EFFECTS OF FOOD SUPPLY, PREDATION, CANNIBALISM, PARASITES, AND OTHER HEALTH PROBLEMS ON BLACK BEAR POPULATIONS

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ABSTRACT

Effects of gunshot and human settlement on black bear numbers and range are well documented, but effects of natural factors are less well known. In this paper, effects of food supply, predation, cannibalism, and health problems on black bear populations are evaluated using information in the literature and data obtained in Minnesota during 1969-1978 from 119 radio-collared black bears and their cubs. Supplies of fruit and mast vary greatly among regions and from year to year. Available evidence indicates that availability of these easily digestible, energy-rich foods is the most important factor influencing growth rate, age of first reproduction, and intervals between litters in black bears. Survival of cubs and yearlings also varies with food supply, but predation also may be a significant factor in cub survival. The extent to which cubs are killed by larger bears, wolves, and other predators is an important area of bear biology requiring further study. Predation on yearlings and older bears appears to be too rare, according to available data, to significantly influence population dynamics, but there is evidence that habitat utilization by black bears may be limited in some areas by grizzly bears. Little information is available on causes of natural mortality among dispersing bears. A variety of health problems have been reported for black bears, but no serious pathological condition has been found to be common and no case of population decimation due to parasites or disease has been reported. The most commonly reported

health problems have stemmed from gunshot, arrows, and trapping Injuries. Of 20 radio-collared bears that died in Minnesota, 18 were killed by bullets or arrows, 1 was killed by wolves, and 1 died of unknown natural causes.

Key words: Growth rate, reproduction, telemetry, starvation, litter size, causes of death, density independent mortality, density dependent mortality, human-related mortality, aggression, dispersal, hibernation.

Some of the factors that limit black bear populations are known. Human settlement is reducing the black bear's range (Cowan 1972) and gunshot is the most common cause of adult mortality in many populations (Lindzey et al. 1976, McCaffrey 1976, Graber 1981, Kohn 1982). Effects of natural factors such as food shortage, predation, cannibalism, parasites, and other health problems on black bear populations often are more difficult to detect because they often exert greatest effect on reproductive rate or on mortality among cubs too young to study by telemetry. As a result, effects of natural factors on bear populations are not well known. In this paper, I review literature regarding effects of natural factors, present data on the effects of these factors on a population in northeastern Minnesota, and identify areas of bear biology that are in particular need of further study.

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Minnesota Data

One hundred nineteen black bears were monitored by telemetry in northeastern Minnesota using methods described previously (Rogers 1977). During 10 years of study (1969-1978), these bears provided 178 bear-years of data in which bears were radio-tracked from 1 January of a given year until death or the end of that year (Table 1). I believe mortality data

for these 178 cases reasonably represents mortality patterns of the study population.

Table 1. Telemetry data by age class for 119 black bears studied in northeastern Minnesota during 1969 to 1978.

Age	Full years of monitoring[a]		Incomplete years of monitoring	
	Males	Females	Males	Females
Cub[b]			10	5
1	15	14	7	6
2	6	9	11	7
3	1	11	10	14
4	1	13	5	15
5+	11	97	14	53
		178		157

[a]*Bears monitored from 1 January until death or end of year.*

[b]*Alt instrumented cubs except one were orphans; all were instrumented after 12 August.*

The same bears also provided 157 cases in which bears were radio-tracked for less than a calendar year due to being instrumented in spring or summer or due to transmitter failure, transmitter removal, or bears moving out of range (Table 1). Data for these 157 cases may differ from mortality patterns of the population to the extent that bears radio-tracked for less than a year were radio-tracked through seasons of higher or lower than average mortality. These 157 cases provide information on causes, if not rates, of mortality. Nearly all of the data are from resident rather than dispersing bears because radio-collars were removed from most sub-adult males before dispersal began.

Cubs that accompanied radio-collared mothers were not radio-collared until 14 months of age in most cases. Mortality data for cubs were obtained mainly by counting cubs in natal dens and recounting them whenever mothers were located by telemetry and when the families denned the next winter.

Cubs typically were born in January and remained with their mothers for about 17 months until June of their second summer.

Effects of Natural Food Shortage

Nutritional condition is a major factor influencing growth, reproduction, and cub survival in black bear populations. In Pennsylvania, where several kinds of nuts and acorns are commonly abundant and some bears supplement their diets with garbage, cubs average over 40 kg bodyweight by fall, females produce their first litters at 3 or 4 years of age, and subsequent litters are produced almost invariably at 2-year intervals (Alt 1980, Kordek and Lindzey 1980). First litters average 2.39 cubs, and subsequent litters average 3.23 cubs according to placental scars (Kordek and Lindzey 1980). These growth and reproductive rates are the highest reported for black bears in the wild.

By contrast, energy-rich foods are less abundant, less varied, and less reliable in Montana than in Pennsylvania (Tisch 1961, Jonkel and Cowan 1971). Cubs there average less than 20 kg in fall, females usually do not produce first litters until 6 to 8 years of age, and subsequent litters are typically at 3-year intervals (Jonkel and Cowan 1971). Litter size averages only 1.7 cubs, and reproduction approached zero when huckleberries *(Vaccinium* spp.) were scarce for three successive years (Jonkel and Cowan 1971).

During studies in northeastern Minnesota, mast was limited essentially to beaked hazel *(Corylus cornuta)* and northern red oak *(Quercus rubra).* The hazel produced few nuts in most years, and few bears from the study area found the oaks because it occurred no closer than 22 km from the study area. Moreover, berries were scarce half the years of study, forcing bears to eat poorly digestible vegetation in those years. Growth and reproductive success averaged only a little higher than in Montana. In years when fruit and nuts were most abundant, cubs averaged 22.1 ± 0.86 kg (N=29) in fall, but when these foods were unusually scarce, cubs averaged only 15.6 ± 0.5 kg (N=39) in fall (Rogers 1976). Females produced their first litters at 4 to 8 years of age (average 6.3 years), depending on food supply, and usually required a summer of abundant fruit and nuts to gain enough weight to initially reproduce. Only 2 of 14 females produced their first litters after summers of scarce food. Subsequent litters were produced at 2 to 4 year intervals, again depending mainly on food supply. By contrast, females with access to garbage produced first litters at 4 or 5 years of age and typically produced subsequent litters at 2-year intervals.

Litter size for all bears averaged 2.74 cubs (Rogers 1976).

Weights of females in fall in Minnesota indicated whether or not they would produce cubs the coming January. Females 3.5 years of age or older that weighed less than 67 kg on 1 October (N=17) produced no cubs even though some of them had been seen with males. Females that weighed more than 80 kg on 1 October and that had not produced cubs the previous spring reproduced in 32 of 34 cases. Females weighing between 67 and 80 kg in fall produced cubs in only 4 of 14 cases, with the 4 litters showing poor survival or being lower in number than the average of 2.74 cubs per litter. One of the 4 litters consisted of only 1 cub. Another, a litter of 3, grew only about half as fast as most others and died at 2-4 months of age. A third litter (3 cubs) starved at 15-17 months of age (Rogers 1977). The natural fate of the remaining litter (2 cubs) was not learned.

Food supply influenced development more during the bears' first year of life than at any other time. Growth of cubs during their 2.0 to 3.5 months of nursing in natal dens depends upon milk supply which, in turn, depends upon nutrients stored by mothers the summer before. Predenning weights of pregnant females indicated not only which females would produce cubs but also what the weights of the litters might be at two months of age ($r^2 = 0.540$, $P<0.001$) (Rogers 1976). After family groups left their dens in spring, foods other than milk became increasingly important to the cubs. Cubs gained significantly ($P<0.0001$) more weight in summers of abundant fruit and nuts than in summers of food scarcity as was mentioned above.

Cubs that survived to fall survived over winter whether food the previous summer was scarce or abundant, but their weights the following March, near the end of the denning period, gave indications as to whether or not they would survive as yearlings (Table 2). Nearly all yearlings that weighed less than 10 kg in late March died within 4 months, as did 7 of 9 that weighed 10 to 13 kg. None of 15 heavier yearlings died.

Table 2. Survival of yearlings as related to body weight.

Body weight at 14 months of age	Number surviving as learned by telemetry	Number surviving as learned by recaptures[a]
< 10 kg	0 of 6	1 of 19
10-13 kg	7 of 9	9 of 18
> 13 kg	15 of 15	22 of 31
All weights	22 of 30	32 of 68

[a]*Recapture data includes both instrumented and non-instrumented eartagged yearlings. Proportion of yearlings surviving tends to be underestimated by recapture data because dispersal reduced chances of recapture for some bears.*

Natural mortality among cubs and yearlings became heavy at the end of 3 successive years of scarce fruit and nuts in Minnesota (1974-1976). Ten of 20 cubs died in 1976 and 3 of 4 yearlings died the following spring (Rogers 1977). During the 3 years of scarce food, the population in the study area declined 35 percent from a bear per 4.1 km in June 1974 to a bear per 6.3 km^2 in June 1977. Major factors in the decline included reproductive failures, cub and yearling starvation, and adults spending more time foraging for garbage, leading to higher mortality from gunshot.

Data obtained during 1969-1978 indicate that at the population densities studied, any density dependent influences on reproductive rate were minor compared with the influence of food supply, which varied widely from year to year. Cub and yearling mortality varied inversely with body weight and appeared also to be determined in a largely density independent manner by food supply. Undetected cannibalism and interspecific predation may have occurred among noninstrumented cubs, but this mortality, too, may be influenced by food supply to the extent that food shortage weakens cubs, increasing their vulnerability, and to the extent that food shortage might predispose adult bears to cannibalism.

Predation by Other Species

Very little is known of predation on cubs. Cubs sometimes weigh less than 2 kg when they leave their natal dens, and

they sometimes are left unattended while their mothers forage (unpublished data). Several common predators are capable of killing cubs (Nelson 1957, Rogers 1977, Rogers and Mech 1981), but adult black bears are practically immune to predation from all North American animals except grizzly-brown bears *(Ursus arctos)* and timber wolves *(Canis lupus).* Black bears are scarcely sympatric with polar bears *(Ursus maritimus)*.

Grizzly bears are widely believed to prey on black bears but the frequency of this is unknown (Rausch 1961). Several authors have presented evidence that black bears avoid grizzlies (Barnes and Bray 1967, Jonkel and Miller 1970, Herrero 1972, Martinka 1976) or the preferred habitat of the grizzly (Burroughs 1961, Jonkel 1967), with some exceptions (Lloyd 1978).

Black bear home ranges commonly overlap those of timber wolves and coyotes *(Canis latrans).* There are several reports of predation by these species on female or young bears but not on adult males. C. C. Dickson (Personal communication, 1980) found that wolves killed an immature black bear in northern Ontario on 18 May 1979. Boyer (1949) reported coyotes killing a yearling black bear, and Young and Goldman (1944) presented a trapper's description of wolves killing a black bear of unknown age and sex. Schorger (1949) related an 1858 newspaper account of wolves killing a trapped bear in Wisconsin.

Data indicate that predation by wolves on black bears is uncommon. During radio-tracking in northeastern Minnesota, only one radio-collared bear was killed by wolves. In that case, a 16-year-old, 72-kg female and her newborn cubs were killed at their den in mid-February 1977 (Rogers and Mech 1981). Analyses of wolf fecal droppings further indicate low predation on bears. Of 1,449 wolf droppings collected in northeastern Minnesota, only 19 (1.3%) contained bear remains (Byman 1972, Frenzel 1974) and at least 16 of the latter were collected near a residential area where bears had been shot (D. Ross, personal communication, 1979). In central Ontario, Voight et al. (1976) also found bear hair in a very few (number not given) of 1,943 wolf droppings. Again, most of the droppings containing bear remains were collected near residential areas, suggesting scavenging of bears killed by gunshot (G. Kolenosky, personal communication, 1979). However, in late August 1982, a well-nourished cub became missing from a radio-collared female in Minnesota, and later that month a wolf dropping containing cub claws was found in her territory. Additional study of cub mortality is needed to determine the extent to which cubs are preyed upon.

Intraspecific Aggression and Cannibalism

The role of resident adult black bears in aggressively preventing immigration into their ranges has been well documented in long-term population and behavior studies (Kemp 1976, Rogers 1977, Young and Ruff 1982). Resident adult males repel immigrating subadult males, reducing future competition for mates and reducing immediate competition for food, with potential benefits extending to offspring and pregnant mates. Females in Minnesota occasionally chase or fight females that encroach upon their territories (Rogers 1977), and an immigrant subadult male ran from a territorial female that did not give chase (Rogers, unpublished data). How often these potential immigrants are killed rather than evicted is unknown. Thorough studies to determine causes of death among dispersing subadult males have not been conducted. The only report I found of a free-ranging subadult male of dispersal age (2 or 3 years of age) being killed by another bear is that of LeCount (1982). In that case, a subadult male with bear bite wounds on its head was captured in June and monitored until Infection from the wounds killed the bear the following winter.

Whether or not immigrants are killed directly, aggression by residents toward them conceivably could prevent their access to preferred food patches and could force them into suboptimal habitat (Rogers 1976, Bunnell and Tait 1981). This, together with the high mobility of dispersing males, may explain the disproportionately high number of subadult males that become nuisances in residential areas (Rogers et al. 1976) and the high number of these bears that are shot (Rogers 1976, Bunnell and Tait 1981). In Minnesota, eartag returns showed that at least 8 (24%) of 33 males that were born in the study area and studied there until the age of dispersal were shot outside that area as dispersing 2- or 3-year-olds. How much these losses of subadult males eventually affected population density is unknown. To properly assess the effect on population density, the losses must be considered in relation to any gains in reproductive success and cub survival among resident bears-as a result of decreased competition for food. This will require additional study.

Several authors have suggested that black bear populations that are not limited by gunshot might be limited by large bears killing smaller ones (Kemp 1972, 1976, Lindzey and Meslow 1977, Bunnell and Tait 1981, LeCount 1982). Thorough study of a population in which human-related mortality is not the usual cause of adult deaths has not been conducted due in part to inaccessibility of such populations, so this idea has not been tested. Indications from studies of black bear

social organization are that both males and females conceivably-could increase their fitness through prudent cannibalism (Rogers 1977). Benefits of killing genetically unrelated bears include food value of carcasses and reduction of competition for food, mates, and space. Costs are expenditures of energy and incurring injuries that lead to reduced reproductive success. Considering risk. of injury, cost:benefit ratios from cannibalism probably are most favorable when bears kill nonkin that are too small or in too vulnerable a situation to inflict significant injury. Numerous researchers have reported that bears behaving abnormally because they are drugged or in traps are attacked (Kemp 1976, Rogers 1977, Beecham 1979, Johnson and Pelton 1980). In natural situations, too, reported victims of cannibalism have been either very young bears or denning bears. Deaths of 6 cubs, 2 yearling males, a yearling female, and 2 adult denning females have been documented as follows:

1. A mother with cubs killed and ate a cub from another litter in Yellowstone National Park in late summer 1930 (Arnold 1930).
2. A male climbed a tree, killed a cub, returned to the ground, and ate it in Yellowstone National Park on 14 July 1959 (M. Hornocker, personal communication, 1974).
3. One of two radio-collared cubs accompanying their mother was killed by another bear in Arizona (LeCount, personal communication, 1982).
4. A cub was killed during or after a fight between two adults in Yosemite National Park on 17 July 1955 (Hartesveldt 1955).
5. A radio-collared yearling female that was traveling with its mother in Arizona was killed by an adult female or a subadult male according to the track size of the attacker (LeCount, personal communication, 1982).
6. A radio-collared yearling male was killed and partially eaten by a 5-year-old male in Alberta, Canada, in early fall 1976 (Tietje, Pelchat, and Ruff, personal communication, 1982).
7. A radio-collared yearling was killed by a male in Alberta, Canada, in 1977 (Ruff and Kemp 1980).
8. A large bear killed and ate a mother and two cubs at a den in the upper peninsula of Michigan in mid-April 1963 (D. Wenzel, unpublished report on file at the Michigan Department of Natural Resources Headquarters at Crystal Falls, Michigan).
9. A 16-year-old radio-collared female was dug out of a den, killed, and partially eaten by a bear in early

October 1976 in Alberta, Canada. Evidence suggested the predator was a male (Teitje, Pelchat, and Ruff, personal communication, 1982).

Additional evidence of attempted or actual cannibalism include reports that a male attempted to catch a cub in Yellowstone National Park (Barnes and Bray 1967); a bear scat collected in May 1973 on Long Island, Washington, contained remains of a cub (Lindzey and Meslow 1977) ; and a 5-year-old radio-collared male was dug out of its den and wounded by another bear in Alberta in mid-October 1976 (Teitje, Pelchat, and Ruff, personal communication, 1982).

Despite these observations, indications are that cannibalism is rare in black bear populations studied to date. Documentation is infrequent even in garbage dumps and national parks where black bears are concentrated and highly visible. No radio-collared yearling, subadult, or adult was killed during studies in Minnesota, although undetected cannibalism of noninstrumented cubs could have occurred. Whether cannibalism is a major cause of mortality in any black bear population and whether such deaths follow any pattern other than opportunistic predation remain to be determined. Telemetry technology has now advanced to the point that instrumenting cubs and radio-tracking dispersing subadults are feasible. Thorough studies of mortality in these bears would significantly increase our knowledge of black bear biology and behavior.

Parasites

Published reports indicate that deaths from parasites are rare in black bears despite the fact that many individuals are parasitized (Rogers and Rogers 1976). During studies in Minnesota, no radio-collared bear died from parasites or was found to be in poor condition due to parasites. In previous studies, 4 wild individuals with infestations of cestodes (Rush 1932, Martin 1950) or nematodes (Chandler 1950, King et al. 1960) were found in poor condition. Whether the parasites were primary or secondary causes of the poor conditions is unknown. In Montana, subadult black bears generally were more poorly nourished than adults and tended to develop heavier infestations of ticks *(Dermacentor andersoni)* (Jonkel and Cowan 1971).

Two captive bears died when ascarid worms *(Baylisascaris* spp.) or broad fish tapeworms *(Diphyllobothrium* spp.) became located in abnormal sites where they blocked vital passageways (Mozgovoi 1953, Rausch 1955).

Little is known of the adaptations of parasites to bear hibernation. At least some of the parasites that derive nourishment from ingesta have life cycles adapted to the period of bear fasting. As examples, ascarid worms pass out of the digestive tract in fall (Rausch 1961, Choquette et al. 1969, Rogers 1975), and Rausch (1961) presented evidence that broad fish tapeworms spend the winter in a destrobilized condition in bears. However, parasites such as hookworms that derive nourishment from the bear's body, rather than from ingesta, may not be lost during hibernation (Rausch 1961), and their effects on hibernating individuals is unknown. At present there is no evidence that parasites significantly influence population dynamics of black bear populations.

Other Health Problems

A variety of health problems have been reported for black bears, but no serious health problem has been found to be common and no incident of population decimation due to disease has been reported. During studies in Minnesota, no radio-collared bear other than malnourished bears or those with human-inflicted injuries (primarily gunshot) showed unusual lethargy that might indicate illness. However, a 21-year-old female, the oldest bear studied, died of unknown causes in her den in March 1972 after losing weight unusually rapidly over winter (Rogers 1977). Whether this death was from disease, an unknown malady of old age, or other natural causes is unknown.

Health problems reported for captive black bears include tuberculosis (Fox 1923), arthritis (Fox 1939), congenital hydrocephalus (Halstead and Kiel 1962), allergy (hypersensitivity angiitis) (Simmonds and Wells 1970), goiter (Schlumberger 1954), Elokomin fluke fever (Poelker and Hartwell 1973), clostridial myonecrosis (Barnes and Rogers 1980), and malignant tumors (Fox 1923). Tumors, including malignant ones, were also found in wild black bears (King et al. 1960, Rausch 1961). A wild black bear cub died of a heart valve defect in Arizona (LeCount, pers. comm. 1982).

Severe dental problems have mainly been found among very old individuals whose deaths would have relatively little impact on population dynamics. Rausch (1961) found periodontal disease in 11 of 14 very old black bears that he believed were approaching the time of death. He found less extensive periodontal disease in 7 of 35 younger bears 12 or more years of age and no periodontal disease in bears estimated to be less than 12 years of age. Manville (1980) found periodontal disease to be common (in 11 of 33) in bears in his study area

in the lower peninsula of Michigan, with some cases being severe even in young bears. However, the problem apparently is a local one because it was not observed in 126 bears from which I extracted teeth in the upper peninsula of Michigan (Rogers et al. 1976) nor during studies in Minnesota. Manville (1980) also found dental caries in 5 of 33 bears. Hall (1945) found them in 6 (3%) of 195 black bears.

Rabies, which can cause large-scale die offs in some species (Sikes 1970), is very rare in black bears (Shoening 1956, Rausch 1975). Attempts to experimentally infect captive black bears showed them to be more resistant to rabies than are canine species (Rausch 1975). Only 10 rabid wild black bears have been reported: 4 from Quebec, 4 from Ontario, 1 from Alberta, and 1 from Arizona (Ontario Ministry of Natural Resources files. Maple, Ontario, September 1982). Rausch (1975) reported that black bears not only required large amounts of rabies virus to contract the disease but that infected individuals carry little or no rabies virus in their saliva. Both factors reduce the chance of rabies spreading in a bear population.

Serologic examination of wild black bears in Idaho revealed antibodies for (in decreasing order of occurrence) tularemia, brucellosis, toxoplasmosis, leptospirosis, trichinosis, Q-fever, St. Louis encephalitis, and Rocky Mountain spotted fever (Binninger et al. 1980). It is unknown whether black bears develop serious clinical symptoms of these diseases; none were noted by Binninger et al. (1980). In the case of tularemia, whose antibodies were found in 19 percent of the sera tested, bears showed ability to survive significant exposure to the disease as indicated by recaptures of bears that originally showed high titers of tularemia antibodies (Binninger et al. 1980). I found no report of disease significantly influencing the dynamics of any species of bear population.

Injuries from gunshot, arrows, steel jaw traps, and neck-snares are common health problems in black bears (King et al. 1960, Rausch 1961). In Minnesota, a radio-collared female died approximately 4 months after being gutshot. Another lived at least 2 years after having the distal third of her lower jaw shot off. Others received massive bullet wounds that took up to a year to close. Eighteen of 20 deaths of radio-collared bears in Minnesota were from gunshot. In the upper peninsula of Michigan, coyote bounty-trappers that I talked to in the summers of 1967 and 1968 said that they caught numerous bear cubs and that they usually killed them, rather than releasing them, in order to avoid possible problems with the cubs' mothers, suggesting an additional significant human-related cause of mortality.

Conclusions

Evidence from Minnesota and other studies indicates that reproduction is controlled mainly in a density independent manner by fruit and mast supplies that fluctuate widely from year to year (Rogers 1976, 1977, Bunnell and Tait 1981). Cub and yearling survival also varies with food supply according to Minnesota studies, but additional information is needed to determine the importance of predation on cubs by bears and other species. Causes of death among dispersing subadult males have been inadequately studied to date. Limited evidence indicates that gunshot is the usual cause of death for them as it is for adults (Rogers 1976, 1977). Human-related mortality has been shown to limit most populations studied to date, whereas black bear range is limited mainly by human settlement (Cowan 1972). Parasites and disease apparently do not significantly limit black bear populations.

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