Characteristics of Black Bear Mortality on the Coastal Plain of North Carolina

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Abstract: Black bear (*Ursus americanus*) mortality data were collected in eastern North Carolina from 1976 to 1992. These data included registered harvest totals from mandatory hunter-harvest records, field reports, and tooth samples from bears dying of all causes (N = 1,107 for harvest; N = 350 for vehicle-kill). Increasing trends in harvest corresponded to establishment of seasons in 11 counties beginning in 1986. Vehicle-kills increased until 1990 but declined during 1991–92. Combined age structures did not differ significantly from the 1976–1985 period (before new seasons established) to the 1986–91 period (after new seasons established). Harvest age structures differed significantly from age structures of vehicle-kill. Bears <4 years old composed 56.2% of the harvest and 70.0% of vehicle-kills during the entire study period. Subadult males (1- and 2-year old classes) composed the largest portion of both harvest (28.8%) and vehicle-kill (32.3%). Harvest age structures did not change significantly between time periods whereas the vehicle-kill age structure did. A shift to younger age classes in vehicle-kills may be related to increased productivity. The age structures of males differed significantly from the age structures of females for both harvest and vehicle-kills. Percent males in the harvest (59.7%) and vehicle-kill (64.2%) differed significantly from parity whereas depredation (65.4%) and illegal kill (54.8%) sex ratios did not. Peak vehicle-kills occurred from June to December. Efforts should be focused on reducing vehicle-kills during the fall because this is the period when the highest average number of females are killed.

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The greatest source of mortality on most bear populations is human-induced (Bunnell and Tait 1985). Most studies conducted on black bear in the Coastal Plain of the southeastern United States have dealt with basic ecology (Harlow 1961, Hardy 1974, Hamilton 1978, Abler 1985, Smith 1985, Hellgren 1988, Lombardo

1993). Very little has been published regarding harvest or vehicle mortality of Coastal Plain black bears (Collins 1974, Wooding and Brady 1987). It is important that characteristics of both harvest and vehicle mortality be documented to help managers understand the effects of different mortality factors on bear populations. Documentation of mortality characteristics is needed for subsequent, more detailed analyses of bear population dynamics and as input for population models. Because North Carolina contains the largest block of occupied black bear range on the Costal Plain of the southeastern United States (J.B. Wooding, pers. commun., Fla. Game and Freshwater Fish Comm.), information about North Carolina's Coastal Plain bear population could be useful to managers of bear populations in that physiographic region. This paper documents mortality trends and sex and age characteristics of harvest and vehicle mortality for a black bear population occupying the Coastal Plain of North Carolina.

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Methods

Although registration of big game harvest has been mandatory in North Carolina since 1976, NCWRC personnel were able to document more bears being harvested than were registered during 1976 to 1983. Therefore, total harvest was determined using field records of known harvest maintained by NCWRC personnel during those 8 years. Records of registered hunter kills were used to calculate harvest for all other years. Numbers of vehicle, depredation, and illegal kills were determined using mortality reports completed by NCWRC personnel for all years. First upper premolar tooth samples from all bears were collected by NCWRC personnel or bear hunters and were sent to a commercial lab (Matson's Lab, Mont.) for aging based on deposition of cementum annuli (Willey 1974).

Sex and age data were divided into 2 periods for analysis: 1976–85 (period 1) and 1986–91 (period 2). These periods were selected based on the history of seasons. Of the 23 counties that have seasons currently, 12 have had bear seasons since 1976, whereas seasons were established in the other 11 counties between 1986–1991. The counties where seasons were open since 1976 will be referred to as counties with established seasons and those counties where seasons were opened between 1986–91 will be noted as counties with new seasons. Six age classes were used for age structure analysis; cubs (<1 year old), yearlings (1 year old), 2 year olds, 3 year olds , 4 year olds, and adults (≥5 years old). These age classes were sufficient to illustrate where major changes in age structures occurred and to ensure that reliable statistical tests could be conducted with adequate frequencies in each cell (>5).

Age data were not complete for 1992; however, reported harvest and vehicle-kill data were available. The 1992 reported mortality data were included to examine possible relationships between harvest and vehicle-kill.

The *Z*-test for comparing binomial proportions was used to determine whether composite sex ratios differed from parity and whether sex ratios differed significantly ($P < 0.05$) by cause of death or between periods (Mendenhall and Ott 1980). Significant differences ($P < 0.05$) in age class distributions between periods and sexes and for different causes of death were detected using a 2-way contingency table and Pearson Chi-square test (Wilkinson 1990).

Results

Mortality Totals

Total reported or documented mortality from 1976–91 was 4,210. Of this total, harvest comprised 84.0% (3,538), vehicle-kill was 11.9% (503), illegal-kill was 2.7% (112), and depredation-kill was 1.4% (57).

Trends

The overall trend in bear harvest has been increasing since 1976 in counties with both established and new seasons (Table 1). After an increase in 1984, harvest was stable in counties with established seasons. The increase in harvest since 1986 corresponded to the gradual opening of seasons in 11 counties. A large increase was documented in 1990, and harvest was stable from 1990 to 1992.

There has been an increasing trend in vehicle-kills from 1976 to 1990, with yearly totals ranging from 7 in 1976 to 81 in 1990 (Table 1). Bears killed by vehicles dropped to 41 in 1991 and to 45 in 1992. Prior to 1987, vehicle-kills composed an average of 16.7% of total documented mortality. From 1987 to 1992 vehicle-kills averaged 11.7% of total mortality. From 1976 to 1985, in counties with established seasons, vehicle-kills ranged from 3% to 21% of total mortality, and have ranged from only 3% to 11% of total mortality since 1986. In those counties with new seasons, vehicle-kills ranged from 7% to 30% of total mortality from 1986 to 1992. Percentage of vehicle-kills in total mortality was 9.0% and 8.1% in 1991 and 1992, respectively. Trends in depredation and illegal kills were not examined because of small sample sizes.

Sex Ratios

The sex ratio in the harvest from 1976 to 1992 (59.3%; 1,686/2,844) and in the vehicle-kill (64.5%; 254/394) was skewed toward males (both $P < 0.01$). The vehicle-kill sex ratio was skewed more toward males than was the harvest sex ratio during years over the entire study period as well as specifically during years over period 2 (both $P < 0.05$). There were no differences between % males in either the harvest or vehicle kill from period 1 to period 2 ($P > 0.05$). The % males killed

Table 1. The number of black bears and % males harvested and killed by vehicles in the Coastal Plain of North Carolina, 1976–92.

Year	Harvest	% Males in harvest	Vehicle-kill	% Males (*N*)[a] in vehicle-kill
Period 1				
1976	124	57.4	7	57.1 (7)
1977	105	51.9	12	66.7 (6)
1978	88	73.9	20	66.7 (8)
1979	131	55.2	13	55.6 (9)
1980	153	59.2	23	47.1 (17)
1981	109	64.3	11	33.3 (9)
1982	93	47.7	27	44.4 (18)
1983	99	65.1	31	75.0 (28)
1984	201	65.5	36	48.2 (27)
1985	137	55.9	40	78.4 (37)
Period 2				
1986 (1)[b]	166 (48)[c]	67.7	35	62.5 (32)
1987 (3)[b]	245 (113)[c]	67.3	23	66.7 (18)
1988 (4)[b]	293 (130)[c]	57.0	43	73.8 (42)
1989 (1)[b]	270 (131)[c]	53.3	62	50.0 (42)
1990 (0)[b]	447 (267)[c]	58.2	81	73.2 (56)
1991 (2)[b]	424 (249)[c]	55.8	41	80.8 (26)
1992 (0)[b]	453 (276)[c]	59.2	45	63.4 (41)

[a] Sample size used to calculate sex ratio; not all documented vehicle-kills were sexed.

[b] Number in parenthesis designates number of counties with newly established seasons.

[c] Number of bears harvested in counties with seasons established since 1986.

while depredating (65.4%; 17/26) and killed illegally (54.8%; 17/31) did not differ from a 1:1 sex ratio (both $P > 0.05$).

Vehicle-kills occurred in all months when totaled for all years from 1976 to 1992 (Fig. 1). The majority of vehicle-kills occurred from June to December. Percent males killed during the summer (June–August) period (76.2%) differed from parity ($P < 0.01$) but did not differ during the fall (September–November) period (52.5%). The % males killed by vehicles in the summer differed from the % males killed in the fall ($P < 0.01$).

Age Structure Characteristics

Ages were determined for 1,017 harvested bears and for 350 vehicle-killed bears from 1976 to 1991. Due to small sample sizes, age structure characteristics of depredation and illegal kills were not examined. The combined age structures for both sexes and both causes of death did not differ from period 1 to period 2 ($P = 0.99$). Age class structure for all mortality was 5.2% cubs, 20.5% yearlings, 21.4% 2-year-olds, 17.8% 3-year-olds, 8.9% 4-year-olds, and 31.3% adults. Combined harvest age structures did not differ between periods ($P = 0.51$). However,

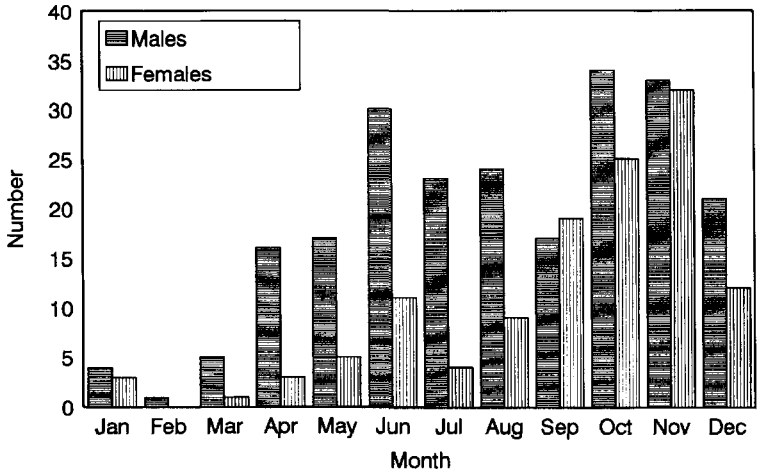

Figure 1. Cumulative number of black bears killed by vehicles by month in the Coastal Plain of North Carolina, 1976–1991.

age structures of vehicle-kills did differ significantly ($P < 0.01$) (Tables 2, 3): yearlings and 2-year-olds composed 38.2% of vehicle-kills during period 1 compared to 51.8% during period 2 (Tables 2, 3) and adults in the combined vehicle-kill age structure decreased from 32.5% in period 1 to 14.36% in period 2.

The harvest age structure for both sexes combined differed significantly from the combined vehicle-kill age structure for 1976 to 1991 ($P < 0.001$). Cubs constituted 13.1% of vehicle-kills compared to only 2.5% of harvest. Adults were represented more in the harvest age structure (34.3%) than in the vehicle-kill age structure (22.4%). Significant differences between harvest and vehicle-kill age

Table 2. Sex and age structures of harvest and vehicle mortality of Coastal Plain North Carolina black bears, 1976 to 1985.

Age class	Male %	Female %	N	Male %	Female %	N
	Harvest			Vehicle kill		
cubs[a]	2.0	1.0	12	8.3	3.2	18
yearlings[b]	14.5	6.1	81	14.0	5.7	31
2 years old	15.3	6.9	87	12.7	5.7	29
3 years old	9.2	4.6	54	9.6	3.2	20
4 years old	5.9	3.8	38	1.9	3.2	8
Adults[c]	18.1	12.7	121	14.7	17.8	51
Totals	65.0	35.1	393	61.2	38.8	157

[a] <1 year old.
[b] 1 year old.
[c] ≥ 5 years old.

Table 3. Sex and age structures of harvest and vehicle mortality of Coastal Plain North Carolina black bears, 1986 to 1991.

Age class	Male %	Female %	*N*	Male %	Female %	*N*
	Harvest			Vehicle Kill		
Cubs[a]	1.9	0.1	13	9.2	5.1	28
Yearlings[b]	13.8	4.5	114	18.5	9.2	54
2 years old	14.3	6.6	130	18.5	5.6	47
3 years old	7.9	5.0	80	8.7	2.1	21
4 years old	5.1	4.3	59	5.6	3.1	17
Adults[c]	22.0	14.6	228	7.2	7.2	28
Totals	65.0	35.1	624	67.7	32.3	195

[a] <1 year old.
[b] 1 year old.
[c] ≥5 years old

structures occurred for both period 1 and period 2 when examined separately (both $P < 0.01$). For period 2, a noticeable difference between the % yearlings and 2-year-olds in the harvest (39.1%) and the vehicle-kill (51.8%) was evident (Table 3). This difference was not detected for period 1 (Table 2).

The male age structure for harvest and vehicle-kill combined for 1976 to 1991 differed significantly from the combined female age structure ($P < 0.001$). Males in the yearling and 2-year-old age classes constituted 29.7% of total mortality whereas only 12.2% were females. For 1976 to 1991 male age structures differed significantly from female age structures when harvest and vehicle-kill were examined separately ($P < 0.01$ both cases). Again, the % yearlings and 2-year-olds was greater in the male age structure than in the female age structure. The male harvest age structure was different than the female age structure for period 2 only, and the vehicle-kill age structure differed between sexes only in period 1 ($P < 0.01$ both cases). The male age structure of harvest was significantly different than the male vehicle-kill age structure for both periods combined and separated ($P < 0.001$). Also, the female harvest age structure was significantly different from the female vehicle-kill age structure for both periods combined and for period 2 ($P < 0.001$). All differences involved less cubs and more adults in the harvest than in vehicle kills. Percent female cubs and yearlings in the vehicle-kill (33.9%) was greater than in the harvest (16.1%).

Discussion

Harvest and vehicle mortality accounted for the majority of documented black bear mortality on the Coastal Plain of North Carolina from 1976 to 1992. Further, these 2 mortality factors were skewed significantly toward males (Table 1) and had the greatest impact on subadult males (Tables 2,3). This vulnerability has been documented in other bear populations on the Coastal Plain and is related to larger

home ranges and breeding and dispersal behaviors of males (Hamilton 1978, Hellgren and Vaughan 1989*a*). From a management perspective, mortality pressure that favors males is desirable because it allows females to reach reproductive age (Hamilton 1978, Kolenosky 1990) and increases female survival rates relative to males (Hellgren and Maehr, in press). The significant differences between male and female age structures for both harvest and vehicle-kills suggest that younger females receive less mortality pressure. Overall, yearling and 2-year-old males accounted for 29.7% of total mortality compared to 12.7% for females in these age classes. Collins (1974) found that 80% of the female reproductive tracts of harvested 3 year olds in North Carolina had corpora lutea. Warburton (1992) found corpora lutea in 80% of 2-year-old female reproductive tracts and in 60% of 3-year-old tracts. Therefore, reduced pressure on early female age classes, such as we found in North Carolina, can result in increased production. This may in part explain why North Carolina's Coastal Plain bear harvest has increased over the last decade.

The age structures of harvest and vehicle-kill differed significantly for the combined sexes and for each sex when examined separately. Cubs and subadult age classes were represented more in vehicle-kills than in the harvest. In all comparisons except for period 1, adults were more represented in the harvest than in the vehicle-kill. There are several possible explanations for these differences. In North Carolina, regulations prohibit the taking of cubs. In addition, many hunters may select for larger bears. Age structures of vehicle-kills could be biased because smaller bears are more likely to be recovered than larger bears who could travel some distance from the road before dying. However, if larger bears are more likely to survive after collisions with vehicles this bias may not be present.

Harvest age structures have not changed significantly from period 1 to period 2 for both sexes combined or separated ($P > 0.05$ in all cases). It seems that the addition of seasons in 11 counties did not appreciably change the age composition of harvest mortality. This stability in age structure composition could be due to selectivity of hunters or avoidance behavior being learned by bears. Alternately, the previously unhunted population may not have harvested for a sufficient time period to show changes in age structures. Further testing of these hypotheses are needed when more data are collected in the counties with new seasons and then compared to data from counties with established seasons.

Age structures of bears killed by vehicles did change significantly ($P < 0.05$) from period 1 to period 2 with a shift to younger age classes. Collins (1974) felt that lower average age could reflect a higher reproductive rate. If production of young increased in North Carolina, this may be more likely to show up in data reflecting vehicle-kills where selectivity is less likely to occur. Alternatively, some shifts in the % adults during period 2 suggest that new seasons may have removed some of the adults that otherwise may have been killed by vehicles. Regardless, these data do document the vulnerability of younger bears to vehicle mortality from 1986 to 1991. An effort to reduce this mortality would be valuable, especially in areas with low bear numbers.

Harvest and vehicle-kills were skewed significantly toward males (Table 1). Males are expected to predominate because of dispersal and breeding behavior (Hamilton 1978, Hellgren and Vaughan 1990) and because it is illegal to kill females with cubs. Females may also receive a disproportionate amount of protection because they have smaller home ranges and tend to travel less distance than males, behavior that may tend to cause them to remain within the 12 areas, totaling 101,819 ha designated as bear sanctuaries by the NCWRC in eastern North Carolina (Warburton 1994). In addition, large national wildlife refuges, certain private timber lands, and other public lands also serve as bear sanctuaries. The resultant increase of females may be responsible to some extent for increases in the Coastal Plain bear harvest over the last decade. How these females eventually die remains speculative. It is difficult to document natural mortality via field reports. However, telemetry studies have not documented natural mortality either (Hamilton 1978, Hellgren and Vaughan 1989*a*). Sex ratios of documented illegal kills and depredation kills did not differ from parity. Hellgren and Vaughan (1989*a*) found that suspected illegal kills (3M, 1F) and depredation kills (2M, 0F) favored males in the area around the Great Dismal Swamp National Wildlife Refuge. Finally, if the sex ratio at birth were skewed toward males, then the skewed sex ratios of mortality might be explained. However, there are no data from the Coastal Plain on birth sex ratios. Better estimations of the sex and age characteristics and the magnitude of illegal and depredation kills would be useful.

Despite theoretical problems, sex ratio may indicate exploitation rate in some cases (Miller 1990, Clark 1991). Clark (1991) found that a population with a higher % males in the harvest was more productive than a population with a lower % males in the harvest. The overall harvest of 59.7% males and the stable trend in % males harvested in North Carolina (Table 1) do not seem to indicate an over-exploited situation. Since 1987, the harvest sex ratio has averaged slightly lower than this due to lower % males harvested in some of the counties with new seasons. It is too early to examine this characteristic in these counties, but it should be monitored closely over the next several years.

Our study shows males were more susceptible than females to vehicle-kill, and this difference peaked during the summer (June–August). Increased movements associated with breeding and dispersal behaviors make males more susceptible to vehicle-kill than females (Hamilton 1978, Hellgren and Vaughan 1990). During the fall (September–November) period, however, both sexes were represented equally. The explanation for this most likely involves food sources. Bears of both sexes seek high energy foods during fall months in preparation for denning (Rogers 1987). From July to September, many bears feed on corn (R. C. Maddrey, unpubl. prog. rep.) and may increase movements in response to the harvest of corn in September. Hellgren and Vaughan (1990) noted that female bears made extensive shifts in ranges during late summer to early fall in order to consume natural fall foods. Alt et al. (1980) indicated that female movements exceeded male movements during September and October. Wooding and Brady (1987) also showed a predominance of females in vehicle-kills during September

and October. The fall peak in road kills is therefore an important time in which to focus efforts to mitigate this source of mortality. Finally, the decrease in % females killed in December can be attributed to females denning before males (Hellgren and Vaughan 1989*b*).

Management Implications

The interpretation of indicators such as harvest trends, age structures, and sex ratios can be somewhat ambiguous (Garshelis 1990, Miller 1990). However, it is encouraging that all the indicators presented in this paper point to a stable to increasing population. This conclusion is supported by other evidence such as expansion of bear range in the Coastal Plain of North Carolina (G.S. Warburton, unpubl. data). Further examination of reproductive characteristics, survival and removal rates of different sex and age classes, and attributes of harvest such as hunter effort should be made to assess the impacts of these mortality factors. In addition, development of an indicator of coastal bear population trends would be useful in interpretation of these data. Monitoring of bear mortality should continue especially in areas with new seasons.

From 1986 to 1990, as seasons were established in 9 counties, harvest and vehicle-kills increased (Table 1). Harvest stabilized in these counties from 1990 to 1992 but vehicle-kills dropped substantially. The % of total mortality due to vehicle-kills also dropped to between 8%-9% during 1991 to 1992 from a high of 30% in previous years. Nichols et al. (1984) suggest that under a completely compensatory mortality hypothesis, when harvest rate is increased, non-harvest mortality should decrease. If vehicle-kills stabilize at the lower levels seen in 1991 and 1992, then perhaps a compensatory hypothesis is supported. Conclusions about the compensatory hypothesis can be made by utilizing the approach outlined in Carpenter and White (1990). This approach would provide useful insight into the mechanisms of mortality in Coastal Plain bear populations.

Measures to protect females and the younger age classes from vehicle collisions could be important in smaller populations. As habitat is fragmented through development and key mast areas are lost (Monschein 1981), bear movements associated with agricultural crops are likely to increase. Expanding human populations and associated road construction, together with increased bear numbers and activity could increase vehicle-kills further. High road densities and fragmented habitat can be associated with low recruitment and high mortality rates (Hellgren and Maehr 1993). The identification of key corridors and crossings is essential in reducing this mortality (Wooding and Brady 1987). As documented in our study, the most important time to reduce vehicle-kills is during the fall. Identification of key habitat variables associated with sections of roads where high numbers of bears are killed by vehicles during this time would be valuable. This type of information would allow biologists to identify key crossings and make better recommendations regarding their protection. Finally, efforts in monitoring vehicle-kills should continue. This information is essential in quantifying non-hunting mortality and providing supplemental data on changes in population levels.

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