ESTIMATES OF BROWN BEAR ABUNDANCE ON KODIAK ISLAND, ALASKA

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Abstract: During 1987–94 we used capture–mark–resight (CMR) methodology and rates of observation (bears/hour and bears/100 km^2) of unmarked brown bears (*Ursus arctos middendorffi*) during intensive aerial surveys (IAS) to estimate abundance of brown bears on Kodiak Island and to establish a baseline for monitoring population trends. CMR estimates were obtained on 3 study areas; density ranged from 216–234 bears/1,000 km^2 for independent animals and 292–342 bears/1,000 km^2 including dependent offspring. Rates of observation during IAS ranged from 1.4–5.4 independent bears/hour and 2.9–18.0 independent bears/100 km^2. Density estimates for independent bears on each IAS area were obtained by dividing mean number of bears observed during replicate surveys by estimated sightability (based on CMR-derived sightability in areas with similar habitat). Brown bear abundance on 21 geographic units of Kodiak Island and 3 nearby islands was estimated by extrapolation from CMR and IAS data, using comparisons of habitat characteristics and sport harvest information. Population estimates for independent and total bears were 1,800 and 2,600. The CMR and IAS procedures offer alternative means, depending on management objective and available resources, of measuring population trend of brown bears on Kodiak Island.

***Ursus* 10:1–9**

Key words: aerial survey, brown bear, density estimation, Kodiak Island, population estimation, *Ursus arctos middendorffi*.

The brown bear population of Kodiak Island is intensively managed because of its high value to sport hunters, wildlife viewers, and photographers. Furthermore, the species is considered an important indicator of ecosystem vitality (Schoen et al. 1994). On the Kodiak National Wildlife Refuge (NWR), which encompasses about two-thirds of the island, responsibility for the welfare of brown bears and their habitat is shared between the Alaska Department of Fish and Game (ADF&G) and the U.S. Fish and Wildlife Service (USFWS). The management goal is to maintain distribution, density, and composition of the brown bear population at or near current levels. This goal places a high priority on objective estimates of population size and trend.

Increasing human activity represents the most serious challenge to brown bear management on Kodiak Island (Smith et al. 1989, USFWS 1993). Factors that are most likely to affect bears are consumptive and non-consumptive recreational use, cabin and lodge development on private inholdings, and natural or human-induced changes in abundance and distribution of Pacific salmon (*Oncorhynchus* spp.). The relative importance of these factors will vary by locality. Because brown bears on Kodiak Island have comparatively small home ranges (Berns et al. 1980, Barnes 1990, Smith and Van Daele 1990), long-term impacts on localized areas are possible. Effective management requires current data on bear population status from representative areas throughout the island.

In this paper we report population data acquired in a series of studies conducted on Kodiak Island during 1987–94. Our objectives were to: (1) determine brown bear density in representative habitats, (2) develop cost-effective methodology for monitoring population status of brown bears, and (3) estimate size of the brown bear population on Kodiak Island and adjacent small islands.

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STUDY AREAS

We worked on 5 areas of Kodiak Island during 1987–94 (Fig. 1). Climate of the region is maritime and characterized by cool temperatures, overcast skies, fog, windstorms, and moderate to heavy precipitation. Maximum temperatures occur in July and August and usually range from 13–18 C; lowest temperatures normally occur during January and February and seldom fall below -6 C. Precipitation occurs primarily as rain near sea level and snow at higher elevations from October to May; an-

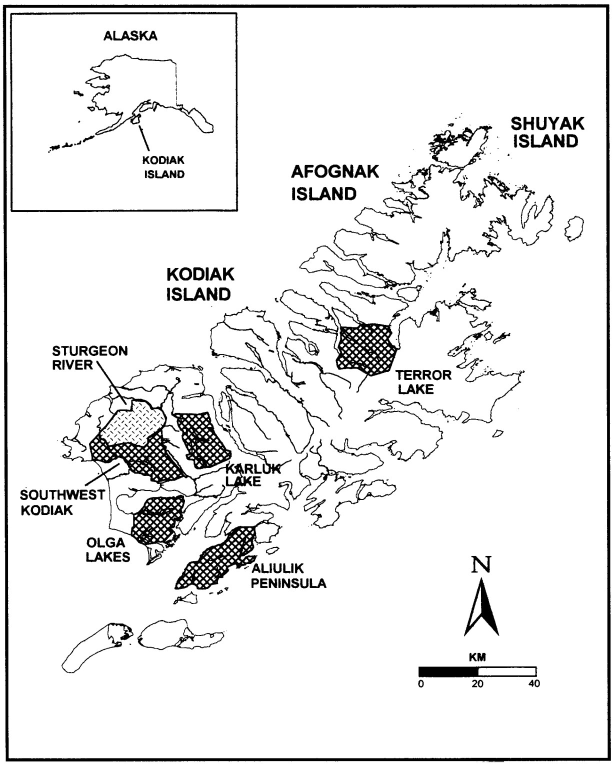

Fig. 1. Study areas used to estimate density, composition, and rates of observation of brown bears during 1987–94. Kodiak Island, Alaska.

nual precipitation usually ranges from 100–200 cm with large fluctuations among years and specific locales.

Terror Lake

Topography of the Terror Lake area (TER; 355 km^2) included rugged segments of coastline, tidal flats, foothills, low ridges interspersed with flat terrain, and steep ridges and peaks that extended to 1,340 m. Slopes <450 m were vegetated by a tall (>1.5 m) shrub–grass–forb complex represented by Sitka alder (*Alnus crispa*), European red elder (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), bluejoint grass (*Calamagrostis canadensis*), and fireweed (*Epilobium angustifolium*). Other dominant flora included balsam poplar (*Populus balsamifera*) and willow (*Salix* spp.) in valleys, Kenai birch (*Betula kenaica*) on lower slopes, and scattered patches of Sitka spruce (*Picea sitchensis*). Alpine (≥450 m) vegetation consisted of various mixtures of low willow, ericaceous shrub (*Ericaceae*), sedge (*Carex* spp.), grasses, and forbs (Atwell et al. 1980, Smith and Van Daele 1990). The TER area had the highest elevations and the most precipitous terrain among study areas.

Southwest Kodiak

The southwest Kodiak area (SWK; 632 km^2) was composed of wide valleys, rolling foothills, and occasional areas of precipitous terrain. Elevation extended to 768 m, but most peaks and ridges were <600 m. Lowlands (15–180 m) included bog and marsh, willow–grass–forb communities, and dry sites dominated by ericaceous shrub. Mid-elevation slopes were vegetated by dense to widely-spaced patches of tall shrubs dominated by Sitka alder and interspersed with clumps of European red elder. Openings in tall shrub habitat were occupied by low-shrub and herbaceous cover. An upland zone (>350 m) was composed of herbaceous meadow, ericaceous shrub, low willow, bare soil, and rock. A microtopography of regularly spaced hummocks (0.3–1.2 m tall) was a common feature throughout SWK (Karlstrom and Ball 1969, Barnes 1990). The Sturgeon River area (STR), a 264 km^2 portion of SWK, was treated as a subunit for aerial surveys conducted in 1992 and 1993.

Aliulik Peninsula

The Aliulik Peninsula area (ALI; 350 km^2) was bounded by ocean on >90% of its periphery and contained 2 distinct physiographic units. The northern portion (47%) was mountainous, with elevation extending to 675 m. Topography and vegetation of the north unit was similar to the foothill and mountain portions of SWK. The south unit (53%) of ALI was primarily a low (<180 m) benchland of ericaceous shrub tundra intersected by numerous draws and drainages. Herbaceous meadows, bogs, shallow ponds, and small (<1 km^2) lakes were present throughout the unit. Willow and Sitka alder occurred primarily in isolated patches, and extensive areas of ericaceous hummock terrain were common (Barnes and Smith 1995).

Olga Lakes

The Olga Lakes area (OLG) encompassed 262 km^2 and was bounded by ocean on about 80% of its periphery. Approximately two-thirds of OLG resembled mountainous portions of SWK and ALI with respect to vegetation and topographic relief. The remainder of OLG was primarily lowland (<180 m) terrain containing herbaceous meadow, ericaceous hummocks, and bog or marsh habitat. Elevation of OLG ranged from sea level to 735 m.

Karluk Lake

The Karluk Lake (KAR) watershed included Karluk (38 km^2), O'Malley (1 km^2), and Thumb (0.5 km^2) lakes and adjoining tributary drainages. Land area of the watershed totaled 267 km^2. Topography of KAR was similar to mountainous portions of SWK, ALI, and OLG except mountain peaks surrounding the lakes rose to higher elevations, ranging from 787–993 m. Midslope and upland plant communities of KAR were comparable to those on mountainous portions of SWK, ALI, OLG; lowland flora of these 4 areas was also similar except for a balsam poplar overstory that dominated stream courses and portions of lake shores at KAR.

METHODS

CMR Density and Composition

Capture–mark–resight (CMR) density estimates were obtained for TER and SWK in 1987 and ALI in 1993 (Barnes and Smith 1995, Miller et al. 1997). These estimates were derived from replicate aerial surveys flown to estimate the ratio of marked (radiocollared) to unmarked bears (Miller et al. 1987). Visual searches of all habitat within study areas were accomplished with pilot–observer teams in fixed-wing aircraft. When a bear was sighted, we used telemetry equipment to determine whether or not the bear was marked. After each survey, we used aerial telemetry to determine which marked bears were in or out of the study area (available to be sighted).

The CMR estimates at TER and SWK used bears that had been radiocollared for other studies (Barnes 1990, Smith and Van Daele 1990); just prior to the CMR surveys in 1987 we radiocollared additional bears to improve representation of some sex–age classes in the samples. At ALI we radiocollared bears in 1992 and 1993 and attempted to capture animals such that sex–age classes in our sample approximated their proportional composition in the living population, using composition results from 1987 CMR studies at TER and SWK as a guide. Within those allocation targets, we captured bears in the order in which they were found by aerial observers. Sample sizes of radiocollared bears were 33 for TER, 28 for SWK, and 29 for ALI. Three, 4, and 5 replicate aerial surveys of TER, SWK, and ALI, respectively, were completed during 27 May–14 June, using experienced survey personnel flying in PA-18 Super Cub (Piper Aircraft Corp., Lock Haven, Pa.) floatplanes.

We estimated population size of independent bears (excluding offspring) and all bears on TER, SWK, and ALI with the maximum-likelihood estimator as detailed by White (1993) and Miller et al. (1997). This estimator provided point estimates comparable to those from Lincoln-Peterson (Eberhardt 1990) and bear-days (Miller et al. 1987) estimators, but with consistently smaller confidence intervals (CI; Barnes and Smith 1995, Miller et al. 1997). We determined both 80% and 95% CIs, and converted population estimates to density (bears/1,000 km^2) estimates. Sightability of independent bears for each density estimate was calculated as the summation of marked bears observed during all replicate surveys divided by the summation among replicates of the number of marked bears present on the study area.

Population composition on TER, SWK, and ALI was determined by calculating Lincoln-Peterson population estimates for single bears (adult and subadult), females with new (<1 year) cubs, females with offspring ≥1 year, new cubs, and offspring ≥1 year. Because offspring were not marked, estimates were made by multiplying the population estimate for the maternal female class by the mean litter size of all families in that class observed during the surveys.

Intensive Aerial Survey

We obtained data on observation rates of unmarked bears (bears/hour and bears/100 km^2) using intensive aerial surveys (IAS) of each study area. IAS were accomplished with the same personnel and type of aircraft used for CMR studies. Survey teams flew 90–150 m above the ground at 115–130 km/hour; the target search effort was 1.5 min/km^2. Study areas were partitioned into 20–150 km^2 search areas delineated by easily-recognized geographic features. Pilot–observer teams and starting times (AM, PM) for individual search areas were alternated to minimize observer and time-of-day bias. We flew approximate 150-m contour intervals in mountainous terrain and straight-line routes spaced about 1-km apart over flat terrain. Data recorded for each sighting of a bear group included time, group type, and group size.

CMR surveys provided IAS data for TER, SWK, STR in 1987 and ALI in 1993. Additional IAS data were collected for STR, OLG and ALI during 21–31 May 1992, for STR and OLG during 22–30 May 1993, and for KAR during 20–31 May 1994. These data were compared with the *t*-test and 1-way analysis of variance (ANOVA). Fisher's least significant difference (LSD) test was used to contrast means when ANOVA indicated a significant ($P < 0.05$) difference. The relationship between observation rate and sightability of radiocollared bears was examined with linear regression.

Estimates of population size were derived from IAS data at OLG and KAR by dividing the mean number of independent bears observed during replicate surveys by estimated sightability. Sightability estimates were taken from CMR data in study areas with similar habitat components.

Population Extrapolation

We estimated brown bear abundance on Kodiak Island and 3 small islands (Amook, Uganik, Sitkalidak) adjacent to Kodiak by extrapolation from CMR and IAS data. The area was partitioned into 21 geographic units based on topography, vegetative composition, brown bear sport harvest statistics (Abbott 1991), and distribution and abundance of human inhabitants. We assigned a density for independent bears to each geographic unit by comparing habitat characteristics of that unit with those of CMR and IAS study sites. We assumed that habitat quality was the primary determinant of brown bear density because the sport harvest is regulated with a permit system that is conservative and distributes hunting pressure uniformly throughout Kodiak Island (Barnes et al. 1995). We estimated a lower density due to hunting on northern Kodiak Island, which supports about 90% of the human population and has a liberal hunting policy to maintain low bear density and minimize bear–human conflicts (Smith et al. 1989). Extrapolated densities were based on point estimates (CMR) for TER, SWK, and ALI, and on indirect estimates derived from IAS data for OLG and KAR.

Population estimates for independent bears were based on density estimates multiplied by the area of individual units, less area of freshwater lakes >1 km^2. An estimate of total bears (including offspring) for each geographic unit was made by multiplying number of independent bears by the mean ratio (1.43:1) of total to independent bears for the 3 CMR density estimates (range = 1.35–1.48:1). Confidence intervals were not determined for independent and total population estimates because subjective procedures were used with IAS data and in the extrapolation process. Total population estimates were rounded to the nearest 100 animals. We considered extrapolated population estimates to represent brown bear abundance during spring.

RESULTS

CMR Density and Composition

Brown bear density estimates from CMR data ranged from 216–234/1,000 km^2 for independent bears and 292–342/1,000 km^2 for all animals (Table 1). Confidence intervals averaged 24% and 39% of the point estimates, respectively, at the 80% and 95% levels. Confidence intervals were narrower at ALI, because of more replicate surveys (n = 5) and higher sightability of radiocollared bears (0.53), than at SWK (n = 4; 0.41) and TER (n = 3; 0.33).

Population composition of independent bears (single, female with new cubs, female with≥1 year cubs) was similar among the 3 CMR study areas ($\chi^2 = 0.952$, 4 df, $P = 0.917$; Table 2). Single animals made up just over half ($\bar{x} = 54\%$) of these populations; maternal females averaged 16% and dependent offspring averaged 30%.

Intensive Aerial Survey

Observation rates of independent bears ranged from 2.9–18.0/100 km^2 and 1.4–5.4/hour (Table 3). During CMR surveys the observation rates were lowest on TER, which had the highest estimated density. We attributed this result to low sightability; rates that independent bears were observed in CMR surveys were positively correlated to sight-ability of radiocollared bears (bears/100 km^2: $r^2 = 0.55$, 11 df, $P = 0.005$; bears/hour: $r^2 = 0.23$, 11 df, $P = 0.11$).

Rates that bears were observed did not differ annually (t-tests, $P > 0.05$) on the 3 areas (STR, OLG, ALI) where

Table 1. Observations, sightability, and estimated density of independent bears and of all bears (including offspring) obtained with mark–resight procedures on Terror Lake (TER, 1987), southwest Kodiak (SWK, 1987), and Aliulik Peninsula (ALI, 1993) study areas, Kodiak Island, Alaska.

	Independent bears					Total bear density		
	Total observed[a]	Sightability[b]	$\hat{N}$/1,000[c] km^2	95% CI	80% CI	$\hat{N}$/1,000[c] km^2	95% CI	80% CI
TER	80	0.33	234	192–304	204–274	342	296–409	311–381
SWK	222	0.41	218	180–275	192–250	323	274–392	290–365
ALI	209	0.53	216	195–247	201–235	292	270–319	277–309

[a] Observations of marked and unmarked bears for all replicate surveys.
[b] Mean proportion of radiocollared bears seen/survey.
[c] Number of bears estimated from mark–resight data.

Table 2. Population composition of brown bears on Terror Lake (TER), southwest Kodiak (SWK), and Aliulik Peninsula (ALI) study areas based on Lincoln-Peterson estimates ($\hat{N}$), Kodiak Island, Alaska, 1987–93.

	Study Area								
	TER (1987)			SWK (1987)			ALI (1993)		
Bear class	$\hat{N}$	SE	%	$\hat{N}$	SE	%	$\hat{N}$	SE	%
Single adult and subadult	63	16	53	96	16	53	62	3	55
Female with new cubs	9	1	8	11	4	6	6[a]		5
Female with ≥1 year cubs	11	2	9	20	4	11	10	1	9
Offspring									
New cubs	17		14	19		10	11		10
≥1 year cubs	18		15	35		19	24		21

[a] Estimate of number of different animals observed during surveys; no marked animals were present in sample to enable a Lincoln-Peterson estimate.

IAS was conducted in consecutive years (Table 3). However, the number of bears observed on STR differed among all years (1987, 1992, 1993) (bears/100 km^2: $F = 10.44$, 7 df, $P = 0.02$; bears/hour: $F = 13.81$, 7 df, $P = 0.01$). Observation rates in 1987 were greater than 1992 or 1993 (Fisher's LSD tests, $P \leq 0.05$).

Observation rates differed among study areas surveyed during 1987–94 (bears/100 km^2: $F = 43.98$, 23

Table 3. Observation rates during aerial surveys, estimated sightability, and estimated density of independent bears, Kodiak Island, Alaska, 1987–94.

				Observation rate			
Area[a]	Year	Replications	Survey rate (min/km^2)	Bears/hour	Bears/100 km^2	Sightability	Density (bears/1,000 km^2)
TER	1987	3	1.5	3.1	7.5	0.33[b]	234[c]
SWK	1987	4	1.5	3.5	8.8	0.41[b]	218[c]
STR	1987	4	1.6	4.6	12.0		
	1992	2	1.8	2.4	6.8		
	1993	2	1.9	2.8	8.5	0.41[d]	190[e]
ALI	1992	3	1.4	4.3	9.9		
	1993	5	1.7	4.0	11.4	0.53[b]	216[c]
OLG	1992	3	1.2	2.0	3.6		
	1993	2	1.3	1.4	2.9	0.41[d]	80[e]
KAR	1994	4	2.1	5.4	18.0	0.45[d]	400[e]

[a] Area: TER = Terror Lake, SWK = southwest Kodiak, STR = Sturgeon River, ALI = Aliulik Peninsula, OLG = Olga Lakes, KAR = Karluk Lake.
[b] Mean proportion of radiocollared bears seen/survey.
[c] Estimated from mark–resight data.
[d] Estimated by comparison with habitats where sightability was assessed from telemetry.
[e] Calculated by dividing estimated sightability into mean no. bears seen/replicate.

df, $P < 0.0001$; bears/hour: $F = 10.69$, 23 df, $P = 0.0001$). For this analysis we pooled 1992–93 data in ALI, STR, and OLG because observation rates did not differ within area in those 2 years. Also, we used 1992–93 data in STR because it was more recent than data collected in 1987 (STR and SWK). The number of bears observed/100 km^2 was highest at KAR and lowest at OLG; bears seen/100 km^2 was higher at ALI than TER and STR, which had similar observation rates (Fisher's LSD tests, $P = 0.05$). The number of bears seen/hour was also highest at KAR; bears seen/hour at ALI was higher than at OLG and STR and did not differ from TER. The number of bears seen/hour did not differ among the OLG, STR and TER areas ($P > 0.05$). Variability (CV) among the 5 study areas for bears seen/100 km^2 ($\bar{x} = 17.0\%$) was less than for bears seen/hour ($\bar{x} = 25.7\%$).

Estimates of density from IAS data required judgments on sightability of independent bears. We selected 0.41 sightability for OLG because, with the exception of 1 breeding pair, all bear observations at OLG were made in the mountainous portion that closely resembled SWK. The resulting population estimate was 21 bears (80 bears/1,000 km^2). Habitat of KAR was also similar to that of SWK except that KAR contained more extensive alpine habitat where sightability should have been similar to that realized on ALI (0.53). Therefore, we selected 0.45 sightability for KAR and obtained an estimate of 107 bears (400 bears/1,000 km^2). The sightability estimates for OLG and KAR were chosen to represent the upper range of sightability and probably resulted in conservative population estimates.

Population Extrapolation

Densities of independent bears estimated from CMR (216–234/1,000 km^2) and IAS data (80–400/1,000 km^2) were the basis for extrapolating densities to geographic units. The estimated population of independent bears on Kodiak Island (1,750) and 3 small islands immediately adjacent to Kodiak Island (50) was about 1,800 animals (Table 4). The corresponding density was 185 bears/1,000 km^2. The estimated total population of brown bears on Kodiak Island was 2,600. Estimated bear density was highest for the Karluk Lake watershed (independent bears, 400/1,000 km^2; total bears, 572/1,000 km^2) and least for some exposed cape areas, a central high-elevation area dominated by rock and snowfield–glacier habitat, and an area on northeast Kodiak Island where most of the human population resides (independent bears, 30–60/1,000 km^2; total bears, 40–90/1,000 km^2). Approximately 42%, 40%, and 18% of the total area was classed as having high (210–400/1,000 km^2), moderate (100–200/1,000 km^2), and low (20–90/1,000 km^2) density of independent bears, respectively (Fig. 2).

Table 4. Extrapolated estimates of brown bear density (bears/1,000 km^2) and abundance based on capture–mark–resight and intensive aerial survey data, Kodiak Archipelago, Alaska.

		Independent bears		
Geographic unit	Area (km^2)	Density	No. bears	Total bears
Karluk Lake[a]	313	400	125	179
Uyak Bay	554	240	133	190
Deadman Bay	373	240	90	129
Zachar-Uganik	1546	230	356	509
Terror Lake[b]	580	220	128	183
North Aliulik[c]	663	220	146	209
South Aliulik[c]	174	210	37	53
Red Lake[d]	1417	200	283	405
Kiliuda Bay	969	190	184	263
Sheratin Bay	111	170	19	27
Uganik Island	148	160	24	34
Kupreanof	225	160	36	51
Larsen Bay	339	150	51	73
Hidden Basin	295	130	38	54
Little River	246	120	30	43
Anton Larsen	171	120	21	30
Halibut Bay	256	90	23	33
Sitkalidak Island	303	70	21	30
Koniag Peak	171	60	10	14
Chiniak Bay	834	50	42	60
Alitak Bay[e]	246	30	7	10
Totals	9934		1804	2579
Rounded population estimates			1800	2600

[a] Includes Karluk Lake study area.
[b] Includes Terror Lake study area.
[c] Includes part of the Aliulik study area.
[d] Includes southwest Kodiak study area and part of Olga Lakes study area.
[e] Includes part of Olga Lakes study area

DISCUSSION

The CMR density estimates for 1987 and 1993 were obtained in areas that encompassed about 1,340 km^2 (14%) of Kodiak Island and represented most of the habitat diversity of the island. Aerial survey data were acquired on an additional 530 km^2 (6%). In total these data represented about 20% of Kodiak Island's habitat and thus provided a reasonable basis for extrapolating density estimates to the remainder of the island. Although the 3 CMR estimates were similar, survey (IAS) data provided evidence that lower and higher bear densities occurred elsewhere. In particular, our estimate of 570 bears/1,000 km^2 for the Karluk Lake drainage is comparable to the estimate (640/1,000 km^2) reported for the same area by Troyer and Hensel (1964). The Karluk Lake area may support a brown bear density similar to that (540/1,000 km^2) observed in Katmai National Park (Sellers et al. 1994, Miller et al. 1997).

We confined our population extrapolation to Kodiak Island and 3 nearby islands with similar habitat components. We avoided extrapolating density estimates to the remainder of the Kodiak Archipelago north of Kodiak Island (Fig. 2) because, unlike Kodiak Island, Sitka spruce dominates much of that area. However, sport harvest data and field observations indicate that those islands (about 19% of the archipelago land mass) support generally lower bear densities than Kodiak Island and probably <12% of the bear population of the Archipelago (Barnes and Smith 1995).

Our estimate of 1,750 independent bears for Kodiak Island was 5% higher than an earlier population estimate based on the 1987 CMR data (Barnes et al. 1988). This disparity represents adjustments based primarily on CMR and IAS data collected during 1992–94 and should not be interpreted as representing a population trend. The improved population estimate that resulted from application of 1992–94 data underscores the need to continually update the information base. Currently there is a need for improved population data for Afognak, Raspberry, and Shuyak Islands and the east side of Kodiak Island.

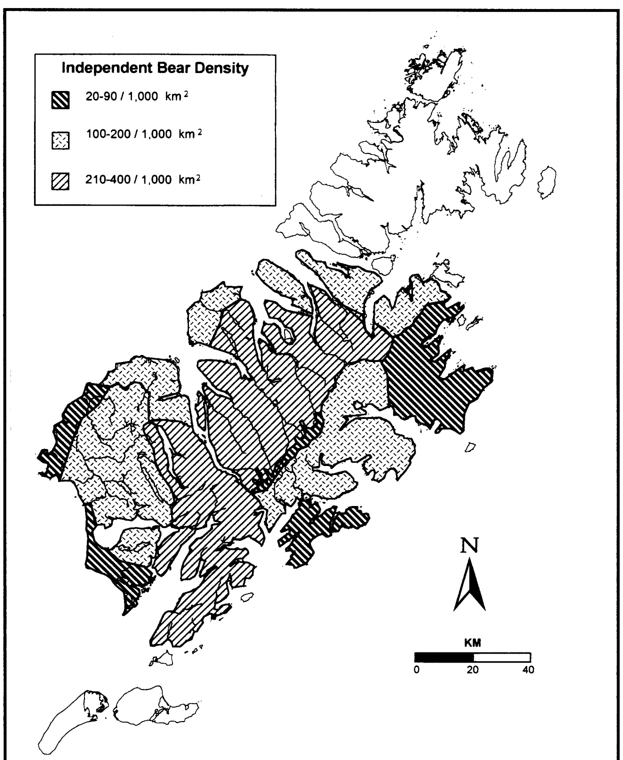

Fig. 2. Estimated density of independent brown bears on Kodiak Island, Alaska.

Estimates of population composition on the 3 CMR study areas did not differ and likely provide a reasonable approximation of the present structure of the Kodiak Island population. On another area of high bear density on the Alaska Peninsula, Sellers (1994) estimated that maternal females composed 18% of the population. This estimate is close to the range we observed (14–17%) and indicates that the 2 bear populations, both of which are managed for sport harvest, have a comparable population structure. Sellers et al. (1994) provided evidence that an unexploited population in Katmai National Park had a lower proportion of maternal females.

Several previous investigations used observation rate (bears/hour) to estimate brown bear density or population trend. Miller et al. (1997) noted a correlation between bears/hour and density, but indicated that density could not be predicted on unstudied areas. Titus and Beier (1993) arrived at a similar conclusion based on bear/hour rates recorded for Admiralty and Chichagof Islands in Southeast Alaska. Sellers et al. (1994) used bears/hour rates to estimate bear density and, despite substantial variation, concluded that estimates derived by that procedure have use for bear management. These workers had the same basic objective that we had, to develop cost-effective procedures to index population size. This need has become increasingly more important because density estimates requiring the capture and marking of animals are very costly.

We used observation rates of bears both as a means of estimating density and to establish a base for measuring population trend. We employed observation rates to estimate density by using sightability data from other areas with similar habitat. However, we concur with Miller et al's. (1997) contention that observation rates can be misleading without habitat-specific sightability data. We observed consistent results between consecutive years on areas where year to year change in density of independent bears was unlikely. This suggests that observation rates may have utility for monitoring population trend. However, we observed decreased observation rates on 1 area (STR) over a 5-year period that could have been caused by sample variation (limited replication), decreased density, or a shift in bear distribution. Titus and Beier (1993) reported high variability between daily bear counts and indicated that utility of observation rates might vary by area. These results indicate the need for additional assessment of observation rates in a variety of habitats.

We observed less variation in bears observed/unit area than bears observed/unit time. This finding probably was attributable to the variable weather (survey) conditions typically encountered on Kodiak Island. Small changes in wind direction and velocity, light intensity, and the distribution of cloud cover and fog can affect the time required to complete searches of specific habitats. These changes, which often occur within individual surveys, probably affect bears/hour rates more than bears/100 km^2 rates.

Use of aerial survey methods (CMR, IAS) to acquire brown bear population data on Kodiak Island is compromised by a relatively short time within which the work can be accomplished. Surveys cannot be initiated prior to the end of spring hunting season (15 May) because the procedure would interfere with hunters. Also, many bears do not emerge from winter dens prior to mid-May (Van Daele et al. 1990, Miller et al. 1997). Surveys should be completed prior to substantial leaf-out (usually 1–10 Jun). Finally, inclement weather often limits the number of surveys that can be completed within the short time. These factors can vary annually and therefore reduce the ability to detect population change. Nonetheless, we suggest that both CMR and IAS procedures yield data useful for bear management.

The CMR and IAS methods produce different types of information that can be complementary. CMR yields more precise density estimates than IAS and contributes sightability data necessary when IAS is used to estimate density on areas of similar habitat. Similarly, estimates of population composition are obtainable from CMR but not from IAS data. The CMR procedure, however, is too costly to employ as a standard management tool. Completion of a CMR study on Kodiak Island requires a minimum of 2 years (1 year of premarking) and a total operations budget (exclusive of salaries) of approximately $40,000 ($US 1996). An IAS on the same area and with the same number of surveys would require 1 year and about $10,000.

IAS can be used on Kodiak Island as a cost-effective method for estimating bear density and as a basis for measuring moderate (5 year) to long-term (≥10 year) population trends. Periodic application of a CMR estimate would be advisable to further calibrate and improve utility of IAS. The IAS procedure can be used to alert managers to a developing problem and to determine the need for more precise population information (e.g. CMR density and composition estimates).

MANAGEMENT IMPLICATIONS

Management of the brown bear sport harvest on Kodiak Island is directed at providing high quality hunting opportunity and maintaining a diversity of sex and age classes. The population estimates detailed in this paper have been applied to specific management units to calculate harvest rates (Miller 1990) and refine management strategy. Additionally, density and composition estimates will be employed in modeling exercises to develop guidelines for different population components. Developing harvest guidelines for adult females and setting measurable objectives for diversity in population composition, including adequate representation of large adult males, are considered important priorities.

Density estimates have also been used to establish priorities for land protection. Important components of brown bear habitat occur on inholdings within the Kodiak NWR; increased recreational activity on these lands could seriously affect bears on localized areas. Protection options include land acquisition or exchange, conservation easements, and cooperative agreements (USFWS 1992).

Effective monitoring of brown bear population trends on Kodiak Island is a key management objective. The CMR procedures we used in this study can be repeated in later years to assess effects of specific projects or determine long-term trends (Miller et al. 1987, Ballard et al. 1990, Schoen and Beier 1990, Smith and Van Daele 1990). IAS can be used on representative areas to supplement CMR information and as a less expensive alternative to CMR. The IAS procedure has been implemented as a standard inventory project of the Kodiak NWR; the inventory plan is to survey 1–2 study sites each year so that current data will be available for each site at approximate 5 year intervals.

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