DEMOGRAPHIC CONSEQUENCES OF BEARS EATING GARBAGE AT DUMPS: AN OVERVIEW

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Abstract: The demographic consequences of bears eating at dumps are complex and in some respects contradictory, as is also true for the consequences of dump closure. Calculation of net consequences requires a simulation model. Digestible lipids, carbohydrates, and protein seem more abundant in garbage than in most natural diets of bears. Eating garbage tends to increase body size and rates of reproduction and survival, and may affect local ingress and egress. At dumps, juveniles may be particularly vulnerable to being killed by conspecifics, and bears of all ages are especially vulnerable to hunters. Closure of a dump could reduce reproductive rate, the number of juveniles killed by other bears, and the number of bears killed by hunters, while conversely increasing the number of bears undernourished or killed as nuisances. Data are available from so few, sparsely documented, cases of dump closure that we do not know which closure methods are best or precisely what impacts to expect from each method. When dumps are to be closed, a variety of methods should be used so that impacts can be assessed and alternatives tested under a policy of "adaptive management".

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Throughout North America, grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), and polar bears (*Ursus maritimus*) supplement their diets with human foods (Craighead et al. 1974; Jonkel et al. 1976; Rogers 1976, 1987; Rogers et al. 1976; Craighead 1979; Herrero 1983; Bruemmer 1984). Bears obtain food from humans by scavenging garbage at dumps; raiding garbage containers, camps, or buildings; stealing food directly from people or being given handouts by people. This paper focuses on the role of feeding at dumps, and on the effects of such feeding and of dump closure on bears and bear-people interactions.

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POPULATION DYNAMICS

The demographic consequences of bears eating garbage or of garbage dump closure are complex and in some respects contradictory. To predict reliably the net direction of demographic change (e.g., whether population density will increase or decrease), and especially to estimate the amount of change, requires a simulation model. Data are needed on sex/age-specific rates of growth, reproduction, migration, and survivorship, as well as on population density, sex-age infrastructure, social organization, and availability and nutritional quality of natural foods and garbage.

Nutritional Value of Garbage

It is a common impression (Rogers 1976, 1987; Rogers et al. 1976; Blanchard 1987; Craighead, pers. commun.) that garbage is richer than most natural diets of bears in calories, simple carbohydrates, lipids, and meat protein. However, there has been no formal analysis of how well human food eaten by bears meets their nutritional requirements.

Individual Differences In The Amounts of Human and Natural Foods Eaten

Barnes and Bray (1967) and Cole (1976) claimed that among black and grizzly bears in Yellowstone National Park, "dump bears" were typically distinct from "wild" ones. However, available data from this and other publications reveal not a dichotomy but a gradient in use of dumps by different individual bears or sex/age classes, ranging from regular use for virtually the entire season, to rare use, to none at all (Craighead et al. 1974; Craighead 1979; Herrero 1983; Blanchard 1987; L. Rogers, pers. commun.; D. Garshelis, pers. commun.; Stringham unpubl. data). I have found no substantive basis for distinguishing "dump bears" as a class except that they are bears which have visited a dump, and have been exposed to conditions peculiar to dumps, such as abundant garbage, more than other bears. That is how the term "dump bears" is used here.

At some dumps and some concentrations of natural food, subadult and/or adult males seem disproportionately abundant, whereas females with cubs seem rare (black bears: L. Rogers, pers. commun., Stringham unpubl. data; polar bears: Taylor et al. 1985). However, other sites are more commonly frequented by females and cubs (black bears: Herrero 1983; D. Garshelis, pers. commun.; grizzly bears: Egbert and Stokes 1976; Glenn et al. 1976; Craighead 1979). Among black bears in central Minnesota, Garshelis (pers. commun.) found that females were most common at a dump before the breeding season, whereas males gradually became predominant during and after the season. He did not state what proportion of these males were subadults.

More research is needed on how the number and sex/age composition of bears at a food concentration vary diurnally, and on how these traits are affected by density/size and sex/age composition of the whole population and by abundance of garbage in relation to natural foods. Information can be obtained with automatic telemetric monitors at garbage dumps which record 24-hour visitation by radio-collared bears, as Garshelis is doing in Minnesota.

Body Size

Energy and protein usually limit rates of growth and reproduction by mammals (Sadlier 1969, Stringham 1988*b*). Bears eating human food can attain especially high growth rates and adult body sizes. In Alaska, captive-reared black bears grew about twice as fast and reached maximum adult sizes about 50% larger than wild black bears (Rausch 1961).

In Michigan, the average weights of adult black bears at dumps were heavier (males 22%, females 57%) than those captured at campgrounds or residential areas (Rogers et al. 1976). Similar results were reported by Russell et al. (1979) for grizzly bears in Jasper National Park, Alberta.

After dumps in Yellowstone National Park and West Yellowstone were closed during 1968-1971 (Cole 1976), body weights of adult grizzly bears fell about 22% for males and 11% for females (comparing data of Craighead and Mitchell 1982 with Blanchard 1987; see Stringham 1985). Smaller sources of garbage remained for several more years. Adults that ate garbage weighed more than those that did not, (males 15%, females 6%). Among females, the weight difference was greatest for those with cubs of the year, less for those with yearlings, and negligible for those unaccompanied by offspring (Blanchard 1987). Weights of grizzly bears feeding at the Cooke City dump, north of Yellowstone National Park, declined after the dump was closed in 1980 (Knight and Eberhardt 1985). Apparently the natural food supply limited the size of those bears -- a situation that may not exist in some other habitats. Regressions of population means for natality, litter size, interbirth interval, and age at primiparity on mean sizes of adult males and females show that reproductive rate is directly related to size in both grizzly and black bears (Stringham 1986*b*, 1988*b*). Correspondingly, bears that feed on garbage are not only larger, but tend to have higher reproductive rates.

Reproductive Rate

In bears, as in other mammals (Sadlier 1969, Stringham 1988*b*), elevated nutritional status tends to accelerate maturation to weaning, and dissociation from the dam (subadulthood), and to adulthood. In northeastern Minnesota, where natural food is often scarce, black bears with access to garbage matured earlier (4.4 years) than those on predominantly natural diets (6.3 years) (Rogers 1987). In central Minnesota, where natural food tends to be more abundant, females that regularly fed at a dump first whelped at age 4, compared to age 4 or 5 years among females on predominantly natural diets (D. Garshelis, pers. commun.). For Yellowstone grizzly bears, maturation rate dropped when garbage dumps were closed, with age at primiparity (generation length) increasing 10% from 5.6 years during 1959-1970 (Craighead et al. 1976) to 6.2 during 1974-1984 (Knight & Eberhardt 1985).

Cole (1976) noted that mean age at primiparity was about 6 years at Yellowstone (1959-1970) and at McNeil Falls in Alaska (Glenn et al. 1976). That is longer than at some other sites where natural food is abundant, for instance on the Alaskan coast (Hensel et al. 1969, Stringham 1988*b*). Cole (1976) hypothesized that the slower maturation rate at Yellowstone and McNeil was due to more intensive social strife as a consequence of the bears aggregating in large numbers to feed on garbage or salmon, respectively. However, the data just reviewed show that maturation rate at Yellowstone National Park slowed, not accelerated, when the Yellowstone dumps were closed. Furthermore, the difference in maturation rates among populations seems adequately explained by just nutritional status, judging from a regression of generation length on body weight (an index of nutritional status) across 12 grizzly populations (Stringham 1986*b*, 1988*b*).

Following closure of the main Yellowstone dumps during 1968-1971, mean cub litter size for the population decreased from 2.24 in 1959-1968 to 1.87 in 1972-1981 (data of Craighead et al. 1974, Cole 1976, and Knight et al. 1985 analyzed by Stringham, 1985, 1986a, 1988a,b); about 70% of the decrease is attributable to dump closure and 30% to climatic conditions. In later years, females that fed at the remaining, smaller dumps averaged 2.17 cubs per litter, compared to 1.92 cubs for females that did not feed at dumps (Blanchard 1987). On the Upper Peninsula of Michigan, cub litter sizes averaged 3.1 at dumps during a study by Rogers et al. (1976), compared to 1.99 elsewhere on the Peninsula during research by Erickson et al. (1964). Rogers et al. (1976) attributed the difference in litter size to garbage feeding. However, differences in natural food supply and in methods of assessing litter size should also be taken into account. In northeastern Minnesota, where natural food is often scarce, mean litter sizes averaged 2.12 for primiparous mothers and 2.51 for multiparous mothers that ate natural diets, compared to litter sizes of 2.50 and 3.4 for primiparous and multiparous mothers, respectively, that also ate garbage (Rogers 1987). In central Minnesota, by contrast, where natural food is usually more abundant, females on predominantly natural diets produce litters as large as those that regularly eat garbage (D. Garshelis, pers. commun.). The positive correlation between postnatal litter size and food supply is well documented in bears, apparently resulting from positive influences of nutritional status on natal litter size and postnatal survivorship (Rogers 1976; Stringham 1985, 1986*a*, 1988*a,b*).

Both the proportion and number of adult females whelping each year are directly related to natural food supply (Jonkel and Cowan 1971; Rogers 1976, 1977; Eiler 1981; Wathen 1983) or combined supplies of natural and human foods (Stringham 1985, 1988*b*). Interbirth interval tends to be inversely related to food supply because better-nourished cubs tend to mature faster (Stringham 1980, 1988*b*). Poorly-nourished cubs may remain with their dam for an extra year, lengthening the interbirth interval from 2 years to 3 years in black bears (Jonkel and Cowan 1971) and up to 4 years in grizzly bears (Reynolds 1976). Conversely, some exceptionally well-nourished black bear cubs might grow fast enough to quit nursing before half-a-year old, allowing the mother to mate then and reduce her interbirth interval to 1 year (D. Garshelis, pers. commun., G. Alt, pers. commun.). Intervals tend to be shorter for females that eat garbage than those that do not, as documented for Minnesota black bears (2 versus 2.3 years) (Rogers 1987) and Yellowstone grizzly bears after the main dumps had been closed but smaller ones remained open (2.5 versus 3.6 years) (Blanchard 1987).

There is also a counter-tendency for a positive correlation between interbirth interval and food supply, where better- nourished litters have higher survivorship, so that fewer interbirth intervals are terminated prematurely by entire-litter mortality. The effects of nutritional status on litter survival, dominating the effects on maturation rate, apparently explain the positive correlation between interbirth interval and food supply found for Yellowstone grizzly bears during 1959-1981 (Stringham 1985, 1988*b*).

Survival Rate

Positive correlations have been shown between survivorship of cubs and older immatures versus body weight or indices of natural food supply for black bears (Rogers 1976, 1983, 1987), or versus combined supplies of natural foods and garbage for grizzly bears (Stringham 1985, 1988*b*).

Even though litter size tends to be directly related to nutritional status (Stringham 1985, 1988*b*), a larger litter sometimes occurs at the expense of smaller cubs (Miller 1963, Alt 1980, Wathen 1983). Unless a rich diet increases nutritional status not only for the mother, but also per cub, the smaller cubs from larger litters may remain runts indefinitely and have lower survivorship (Rogers 1976). Conversely, reduction in food supply, which lowers litter size and adult body sizes, might sometimes increase mean body size for juveniles (Stringham 1985, 1988*b*). Further study is needed to determine how food supply affects survivorship relative to litter size.

Cole (1976), Glenn et al. (1976), and others have argued that mortality rates of juveniles might be elevated at dumps and at natural sites where bears aggregate to feed. This theory is based on changes in mortality rate observed when a dump was closed, observations of mortality at feeding aggregation sites, and higher estimates of mortality rate in populations that aggregate. Mortality rate for Yellowstone grizzly cubs apparently fell after the dumps were closed, despite declines in sex/age-specific body weights (data of Craighead et al. 1974 were compared with those of Knight et al. 1985 by Stringham 1988*b*, unpubl. data).

Some grizzly cubs are killed by conspecifics at aggregation sites, perhaps because of elevated social strife due to crowding or food competition, and/or to the increased exposure of the cubs to dangerous conspecifics. That may be why females with cubs of the year tend to avoid aggregations, especially during the spring and early summer, before the cubs are sufficiently swift and agile to outrun enemies. The same thing happens in polar bears (Taylor et al. 1985). Among black bears, the vulnerability of cubs at aggregation sites may be reduced by the ability of cubs to climb trees to escape enemies, and the practice by some females of leaving their cubs in trees on the periphery of an aggregation site (L. Rogers, pers. commun.; Stringham, unpubl. data). Observations should be made to learn whether the availability of large trees near a dump, especially easily climbed ones with rough bark such as hemlock (*Tsuga canadensis*) or white pine (*Pinus strobus*) (L. Rogers, pers. commun.), influences the tendency of females with cubs to feed there. This influence might be less important as cubs mature and are better able to outrun enemies.

Among grizzly bears, the decline in mean litter size between cub and yearling ages was about 5-fold higher in 2 populations (Yellowstone and McNeil) where large numbers of bears aggregated than in 16 populations where the bears were normally more dispersed and formed only small aggregations, if any (Cole 1976, Glenn et al. 1976, Stringham 1988*b*). Cole (1976) and Glenn et al. (1976) interpreted this as evidence that cub mortality rates were correspondingly elevated at Yellowstone and McNeil. However, more reliable estimates of cub mortality rate, based on relative numbers of cubs versus yearlings, suggest that grizzly cub mortality rate is not related to size of the feeding aggregation (Stringham 1988*b*). Studies by Egbert and Stokes (1976) showed that strife among grizzly bears at McNeil Falls tended to decline as the bears became more familiar with one another over the course of the annual salmon fishing season. This was overlain by an inverse relationship between strife and salmon abundance, with strife tending to increase again as the salmon run waned. Further studies need to be made of how duration of aggregation and food supply affect the intensity of strife and how much habituation carries over between years for bears that survive and return -- something that might be inversely related to hunting pressure.

We also need to determine whether rates of mortality and illness for adults are elevated at dumps. Dump bears seem particularly vulnerable to hunters (J. O'Pezio, pers. commun.; D. Garshelis pers. commun.). There has been no study to determine whether bears suffer illness from ingesting food contaminated with toxins (e.g., household chemicals), trash (e.g., plastic), or pathogens from livestock or humans (e.g., trichinosis or canine adenovirus); however, bears seem more resistant to disease than most animals (Rogers 1983, 1987). Perhaps the infrequency of aggregation impairs disease transmission. Any reduction in mortality or illness from these factors, when a dump is closed, could help compensate for any simultaneous increase in the number of bears killed as nuisances.

Density Of Adult Females

Cub production should be directly related to abundance of adult females unless this is impaired by density dependent negative feedback. Reduction in abundance of adult female following closure of the Yellowstone dumps seems to have had even more impact on cub production than did the decline in per capita reproductive rate (Craighead et al. 1974, Knight and Eberhardt 1985).

Density Of Adult Males

Breeding is not the only way in which densities of adult and subadult males can affect demography. Bears sometimes kill each other. Juveniles and subadults seem particularly vulnerable, especially to older males (Rogers 1983; Stringham 1985, 1988*b*; Taylor et al. 1985). Adult males might also control egress and ingress by juvenile and subadult males (Young and Ruff 1982). There was a negative correlation between abundance of adult males and cub production and survival among Yellowstone grizzly bears during 1959-1970 (Shaffer 1978, 1983; Stringham 1980, 1983, 1985, 1988b; McCullough 1981). This correlation might have resulted from any food competition between adult males and other bears, infanticide, and possibly impairment of female reproduction by the adult males (Stringham 1985, 1988*b*). A change in mortality rate for adult and subadult males could thus affect cub production or survival. We need to learn whether this relationship depends on the number or proportion of males from a population killed by hunters, on the social ranks of these males, or on their kinship to the dams and cubs.

In at least some primates, sires of resident young are less likely than other males to kill these young or inhibit reproduction by resident females (Hrdy 1979). If the same were true in bears, then harvest of resident adult male bears might allow resident subadult or immigrant males to impair female reproductive success, whereas harvest of subadult and transient males might have the opposite effect (Stringham 1985, 1988*b*).

Simulation Modelling

The kinds of data discussed above should be incorporated into a simulation model for estimating the maximum tolerable declines in size and in growth rate for a bear population, as a basis for calculating the biologically and socially tolerable rates of dump closure. If the rate of closure cannot be controlled by the wildlife manager, the only means of ameliorating closure impacts might be providing supplemental food for the bears, choosing the season when closure occurs, changing harvest rate, and training (e.g., aversively conditioning) the bears to avoid humans or human food.

BEAR NUISANCE ACTIVITY: DIRECTIONS FOR NEW RESEARCH

Wildlife biologists have long had to deal with bear responses to garbage consumption and dump closure. But seldom has their practical experience been documented or the contradictions between their observations explained. Consider 2 examples: (1) Rogers (pers. commun.) noticed that towns and campgrounds in bear habitat of the Great Lakes region had less nuisance activity if there was a nearby dump where the local bears fed. Yet other biologists believe that dumps increase nuisance activity (J. O'Pezio, pers. commun.). None of these biologists has published data for the comparisons upon which their conclusions are based. (2) With black bears at the town of Tahawus in New York's Adirondack Park during the 1950's (R. Sage, pers. commun.), and with grizzly bears in Yellowstone National Park (Craighead 1979) a decade later, dump closure was followed by dramatic increases in nuisance activity and by resulting increases in the number of bears eliminated from the population by control actions. But we do not know how typical this is, how to predict strength of the impacts on bears or people, or how to control the impacts. Indeed, one can derive few reliable generalizations from available information about the consequences for bears and bear-people interactions of different methods of managing bears relative to dumps.

However, the available information does help one narrow the focus of research by asking more specific questions, as detailed below.

Abruptness Of Closure

Closure of garbage dumps at Yellowstone National Park caused a major reduction in the grizzly bear population (Craighead 1979), whereas closure of dumps in the Adirondack Park had no noticeable effect on its black bear population (J. O'Pezio, pers. commun.). The impact of closure might be directly related to the abruptness of closure, that is to the proportion of the population affected per year. In Yellowstone, the Trout Creek Dump was sometimes visited by over 100 grizzly bears a night, and commonly by over 30; most of the roughly 200 bears in Yellowstone fed on garbage at least occasionally (Craighead 1979). Thus most bears were directly affected by the abrupt closure over a 4-year period of both major dumps and 1 minor dump in the Park, as well as 1 major dump at the nearby town of West Yellowstone. The 2 municipal dumps north of the Park, at Gardiner and Cooke City, remained open several more years (Craighead 1979; Knight et al. 1981). By contrast, of the roughly 3,600 black bears in the Adirondack Park, only a small fraction seem to have been affected each year by dump closures. Closure of more than 100 dumps has been spread over the last 25 years (S. Free, pers. commun., J. O'Pezio, pers. commun.), and the number of bears feeding at each dump was apparently much smaller than at Yellowstone. Few of the hundreds of local residents and bear-watching tourists I questioned claimed to have seen more than 20 bears at any of these dumps, and usually no more than 5 to 10 bears. During 1987, only about 10 Adirondack dumps were still open to bears. The 2 dumps that I monitored were each visited by no more than 12 bears between morning and midnight, and apparently by few if any other bears during rest of the night (Stringham, unpubl. data). It is not known how the amount of garbage available to bears in the Adirondacks compared with that at Yellowstone.

Is feeding on garbage sometimes traditional, learned by cubs from their mother? Does gradual dump closure allow the trait to spread and thus to increase bear-people conflicts more than would abrupt closure (Cole 1976)? Conversely, does social intolerance among the bears or some other social factor limit use of dumps; does this limit shrink as garbage supply declines?

Habituation

It is a common belief that bears that fear people are unlikely to attack people or become nuisances, and that loss of fear through frequent contact with people - or habituation - makes them more dangerous. Habituation is facilitated where bears encounter non-aggressive people, for instance at a park or a dump. Proposals have been made to counter habituation by aversively conditioning or by hunting habituated bears, even in national parks.

Efforts to protect people from attack by bears should take into account the distinction between offensive and defensive attack (Herrero 1985). Offensive attack by an animal normally occurs in situations of dominance assertion or predation. Defensive attack is directed at enemies that seem dangerous, for instance a predator or competitor encountered by surprise at close range. Methods used to prevent offensive attack should not promote defensive attack. Skunks and porcupines deter attacks by engendering respect, by making enemies fear retaliation, not by making them fear aggression. So too, the chances that a bear will attack people either offensively or defensively might be minimized by teaching it to respect people rather than to fear them ("respect" and "fear" refer here to behaviours, not emotions).

How can a bear's fear of unprovoked human aggression be minimized without sacrificing the bear's respect for people? How do the consequences of a bear's habituation and respect towards people differ when developed at a dump, a campground, a roadside panhandling site, or in an area where the bear usually encounters only small groups of hikers or campers? Under what circumstances are bears habituated to people at a dump likely to become nuisances, either while the dump is open or after it has been closed? How specific are habituation and respect to the site/situation where they were learned?

Supplemental Feeding

If food for bears (e.g., concentrated edible garbage or ungulate carrion) is transported to sites removed from human activity, how effective is this at keeping the bears away from people, at optimizing habituation and respect, or at minimizing nuisance activities? Supplemental feeding at an isolated site was used to a limited degree during the Yellowstone dump closures (Cole 1976) and is planned in Minnesota (D. Garshelis, pers. commun.). How do the number, size, and distribution of nearby rich natural and/or artificial feeding sites influence the vulnerability of a developed area to nuisance activity by bears? How should each supplemental feeding site be situated relative to the developed area? How might supplemental feeding sites be designed as areas for viewing bears -- as is planned in Minnesota (D. Garshelis, pers. commun.) -- that enhance mutual respect by bears and people? If the supply of supplemental food will eventually be eliminated, how can it be reduced so as not to force the bears into nuisance activity? For instance, should each supplemental site be located in a prime natural feeding area that will continue to provide abundant food after supplemental feeding ends? Should feeding be maintained/resumed when natural foods are scarce and bears are thus most likely to become nuisances (Hatler 1967; Rogers 1976, pers. commun.)? Should supplemental feeding be terminated abruptly or gradually?

Characteristics Of The Bear Population

How is the amount of nuisance activity resulting from dump closure related to social organization of the bears, their sex-age composition, and the size or biomass of their population relative to the natural food supply? Are immigrant bears, such as transient subadult males, more or less likely than resident bears to become nuisances? Under what circumstances does social intolerance towards immigrants by resident bears living near people minimize nuisance activity by the immigrants? Conversely, does social intolerance by conspecifics impede attempts by dump bears to readapt to natural patterns of feeding and habitat use, to "revert to the wild," after a dump is closed? Does "reversion" by dump bears meet less resistance from local bears that do not use dumps if only a few dump bears make the transition each year?

Harvest Of Dump Bears

Is nuisance activity after closure of a dump inversely related to the number or proportion of the dump bears soon killed by hunters? Under what circumstances is harvest the preferred method of minimizing nuisance activity?

Timing of Closure

What is the best season for reducing the supply of garbage or of supplemental food? Should it occur during hibernation, after some of the dump bears have been killed by hunters and "replacements" will not be lured to the dumps by garbage (J. O'Pezio, pers. commun.)? Or should closure occur during a season when surviving dump bears can adapt to the decline gradually? Is winter closure preferable in a region where most dump bears were harvested during the preceding autumn? Is summer closure preferable where hunting pressure is light?

Hypothesis Testing And Adaptive Management

Research to answer questions such as those posed above can be facilitated if potential answers are derived prior to new fieldwork and phrased as alternative hypotheses which can be tested by the fieldwork, according to the principles of Strong Inference (Platt 1964, Wilson 1975).

Where feasible, relationships between bears and dumps should be managed experimentally so that the consequences of alternative methods can be assessed. To optimize long-term management, the requirements of short-term management need to be balanced with those of research in selecting the array of bear-dump management methods (experimental protocols) to be tested. For example, one might test more extreme versions of management practices -- such as elimination of all versus none of the dump bears prior to closure - to determine how much effect this has on the subsequent levels of nuisance activity; these extremes can provide more information than tests made with just the particular management practices thought *a priori* to be best. Long-term policies should be adopted only after adequate data are in hand to predict and preferably control the consequences of each method. This is what Walters and Hilborn (1978) termed "adaptive management."

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