

INTERPOPULATION APPLICABILITY OF EQUATIONS TO PREDICT LIVE WEIGHT IN BLACK BEARS

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Abstract: Body measurements and live weights were obtained from 3 black bear (*Ursus americanus*) populations in Montana. Although high correlation coefficients were usually found between \log_{10} of weight and \log_{10} of chest girth and between weight and a body size index (total length times chest girth squared), the regressions were significantly heterogeneous ($P < 0.05$) between males and females and between the females of 1 population and the other 2 populations. Interpopulation and sexual variations in the body proportions of black bears preclude the development of 1 accurate equation for the species or even for the populations found in Montana; however, both the intercepts and the exponents of the chest girth and the \log_{10} weight— \log_{10} chest girth equations were significantly correlated ($P < 0.025$) with the elevations of 8 study areas, suggesting that equations may be developed that are valid within elevational zones.

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An available model permits managers of black bear populations to estimate the maximum mortality rate that a population can sustain. It requires estimates of mean litter size, mean interval between litters, and age at 1st reproduction for females (Bunnell and Tait 1981). Only data on litter size are easily obtained in the field. The age of 1st reproduction in bears is nutritionally determined (Rogers 1976, Bunnell and Tait 1981) and can be inferred from growth rate data (Beecham 1980, Bunnell and Tait 1981, Kingsley et al. 1983). Reproductive activity in black bears apparently begins after they attain a spring body weight of about 50 kg (Beecham 1980).

Because the age of 1st reproduction varies among populations (Rogers 1976, Beecham 1980), managers must determine it for each population. In Montana, many bears are handled annually in response to damage complaints. Most often, these bears are immobilized, but they are rarely weighed because the personnel are often working alone and usually do not have access to scales. If an accurate estimate of weight could be obtained from 1 or 2 body measurements, managers could obtain much more weight data from female black bears. Hunters would also be interested in a method to help them estimate the live weight of the bears they harvest.

High correlations between chest girth measurements and body weight have been reported from all species of North American bears (Payne 1976, LeCount 1977, Stirling et al. 1977, Glenn 1980, King-

sley et al. 1983, Nagy et al. 1984, Waddell and Brown 1984). However, it is important to know if 1 formula is adequate for bears throughout a large area. Nagy et al. (1984) found no difference in chest girth—weight relationships between 2 grizzly bear (*U. arctos*) populations in the Yukon and Northwest territories, but both of these differed significantly from grizzly bears in Alberta. Data from both sexes have been pooled in other studies (Payne 1976, Stirling et al. 1977, Glenn 1980, Nagy et al. 1984). Here we examine the applicability of these relationships between sexes and among 3 populations of black bears in western Montana and 5 additional populations across North America.

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STUDY AREA

The Absaroka-Beartooth Mountain complex is in Park, Sweet Grass, and Stillwater counties in south-

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western Montana. The study area is relatively high in elevation (1,463–3,270 m) and dry (36–152 cm annual precipitation). Forests are dominated by lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*), and Engelmann spruce (*Picea engelmannii*). The Cabinet Mountains are in Lincoln and Sanders counties in the northwestern corner of Montana. This study area is lower in elevation (610–2,644 m) and much moister (76–280 cm annual precipitation). Forests are dominated by western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), western larch (*Larix occidentalis*), grand fir (*A. grandis*), and subalpine fir. The East Front of the Rocky Mountains lies along the east face of the Continental Divide in Lewis and Clark, Teton, Pondera, and Glacier counties, northwestern Montana. It is intermediate in elevation (1,280–2,683 m) and is also dry (31–167 cm annual precipitation). Forests are dominated by subalpine fir, lodgepole pine, limber pine (*P. flexilis*), Douglas-fir, and aspen (*Populus tremuloides*).

METHODS

After capture, bears were weighed with spring scales to the nearest pound (later converted to kilograms). Total length was measured with a steel tape from the tip of the nose to the tip of the tail, following the curvature of the head and body. Chest girth was measured immediately behind the front legs with the tape snugged at moderate and uniform tightness.

Only spring bear weights (before 20 July) were used (65 males and 31 females in Absaroka-Beartooths, 82 males and 42 females in the Cabinets, and 38 males and 11 females on the East Front). The ranges of scale weights of the bears were 13.6–145.2 kg in the Absaroka-Beartooths, 9.1–129.5 kg in the Cabinets, and 22.7–143.2 kg on the East Front. The Absaroka-Beartooth data were taken in 1982–85, those from the Cabinets in 1983–85, and those from the East Front in 1984–85.

Linear regressions were calculated using the least

squares method with a computer statistical package (Lund 1983). Residual variances were compared for heterogeneity with a 2-tailed F test (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Several measurements of body size were evaluated for their relationship with body weight (Table 1). All of the resulting linear correlations were significant ($P < 0.05$), but the best fits were usually obtained with a log-log regression of chest girth and weight and a body size index (total length times chest girth squared; B. N. McLellan, Akamina-Kishinena grizzly bear progress report—1980, B. C. Fish and Wildl. Branch, Cranbrook, 1982) and weight. The regressions for the females from the Absaroka-Beartooth area had a consistently poorer fit than the corresponding regressions from the Cabinets and East Front (Table 1).

Variances were heterogeneous for many of the male-female comparisons within populations, but this appeared to vary among populations. Heterogeneous variances were found between the male and female regressions based on chest girth (log), body index, and length in the Absaroka-Beartooth area ($P < 0.05$); between males and females for the body index, chest girth (linear), and length regressions in the Cabinets ($P < 0.025$); but only between the sexes for the length regression on the East Front ($P < 0.005$). Although this analysis suggested that some male and female regressions could be combined in some areas, we concluded that there were enough significant differences to warrant separating the sexes in calculating predictive equations.

Data from the males were less variable than data from females among areas. The only significantly heterogeneous variance among all of the combinations of regressions and areas for males was the length regression for East Front males, which differed from those in the Absaroka-Beartooths ($P < 0.05$) and Cabinets ($P < 0.025$). The remaining data were ho-

Table 1. Coefficients of determination (r^2) for 4 regressions of body measurements-weight relationships in 3 Montana black bear populations.

Regression variables ^a		Absaroka-Beartooth		Cabinets		East Front	
Dependent	Independent	Male N = 65	Female N = 31	Male N = 82	Female N = 42	Male N = 38	Female N = 11
Log ₁₀ W	Log ₁₀ G	0.9524	0.4085	0.9485	0.8398	0.9416	0.7104
W	L × G ²	0.9518	0.4335	0.9536	0.8583	0.9467	0.7530
W	G	0.9406	0.3510	0.9226	0.8321	0.9439	0.6743
W	L	0.8035	0.4722	0.8014	0.6957	0.7486	0.6634

^a W = weight in kg, G = chest girth in cm, L = total length in cm.

Table 2. Equations for predicting live weights of black bears in Montana from body measurements.

Population ^a	Sex	Equation ^b	r ²	N
All	Male	W = 0.00191G ^{2.377}	0.9262	185
		W = 7.673 + 0.00005891I	0.9169	185
CM and EF	Female	W = 0.00955G ^{2.007}	0.8154	53
		W = 8.978 + 0.0000579I	0.8295	53
AB	Female	W = 0.14161G ^{1.353}	0.4085	31
		W = 21.32 + 0.0000354I	0.4335	31

^a CM = Cabinet Mountains, EF = East Front, AB = Absaroka-Beartooth.

^b W = weight in kg, G = chest girth in cm, I = body index (chest girth squared times length in cm).

homogeneous ($P > 0.05$), indicating that they were not drawn from statistically different populations. Therefore, the data for males were combined to calculate predictive equations based on chest girth (log) and the body index (Table 2).

Data from females from the East Front and Cabinets showed no heterogeneous variation between any of the regressions, so they were combined (Table 2). The females in these combined populations differed from those in the Absaroka-Beartooth area in all regressions ($P < 0.001$) except the length regression ($P > 0.10$).

The heterogeneous variances we found among the populations indicate that 1 accurate statewide equation cannot be developed for all black bears in Montana. The predicted weights from selected chest girth measurements differ widely, not only among populations in Montana but among other populations as well (Table 3). Even in the lower weights (< 50 kg), where these regressions are most accurate (Cherry and Pelton 1976), there is considerable variation in regressions developed in different areas (Table 3).

Because of genetic or habitat differences, there may be regional variations in the physical proportions of bodies of black bears that contribute to the differences shown in Table 3. Altitude may also influence body proportions in black bears, as it does in humans. For example, an enlarged thorax is a distinguishing feature of the native highland human (Frisancho 1979). Indeed, we found significant correlations between the highest point of 8 study areas and both the exponent of chest girth (exponent = 2.665 - (0.00013) (elevation), $r = -0.846$, $P < 0.01$) and the intercept (intercept = 0.00005 + (0.000001) (elevation), $r = 0.823$, $P < 0.025$) of the chest girth (log) equations (Table 4). We combined data from males and females from our study areas for this comparison, because the other equations in Table 4 were derived from data from both sexes.

SUMMARY

Regressions using chest girth, with or without total length, appear to be relatively accurate to predict the

Table 3. Calculated weights of black bears from chest girth measurements using 8 equations.

Area	Weight (kg) at given chest girth			Source
	50 cm	75 cm	100 cm	
Insular Newfoundland ^a	15.0	43.3	92.1	Payne (1976)
Pennsylvania ^a	16.6	46.3	95.9	Alt (1980)
Arizona ^a	17.0	46.4	94.8	LeCount (1977)
Maine ^a	17.1	48.6	102.1	Hugie (1980)
Tennessee ^a	18.7	46.4	88.3	Cherry & Pelton (1976)
Montana males ^b	20.9	54.7	108.4	This study
Montana females				
East Front & Cabinets ^b	24.5	55.4	98.6	This study
Absaroka-Beartooth ^b	28.2	48.8	72.0	This study

^a Calculated from equations in Table 4.

^b Calculated from equations in Table 2.

Table 4. Weight-chest girth equations for black bears in 8 study areas.^a

Area	Equation ^b		Highest elevation (m)	Source
Insular Newfoundland	$W = 0.00053G^{2.620}$	(173)	815	Payne (1976)
Maine ^c	$W = 0.00070G^{2.582}$	(17)	548	Hugie (1982)
Pennsylvania ^c	$W = 0.00082G^{2.534}$	(143)	979	Alt (1980)
Arizona ^c	$W = 0.00103G^{2.482}$	(> 50)	2,300	LeCount (1977, pers. commun.)
Cabinet Mtns, Mt	$W = 0.00207G^{2.374}$	(124)	2,664	This study
Tennessee ^c	$W = 0.00295G^{2.238}$	(77)	2,025	Cherry & Pelton (1976)
East Front, MT	$W = 0.00303G^{2.273}$	(49)	2,863	This study
Absaroka-Beartooth, MT	$W = 0.00292G^{2.255}$	(96)	3,270	This study

^a Males and females combined in all areas.

^b W = weight in kg, G = chest girth in cm, sample size in parentheses.

^c Metric equation calculated from data in the paper.

body weight of black bears (Table 1); however, interpopulation and sexual variations in body measurement-weight relationships make it impossible to derive a single equation for the species. Our data do suggest that equations may be developed that are valid within elevational zones. Perhaps the most accurate equations for large areas would be equations that are developed within geographic regions and elevational zones.

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