Influence of mast production on black bear non-hunting mortalities in West Virginia

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Abstract: Food availability influences movements, population dynamics, and harvest of black bears (*Ursus americanus*) in the Appalachian Mountains. We compared combinations of hard and soft mast indices to black bear non-hunting mortalities in West Virginia, USA, 1980–2004. Mast conditions were inversely related to non-hunting black bear mortalities. We constructed regression equations to predict non-hunting bear mortalities and used Akaike's Information Criterion (AIC) to compare fit of each model to the data. Oak (*Quercus* spp.; $\Delta AIC_c = 0.000$), oak + hickory (*Carya* spp.; $\Delta AIC_c = 0.251$), all hard mast ($\Delta AICc = 6.41$), and hard mast + black cherry (*Prunus serotina*; $\Delta AIC_c = 7.06$) were considered the best competing models for explaining non-hunting black bear mortalities. Managers may use this data to help explain and predict the importance of hard mast conditions on non-hunting black bear mortalities.

Key words: black bear, hard mast, hickory, mast, mast production, non-hunting mortalities, oak, soft mast, *Ursus americanus*, West Virginia

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Food availability can affect home ranges, hunting movements, harvest, and distribution of black bears (*Ursus americanus*; Garshelis and Pelton 1981, Pelton 1989, Schooley et al. 1994, Noyce and Garshelis 1997, Vaughan 2002, Ryan et al. 2004). Black bear diet and habitat selection vary seasonally depending upon food abundance (Beeman and Pelton 1980, Graber and White 1983, Clark et al. 1987, Costello and Sage 1994, Kasbohm et al. 1998). Soft mast is the staple of the black bear's summer and early fall diet (Garshelis and Pelton 1981, Eagle and Pelton 1983, Graber and White 1983, Kasbohm et al. 1998). However, black bears may shift their fall home range to take advantage of hard mast when it becomes available (Beeman and Pelton 1980, Eagle and Pelton 1983, Grenfell and Brody 1986, Kasbohm et al. 1998).

Acorns are the most important fall food source for black bears throughout the Appalachians (Cottam et al. 1939, Beeman and Pelton 1980, Garner 1986, Pelton 1989, Vaughan 2002). Acorns and other seeds represent the most valuable and energy-rich native plant foods available in the dormant season. Only during years of complete mast failure does forage abundance exceed that of mast (Healy et al. 1997). During years of oak failure, black bears may respond by using an area of high acorn concentration, intensively using small areas, or undertaking long-range movements (Pelton 1989). Non-hunting mortalities (roadkills, illegal kills, depredation permits, etc.), nuisance complaints, harvests, and attraction to human-related foods typically increase during years of mast failure (Rogers 1976, McCarthy and Seavoy 1994, McDonald et al. 1994, Ryan et al. 2004).

Mast survey data have been collected annually in West Virginia since 1970 (Pack 2000). We used this long-term data set to study the relationship of mast conditions to non-hunting black bear mortalities. Our objective was to determine if there were relationships between West Virginia's extensive and qualitative mast surveys and black bear non-hunting mortalities. We hypothesized that non-hunting mortality would be lower during years of abundant mast than when mast crops were poor.

Study area

Strausbaugh and Core (1978) divided West Virginia into 3 physiographic provinces: the Western

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Hill Section, the Allegheny Mountain and Upland Section, and the Eastern Ridge and Valley Section. The Western Hill Section was characterized as a central hardwood forest with habitat types ranging from oak (*Quercus* spp)–hickory (*Carya* spp.) on dry sites to floodplain communities along the Ohio River. Sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), and yellow birch (*Betula alleghaniensis*) dominate the Allegheny Mountain and Upland Section; however, oak and black cherry (*Prunus serotina*) may dominate lower elevations and drier sites, and were very important to wildlife (Pack et al. 1999). The Eastern Ridge and Valley Section was predominantly a composition of oak–hickory–pine (*Pinus* spp.). Elevation ranged from 73 to 1,524 m (Strausbaugh and Core 1978).

Methods

Statewide mast conditions were surveyed annually during August, 1980–2004. Division of Forestry personnel, Division of Natural Resources personnel, and volunteers rated 9 hard mast species: American beech, walnut (*Juglans* spp.), hickory, white oak (*Q. alba*), chestnut oak (*Q. prinus*), black–red oak (*Q. velutina–Q. rubra*), yellow-poplar (*Liriodendron tulipifera*), scarlet oak (*Q. coccinea*), and scrub oak (*Q. ilicifolia*). In addition, they rated 9 soft mast species: black cherry, grapes (*Vitis* spp.), hawthorn (*Crataegus* spp.), crabapple (*Pyrus* spp.), flowering dogwood (*Cornus florida*), blackberry (*Rubus* spp.), greenbrier (*Smilax* spp.), sassafras (*Sassafras albidum*), and apple (*Malus* spp.). The long-term average index for apple was used during 1980–82 because it was not measured during those years. Walnut was not included in hard mast correlations because it is used infrequently by the wildlife species studied (Huntley 1989). Yellow-poplar was considered a soft mast species for analysis.

We instructed surveyors to visit the same areas each year in August and conduct one survey at a high elevation site on or near the ridgeline and one at a low elevation site closer to the corresponding water drainage. Generally, >250 sites covering the entire bear range were surveyed each year. Surveyors recorded location, county, date, elevation, and aspect. Each surveyor described available fruit as abundant (above normal), common (normal), or scarce (below normal). A mast index was calculated for each species by adding the percent of surveyors reporting mast as abundant and one-half of the percent of the surveyors reporting mast as common. Scarce was given a value of zero (Uhlig and Wilson 1952). Index values for each species ranged between 0–100 each year.

Table 1. Correlation (*r*) between black bear non-hunting residual mortalities and mast indices in West Virginia, 1980–2004.

Mast index	*r*
Oak	−0.7347
Oak + hickory	−0.7088
Hard mast	−0.6476
Hard mast + black cherry	−0.6356
Soft	−0.2804

We obtained black bear non-hunting mortality reports from Division of Natural Resources personnel and assumed a constant reporting rate because Division of Natural Resources personnel were required to report each mortality. Black bear non-hunting mortalities increased over the study. We used simple linear regression equations to correct for these changes over time, using (actual) year as the independent variable.

We computed pairwise associations between the black bear non-hunting residuals (difference between predicted versus actual mortalities) and combinations of hard and soft mast indices using the sample Pearson correlation coefficient *r* (SAS Institute 1987). Correlation coefficients indicated the relationship between non-hunting mortalities and various mast indices after correcting for changing non-hunting mortality trends.

We compared black bear non-hunting mortalities with 5 combinations of mast: oak, oak + hickory, all hard mast, all hard mast + black cherry, and soft mast. We selected these mast conditions based on predominant cover types for the state, availability, and species preference by black bears.

Because black bear non-hunting mortalities were pairwise correlated with all mast indices (Table 1), we constructed regression equations that can be used to predict (or explain) them. We used Akaike's Information Criterion (Akaike 1973) and the methodology of Burnham and Anderson (2002) to select appropriate models. We used the 5 previously described indices, a global model (all mast species individually), a null (year) model, a partial model with beech, hickory, white oak, black–red oak, chestnut oak, scarlet oak, and black cherry, and a mast model with every mast species averaged by year. Year was included in all models to account for

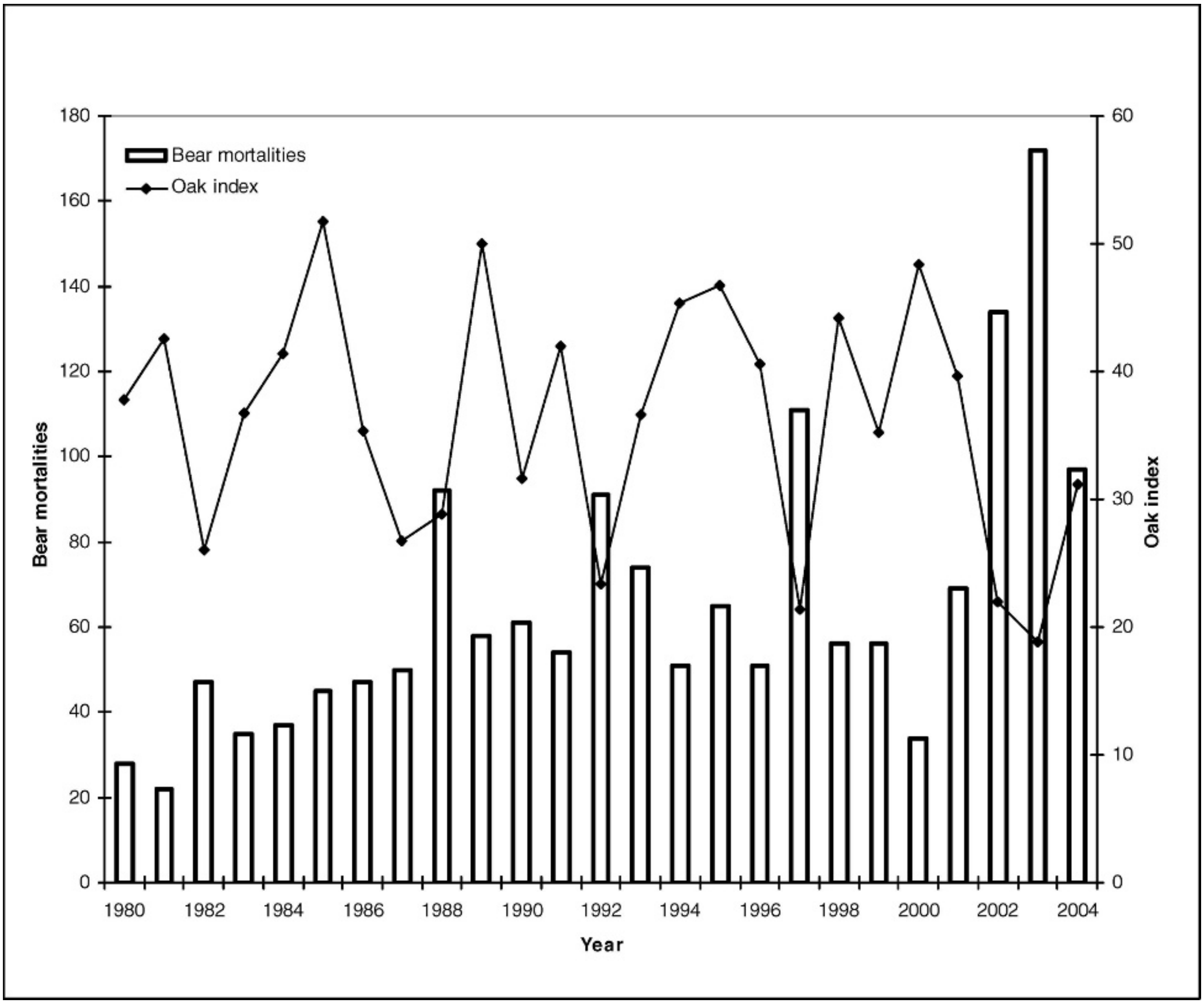

Fig. 1. Relationship between non-hunting black bear mortalities and oak mast index in West Virginia, 1980–2004.

changes in mortalities over time. We used AIC_c to correct for small sample size bias. The best approximating model was selected based on minimum AIC_c, ΔAIC_c, and Akaike weights (w_i) (Burnham and Anderson 2002). We considered models within 2 ΔAIC_c units of the best model as substantial models for explaining harvest. In addition, we considered models within 7 ΔAIC_c in our discussion.

Results

Mast conditions fluctuated by year with bumper crops produced in 1983, 1984, 1989, and 1998. Complete mast failures occurred at approximately 5-year intervals with the most extreme failures in 1982, 1992, 1997, 2002, and 2003. Non-hunting mortalities ranged from 22 to 172 (Fig. 1). Non-hunting residuals were negatively associated with mast indices (Fig. 2). Roadkills accounted for 44% of the 1,635 non-hunting mortalities during the study, followed by illegal kills (23%), damage complaints (22%), and other types of mortalities (13%).

There was a negative relationship between each hard mast index tested and black bear non-hunting mortalities (Table 1). Oak mast conditions had the highest negative correlation with black bear non-hunting mortalities ($r = -0.7347$). We found moderate levels of model uncertainty in the model selection process (Tables 2 and 3). Oak had the highest r^2 (0.7408) and Akaike weight (w_i; 0.737);

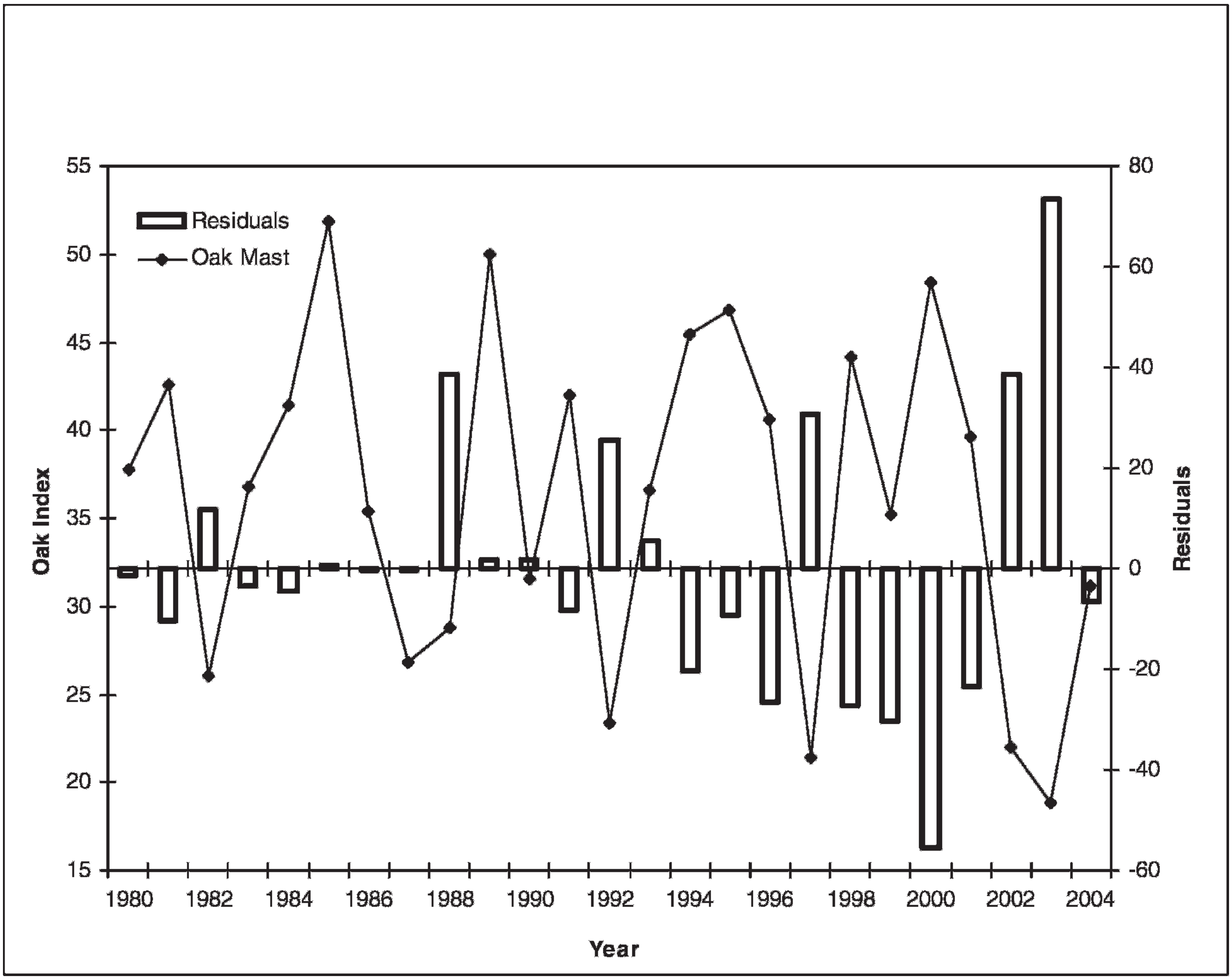

Fig. 2. Relationship between non-hunting black bear mortality residuals and oak index in West Virginia, 1980–2004.

however, oak + hickory was a highly competing model (Tables 2 and 3). Two other models had r^2 above 0.65 and ΔAICc ≤ 7 (Tables 2 and 3).

Discussion

Our results supported the hypothesis that abundant mast negatively influences non-hunting black bear mortalities in West Virginia. Soft and hard mast correlations supported the findings of previous studies that both are important food sources to black bears throughout the year, but oak mast (i.e., acorns) may have the largest influence (Pelton 1989, Costello and Sage 1994, McCarthy and Seavoy 1994). Oaks are the most important woody plant species in relation to the 6 major game species in the

Table 2. Models (ranked in order of support) relating influence of mast indices to black bear non-hunting mortalities in West Virginia, 1980–2004, where *K* = number of parameters, AIC_c = AIC corrected for small sample, $\Delta AIC_c = AIC_c – AIC_c$ minimum.

Model structure	*K*	AIC_c	ΔAIC_c	Akaike weight
Oak	4	152.29	0.00	0.737
Oak + hickory	4	154.80	2.51	0.210
Hard mast	4	158.70	6.41	0.030
Hard mast + black cherry	4	159.36	7.06	0.022
Mast	4	165.02	12.73	0.001
Null	2	167.45	15.16	0.000
Soft	4	170.78	18.49	0.000
Partial	10	186.45	34.16	0.000
Global	19	368.42	216.13	0.000

Table 3. Predictive regression equations using year and mast indices for non-hunting black bear mortalities (Y) with a $\Delta AIC_c \leq 7$ in West Virginia, 1980–2004.

Regression equation	r^2
Y = −4749.41 + 2.4559 (year) − 2.1377 (oak index)	0.7408
Y = −5002.33 + 2.5845 (year) − 2.1235 (oak + hickory index)	0.7134
Y = −4973.23 + 2.5652 (year) − 1.8566 (hard mast index)	0.6651
Y = −4949.44 + 2.5589 (year) − 2.0929 (hard mast + black cherry index)	0.6561

Southern Appalachian Region (Huntley 1989) and are the driving force behind black bear population dynamics and movements (Pelton 1989, Vaughan 2002).

Road kills were the most common type of mortality in this study. Long-range movements associated with oak mast failure (Pelton 1989) may make bears more likely to cross roads. In addition, black bears are more likely to be attracted to human–related food sources and create nuisance situations during mast failures (Rogers 1976, McDonald et al. 1994). In West Virginia, there was an increase in the number of nuisance complaints during mast failures and an increase in the number of bears destroyed on damage complaints. The highest numbers of reported non-hunting mortalities occurred during years of near-complete oak mast failure and the lowest numbers during bumper oak mast years (Fig. 1).

Acorns are the primary fall food source of black bears in the Appalachians (Pelton 1989, Vaughan 2002), but Clark et al. (1987) noted that acorn and hickory nut consumption were both positively correlated with mast abundance in Arkansas. West Virginia is ≥75% forested, with oak–hickory habitat being the most dominant. Our data showed that although oaks were the dominant food source affecting non-hunting mortality of black bears, hickory must also be considered a primary food source and therefore an important factor in predicting non-hunting mortalities. This may be an important factor to consider when there is a mast failure of one species but an abundant crop of the other.

Summer and early fall habitat use may be related to soft mast conditions and black bears may delay seasonal home range shifts during years of soft mast abundance (Garshelis and Pelton 1981). In the Shenandoah National Park, Virginia, USA, black bears increased their use of soft mast in areas of gypsy moth (*Lymantria dispar*) defoliation (Kasbohm 1994); however, survival rates were not lower than before defoliation (Schrage and Vaughan 1998). Although West Virginia is a heavily forested state, soft mast showed a negative relationship with non-hunting mortalities but was not as important a factor as hard mast. In habitats where soft mast comprises a larger portion of a bear's diet than in West Virginia, the relationship between soft mast and non-hunting mortalities may be important for managers to consider.

It was legal to use bait to hunt white-tailed deer (*Odocoileus virginianus*), but not black bears, in West Virginia and hunting seasons for these species largely coincided during our study (West Virginia Division of Natural Resources 2006). Black bear bow harvests increased over the study, with the most noticeable peaks during years of hard mast failure (Ryan et al. 2004). Because bait (e.g., corn, apples, horse feed) attracted both species, it could have presented hunters illegal opportunities to take black bears. Baiting for white-tailed deer has become more prevalent in West Virginia (Ryan et al. 2006), and possible illegal harvest of black bears should be considered by managers when recommending hunting seasons, especially during hard mast failures.

The majority of non-hunting mortalities occurred between 15 August and 31 December, and this pattern was most pronounced during mast failures. Monthly data of non-hunting mortalities throughout the year were not available for the entire study period, but were available for 2003 and 2004 (Fig. 3a and 3b). Despite the small sample of years, we feel confident that the patterns shown in Fig. 3 are general and reflect dynamics in years for which data were unavailable. Further, both spring 2003 and spring 2004 followed poor fall mast crops that produced little over-wintered oak mast for bears following den emergence. Thus, we were not surprised to see a minor spike in non-hunting mortalities during spring in these years.

Mast surveys have been used in West Virginia to forecast game harvests for 30 years. Our results support the long-assumed statewide relationship between mast conditions and non-hunting black bear mortalities; regional predictions may be made where data are available (Rieffenberger et al. 2000). The mast survey methodology used in West Virginia is simple to conduct and analyze and would be easily

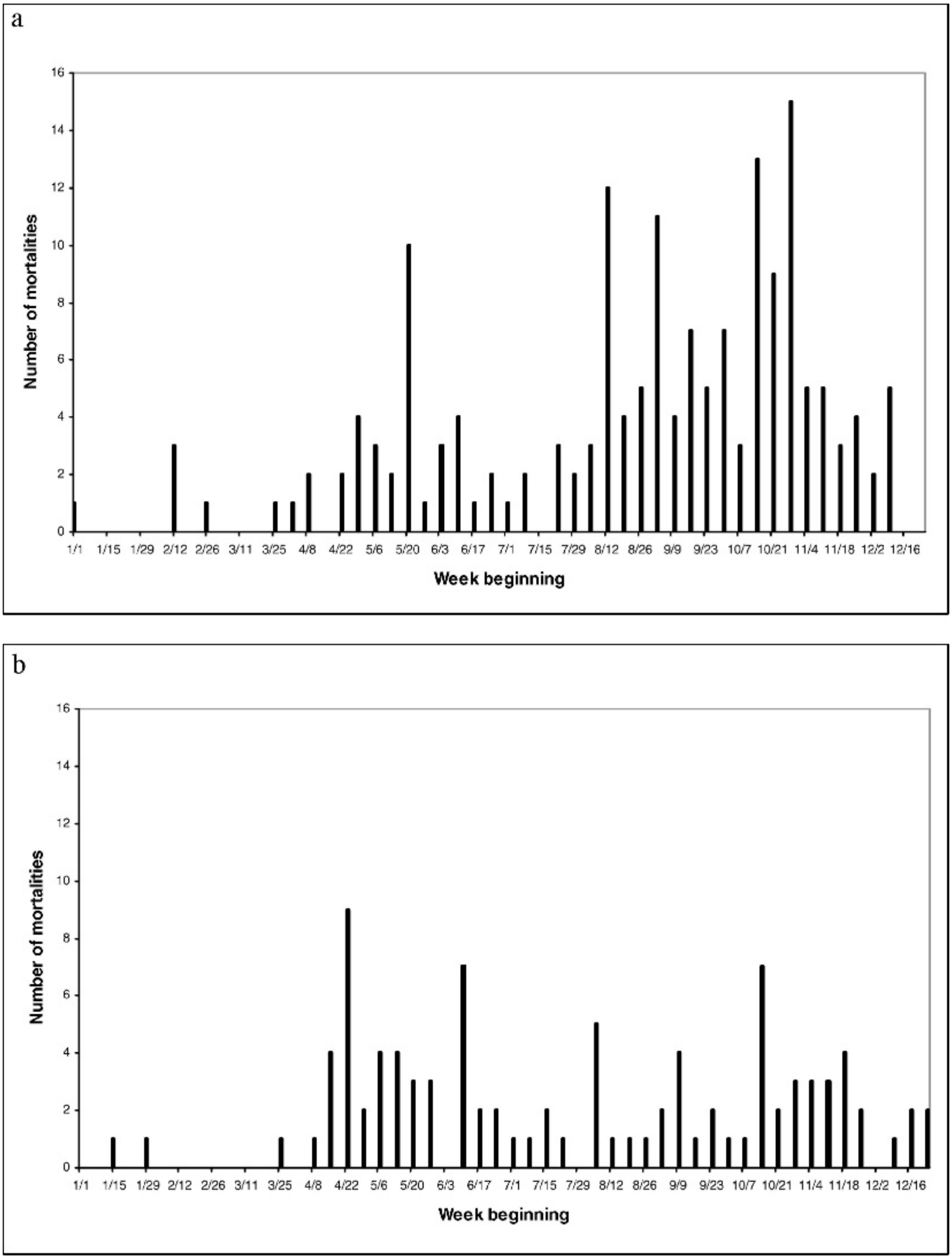

Fig. 3. Number of non-hunting black bear mortalities by week for 2003 (a) and 2004 (b) in West Virginia.

initiated by agencies wanting to monitor mast. Although our mast survey was qualitative, it was useful in demonstrating relationships between mast conditions and black bear non-hunting mortalities; it may further be improved with techniques outlined by Fearer et al. (2002).

Many agencies, especially those lacking demographic data, use non-hunting mortalities as a population trend index. However, we caution that large fluctuations in the number of mortalities may be caused by factors other than population size. Managers who use non-hunting mortalities as an index to open, close, or adjust hunting seasons should consider mast availability before making management decisions.

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