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Effects of Mast and Berry Crop Failures on Survival, Growth, and Reproductive Success of Black Bears

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Knowledge of factors that limit black bear (*Ursus americanus*) populations is essential for proper management of that species and its habitat, but there have been few attempts to identify the key factors limiting black bear numbers. The black bear has few natural enemies, and its omnivorous food habits are commonly (but erroneously) believed to ensure an adequate food supply of some sort each year regardless of the failures of a few preferred foods. So by process of elimination, it often has been deduced that black bear numbers must be self-limited by social factors. However, recent studies in Minnesota (Rogers 1976) have shown that the social system of black bears varies with the distribution and abundance of food and probably serves to increase foraging efficiency, which leads to increased survival and enhanced reproductive success. Hence, instead of limiting populations below densities that can be supported by long term food supplies, social order may permit higher densities than otherwise might be possible. No evidence was found that social factors retarded growth and maturation other than through interference with feeding activities. Such interference appeared to be minimized by the observed social order.

Salient points of the social system as described by Rogers (1976) are the following: (1) Adult females are territorial but usually accommodate their offspring within the maternal territory for at least the years when the offspring are small and would have difficulty maintaining exclusive feeding areas elsewhere. (2) Adult males each establish a perennial mating range within which are territories of several mature females. (3) Transient young males often are prevented from settling in the ranges of established males where the transients would compete for food with the offspring and pregnant mates of the established males. Hence, the aggressive nature of adult males probably serves to increase rather than decrease the survival of their offspring. (4) The usual well-dispersed distribution of foods dictates solitary foraging, but where food is clumped, as in garbage dumps, aggregations occur; and social order adjusts accordingly.

Existing reports do not support the popular notion that black bears are able to secure an adequate diet each year. Unpublished records of the Wisconsin Department of Natural Resources for 1954-1969 clearly show that failures of berry and mast crops, especially blueberries (*Vaccinium* spp.) and members of the red oak (*Quercus* spp.) group, correlate with marked increases in bear damage to farm crops, beehives, and livestock. The number of bears killed for such activities exceeded 100 only in years in which blueberry and/or acorn production fell below 20-25 percent of a full crop. Schorger (1946) reported an unusual influx of black bears into the vicinity of Duluth, Minnesota, during a shortage of wild fruits. Hatler (1967) reported that during a year of widespread failure of the blueberry crop in Alaska there were numerous emaciated black bears, increased use of garbage dumps, and several attacks on man. Rausch (1961) found that well fed captive black bears in Alaska developed more rapidly than wild ones Jonkel and Cowan (1971) reported that in Montana reproduction in black bears approached zero when huckleberries (*Vaccinium* spp.) were scarce for three successive years.

The list of foods to which black bears can turn during shortages of preferred foods is not as long as generally is thought. The black bear lacks a cecum and has a simple stomach that is too acid to support the microflora and microfauna needed for digestion of cellulose. So the black bear's ability to digest vegetation is limited, and it must rely on a few of the more digestible herbs and on the parts of plants in which nutrients are concentrated as in berries, nuts, buds, catkins, tubers, and meristem. When forced by food shortages to feed on grass, the black bear loses weight or only slowly gains weight (Jonkel and Cowan 1971, personal observations). Its ability to secure some of its foods is enhanced by its adeptness as a tree-climber. But in evolving the short, sharply recurved claws that enable it to climb so well, it gave up some of its facility for digging; consequently, it seldom digs out burrowing rodents as does the grizzly. However, it does spend a great deal of time securing other forms of animal food such as colonial insects, carrion, and in some areas, fish. A free-ranging black bear in Minnesota spent more than three quarters of her foraging time in midsummer investigating sources of ants (Rogers 1976).

Assessment of the foods of the black bear makes it apparent that most are available only briefly or are too small and scattered to be gathered rapidly. The few foods that potentially are abundant, long-lasting, and easily secured are dependent upon the annual vagaries of temperature and precipitation with the result that over much of the range of the black bear there tends to be a surfeit of food in some years and, as will be shown, absolute or relative shortages (as defined by Andrewartha and Birch 1954) in others. This paper describes effects of shortages of mast (mainly *Corylus cornuta*) and berries (mainly *Vaccinium* spp., *Prunus* spp., *Cornus* spp. and *Rubus* spp.) on the survival, growth, maturation, and reproductive success of black bears as determined during a 7 year study in the aspen-birch-conifer forests of northeastern Minnesota. Development of wild vs. well fed captive black bears also are compared.

Methods

Methods were described by Rogers (1976). In brief, 272 black bears were ear-tagged, and 105 were radio-tagged during the seven years of study. Instrumented bears were radio-tracked to dens where they were weighed in autumn and spring. At the same times, growth and survival of litters of instrumented females were recorded.

Data on food habits were obtained from analyses of 1,120 fecal droppings and from observations of foraging bears. The abundance of each bear food was assessed during the radio-tracking of instrumented bears through all types of habitats. Abundance varied so greatly from one year to the next that ocular estimates were more than adequate for determining relative abundances. For this paper, food supplies are categorized as scarce, fairly abundant, or exceptionally abundant. During 1973-1975, 42 permanent transects were established in various habitats for more precise quantification of food abundance. Those data corroborate the ocular estimates for those years and will be presented in a future paper (Elwell, Arimond, and Rogers, in preparation).

Data on captive bears were obtained from records for 11 that were born in northern Minnesota and taken from the wild at 3-8 weeks of age.

Results and Discussion

Weights and measurements of captive vs. wild black bears showed that captive wild black bears that received rich diets developed more rapidly than wild ones even when the captives were caged with larger bears that dominated them. Captive bears of either sex commonly matured at 2.5 years of age, with females producing their first cubs at 3 years of age. By contrast, five wild females that had ready access to garbage did not produce cubs until 4 or 5 years of age (average 4.4 years), and nine that had little or no access to garbage produced first litters even later at 4 to 7 years of age (average 5.6 years). In other words, the better nourished bears developed more rapidly even though they experienced more contact with other bears, suggesting that any effects of social factors on growth and maturation as might be mediated through the endocrine system (Christian 1950, Christian and Davis 1964) were minor relative to nutritional factors at the densities encountered in this study.

Whelping data for wild bears were obtained following 2 years of exceptionally abundant food, 2 years of moderately abundant food, and 3 years of scarce food. Of the nine females with little or no access to garbage, five produced their first litters after years of exceptionally abundant food; three produced first litters following years of moderately abundant food, and only one produced her first litter following a year of scarce food. Moreover, in years of scarce food, some multiparous females that normally would be expected to be pregnant (because they had not been accompanied by cubs during the mating season, and black bears tend to be alternate-year breeders) gained less weight than usual and failed to reproduce. Such failure was especially common in virgin forests on the Laurentian Shield where food was particularly scarce. In summation, only 33 percent (14/43) of the females 5 years of age or older were accompanied by cubs following years of scarce food; whereas 44 percent (17/39) were with cubs following years of moderately abundant food, and 59 percent (23/39) were with cubs following years of exceptionally abundant food.

Females that did not gain sufficient weight prior to denning usually failed to produce cubs. Females 3.5 years of age or older that weighed less than 148 pounds (67 kg) on 1 October (N=16) produced no cubs, but those weighing more than 176 pounds (80 kg) on that date produced cubs in 28 of 30 cases in which the females had been without cubs the previous mating season. The two exceptional cases involved (1) a female with a broken leg and (2) a female that probably did not conceive (Rogers 1976). Females weighing between 148 and 176 pounds (N=8) had variable reproductive success. As examples, a 148 pound (67 kg) female produced three cubs that grew more slowly than most and died at 2-4 months of age. A 150 pound (68 kg) female produced two cubs that also grew very slowly, but the natural fate of these cubs was not learned because their mother abandoned them when hikers disturbed the den in April. The same mother reached a weight of 154 pounds (70 kg) the following autumn and produced three cubs which survived at least through their first summer. A 167 pound (76 kg) female produced only a single cub. Females weighing 152, 156, 169, and 174 pounds failed to produce cubs even though they were observed with males during the mating season or were captured during that time and found to be in estrus.

Although ovulation and conception occur in June or early July when accumu lation of body stores has scarcely begun, implantation of blastocysts occurs in November or December after accumulation of body stores has been completed (Wimsatt 1963). This sequence of events together with the fact that females that were observed with males during the mating season usually failed to produce cubs if they did not gain sufficient weight lead one to speculate that bears may physiologically assess their supply of stored nutrients in the fall and prevent implantation in years when stores are too low to support both themselves and their young through the denning period. If such a protective mechanism were to exist in any mammal, it would be expected in bears because, of all mammals, they are the only ones in which the mother does not feed during a denning period of up to 7 months which includes the entire period of post-implantation development of the fetuses and approximately 3 months of the lactation period.

Nutritional stress upon females that raised cubs was evidenced by the fact that they often retired to their dens in fall weighing little more than when they had led their newborn cubs from the natal dens the previous spring. By the following spring, when the cubs (as yearlings) were nearly ready to begin travelling independently, mothers often weighed less than half as much as during the autumn preceding parturition. However, mothers that found rich food supplies did not undergo such drastic weight losses, and in some cases gained as much during years of lactation as they did in other years.

Food supply influences the development of bears more during the first year of life than at any other time. Growth during the 2.0 to 3.5 months of nursing in the natal den depends upon the milk supply which, in turn, depends upon the nutrients stored by the mother the year before. Predenning weights of pregnant females provided indications not only as to which females would produce cubs but also as to the weights of the litters at two months of age ($r^2 = 0.540$, $P<0.001$, $N=24$ females and 24 litters). Birth dates for light as well as heavy litters were pinpointed in the last week of January indicating that weight differences observed in dens in late March were due mainly to differential growth rather than to differences in ages of cubs.

Soon after cubs left their dens they began to supplement their diets with solid foods. They gained weight significantly ($P<0.0001$) more rapidly in years of abundant food than in years of scarcity. Predenning weights in years of abundant food averaged 48.6±1.9 pounds (22.1 ±0.86 kg, N=29) vs. an average weight of only 34.4±1.1 pounds (15.6±0.5 kg, N=39) in years of scarcity. At 6 months of age, well fed captive cubs weighed two to five times as much as wild ones.

More than 90 percent of the mortality among cubs and yearlings was from natural causes. Relatively few died from human-related causes that included cars, trains, electrical powerlines, gunshot, and disturbances of dens. Natural mortality among cubs and yearlings appeared to be nutrition-related because lightweight individuals suffered heavier mortality. Cubs that weighed less than 4 pounds (1.8 kg) in late March (N=15) experienced approximately four times greater mortality prior to family breakup (67 percent died) than did heavier cubs (N=47). Mortality was not as great among 22 yearlings, but the two (18 percent) of them that did die of natural causes weighed less than the median weight of 29.5 pounds (13.4 kg) in late March. Both were members of a cohort of six that not only was born in a year of poor food but that lived as yearlings in a second such year. It is unknown whether lightweight cubs and yearlings actually died of starvation or whether malnourishment predisposed them to die from other causes. The three carcasses that were found were almost entirely consumed by wolves (*Canis lupus*) or larger bears by the time they were found, and causes of death could not be determined from the fragments of bone that remained.

Mortality among cubs increased with litter size (Table 1). On the average, litters of three resulted in the maximum number of offspring per litter added to the population at weaning, and litters of three were strongly modal.

Table 1. Litter size and survival.

Number In litter	Litters	Cubs	Percent mortality Prior to weaning	Average number of cubs surviving per litter at family breakup
1	2	2	0.0	1.0
2	8	16	12.5	1.75
3	22	66	18.2	2.45
4	3	12	50.0	2.00
Combined	35	96	20.8	2.17

Examinations of litters in natal dens showed that brown phase females produced significantly ($P<0.01$) larger litters on the average than did black females. Five litters from brown females averaged 3.40±0.24 cubs (range 3 to 4 cubs), whereas 24 litters fromblack females averaged only 2.46±0.15 cubs (range 1 to 3 cubs). However, cubs of brown females (N=17 cubs) weighed only 3.5±0.22 pounds (1.6±0.10 kg) on the average at 2 months of age, which was significantly ($P<0.001$) lighter than the average for cubs of black females (4.8±0.13 pounds, 2.2 ±0.06 kg, N=54).Thus, cubs of brown females experienced higher mortality in years of poor food. By the time the cubs were independent, litters of brown females (N=8 litters) contained the same number of cubs on the average (2.25) as litters of black females (N=36 litters). Conclusions based on these data should be regarded as tentative, however, because data from brown phase females were obtained from only five mothers that could have been from as few as only one or two family lineages.

Outside the study area, four black females that lived around large garbage dumps were observed with litters of four in late summer, suggesting that females that feed at large garbage dumps produce larger litters on the average and/or that survival is higher among well fed cubs nursed by well fed mothers. Rogers et al. (1976) reported that litters observed at sources of garbage in the Upper Peninsula of Michigan were significantly ($P<0.01$) larger on the average (3.1 cubs per litter, N=7 litters) than those observed by hunters in the same area but largely away from sources of garbage (1.99 cubs per litter, N=129) (Erickson et al. 1964).

In contrast to the causes of mortality among cubs and yearlings, more than 90 percent of the known mortality among bears 2 years of age or older was from human-related causes. However, little is known about the causes of mortality among dispersing subadult males because few of them were radio-tracked after they left the study area. It would not be surprising to find that they experience considerable natural mortality upon leaving the familiar area in and around their mothers' territories. Dispersing subadults not only must find new sources of food but they must do so in the face of stiff competition from unrelated bears that frequently displace them from newfound feeding areas (Rogers 1976). Many of them move straightline distances of more than 100 miles (161 km) before finding places to settle. Jonkel and Cowan (1971) captured subadults in May and June that were so thin and weak that they easily were handled without drugging. These apparently undernourished bears probably were vulnerable to a variety of mortality factors if not actual starvation. It would not be surprising if some of them eventually were killed by predators including other bears.

In addition to natural mortality, dispersing males often are killed as nuisances or by hunters as a result of their tendency to exploit sources of garbage. Thin and hungry transients easily overcome their fear of human habitation when there is the prospect of a nutritious meal. Moreover, the areas around sources of garbage often are free of large resident males because the latter have been killed as nuisances by landowners or as trophies by hunters. Young males that feed on abundant nutritious foods such as can be found in garbage dumps grow faster than otherwise (Rogers et al. 1976) and thereby hasten the day when they can compete successfully for space and mates. In Michigan, 34 percent of the bears (excluding cubs) captured at sources of garbage were 2-, 3-, and 4-year-old males (Rogers et al. 1976).

The main human-related cause of mortality for bears 2 years of age or older was being shot while attempting to secure garbage near human habitation. Such mortality was highest during years when natural foods were scarce as also was found to be the case in Wisconsin (see page 431). In the 7 years of study in Minnesota, nine radioed bears were killed as nuisances during 3 years of scarce natural food, and only three were killed as nuisances during 4 years of moderately or exceptionally abundant natural food. Additionally, at least 26 bears were killed within 6 miles (13 km) of the study area the year before the study began. Berries were extremely scarce that year (1968) according to reports by conservation officers, forest rangers, and local berry pickers (Rogers 1970). Cub survival probably was low that year because a gap in the age structure dating to 1968 was evident throughout the 7 years of study. Following the high mortality in 1968, the resident population of the 110 mile^2 (285 km^2) study area went through a period of recovery and then more or less stabilized at 60-67 bears for the last 4 years of study (Rogers 1976). The resident population remained fairly constant for those 4 years even though 60 cubs were born in the study area, and at least 53 transients traversed it.

It is difficult to prove what limits wildlife populations because of the large number of factors that must be considered. Nevertheless, annual fluctuations in food supply influence vital population characteristics so greatly that it is difficult to escape a conclusion that nutritional factors primarily are responsible for adjustment of the adult population of black bears in northeastern Minnesota to levels that can be sustained through frequent years of scarce food. Such a conclusion appears even more logical when densities of black bears in logged vs. virgin areas are compared. Food is more abundant in the logged areas due, in part, to increased sunlight at the shrub level (Elwell, Arimond, and Rogers, in preparation). Preliminary analyses of population data suggest that bear density also is higher in the logged areas than in the nearby virgin forests of the Lauren-tian Shield despite much greater human-related mortality in the logged areas.

If nutritional factors are important in limiting black bear populations as they appear to be, then habitat improvement programs should be useful in the management of black bears. Additional study is needed to determine the nutritional requirements of bears and to determine which nutrients are supplied by which foods in order to better understand how black bears are affected by failures of particular crops.

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