

RESPONSES OF A BLACK BEAR POPULATION TO A CHANGING ENVIRONMENT

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Abstract: Black bear (*Ursus americanus*) population dynamics on Long Island in Willapa Bay, Washington, were monitored between 1973 and 1982. The population apparently grew from a small nucleus of bears present after major logging efforts stopped in 1968 to a peak of 33–36 bears over 1 year of age in 1975–76. Twenty-two bears remained on the island in the spring of 1982. Successional changes in plant communities in clear-cut areas altered their food value to bears through this period. By 1976 female progeny were generally no longer accepted into the breeding population and population productivity began to decline. Each of 5 radio-collared adult females raised young to 9 months of age in 1974 or 1975, whereas only 3 of 11 were successful in 1981 or 1982. Observations of marked bears and ages of trapped bears also documented the decline in production. By 1980 some resident bears began to include parts of the mainland in their home areas. Changes in size, productivity, and behaviors of this population illustrate the mechanisms employed by black bears in response to ephemeral habitats.

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Animal population dynamics result largely from changes in natality and mortality rates, although immigration and emigration rates occasionally contribute. Bunnell and Tait (1981) concluded in their review of the genus *Ursus* concluded that reproductive rates within this genus were nutritionally regulated in a generally density-dependent fashion. Evidence of the influence of food shortages on the reproductive performance of female black bears was provided by Jonkel and Cowan (1971) and Rogers (1976). Young and Ruff (1982) generally concurred with Bunnell's and Tait's conclusions. They found that although food availability might determine the long-term mean size of the Alberta black bear populations with which they were working, fluctuations about this mean were regulated by adult males in a density-dependent fashion. Kemp (1976) had speculated earlier that long-term regulation of density in this population was accomplished by adult male-induced mortality in the subadult cohort. McCullough's (1981) analysis of data from the Yellowstone grizzly bear (*U. arctos*) population led him to a similar conclusion: recruitment into that population was limited by the adult male cohort. Such control by males was apparently effected by conspecific killing and behavior that caused subadults to emigrate.

The wide range of values for factors determining natality rates for a population (age at 1st breeding, litter size, frequency of litters) exhibited by black bears across their geographic range (Bunnell and Tait 1981) suggest they may select from an array of reproductive strategies to fit specific environmental conditions. Dispersal schedules also vary. Presumably, some survival advantage is conferred to offspring by delaying dispersal age. Adult density,

generally that of males, will undoubtedly influence progeny's age at dispersal and rates of settlement of immigrating subadult males (Beecham in press, Young and Ruff 1982). Female offspring, on the other hand, often are accepted into the resident population and commonly share part of their mother's range (Jonkel and Cowan 1971, LeCount 1982).

Thousands of square kilometers of forests are clear-cut annually in the Pacific Northwest. Logging, in effect, may create habitat that produces foods for early to mid successional species such as black-tailed deer (*Odocoileus hemionus columbianus*, Brown 1961) and elk (*Cervus elaphus*, Harper 1971). The improvement in habitat quality is, however, ephemeral. Growing ungulate populations soon have less available food as vegetative communities mature; ungulate numbers decrease to roughly preharvest levels. Black bear populations in forested habitats altered by clear-cut logging appear to exhibit dynamics similar to those of ungulate populations.

This paper describes the characteristics of an island black bear population over a 10-year period in habitat altered by clear-cut logging. Based on these observations we predict changes that will occur in the black bear population as a result of a clear-cut logging program proposed for the island.

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STUDY AREA

The study was conducted on Long Island, a 2,105-ha island in the southern portion of Willapa Bay of southwestern Washington. The island, vegetatively and topographically similar to much of coastal Oregon and Washington, falls within the *Picea sitchensis* vegetation zone (Franklin and Dyrness 1973). Logging has dominated land use on the island, as it has in surrounding coastal forests. Logging began slightly before the turn of the century and continued intermittently until 1968. About 44% of the forested portion of the island was clear-cut in the 1950s and 1960s. Postharvest treatments to speed reforestation (planting, herbicides, fertilization) were uncommon. The road network resulting from logging programs provided access to most of the island.

Although influenced locally by degree of scarification and site quality, successional patterns of the vegetative communities following logging on the island were similar to those observed elsewhere in coastal forest of the Pacific Northwest (Franklin and Dyrness 1973, Long 1973). The grass-forb stage dominated cutover areas for 3–5 years until gradually replaced by shrub species primarily, salal (*Gaultheria shallon*), evergreen huckleberry (*Vaccinium ovatum*), and red huckleberry (*V. parvifolium*). The shrub stage dominated for about 10 years until it in turn was suppressed by conifer regeneration. After 20 years, closure of the overstory was nearly complete in most areas. Shrub species disappeared from the understory in areas of dense conifer regeneration but reappeared

gradually as 2nd-growth stand matured. Shade, however, severely limited fruit production by shrubs occupying the understory of these stands.

Barber (1983) estimated stem density and berry production per stem in varying age clear-cuts on the island for the 3 fruit-producing species that dominated the bear's diet. Mean stem density of salal, evergreen huckleberry, and red huckleberry in clear-cuts 11–16 years of age was 35,388 (SE = 4,910), 619 (SE = 305), and 1,656 (SE = 447) per ha, respectively. The mean number of berries per stem for these 3 species in these clearcuts was 7 (SE = 3), 249 (SE = 59), and 59 (SE = 17), respectively. Stem density of salal, evergreen huckleberry, and red huckleberry in clearcuts 20–27 years of age was 669 (SE = 164), 625 (SE = 232), and 44 (SE = 19) per ha for the 3 species respectively. Berry production per stem was also reduced in these older clearcuts to means of 0, 6 (SE = 3), and 1 (SE = 0.7) for the 3 species.

In 1973, 22% of the island consisted of clearcuts 5–10 years of age, and an additional 16% consisted of clearcuts 14–21 years of age. By 1980, however, only 16% of the island supported clear-cuts less than 21 years of age, and all of these were between 12 and 17 years of age. As a result of vegetative succession, clear-cuts on the island produced progressively less food for the bears through the term of the study. By 1980, from the standpoint of food abundance alone, the island's carrying capacity for bears was only 50% of what it had been in 1973.

The island is separated from the mainland by as little as 300 m on its southern end; about 30% of its shoreline is less than 0.5 km from the mainland. During low tides most of the area between shorelines is exposed mudflats.

Only archery hunting was allowed on the island. The 6-week season typically began in the 4th week of October through 1979. In 1980, to make the island's season comparable to that on the mainland, the season began on 6 September. The island was closed to bear hunting in 1981. Hunting intensity on the adjacent mainland varied during the study period, but bear hunting regulations were very liberal until about 1976. We interpreted this to mean that until 1976 bear density on the mainland was more suppressed than on the island.

METHODS

Size and composition of the black bear population on Long Island were monitored between 1973 and

1982 through a combination of trapping, visual observations, and telemetry relocations. Bears were trapped in 1973–74, 1978, and 1980–81 and radio-monitored during the 1973–74 and 1980–82 periods. Bears were relocated daily, and selected bears were relocated more frequently. Visual observations of bears complemented other data during the years of trapping and provided the only data in 1975 and 1970. Level of trapping effort and methods were similar among years.

Bears were captured using Aldrich foot snares, culvert traps, and occasionally using trained dogs. The right upper lip of each bear was tattooed with an identification number, and ears were tagged with unique combinations of colored ear tags or ear tags that held colored patches of material in place. Radio-transmitter collars were also color-coded to allow identification. A more complete description of capture methods is found in Lindzey and Meslow (1977a). Each bear was examined for scars and wounds. Counts of annuli in the cementum of a 1st premolar provided estimates of each bear's age (Stoneberg and Jonkel 1966). Radio-tagged females were examined in their dens during the winters of 1973–74, 1980–81, and 1981–82.

We attempted to place traps in a pattern that would potentially reach each bear on the island; however, some timbered areas distant from roads were not trapped. These areas were searched for sign and often baited to detect the presence of unmarked bears. Additionally, each bear that was captured in a timbered area distant from clear-cuts was subsequently observed in 1 or more clear-cut areas, suggesting that trap sites were available to each bear on the island. Visual observations of bears were made from vantage points that overlooked clear-cut areas, shorelines, and tidelands associated with the major slough systems entering the island. Although visibility deteriorated in clear-cuts as conifers became more dominant, bears were highly visible on tidelands and shorelines throughout the study.

Spring population estimates (1 May) were determined by combining trapping records with visual observations of marked bears and correcting for known deaths, dispersal, and production. Annual estimates were corrected as necessary upon subsequent capture of unmarked bears of sufficient age and reproductive status to make their presence probable during earlier years.

Movement patterns of radio-collared bears were evaluated to identify the possible presence of additional bears. Areas of suitable habitat used only in-

frequently by collared females and frequented by breeding males during the breeding season, were investigated further for sign of additional females.

When possible, we estimated the age and sex of unmarked bears based on size, location on the island, and behavior of adjacent radio-collared bears. Estimates of production were based on performance of radio-collared females. Male-female associations were carefully monitored during the breeding season (Barber and Lindzey, this volume). Dens of the females were visited in late January or February, and the immediate vicinity of each was searched at that time and after the females emerged in the spring. Females with cubs were monitored closely to document cub survival.

RESULTS

Fifty-one bears over 1 year of age were captured on the island during the 10-year period: 23 bears were captured in 1973–74, 22 in 1978, and 28 in 1980–81 (Tables 1 and 2).

Population Size

Based on age of bears trapped in 1973–74 the black bear population on the island apparently began to grow during the mid-1960s from a small number of bears that had remained during the extensive logging in the 1950s and the 1960s (Lindzey and Meslow 1977). By 1973, 24 bears over 1 year of age were present on the island and by 1975 the population had increased to 33, with the greatest increase occurring in the adult (3+ years) female cohort. The total number of bears on the island in 1978 was only slightly less than it had been in 1975. Absolute numbers remained about the same in 1980 but began to decrease in 1981; by 1982 only 22 bears were present on the island. Adult females comprised the majority of bears in the population through the 10-year period and were responsible for most of the change in numbers. Mean age of the population, excluding cubs, increased from 3.8 in 1973 to 7.5 in 1981 (Tables 1 and 2).

All radio-collared adult females gave birth to cubs in 1973 or 1974 and successfully raised all or part of the litter until the following fall 1974 ($N = 6$). The youngest females to give birth were 4 years of age during this period, and average litter size of all females was 1.83 ($N = 6$). None of 11 adult females monitored in 1980, however, was accompanied by cubs. Two of these females were killed by archers, and a 3rd left the island before the 1980–81 winter.

Table 1. Age of female black bears on Long Island, Washington, 1973–82.*

Age	Year										
	73	74	75	76	77	78	79	80	81	82	
1	5	1	5 ^b	4	1	1	—	2	—	2 ^b	
2	—	5	1	5	4	1	—	—	1	—	
3	2	—	5	1	—	4	1	—	—	1	
4	—	2	4 ^c	5	1	—	3	2 ^c	—	—	
5	4	—	2	4	5	1	0	3	2	—	
6	—	4	—	2	4	5	1	—	1	1	
7	2	—	4	—	2	4	5	1	—	—	
8	—	2	—	4	—	2	3	4	1	—	
9	1	—	2	—	3	—	2	2	4	1	
10	—	—	—	2	—	3	—	2	2	4	
11	—	—	—	—	2	—	2	—	1	1	
12	1	—	—	—	—	2	—	2	—	1	
13	—	—	—	—	—	—	—	—	1	—	
14	—	—	—	—	—	—	—	—	—	1	
Unk. adults	—	2	—	—	—	—	—	2	2	2	
Unk. subadults ^d	—	—	—	—	—	1	—	2	2	2	
Total	15	16	23	26	22	24	17	22	17	16	
Adults	10	10	17	17	16	21	17	18	14	12	

* Composition estimated for 1 May. Data for 1973, 1974, 1980, and 1981 are from trapping, telemetry, and observations; year 1982, from telemetry and observations; year 1978, from trapping and observations; years 1975 and 1979, from observations and interpolation between preceding and following years; and years 1976 and 1977, from interpolation between preceding and following year.

^b Assumes 1:1 sex ratio of previous years' surviving cubs.

^c Assumes emigration to island in summer as 3-year-olds.

^d Subadults (< 3 years) of unknown sex.

The remaining 8 females were observed in their dens in late February 1981. Five of these females had cubs: 4 had 2 and 1 had 3. Three females had no cubs in their dens. Seven of these 8 females had been observed in estrous or were located with males during the

preceding (1980) breeding season (Barber 1983). The remaining female, 1 of those without cubs, was not captured until after the 1980 breeding season. By the 2nd week of May 1981 only 3 of the 5 females that had cubs in their den were still accompanied by cubs;

Table 2. Age of male black bears on Long Island, Washington, 1973–82.*

Age	Year										
	73	74	75	76	77	78	79	80	81	82	
1	3	—	5 ^b	—	—	1	—	4	—	2 ^b	
2	—	3	—	5	—	1	1	—	1	—	
3	5	—	3	1 ^c	—	2 ^c	3 ^c	—	—	—	
4	—	5	—	3	1	—	1	3	—	—	
5	—	—	2	—	—	1	0	1	2	—	
6	—	—	—	1	—	—	1	—	1	—	
7	1	—	—	—	1	—	—	1	—	1	
8	—	1	—	—	—	1	—	—	1	—	
9	—	—	—	—	—	—	1	—	—	1	
10	—	—	—	—	—	—	—	1	—	—	
11	—	—	—	—	—	—	—	—	1	—	
12	—	—	—	—	—	—	—	—	—	1	
Unk. adults ^{c,d}	—	2	—	—	—	—	—	2	2	2	
Total	9	9	10	10	2	7	7	11	7	6	
Adults	6	6	5	5	2	5	6	7	6	4	

* Composition estimated for 1 May. Data for 1973, 1974, 1980, and 1981 are from trapping, telemetry, and observations; year 1982, from telemetry and observations; year 1978, from trapping and observations; years 1975 and 1979, from observations and interpolation between preceding and following years; and years 1976 and 1977, from interpolation between preceding and following year.

^b Assumes 1:1 sex ratio of previous years' surviving cubs.

^c Assumes emigration to island in summer as 2-year-olds.

1 had 1 and 2 still had 2. One female had abandoned her 3 cubs in the den and the fate of the 2 cubs of the other female is unknown. We captured 4 other adult females later that year (May and July 1981): 3 of these females had no cubs and the 4th had a single cub. By that November only 2 of the 4 females that had cubs in July still had cubs; each had 2. The following year (1982) 5 of the 8 adult females that remained on the island and were not accompanied by young-of-the-year had cubs by late February. Only 2 of these 11 cubs survived until early May. One female produced cubs as a 4-year-old in 1979 however, suggesting that age at 1st breeding remained young in the population. Average size of litters in 1980–81 was 2.2. Females with cubs characteristically emerged from dens between the 1st and 3rd weeks of April (Lindzey and Meslow 1976, Barber 1983).

Composition of the population in 1978 suggested that production in the population had begun to decline as early as 1977 (Table 1). We captured only 2 1-year-old bears and observed 1 other that may have been a 1-year-old. If only half ($N = 9$) of the adult females had given birth to 2 cubs each the previous year (1977) and they had survived, 18 1-year-olds should have been present in 1978. Additionally, we observed only 2 or possibly 3 cubs in 1978. Only 2 2-year-old bears (born winter 1976–77) were present on the island in 1978, suggesting reduced production or survival in 1977 as well, although this cohort presumably could have dispersed before our trapping efforts in 1978.

Dispersal-Recruitment

Observation of dispersal between 1973 and 1975 (Lindzey and Meslow 1977b) indicated that male progeny dispersed during the spring or early summer as 4-year-olds. Most female progeny, on the other hand, appeared to be accepted into the resident population. Four female bears born in 1972 and tagged in 1973 were present in 1978, and 3 were still present in 1980; none of 3 males born the same year were located on the island after 1974. Additionally, a male born in 1973 was not observed on the island after 1974.

Most progeny, male and female, apparently dispersed from the island in 1974 or after. We estimated that a minimum of 10 cubs were born in 1974, but no 4-year-old bears were captured in 1978 and none belonging to this cohort were captured in 1980 or

1981. Six 3-year-old bears (2 males, 4 females) were, however, present in 1978, presumably representing 1975 births or perhaps individuals that had immigrated from the mainland. By 1980–81, only 2 of these bears (1 male, 1 female) remained on the island. Of 5 1-year-old bears captured in 1980, 2 died on the island and the 3rd, a male, dispersed.

Physical Interactions

Scarring and wounds on bears that may have been inflicted by other bears, were uncommon in each period. No bears were killed by other bears while they were in snares in 1973–74 or 1978; however, 2 1-year-old bears (1 male, 1 female) were killed by another bear in 1980 while they were in snares. We believe that both of these subadults were killed by the same 4-year-old, radio-collared male. Additionally, 2 other free-ranging, collared males (a 1-year-old and a 2-year-old) were consumed by another bear after they had apparently been killed by that bear. Two adult females and their cubs were killed while in their dens and partially consumed by other bears during March of 1982.

Morphometric Variation

Although comparisons of weights of bears among trapping periods is tenuous because the distribution of capture dates differed, there appeared to be little difference in weights of adult females. Average weights were 63.4, 51, and 57.2 kg for the 3 periods, respectively. The weights of 4 females that bred in 1973–74 and were present in 1980–81 also changed little (58.3–55.9 kg, 68.5–56.8 kg, and 78.2–74.6 kg). It is interesting, however, that both average weights and the weights of the 4 females were less during the later study phase.

DISCUSSION

We believe that the changes observed in the island's bear population were in response to varying levels of food abundance brought about by normal succession in the vegetative communities of clear-cut areas. Initially the island offered extremely abundant food resources, but this abundance peaked about 1976 and declined markedly over the next 6 years. Changes in black bear population size corresponded with changes in food resources. Variations in levels of production, cub survival, recruitment, dispersal of progeny and adults, and conspecific aggression within the population facilitated both the growth and decline.

Observations of females during the breeding season indicated that they all had bred (Barber and Lindzey 1983). Further, because they are induced ovulators it seems likely that fertilization rates were high (Bunnell and Tait 1981) and that most, if not all, females were pregnant after the breeding seasons. On 6 occasions (1980 and 1981) females apparently did not give birth to cubs, although we visited dens as late as 2–3 weeks after the estimated birth period (Lindzey and Meslow 1977a). The missing cubs could have been consumed or removed from the den. We found no sign of cubs in or near these dens, however, and it also seems unlikely, because of the physical state of bears during dormancy (Nelson 1973), that females would have eaten their cubs. Termination of pregnancy before the cost of the developing fetuses was incurred seems an efficient strategy for females in a nutritionally tenuous condition. In bears this could be accomplished by simply not implanting the blastocyst after the delay period, as suggested by Bunnell and Tait (1981). Similarly, rejection of young cubs by nutritionally stressed females would be a sound strategy for long-lived species. Stirling et al. (1976) observed that underweight female polar bears (*U. maritimus*) often gave birth and subsequently lost cubs rather than not give birth at all. Complete litter loss was the rule for bears on the island that left the den with cubs and subsequently lost them. Rogers (1976) identified the relationship between food abundance and reproductive success in black bears in Minnesota.

Conspecific aggression, the death of 2 bears during the archery season, and to a lesser extent emigration, caused the population decrease during the study's last 3 years. Six bears—2 adults and 4 subadults—were killed by other bears during this period, and 2 died from trap-related injuries. Age at dispersal had decreased after about 1974, and male and female progeny apparently emigrated—presumably in response to pressures exerted by the residents. It seems probable that conspecific aggression will continue to influence the dynamics of this population as habitat quality on the island continues to deteriorate with respect to food abundance.

Adult males have been assumed to regulate populations through aggression that directly or indirectly kills subadults or accelerates their dispersal from the population (Kemp 1974, McCullough 1981, Young and Ruff 1982). It seems plausible, however, that adult females contribute in a similar manner to a population's dynamics. The acceptance of female

progeny into the resident population appears more likely the province of resident females, the cohort with which new females would compete most directly. Male progeny compete for food resources with male and female residents; potentially they compete for females with adult males and thus should elicit aggressive behaviors from both sexes of adults that result in dispersal. The adult female cohort predominated in the island population throughout the study period. Numbers of adult males, on the other hand, changed little but decreased proportionately as population size increased.

Emigration of adults from the island has occurred as the population seeks to balance its numbers with decreasing resources. By 1980 2 of the long-time resident females (10 and 12 years of age) began to include parts of the mainland in their ranges. One of these females subsequently remained on the mainland in 1981. Another 12-year-old female moved to the mainland in 1982 and apparently remained (Barber 1983). Breeding males remained on the island year-around in 1973–74 (Lindzey and Meslow 1977b); however, they resided on the island only during the breeding season in 1980–82 (Barber 1983).

High densities of black bears in coastal forests that have been modified by logging are common (Poelker and Hartwell 1973). Despite their relatively low reproductive potential, black bear populations can increase relatively rapidly when provided high-quality food resources and some adjoining cover. Newly created habitats may be filled quickly by dispersing subadults, female young produced by the small numbers of bears that resided in the forests before logging, and adults emigrating from surrounding areas where succession has reduced carrying capacities.

We expect the Long Island black bear population to continue diminish in size until about 1988 if no logging takes place in the interim. Food availability should be at its lowest point at this time. The adult emigration that began in 1981 will probably be the major contributor to the future decline in numbers. Reproductive performance should remain poor unless declining densities allow the remaining females to increase their ranges and find sufficient nutrient resources to successfully raise young. If the proposed logging program for the island is implemented, 412 ha of timber will be harvested by clear-cutting 2-year intervals over a 12-year period. Although the influence of logging operations on bears is unknown, our observations on the island suggest the population should begin to increase 3–5 years after the initial

block cut and reach maximum density 4–6 years after the last.

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