest. We performed all correlations on data from the entire province, and separately within each of the 3 administrative regions. Sudbury District in NER consistently had more occurrences than other Districts, which we attributed to unique landscape characteristics where the interspersion of suburban development and blueberry (Vaccinium spp.) barrens associated with soils acidified by past smelting activity (Winterhalder 1996) brought large numbers of bears into close proximity with humans during the fruiting season for blueberries. We also attributed the high level of occurrences to a long-term research study of problem activity by black bears near Sudbury, where researchers actively solicited reports of problem bears near developed areas (Landriault et al. 2009). To control for the influence of data from Sudbury District, we duplicated occurrence data for NER and the province excluding occurrences from there, and tested for trends and correlations with food availability and prior harvest using both the complete and the censored data sets.

We used correlations between calendar year and each of occurrences, traps set, total harvest, and the number of hunters to test for temporal trends ($\alpha = 0.05$, 2-sided). For all other correlations we used 1-tailed tests because our hypotheses included the expected type of relationship (positive or negative). We crossed the BFI with occurrences, traps set, total harvest, hunter success rate, the proportion of females in the harvest, and the proportion of adult females in the harvest to address objectives 3 and 4. For objective 5, we would have preferred to cross occurrences and traps set with harvest in the previous year, and the 2- and 3-year moving average of prior harvests. However, we were concerned about potential confounding effects of temporally autocorrelated BFI data when correlating number of occurrences and traps set with harvest in only the previous year. Soft mast production varied synchronously and exhibited negative autocorrelations with production in the previous year over much of NER and SR from 1998 through 2009 (Howe et al. 2012). Our BFI included all of the species studied by Howe et al. (2012), and exhibited similar negative autocorrelations at a 1-year lag, both province-wide ($\rho = -0.79$; $P = 0.048$, 2-tailed) and within NER ($\rho = -0.93$; $P = 0.007$, 2-tailed). In our data from NER and across Ontario, years with poor food, high levels of HBC, and large harvest tended to be followed by years with better food, lower levels of HBC, and smaller harvest. This tendency could have led to spurious negative correlations between HBC and harvest in the previous year if both HBC and harvest were responding similarly to variation in food availability. Therefore, we crossed measures of HBC only with the 2- and 3-year average of prior harvests in NER and Ontario. We addressed objective 6 using correlations between total harvest and the number of hunters. We manually calculated measures of agreement in the direction of change in food availability across years. We performed all correlations in R version 3.0.2 (R Development Core Team 2013). We calculated the null distribution of the Spearman Rank correlation statistic ($\rho$) as the pre-computed exact distribution for $n \leq 22$ following van de Wiel and Di Bucchianico (2001) as implemented in the “pspearman” package (Savicky 2009).

**Results**

Pairs of District-specific BFI values agreed in their change in direction from one year to the next 77.5%
of the time in NER and 85% of the time in SR (indicating synchrony), but only 54% of the time in NWR. Most cases of disagreement in NER occurred during 2010, when late spring frosts (which can kill flowers and hence reduce fruit production; Usui et al. 2005) of varying severity occurred in different Districts within the Region. Regional BFI scores agreed in their direction of change 100% of the time when NER and SR were compared, but only 43% of the time when NER or SR were compared with NWR.

On average, nearly 10,000 occurrences of HBC were reported, >1,000 traps were set, and nearly 20,000 licensed hunters harvested approximately 5,600 bears (of which 36% were females), annually during the study period (Table 2). The Northeast Region had the greatest numbers of occurrences and bears harvested (Table 2). Hunter success rates were noticeably lower in SR than in other Regions (Table 2). Most hunters in NER and NWR were non-residents who targeted bears and hunted over bait, whereas a greater proportion of hunters in SR were residents who hunted bears opportunistically while hunting white-tailed deer (Odocoileus virginianus) or moose (Alces alces; Dix-Gibson 2012).

The number of hunters in NWR declined during the study (ρ = −0.88, P = 0.007), though there was no significant trend in total harvest (ρ = −0.69, P = 0.069). There were no other significant trends across years in measures of HBC (occurrences, traps set) or harvest metrics (total harvest, or the no. of hunters) at either the provincial scale or within other Regions (Table S1).

The number of occurrences was significantly negatively correlated with the BFI at the provincial scale (ρ = −0.79, P = 0.014), and in both NER (ρ = −0.67, P = 0.042) and SR (ρ = −0.98, P < 0.001; Fig. 2). Correlations were stronger when data for Sudbury District were excluded (for Ontario, ρ = −0.88, P = 0.004; and for NER, ρ = −0.83, P = 0.008; Fig. 2). The number of traps set was also negatively correlated with the BFI at the provincial scale (ρ = −0.86, P = 0.012) and for both NER (ρ = −0.89, P = 0.006) and SR (ρ = −0.75, P = 0.033; Fig. 2).

Total harvest was negatively correlated with food availability for Ontario (ρ = −0.90, P = 0.002) and for NER (ρ = −0.83, P = 0.008; Fig. 3). Hunter success rate was negatively correlated with the BFI in NER (ρ = −0.83, P = 0.008). The proportion of females in the harvest was negatively correlated with the BFI in Ontario (ρ = −0.86, P = 0.005), and in NER (ρ = −0.81, P = 0.008; Fig. 3), though there were no significant correlations with the proportion of adult females in the harvest.

There were no significant correlations between occurrences or traps set and the 2- or 3-year moving averages of prior harvests at any spatial extent (Table S1). There were no significant correlations between either occurrences or traps set and total harvest in the previous year in NWR or SR (Table S1). We did not test for correlations between total harvest in the previous year and measures of HBC in Ontario or NER because food data were temporally autocorrelated.

Total harvest was significantly positively correlated with the number of hunters in SR (ρ = 0.74, P = 0.023), but not in other Regions or at the provincial scale.

**Discussion**

Synchronous variation in food availability for black bears over a vast landscape, including much of
northeastern and southern Ontario, enabled us to detect significant negative correlations between food availability and each of HBC and harvest at landscape scales. No significant relationships were detected in NWR, where the BFI did not vary synchronously among Districts (BFI data from NWR were sparse compared with other Regions). Significant correlations at the provincial scale were likely a result of the consistent patterns of variation in the BFI and measures of HBC and harvest that prevailed in NER and SR. Our BFI was largely based on annual rankings for soft-mast–producing species, which were previously shown to vary synchronously within and among species over subsets of our study area (Obbard et al. 2003, Howe et al. 2012, Romain et al. 2013). Similar synchrony in soft mast production was also observed over large areas of Minnesota, USA (Garshelis and Noyce 2008), and Yukon, Canada (Krebs et al. 2010). Because black bear behavior, reproduction, vulnerability to harvest, and propensity to come into conflict with humans are closely linked to variation in food supply (Garshelis and Pelton 1981; Rogers 1987; Noyce and Garshelis 1997; Costello et al. 2003; Ryan et al. 2004, 2007; Obbard and Howe 2008; Howe et al. 2010), an understanding of spatiotemporal patterns in forage production is likely to be important to other studies of black bears at landscape scales.

Variation in berry production is at least partially attributable to variation in weather conditions during flowering and fruiting (Laine and Henttonen 1983; Selás 1997, 2000; Usui et al. 2005; Krebs et al. 2009; Holden et al. 2012; Howe et al. 2012). Widespread droughts helped synchronize berry production within and among species over much of NER.
and SR from 1998 to 2009 (Howe et al. 2012). Major climatic oscillations, such as the North Atlantic Oscillation and the El Niño Southern Oscillation, influence weather conditions similarly over large areas, so they could promote spatially synchronous variation in fruit production (Hurrell et al. 2003, Stenseth et al. 2003). The effects of the North Atlantic Oscillation and El Niño Southern Oscillation differ qualitatively within Ontario, notably along the boundary between Canada’s Continental and Atlantic climatic regions, which roughly bisects NWR into eastern and western halves (Bonsal et al. 2001). This may explain the lack of spatial synchrony in BFI data, and lack of significant relationships between the BFI and HBC or harvest in NWR though it seems likely that the sparse BFI data from NWR was also a contributing factor. The influences of major climatic oscillations on local weather are somewhat predictable (Hurrell et al. 2003). If we could identify relationships between climate indices measured during the winter and berry production the following growing season, we would have an opportunity to predict food shortages and associated increases in vulnerability to harvest and HBC, as demonstrated by Zack et al. (2003). For example, Holden et al. (2012) recently showed that maximum snow-water equivalent can influence production of serviceberries (Amelanchier spp.), which are an important food for black and brown bears (U. arctos) in western North America. The potential to predict food supply for bears from winter weather variables or climate indices warrants additional research.

Although measures of HBC and harvest metrics varied among years, they did not change directionally over time except for the decline in the number of hunters in NWR. This decline was attributable to a >20% decline in the number of non-resident hunters in NWR after 2008 (Dix-Gibson 2012), which was likely an effect of the economic downturn in the United States. Our sample sizes ($n = 7$ or 8 yr) limited our ability to test for trends while accounting for variation associated with changes in food supply, but with longer time series multivariate approaches could improve our ability to detect trends in fluctuating data.

In our study, the frequency of HBC was negatively correlated with food availability in 2 of 3 Regions (NER, SR), and across all of Ontario. The reporting rate for HBC, and therefore our occurrence data, could vary with changes in media coverage and management policy (Garshelis and Noyce 2008, Gore and Knuth 2009, Howe et al. 2010). However, during our study, management policy in Ontario was constant. Serious attacks on humans in Ontario occurred in September 2005 and May 2010. Provincially, occurrences were large in 2005 (the third-highest in our time series), but this coincided with the second-poorest year for bear foods. During 2006, occurrences were low, coinciding with a high BFI score, so it seemed there was no lag effect of publicity surrounding the 2005 attack. Similarly, occurrences were about average during 2010 and there were fewer occurrences during 2011 than any other year, so the highly publicized attack in May 2010 apparently had little effect on the reporting rate for HBC. Furthermore, traps were set by OMNR staff only where deemed necessary after a site investigation, thus providing a measure of HBC that was less dependent on the reporting rate, and relationships between the BFI and the number of traps set were similar to those between the BFI and occurrences. Though we cannot infer causal relationships from correlation analyses, our results corroborate previous studies that demonstrated negative relationships between the frequency of conflict between humans and American black bears and fruit or nut production by preferred forage species (Jorgensen et al. 1978, Peine 2001, Ryan et al. 2007, Garshelis and Noyce 2008, Howe et al. 2010, Baruch-Mordo et al. 2014). Where humans coexist with established bear populations, annual variation in the frequency of HBC is apparently well-explained by variation in food supply for bears. However, we acknowledge that this might not be true where bear populations are recovering or expanding their range (Cotton 2008), or where human development or recreational use is expanding quickly into occupied bear habitat (Singer and Bratton 1980, Miller 1990, Schirokauer and Boyd 1998).

Total harvest and the proportion of females in the harvest were also negatively correlated with food supply in NER and at the provincial scale. Apparently bears, particularly female bears, were more vulnerable to harvest when food was scarce, as previously observed in Minnesota and Virginia where baiting was also a common hunting method (Noyce and Garshelis 1997, Ryan et al. 2004). Increased vulnerability to harvest likely resulted from increases in home range size and movement rates during poor food years (Garshelis and Pelton 1981, Pelchat and Ruff 1986, Rogers 1987, Garshelis...
and Noyce 2008), and increased attraction of bears to hunters’ baits (Noyce and Garshelis 1997, Ryan et al. 2004). In the case of female bears, food stress associated with the need to gain considerable body mass in order to produce cubs the following winter, or with the energetic costs of lactation, may have exacerbated these effects. However, despite detecting an increase in the proportion of females in the harvest, we did not detect an increase in the proportion of adult females in the harvest during poor food years in our study. In Ontario, sex is reported for approximately 83% of bears harvested, whereas only approximately 40% of premolar teeth are submitted for aging (Dix-Gibson 2012). Because ages are known for only about 40% of females harvested, increasing the proportion of teeth submitted might enable us to tease out any effects of food supply on adult females.

We found no significant correlations between harvest and subsequent HBC. Although it may be intuitive to assume that harvesting more bears should reduce HBC, empirical support for this assumption is lacking despite considerable research (Garshelis 1989, Treves and Karanth 2003, Huygens et al. 2004, Tavss 2005, Treves 2009, Howe et al. 2010, Treves et al. 2010). Based on a survey of North American jurisdictions regarding harvest management regimes and trends in HBC, Hristienko and McDonald (2007) argued that more liberal hunting regimes would reduce HBC. However, they presented no quantitative data demonstrating that liberal harvesting anywhere actually reduced the frequency of HBC; liberal hunting regimes may simply promote greater public acceptance of bears, thus resulting in fewer complaints (Treves and Karanth 2003, Howe et al. 2010).

We acknowledge that our short time series and the lack of significant trends in either total harvest or HBC may limit the scope of inference from our data with respect to effects of harvest on the frequency of HBC. However, given the degree to which natural food supply for black bears varies among years (Costello et al. 2003, Usui et al. 2005, Romain et al. 2013, Koenig and Knops 2014), and the importance of bottom-up processes to bear demography (McLellan 2011), it seems likely that bears at a range of population densities will attempt to access anthropogenic food sources and come into conflict with humans when natural foods are scarce. We suggest that reducing the associated risk of HBC through harvest would require high harvest levels that reduce populations to very low densities. This might be at odds with the objectives of maintaining viable populations and providing sustainable sport-harvest opportunities over the long term. A better strategy for management agencies would be to develop a thorough understanding of causes of HBC in their jurisdiction (Baruch-Mordo et al. 2008), promote programs that focus on practical solutions that deny bears access to the many kinds of anthropogenic attractants, and develop educational programs that encourage the public to accept responsibility for their role in the human–bear conflict dyad.

In SR, total harvest was a function of the number of hunters rather than food supply. This could reflect an increase in hunting pressure in SR since 2008, the greater diversity of autumn foods in SR, or differences in hunting methods among Regions. Although we did not detect significant trends in the number of hunters or total harvest, both were highest during the last 3 years of the study in SR, which would have contributed to the significant correlation. Black bears in the boreal forest of Ontario rely heavily on the fruits of a few plant species (blueberry, bunchberry [Cornus canadensis], raspberry [Rubus sp.], mountain-ash, pin cherry [Prunus pensylvanica], and beaked hazel [Corylus cornuta]) during the hunting season (Romain et al. 2013). Fruit production by these species, and consumption by black bears, varies considerably among years (Usui et al. 2005, Romain et al. 2013). Furthermore, fruit production by many of these species is adversely affected by late spring frosts and by dry or cool summer weather conditions (Usui et al. 2005, Howe et al. 2012, Romain et al. 2013). Should several of these crops fail in the same year, bears would likely be strongly attracted to hunters’ baits. Conversely, in SR oak (Quercus spp.) and beech (Fagus grandifolia) may provide more abundant natural food during the hunting season when available, and bears have more opportunity to exploit alternative foods such as feral apples, agricultural crops, fruit trees, beehives, garbage, and other anthropogenic food sources. Therefore, the vulnerability of bears to harvest in SR might be less sensitive to poor production by the species included in our BFI. Differences in hunting methods among Regions may also be relevant. Most non-residents hunted over bait through the services of an outfitter, but many residents hunt bears opportunistically without the use of baits, and the proportion of bears taken by non-resident hunters was larger in NER (66%) than in

SR (23%; Dix-Gibson 2012). Therefore, the success of hunters in SR may be less dependent on the attractiveness of bait than success in NER.

The large number of correlations we performed increased the chance of Type I errors arising in our study. We did not correct significance thresholds for multiple comparisons because the power of tests was already low because of small samples, and we acknowledge that significant results could have occurred randomly. However, we suggest that given the consistency of the correlations among the BFI, HBC, and harvest metrics where food varied synchronously, it is unlikely that these were randomly occurring Type I errors rather than real patterns.

**Management implications**

Rank indices of food availability, such as our BFI, can be obtained at low cost and have proven useful in explaining annual variation in black bear harvest metrics and in the frequency of HBC (Noyce and Garshelis 1997; Ryan et al. 2004, 2007; Garshelis and Noyce 2008; Howe et al. 2010). We recommend that food availability surveys be continued or expanded in Ontario, and implemented by other jurisdictions that manage black bears but do not currently measure food availability.

This study was made possible by the implementation of province-wide, standardized collection of food availability and HBC data in 2004. Consistent management from 2004 to 2011 reduced the potential for confounding effects of management regime changes on harvest metrics or the reporting rate for HBC. We did not augment the time series with data from more recent years because in 2012 the agency’s response to reports of HBC changed. Site visits were not conducted as frequently, and bears were not trapped and relocated except under exceptional circumstances. We suspect that the public responded to this change with a reduction in the reporting rate for HBC. The number of reported occurrences dropped sharply during 2012 (to 5,800 province-wide) despite widespread soft-mast failures, and dropped again during 2013 (to 2,419). Similarly, in Minnesota, calls about HBC to the managing agency decreased and remained low after the agency stopped trapping and removing bears from the site of HBC (Garshelis and Noyce 2008). The potential effects of changes in the management regime on the reporting rate for HBC should be considered when drawing inferences from changes in the number of incidences of HBC reported by the public.

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**Literature cited**


Supplemental material

Table S1. Spearman rank correlations for occurrences, traps set, total harvest, and number of hunters set against year and bear food index (BFI); for occurrences and traps set against harvest in year prior, or 2- and 3-year moving average of prior harvest; for total harvest set against number of hunters; and for proportion (Prop) of adult females (ad F) in the harvest and mean age of harvest set against bear food index. Spatial extents are Northeast Region (NER), Northwest Region (NWR), Southern Region (SR), or all of Ontario (Prov). Data are for Ontario, Canada, 2004–2011.