

# MORPHOMETRIC CHARACTERISTICS OF BROWN BEARS ON THE CENTRAL ALASKA PENINSULA

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*Abstract:* On the central Alaska Peninsula 344 different brown bears (*Ursus arctos* L.) were measured during 502 captures in 5 spring seasons, 1970-75. Height at shoulder, chest girth, total body length, body length, neck circumference, hind-foot length, zygomatic width, skull length, total skull size, and body weight were measured and classified by sex and cementum age. Growth rates were plotted. No morphometric differences were detected between sexes at 6 months of age, but sexual dimorphism was evident by 1.5 years of age and persisted through life. Except for zygomatic width, female bears attained at least 95 percent of ultimate body dimensions between ages 4 and 6 years and males between ages 6 and 8 years. Zygomatic width was the last dimension to attain ultimate size. Extensive size overlap was demonstrated among bears 1.5 years and older of the same sex. Superior size-weight correlations were derived from zygomatic width. It was demonstrated that the sex of bears over 9 years of age could be determined on the basis of total skull size. Serial measurements of adult bears were tested for accuracy of repetitive measurements. Skull dimensions were the least affected by inaccuracies in measuring technique. Correlations ( $r^2$ ) for models tested revealed that skull dimensions were the best indicators of growth rate. Of the 10 dimensions studied, none provided a reliable age substitute for counting cemental annuli.

Rausch (1962) and Pearson (1975) mentioned the small size of brown bears inhabiting interior regions of Alaska and Canada. There are few published data, however, that described size of brown bears inhabiting coastal regions of southern Alaska. The Alaska Peninsula and Kodiak Island group may contain the largest living brown bears. Erickson (1965) reported that exceptional specimens from these areas may attain weights of 590 kg. Coastal bears are usually larger than interior forms; differences in size are probably genetically determined and influenced by climatic and nutritional conditions. The objective of this investigation was to describe morphometric characteristics, using sex and age correlates, of a brown bear population in a coastal environment of southwestern Alaska. I also evaluated the utility of body dimensions as indicators of age, sex, and weight.

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## STUDY AREA

The study area (approximately 8,547 km<sup>2</sup>), located on the central Alaska Peninsula, is bounded on the southeast by the Pacific Ocean, on the northwest by Bristol Bay, on the northeast by Mount Aniakchak (1,021 m), and on the southwest by Mount Veniaminof (2,226 m). A detailed physiographic description of the region was presented by Glenn and Miller (1980).

## METHODS

Bears were immobilized and marked using techniques described by Glenn and Miller (1979). Approximately 100 bears were captured each June from 1970 through

1972, and in June 1974 and 1975. Because all measurement data were collected in spring, size difference associated with seasonal variation was small.

A steel tape graduated in millimeters was used to record 6 different body and 2 different skull measurements from 344 immobilized brown bears; 502 sets of measurements were taken. Most of these bears were also weighed.

Body dimensions were as follows: height at shoulder — distance from superior angle of the scapula to the tip of the longest claw; body length — excluding tail, the distance along the lateral side of the body between the tuber scapulae and the base of the tail; total length — distance between the tip of the nose and tip of the tailbone, with the measuring tape following the contour of the head and spine; hind-foot length — distance from the heel to the tip of the longest claw; chest girth — circumference of chest just posterior to the posterior edge of the scapulae; neck circumference — distance between the occiput and the base of the neck. Circumferential measurements were made with the steel tape held snugly.

Cranial measurements were taken by positioning the points of calipers and pressing them firmly against the skin and underlying bone. Skull length was determined by measuring the distance between the most anterior surface of a first upper incisor and the posterior protuberance of the parietal crest. This measurement was taken after the bear's head had been tilted toward its chest, thereby providing better exposure of the posterior reference point. Zygomatic width was measured at the widest point of the zygomatic arches. For purposes of this paper, total skull size was considered to be the sum of zygomatic width and skull length, and total body size the sum of the 8 variables.

Bears weighing less than 90 kg were weighed with a hand-held 90.7-kg capacity spring scale. Heavier bears

were suspended beneath a helicopter in a cargo net, and weights were recorded by the pilot from a digital readout electronic weighing system (Chadwick Inc., Beaverton, Oregon) accurate to  $\pm 2.3$  kg.

One upper first premolar and one lower first premolar were taken from each bear older than cubs-of-the-year. Age of these animals was determined by sectioning these teeth and counting cemental layers (Mundy and Fuller 1964, Craighead et al. 1970, Willey 1974).

Because few adult males were captured, fleshed skulls of Alaska Peninsula bears over 9 years of age, obtained from hunters, were used to compare cranial differences between sexes. To allow conversion of fleshed skull measurements to the live head size, a conversion factor was developed for a subsample ( $N=4$ ) of skulls from male bears by comparing the difference in size before and after skulls were fleshed. The conversion factor for skulls from females was based on the difference between the mean skull size of the fleshed sample ( $N=22$ ) and the mean skull size of the live sample ( $N=54$ ). The zygomatic width of fleshed skulls averaged 93 percent of the live head width for males and 97 percent for females; skull length of fleshed skulls averaged 97 percent of live head length for both sexes, and total skull size of fleshed skulls averaged 96 percent of live head size for males and 97 percent for females.

For purposes of comparison, skull dimensions were considered ultimate by 15 years of age and body measurements were considered ultimate by 10 years of age. The value for percentage of each ultimate body dimension was determined by dividing the mean size of each age-class by the mean value of the ultimate body size. For example, mean body length of 6-month-old females, 46.9 cm, divided by 123.4 cm, the mean size of the 10+ -year-old (ultimate size) females, is 38 percent.

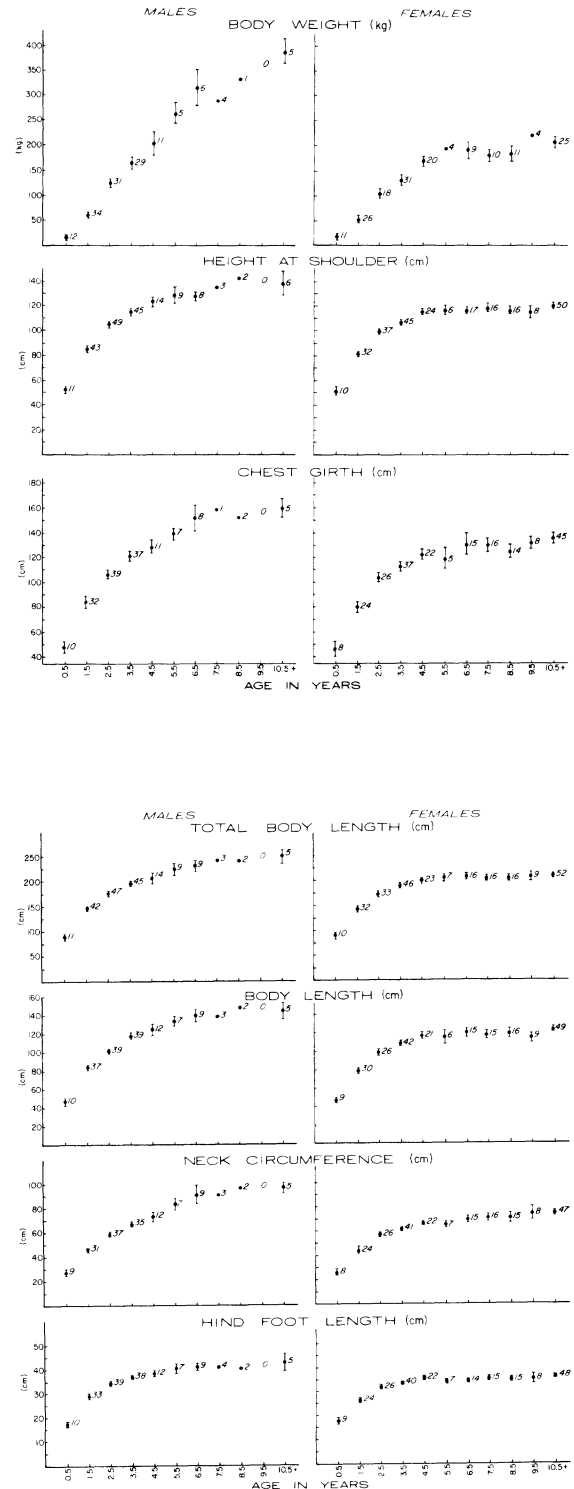
RESULTS

Characteristics of Growth

Fig. 1 provides a graphical presentation of body measurements made on Alaska Peninsula brown bears, reflecting the rate and duration of growth by sex and age. Sample size varied with each dimension but usually included more than 225 females and more than 150 males.

No sex-related differences in body size were apparent at age 6 months, but yearling males were significantly larger ( $P<0.001-0.05$ ) than yearling females in zygomatic width, total skull size, height at shoulder, and hind-foot length. Males at age 2 years were significantly

Fig. 1. Change in body size by age-class of brown bears captured on the Alaska Peninsula during June 1970-72 and 1974-75. Vertical lines extending through the means represent 95 percent confidence limits on means. Numbers represent sample sizes.





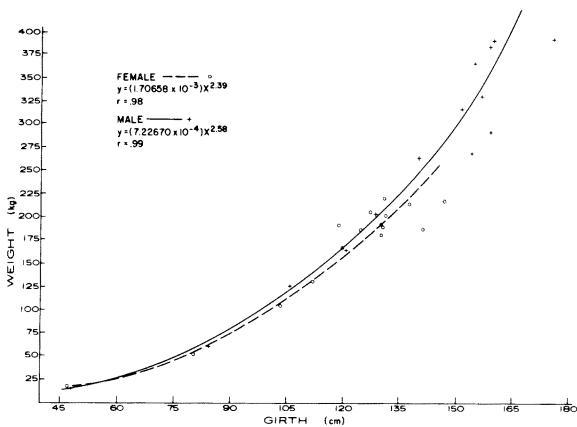


Fig. 2. Curvilinear relationship of chest girth to spring weight of live-captured brown bears, Alaska Peninsula, 1970-72 and 1974-75.

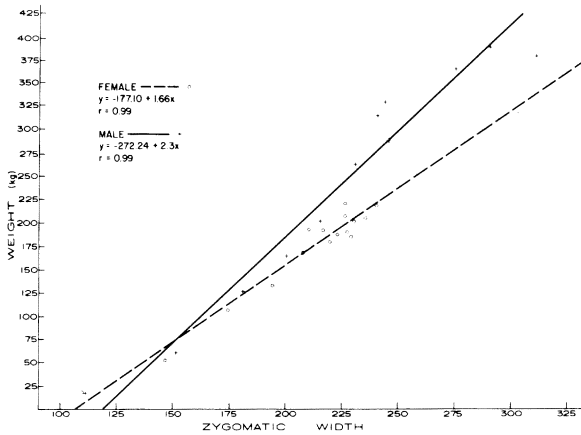


Fig. 3. Linear relationship of zygomatic width to spring weights of live-captured brown bears, Alaska Peninsula, 1970-72 and 1974-75.

recorded. Between 23 June and 15 August, this male increased in weight from 97.8 kg to 125.0 kg, a net increase of 27.3 kg (22 percent) in 53 days.

Size overlaps among age-classes characterized the Alaska Peninsula bear population. Statistical comparison (0.05 level of significance) by sex between age-classes for the expected range in body dimensions resulted in the following conclusions: (1) no dimension overlap occurred between bears aged 6 months and 1.5 years; (2) except for cranial dimensions and weight of males, yearling bears, were separated in size from bears 4 years old and older but not from bears 2 and 3 years old; and (3) except for weight and skull dimensions, sizes of 2-year-old males overlapped the sizes of other males in most age-classes between ages 1.5 and 6.5 years, and 2-year-old females overlapped in size between 1.5 years and older. When cranial dimensions and weights of males were considered, size separation for each sex was evident in bears between ages 1 and 3 years. Beyond ages 3.5 years in females and 4.5 years in males, these dimensions overlapped. When the actual range in each

body dimension was compared with the expected range, data support conclusions at the 0.05 level of significance.

### Measurement Reliability

Computing the coefficient of determination ( $r^2$ ) for the linear fit of weight data and the logarithmic fit of body size data (ages 6 months through ages 10 years and older) provided an indication of dimension value. For these models, correlations were highest for the 3 skull dimensions (males,  $r^2=0.92-0.94$ ; females,  $r^2=0.85-0.91$ ) and lowest for the 6 body size dimensions (males,  $r^2=0.84-0.88$ ; females,  $r^2=0.76-0.79$ ). Correlations for weight were similar to correlations for body size (males,  $r^2=0.82$ ; females,  $r^2=0.84$ ).

Serial measurements on 13 females 10+ years old captured 28 times provided data with which to calculate the degree of reliability of measurements. The difference between maximum and minimum size for each dimension for each year was determined and expressed as a percentage of the maximum measurement. The mean percentage value was then determined for the sample. Each dimension with its corresponding percentage values follows in order of decreasing reliability: skull length, 0.9 percent; total skull size, 1.3 percent; zygomatic width, 2.1 percent; total body length, 5.2 percent; hind-foot length, 5.3 percent; height at shoulder, 5.4 percent; body weight, 6.3 percent; body length, 6.8 percent; chest girth, 10.1 percent; and neck circumference, 10.5 percent.

### Characteristics of Skull Growth

Annual increments in zygomatic width and skull length were analyzed to determine their applicability for predicting mean age of male and female bears. The power curve and formulae used to show this relationship are presented in Fig. 4. Zygomatic widths show a higher relationship (males,  $r=0.98$ ; females,  $r=0.97$ ) than skull lengths (males,  $r=0.95$ ; females,  $r=0.92$ ). These data made it possible to accurately predict mean age of young bears. Corresponding ages for mean zygomatic width were discrete through age 3 years for females and through age 4 years for males. Age predictions within older age-classes were not precise but closely approximated true mean age.

Zygomatic width was at least 98 percent complete in 12 of 14 recaptured females by age 10 years. Five females had attained this maximum growth dimension by age 8 years. One female (19) was captured at ages 5, 6, 8, and 10 years; her respective zygomatic widths at these ages were 210 mm, 213 mm, 216mm, and 216 mm. Another female, captured at ages 8 and 11 years

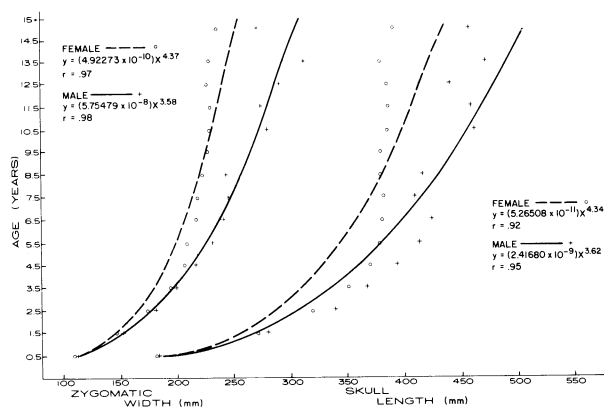


Fig. 4. Curvilinear relationship of zygomatic width and skull length to age of brown bears captured on the Alaska Peninsula during June 1970-72 and 1974-75.

(864), maintained a width of 219 mm. After females had attained the age of 8 years, annual increments in serial skull widths were difficult to detect. Skull length was at least 98 percent complete in most recaptured females by age 6 years. Two females attained this dimension by age 5 years. One female (747), captured at ages 5, 6, 7, 9, and 10 years, had respective skull lengths of 384 mm, 391 mm, 395 mm, 396 mm, and 394 mm. After females had attained the age of 6 years, annual increments in serial skull lengths were difficult to detect, as indicated in the preceding example. Sample size was too small to determine the mean ages at which males complete 98 percent of ultimate skull width and length. Serial measurements of 2 adult males, however, suggested that zygomatic width is 98 percent complete by age 12 years and skull length by age 8 years.

There was no overlap in total skull size of male and female bears older than 9 years. The minimum size of fleshed male skulls was greater than 644 mm and maximum skull size of females was smaller. Similarly, there were no overlaps between the expected ranges in fleshed total skull sizes of males (range, 651-727) and females (range, 577-636). Within the sample of live males, those older than 9 years had significantly larger ( $P < 0.001$ ) skulls than female bears of the same age. Findings were also similar when comparisons were made between the sample of fleshed male skulls and the sample of live female skulls adjusted to fleshed skull size. The total skull size of the smallest capture male (423, age 11 years) was 681 mm (654 mm converted to fleshed size); the skull of the largest female (825, age 15 years) measured 654 mm (634 mm fleshed). Bear harvest records ( $N=535$ ) show that the largest adult female skull (certificate no. 4230) originating from the Alaska Peninsula measured 638 mm fleshed.

## DISCUSSION

Although between-year comparisons of body dimensions of males aged 6 years and older and of females aged 10 years and older were based on small samples, serial measurements of adult bears and measurements derived from all family members of family units both supported definition of size characteristics.

Because there were no statistical differences in size between 6-month-old male and female bears, morphometric data for both sexes can be combined. Beyond age 6 months, *t*-tests and range values for the expected dimensions of body size justify separation of male and female morphometric data. As age increased, there was an increasingly apparent difference in body dimensions between sexes (Fig. 1). Maximum female growth was attained approximately 2 years before that of males.

Except for zygomatic width, weight, and the weight-related dimensions of neck and chest girth, females reached 95 percent of ultimate size by age 4.5 years and males by age 6.5 years. The female age of physical maturity corresponds to the age of sexual maturity reported by Glenn et al. (1976) for brown bears at McNeil River, Alaska. Pearson (1975) reported that observed known-age female brown bears of the Yukon Territory, Canada, were not sexually mature under age 6.5 years.

Spring weights of female bears increased rapidly through age 5 years. Subsequent weight gain appear to depend mostly on a bear's individual size and seasonal physical condition. Serial between-year weights of ultimate-size bears indicated less than 10 percent variation. The heaviest male (18) weighed 442 kg and was 10 years old. The heaviest female (825) weighed 277 kg and was 15 years old. Mean weights of 5 males and 25 females over 9 years of age were 389 kg and 207 kg, respectively. The weights of these adults were considerably heavier than mean weights given by Pearson (1975) for adult (minimum age and dates of weighing not given) brown bears in interior Canada. Data comparisons indicate that Alaska Peninsula males were 2.8 times heavier and females 2.2 times heavier than interior Canada males (139 kg,  $N=40$ ) and females (95 kg,  $N=21$ ) respectively. The degree of size difference attributable to environmental or to genetic factors has yet to be determined. Growth rates of brown bears raised in captivity suggested that adult size is generally fixed. Growth response under captive conditions, however, may not reflect comparable size response in free-roaming bears that are subjected to extreme changes in climatic, dietary, and other environmental conditions.

Chest girth and zygomatic width showed a close cor-

relation to weights. Subjective examination of the power curve for chest girth (Fig. 2) indicates that male and female weight data can be pooled as 1 model that would serve to estimate weight. Although either measurement can be used to estimate spring weight, in certain instances 1 measurement may prove more applicable than the other when models are determined at other seasons of the year.

Only within broad limits does body size relate to age. Beginning at age 1.5 years, bears of the same sex and age exhibited a wide range in body size within and between litters. Differences in size are probably influenced by genetics, time of birth, nutrition, parental care, sibling competition, and many other factors. Two examples serve to illustrate these differences. The weights of 3 sibling males (80, 82, 83) ages 1.5 years were 27.3 kg, 31.8 kg, and 48.2 kg, respectively. Their respective total lengths were 116 cm, 123 cm, and 145 cm, and heights at shoulder were 69 cm, 74 cm, and 78 cm. The stage of eruption of the permanent canine teeth also varied greatly among these yearling males. The lengths of their left upper canine, as measured above the gum line, were 8 mm, 0 mm, and 11 mm, respectively. In the other example, the average weight of 2 sibling females (24, 25) ages 1.5 years, 30.7 kg, was considerably less than that of 3 sibling females (840, 841, 842) of the same age in a different litter, 53.6 kg. Adult skull sizes varied greatly. For example, the total skull size of male 423 at 16 years was 681 mm, which is considerably smaller than the 720-mm total skull size of male 112 at age 6 years. All body dimensions exhibited a high degree of variation beyond that attributable to age.

Variation in size of young was so great that visual age determination is essentially impractical. Trained observers on the ground could distinguish cubs up to age 8 months from older animals with little difficulty, but by late October aerial observers flying in fixed-wing aircraft or helicopters had difficulty distinguishing large, well-furred cubs 10 months old from small young older than 1.7 years. Except for cubs-of-the-year, it is unlikely that experienced observers could accurately determine age of free-roaming young in family groups.

Even after capture, errors occurred in estimating age of young within 15 of 62 family groups (24 percent error). Age estimates were further complicated by the fact that some adult females retained their young for 3.5 years. (It is normally considered that young are retained only until 2.5 years of age, Glenn et al. 1976.)

When sex and age are known, all body measurements have descriptive value; only a few, however, are of practical significance. Of the 9 dimensions considered, skull measurements were the best indicators of growth rate and measurement reliability. This conclusion is supported by serial data, tested for dimension variation, and by correlations ( $r^2$ ) for dimension models. Such data demonstrated that skull measurements provided the most sensitive indicators of annual growth increments and were least affected by any or all of the following variables: position of the body when measured, tension on the measuring tape, use of indistinct reference points for measurements, annual differences in the bears' physical condition, and individual differences in technique of measurement. For these reasons, collection of skull measurements should receive priority.

On the Alaska Peninsula, the sex of bears over 9 years old can be determined on the basis of total skull size. This finding is especially useful when the sex of a fleshed skull of a mature bear is unknown. If age determined from tooth cemental layers is greater than 9 years, a fleshed skull can be considered that of a female if its size is less than 644 mm. Conversely, it can be considered the skull of a male if its size is greater than 644 mm at any age.

The potential for age prediction based on mean skull dimensions was tested by using models for zygomatic width and skull length (Fig. 4). Although correlations ( $r$ ) between zygomatic width and age were high, I believe the method has almost no utility in predicting the age of individual bears because of the wide range in skull size among bears of the same sex and age. At this time it appears that counting of cemental layers is the only reliable method for determining the age of individual bears.

#### LITERATURE CITED

CRAIGHEAD, J. J., F. C. CRAIGHEAD, JR., AND H. E. MCCUTCHEM. 1970. Age determination of grizzly bears from fourth premolar tooth sections. *J. Wildl. Manage.* 34(2):353-363.

ERICKSON, A. W. 1965. The brown-grizzly bear in Alaska, its ecology and management. Alaska Dept. Fish and Game Fed. Aid in Wildl. Restor. Proj. W-6-R-5, Rep. 5. 42pp.

GLENN, L. P., J. W. LENTFER, J. B. FARO, AND L. H. MILLER. 1976. Reproductive biology of female brown

- bears (*Ursus arctos*), McNeil River, Alaska. Pages 381-390 in M. R. PELTON, J. W. LENTFER, AND G. E. FOLK, JR., eds. Bears — their biology and management. IUCN Publ. New Ser. 40.
- . AND L. H. MILLER. 1980. Seasonal movements of an Alaska Peninsula brown bear population. Pages 307-312 in C. J. Martinka and K. L. McArthur, eds. Bears — their biology and management. U.S. Government Printing Office, Washington, D.C.
- MUNDY, K. R., AND W. A. FULLER. 1964. Age determination in the grizzly bear. *J. Wildl. Manage.* 28(4):863-866.
- PEARSON, A. M. 1975. The northern interior grizzly bear *Ursus arctos* L. *Can. Wildl. Serv. Rep. Ser.* 34. 86pp.
- . 1976. Population characteristics of the arctic mountain grizzly bear. Pages 247-260 in M. R. PELTON, J. W. LENTFER, AND G. E. FOLK, JR., eds. Bears — their biology and management. IUCN Publ. New Ser. 40.
- RAUSCH, R. L. 1962. Geographic variation in size in North American brown bears, *Ursus arctos* L., as indicated by condylobasal length. *Can. J. Zool.* 41(1):33-45.
- WILLEY, C. H. 1974. Aging black bears from first premolar tooth sections. *J. Wildl. Manage.* 38(1):97-100.