BROWN BEAR DENSITY, DENALI NATIONAL PARK, ALASKA, AND SIGHTING EFFICIENCY ADJUSTMENT

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Abstract: Aerial surveys conducted in 1983 over a stratified random sample from about 2,500 km^2 in the northeastern part of Denali National Park were used to estimate the brown bear (*Ursus arctos*) population. Twenty-three flights, totaling 68 hours, were made in a low-flying, fixed-wing aircraft; the sample coverage totaled 4,590 km^2. Aerial counts were calibrated against simultaneous, multi-observer ground coverage. A new technique combining digitized topographic and vegetation information was used to adjust for sighting efficiency. Calibration results and plot characteristics were combined to estimate sighting efficiency on all plots. The minimum density estimates for the study area, based on animals seen, were 1/44, 1/70, and 1/476 km^2 for individual bears, bear units, and families, respectively. The same values expanded by estimated sighting efficiency were 1/31, 1/49, and 1/163.

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The National Park Service estimated relative and absolute densities of brown bears in much of the eastern half of Denali National Park in 1983. Relative densities are used to determine areas visitors should avoid, thus reducing personal injury and property damage. Absolute density of the bear population is basic management information, desirable particularly because of the tenuous status of the species in United States parks in the contiguous states and Denali's international biosphere reserve status.

The most important objectives for this study were to (1) estimate the number of brown bears in the higher and more open portions of the Park and (2) extrapolate this information to order-of-magnitude density estimates for other portions of the Park.

There is little published information on the density of brown bears in large areas. The wide range of topography and vegetation in brown bear habitat contributes to the costliness of obtaining such data. Indices based on sighting frequency, track counts, and other information are not enumerated here because most have not proven useful beyond the initial area of concern. Erickson and Siniff (1963) reported on aerial survey techniques for assessing brown bear populations on the Alaska Peninsula; their paper included information on their experience with the effects of time of day, wind, and observer variation. Dean (1976) included density estimates for individual bears and families in Mount McKinley National Park (now Denali); these were based on limited, unstructured aerial surveys and substantial ground observation. The work was done between 1957 and 1962; additional information was added between 1972 and 1974. Murie's (1981) density estimates based on ground observations concentrated on the years 1959–70. Murie's work, all Dean's earlier studies, and the 1983 work in Denali focused on the same region. Miller and Ballard (1982) calculated brown bear density for an interior area just south of the Alaska Range and approximately 60 km southeast of Denali National Park. These authors used a Petersen Index with mark and recapture data. Miller et al. (this volume) modified their earlier approach and effectively produced a bounded area and thus better met the standard Petersen Index assumptions. Their work provided density information for a new area as well.

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STUDY AREA

Denali National Park lies in the central Alaska Range of interior Alaska. The 1983 sample represented approximately 2,500 km^2 north of the crest of the Alaska Range, east of 150° 20′ West longitude and south of 64° 49′ North latitude (Fig. 1). Murie (1944, 1981), Wahrhaftig (1958), and Dean (1976) characterize the area. Washburn's high oblique aerial photograph (Wahrhaftig 1958, plate 12) clearly illustrates topography and forest distribution in much of the area.

The northern part of the study area included the Outside Range, a zone of foothills and more weathered mountains lower than the peaks in the Alaska Range. The valleys in the Outside Range were highly dissected and variously oriented, except for those of the principal rivers. Elevations ranged from about 750–1,800 m. There were numerous relatively rounded ridges and hilltops, as well as many sharp-spined ridges. Many valleys were narrow and steep-walled. Shallow gullies were common. There were few broad rolling or level areas. There was a higher proportion of tall vegetation, both trees and shrubs >1.5 m, in the Outside Range than in the higher mountains.

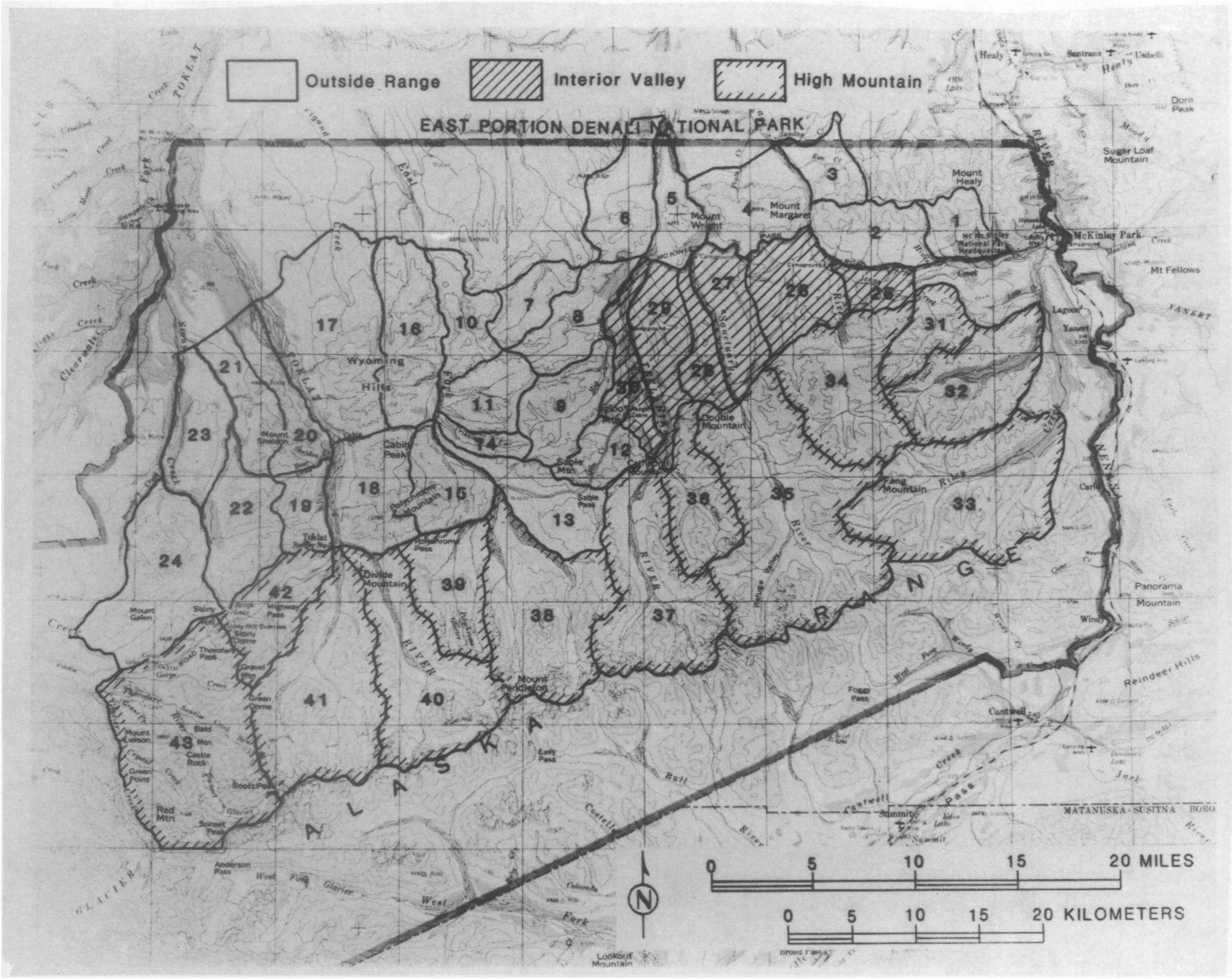

Fig. 1. Strata and plot boundaries for Denali National Park, Alaska, 1983 brown bear density survey.

In the east-central section of the study area there was a relatively broad valley broken into sections by the northward trend of the Savage, Sanctuary, and Teklanika rivers. Comparatively level ground in the east rose gradually toward the west, becoming hillier with both long north-south ridges and an increasing number of low knobs, moraines, and other features. Low shrub and forest types dominated this intermontane valley.

The southern section of the region surveyed consisted of high, jagged mountains of the Alaska Range, with most valley troughs running north-south. Elevations ranged from about 900 m to well over 2,000 m. Many peaks and ridges were very sharp and precipitous with extensive bare rock and talus. Vegetation was generally limited to valley bottoms and lower slopes. Herbaceous tundra and extensive areas of low shrubs dominated but were laced with strings of tall shrubs, mostly willow (*Salix* spp.). Occasional stands of coniferous or mixed forest occurred along the main rivers near the northern edge of this subregion. Forest stocking densities varied greatly; crown closure <25% was common.

Stelmock (1981) and Heebner (1982) provided extensive, detailed information on the vegetation of the study area. We had previously mapped broad vegetation patterns with LANDSAT-II data.

METHODS

I based the 1983 brown bear density estimates on aerial surveys conducted with a stratified random sampling scheme. We made 21 flights in a 150-horsepower Supercub aircraft with a long propeller.

Stratification

The 3 strata used (Fig. 1) reflected the major physiographic zones. Stratum I, the Outside Range, included approximately 965 km^2. Stratum II covered approximately 206 km^2 in the interior valleys of the Teklanika, Sanctuary, and Savage rivers. The high mountains and associated valleys of the main part of the Alaska Range constituted Stratum III, an area of about 1,277 km^2.

Spatial and Temporal Distribution of Sample

I allocated unequal effort to get greater precision in areas of greater bear density and/or high use by hikers as well as in large areas. The planned total allocation was 8, 2, and 10 flights to strata I, II, and III, respectively.

The phenology and size of the berry crop had great potential for influencing aerial counts; therefore, I divided the sampling season into "preberry" and "berry" periods, with the dividing point set between 23 and 24 July on the basis of past experience.

I planned 2 flights each week, randomly allocated to strata, plots, and half plots within Stratum III. The preberry and berry periods received separate scheduling; each had 4, 1, and 5 flights planned for strata I, II, and III, respectively.

Slight modifications of randomization were sometimes necessary to accommodate the realities of weather, finances, and gas loads. The final flight sequence resulted from rearranging the sample plot selection sequence to the extent necessary to permit flying all of the plots that could be covered in 1 flight with minimal backtracking. Most often sequence rather than priority changed. A slight, but probably inconsequential, bias gradient toward the east end of the study area resulted. No attempt was made to quantify this bias.

Two flights made on June 14 and 18 served for retraining and developing observer-pilot coordination; the data were not used. Table 1 shows the allocation of actual survey flights.

Table 1. Allocation of aerial bear survey effort, Denali National Park, Alaska, 1983.

Stratum no.	Flight date	Time (h)	Area flown in stratum (km^2)	No. bears seen on plots	Start time	Pilot
I	Jun 23	0.3	54	3	0505	Candler
III	23	3.0	481	5		
I	28	2.7	131	7	0805	Candler
I	29	3.7	183	10	0511	Candler
III	Jul 5	3.8	313	5	0518	Candler
I	6	3.1	139	4	0509	Candler
II	12	3.5	352	6	0509	Rosso
III	21	3.0	248	3	0520	Ellis
I	21	3.0	189	3	0511	Ellis
III	22	3.1	328	6	0501	Ellis
I	26	3.3	159	3	0506	Ellis
I	28	1.5	40	0	0525	Ellis
I	29	3.3	137	9	0510	Ellis
III	Aug 3	3.8	273	9	0600	Ellis
I	3	3.1	155	0	1221	Ellis
III	10	2.6	197	3	1704	Rosso
III	11	3.4	279	4	0613	Rosso
III	17	4.7	316	9	0613	Mullins
III	26	3.3	273	6	1145	Mullins
I	27	2.6	94	1	0924	Mullins
I	28	3.9	110	6	0626	Mullins
I	29	1.7	67	4	0625	Mullins
II	29	1.3	72	2		
Stratum I total		28.9	1,321	41		
Stratum II total		8.1	561	17		
Stratum III total		30.7	2,708	41		
Total		67.7	4,590	99		

Flying Methodology

Most flights started fairly early with a compromise between low light intensity and increasing turbulence. All flights used in the analysis were made with Dean as observer, but 4 different pilots were assigned to the job. All the pilots had previous experience in low-level flying and were very competent. They quickly developed a search image for bears. The potential problems due to pilot turnover did not become evident, but our results probably would have been improved with more consistency.

We constantly attempted to ensure complete coverage of the surveyable area within designated plots. During plot searches the aircraft was usually from 60 to 150 m above the ground surface; general topography, minor relief, wind, and vegetation all influenced the working height. The flight pattern on most plots began following the contour just above the upper limit of vegetation, usually about 1,200 m. By working the perimeter of the plot and then gradually shifting lower and toward the center we were able to cover most of the area with frequent repetition. This procedure worked very well for the long river valleys of the High Mountain stratum, especially near the headwaters where tall vegetation was rare or absent. On flatter areas the pattern followed drainages or consisted of parallel transects with sufficient overlap to minimize the risk of missing a bear. Moderately rough terrain without major valleys, i.e., the Outside Range, was the most difficult to fly completely and consistently. The working elevation changed almost constantly because of minor surface roughness, and there was often considerable tall vegetation. In such areas the flight pattern often followed small ridges, hillsides, and stream gullies. There were frequent instances of 2nd- or 3rd-time coverage of a particular spot due to changes in general direction and the dendritic nature of the navigation cues.

Calibration Against Ground Counts

Calibration flights were used to determine the proportion of the bears on the surveyed plots seen from the air. The initial "blind" approach in which neither I nor the pilot knew the calibration schedule was abandoned. Ground personnel were too visible, and significant logistical advantage was gained through coordination. The pilots generally mistook the calibrators for backcountry campers and were usually unaware of the test situation. Our technique and intensity appeared unchanged during calibrations.

Most tests involved several observers at strategic lookouts to give maximum coverage of the plot. The ground observers were experienced and used binoculars, spotting scopes, or both. All ground observers remained at their lookouts for 3 hours within which time we did the aerial survey. Most if not all large mammals on the area would have moved into view during the 3-hour period for ground observation, even if they had been lying down initially. Ground observers recorded all sightings and movements of large mammals with time notations on 1:63,360 topographic maps. These observers noted plot boundary crossings as well. All large mammals were included to increase the number of comparisons possible even though each species tends to have different sightability. The parts of the plot visible from each lookout were mapped as well. A technician compiled the ground observations, sorting out duplications, and compared them to the aerial results.

Plot Characterization

The boundaries of the bear survey plots were digitized at 1:250,000 and registered over digital terrain (U.S.G.S. data at EROS Data Center, Anchorage) and vegetation data (Dean, F. C. and D. K. Heebner, LANDSAT-based vegetation mapping of Mount McKinley National Park region, Alaska., unpubl. rep. to U.S. Dep. Int., Natl. Park Serv. Univ. Alaska-Fairbanks, 1982, 198pp.) Each plot was characterized in terms of vegetation type coverage and the proportions in user-specified classes for elevation, slope, and aspect. Because rough terrain and tall vegetation reduce survey efficiency, I developed aspect and slope indices, to be described later, and combined them with vegetation coverage data. This information was used to adjust survey results for sighting efficiency.

Aspect Index. — The logic underlying the aspect index was that, except for flat ground, the more uniformly distributed aspect was among the 8 compass octants the greater the likelihood the ground was dissected or irregular. The aspect index was calculated as follows:

$$\text{Aspect Index} = (A - B) + (C - D) + E$$

Where if a half-sum is the sum of any 4 contiguous octant percentages, and

A = the largest half-sum;
B = the half-sum opposite A (i.e., 100 − A);
C and D = half-sums at right angles to A;
E = mean value for nonzero octants in A.

This results in an index value of 0.0 for flat ground, 12.5 for uniform aspect distribution, and 300 for a hypothetical plot tilted entirely in 1 direction.

Slope Index. — Seven classes of slope percent were selected: 0–5%, 6%–10%, 11%–15%, 16%–20%, 21%–30%, 31%–40%, and >40%. The slope index emphasized flatness, following the likelihood of seeing all bears present. The slope index was figured as follows:

$$\text{Slope Index} = (A/B)(2C/D)$$

Where A = % of total plot area with slope ≤20%;
B = of total plot area with slope >20%;
C = % of plot area with slope ≤5%;
D = % of plot area with slope ≤15%.
(None are allowed to go <1.0 for computation.)

The index ranges from 198 for flat ground to 0.02 if all slopes exceed 20%.

Sighting Efficiency Factor. — The efficiency factor was set at 0.6, 0.8, or 0.9; the latter value was probably often an underestimate. This is conservative in 1 sense, but note that as the efficiency factor decreases, the population estimate increases. Thus overconservatism in the efficiency factor leads to an inflated final population estimate. Experience and the worst outcome of the ground-air calibrations during 1983 suggested that 0.6 was a reasonable minimum efficiency.

Figure 2 shows the guidelines used to set the efficiency factor for each plot. Field experience indicated adjusting plot efficiency factors beyond the level prescribed by the criteria in only 7 cases. Table 2 relates the efficiency factors to plot characteristics.

RESULTS

Calibration Counts

The aerial counts of bears agreed with the respective ground counts in 6 of the 7 cases (86%). In the divergent case the aerial observer saw 2 of the 3 bears seen by ground observers. Aerial counts of all large mammals combined were 100%, 46%, 100%, 100%, 80%, 166%, and 80% of those seen on the plots by the ground teams. The poorest aerial performance was on an Outside Range plot that had a very difficult terrain-vegetation combination.

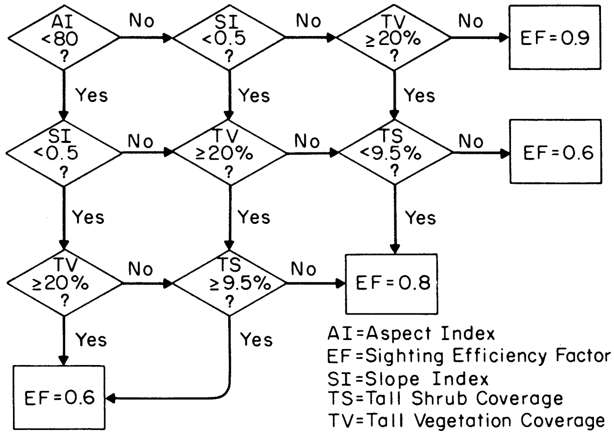

Fig. 2. Decision paths for determining sighting efficiency factors for plots used in Denali National Park, Alaska, 1983 brown bear density survey.

Bear Population Estimates

Densities based only on animals seen, clearly minimal estimates, as well as those expanded by the efficiency factors discussed earlier, are shown in Table 3 for each of the strata. Extrapolated numbers and weighted mean densities of individual bears, bear units, and families are also given for the entire study area. The term "bear unit" denotes a solitary bear or a variable number of bears clearly functioning as a single group when seen, i.e., mating pairs, families, subadults traveling together. The minimum density estimates for the study area, based on animals seen, were 1/44, 1/70, and 1/476 km^2 for individual bears, bear units, and families, respectively. The same values expanded by sighting efficiency factors (0.6, 0.8, 0.9) were 1/31, 1/49, and 1/163.

I estimated means, variances, and confidence limits for the density estimates using a bootstrap approach (Efron 1982, Diaconis and Efron 1983). The raw plot data were expanded by sighting efficiency factors of 0.5, 0.8, and 0.9 for reasons described later the text. One thousand density estimates were generated for each of the 3 status groups; sampling and computations paralleled those used initially. Mean densities and variances (in parentheses) for individual bears, bear units, and families were 0.034/km^2 (2.48×10^{-5}), 0.022/km² (7.77×10^{-6}), and 0.007/km² (1.77×10^{-6}), respectively. For individuals 95% of the density estimates fell between 0.0249–0.044/km²; for bear units this range was 0.016–0.027/km². The range for families was 0.004–0.009/km².

DISCUSSION

Here I present a minimum population figure based on animals counted and a figure expanded by appropriate use of sighting efficiency.

Table 2. Efficiency estimates, bears seen, aspect, slope, and vegetation information for 1983 Denali National Park bear plots.

Plot	Effic. factor[a]	Number bears	Aspect index	Slope index	Total tall vegetation (%)	Tall shrub (%)
1	0.8	4	168.50	0.097	26.9	7.9
2	0.8	7	134.85	0.431	16.5	8.4
3	0.9	1	125.59	2.604	10.1	1.6
4	0.6	1	49.39	0.460	25.5	9.5
5	0.6	0	42.51	0.638	36.2	11.1
6	0.6	0	101.22	1.395	29.0	15.8
7	0.6	3	51.16	0.732	33.9	18.8
8	0.6	0	75.15	0.843	32.3	14.3
9	0.6	0	44.06	0.206	30.6	5.8
10	0.6	0	84.23	0.433	30.0	9.7
11	0.6	5	63.83	0.282	38.7	12.7
12	0.6	3	53.30	0.198	23.6	9.4
13	0.9	7	89.67	1.754	12.4	6.8
14	0.6	0	77.39	0.310	38.7	5.4
15	0.6	5	55.97	0.535	27.7	12.7
16	0.6	2	76.53	0.386	23.5	15.9
17	0.8	0	78.19	0.832	15.5	7.5
18	0.6	3	59.33	0.764	20.9	9.7
19	0.6	0	130.45	0.977	29.8	12.9
20	0.6	0	98.11	0.756	33.4	15.5
21	0.6	0	85.89	0.568	24.9	11.7
22	0.8	0	109.52	0.429	20.2	5.6
23	0.6	0	66.89	2.139	24.7	12.0
24	0.8	0	47.50	0.617	13.3	4.8
25	(+)0.9	0	51.72	33.922	31.0	1.2
26	(+)0.9	2	51.73	88.843	22.7	1.9
27	(+)0.9	3	107.54	77.743	25.3	0.4
28	0.8	5	106.35	43.046	26.8	5.6
29	0.6	7	128.03	6.052	52.9[b]	4.1
30	0.6	0	70.73	12.287	42.2[b]	2.6
31	0.6	0	38.38	0.352	28.8	7.3
32	0.6	6	39.89	0.130	34.4	8.9
33	(−)0.6	0	32.85	0.123	13.7	3.9
34	(+)0.8	8	66.07	0.203	28.8	7.0
35	0.8	10	38.25	0.473	8.3	2.7
36	(+)0.9	0	72.86	0.067	4.2	0.6
37	0.8	8	35.69	0.416	5.5	2.2
38	(+)0.9	0	75.12	0.589	1.7	0.2
39	0.9	1	84.15	1.784	4.9	1.1
40	0.8	3	38.25	0.399	1.5	0.4
41	0.8	2	52.47	0.378	2.2	1.1
42	0.8	1	39.80	0.487	8.0	4.9
43	0.8	2	59.72	0.383	0.0	0.0

[a] Efficiency factor (+ or −) adjusted 1 step from value specified by rules.
[b] Substantial area of open conifer; essentially equivalent to Tall Shrub.

The minimal and the expanded bear population estimates seem low. The figure for families is perhaps the most clearly an underestimate. I used very conservative criteria relating to morphology, coat color, age and number of young, and timing and locations of sightings to assess all my 1983 ground and aerial observations; I identified 12 distinct families with very low, though unquantifiable, risk of duplicate counting. It seemed unlikely for several reasons that I saw 75% of all the families in the study area. Most ground observations were made in the road corridor. Aerial sighting efficiencies, particularly for Stratum I, are probably overestimated; and a significant area of conifer forest and tall shrub was essentially excluded, principally from Stratum I. Although this forest type is used by bears, experience does not suggest that it is prime habitat within the Park.

Another indication that the estimate is low can be obtained from calculating an average litter size for all families from the information in Table 3. Dean (1976) and Murie (1981) presented mean litter sizes of approximately 1.7–1.8. The mean litter size for the set of 12 clearly separable families derived from the combined aerial and ground observations in 1983 was 1.83. The calculated value based on the minimal survey data was 4.2, obviously a high figure; that based on the expanded 1983 aerial data was 1.93. If one reduced the efficiency factor for the plots listed as 0.6 to 0.5, the mean litter size calculable from information paralleling that in Table 3 would be 1.87 (84 individual bears, 54 bear units, 16 families). Thus some, but not a severe, reduction of the efficiency factor might be appropriate. No attempt has been made with these data to elucidate differential sightability of large versus small bear units or of families with larger vs. smaller young.

Comparison of the 1983 results with information derived from earlier work in Denali National Park and with other work done in the region is worthwhile. Murie (1981) estimated a density of 0.035–0.074 bears/km² for roughly the same part of the Park as was surveyed in 1983. His estimate was based on long acquaintance with the area and close observation of bears over several years. Dean (1976) reported density figures for his intensive and total study areas; these were based on a systematic and extremely conservative examination of his sighting records. The procedure involved minimizing potentially duplicative records arising from loss of young and other factors. Density estimates for individual bears ranged between 0.026 and 0.041 bears/km²; the mean for the 4 years

Table 3. Brown bear density, Denali National Park, Alaska, 1983.

Stratum[a]		Individuals	Bear units	Bear families	Individuals	Bear units	Bear families
I. Outside Range	Minimal	41	26	8	0.031	0.020	0.006
Area = 965	Expanded[b]	59.3	39.4	11.0	0.045	0.030	0.008
Surveyed = 1,321							
II. Interior Valley							
Area = 206	Minimal	17	10	4	0.030	0.020	0.007
Surveyed = 561	Expanded[b]	23.5	13.7	5.7	0.042	0.025	0.010
III. High Mountain							
Area = 1,277	Minimal	41	26	7	0.015	0.020	0.003
Surveyed = 2,708	Expanded[b]	53.6	33.2	9.6	0.020	0.012	0.004
		Extrapolated numbers			Weighted means		
Total study area (2,448)	Minimal	56	35	5	0.023	0.014	0.002
	Expanded[b]	79	50	15	0.032	0.020	0.006

[a] All areas and densities shown in square kilometers.
[b] Expanded using sighting efficiency factors discussed in text.

was 0.034. The comparable expanded 1983 figure was 0.032 individual bears/km^2. The 4-year mean of 0.01 family/km^2 (Dean 1976) and the 1983 expanded estimate of 0.006 family/km^2 were reasonably close. The general agreement between earlier estimates and the 1983 figures suggests that very cautious use of observational data may be justified when high precision is not required.

Miller and Ballard (1982) estimated brown bear density in the headwaters of the Susitna River, an area approximately 60 km southeast of Denali National Park and on the south side of the Alaska Range. Assumptions underlying mark-and-recapture methods are difficult to meet; however, their figure of 0.024 individual bears/km^2 is very close to the 1983 base estimate for Denali and not greatly different from the expanded 1983 estimate or earlier ones (Dean 1976). The brown bear density reported by Miller et al. (this volume) falls between the minimum and expanded weighted means for the Denali study area.

LITERATURE CITED

DEAN, F. C. 1976. Aspects of grizzly bear population ecology in Mount McKinley National Park. Int. Conf. Bear Res. and Manage. 3:111–119.

DIACONIS, P., AND B. EFRON. 1983. Computer-intensive methods in statistics. Sci. Amer. 24:116–126, 128, 130, 170.

EFRON, B. 1982. The jackknife, the bootstrap, and other resampling plans. Soc. Industrial and Appl. Math., Philadelphia, Penn. 92pp.

ERICKSON, A. W., AND D. B. SINIFF. 1963. A statistical evaluation of factors influencing aerial survey results on brown bears. Trans. North Amer. Wildl. and Nat. Resourc. Conf. 28:391–409.

HEEBNER, D. K. 1982. The numerical analysis of vegetation plots in Denali National Park and Preserve. M.S. Thesis, Univ. Alaska-Fairbanks. 243pp.

MILLER, S. D., AND W. B. BALLARD. 1982. Density and biomass estimates for an interior Alaskan brown bear, *Ursus arctos*, population. Can. Field-Nat. 96:448–454.

MURIE, A. 1944. The wolves of Mount McKinley. Fauna of the Natl. Parks of the U.S., Fauna Ser. No. 5. U.S. Gov. Print. Off., Wash., D.C. 238pp.

———. 1981. The grizzlies of Mount McKinley. Sci. Monogr. Ser. No. 14. U.S. Dep. Int., Natl. Park Serv., Wash., D.C. 251pp.

STELMOCK, J. J. 1981. Seasonal activities and habitat use patterns of brown bears in Denali National Park — 1980. M.S. Thesis, Univ. Alaska-Fairbanks. 118pp.

WAHRHAFTIG, C. 1958. The Alaska Range. Pages 48–60 in Howel Williams, ed. Landscapes of Alaska, their geologic evolution. Univ. Calif. Press, Berkeley.