AERIAL SIGHTABILITY AND CLASSIFICATION OF GRIZZLY BEARS AT MOTH AGGREGATION SITES IN THE ABSAROKA MOUNTAINS, WYOMING

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Abstract: In 1991–92, we simultaneously observed grizzly bears (*Ursus arctos horribilis*) from the ground and air at moth aggregation sites east of Yellowstone National Park, Wyoming, to determine the ability of aerial observers to sight and classify bears. The Interagency Grizzly Bear Study Team (IGBST) uses aerial surveys to count and monitor the reproductive success of unduplicated females with cubs (0.5-year olds) in the Greater Yellowstone Ecosystem (GYE). Much of their effort is focused in alpine talus areas because females with cubs congregate there to forage on army cutworm moths (*Euxoa auxiliaris*). Aerial observers sighted 92% (49/53) of all bears, 85% (22/26) of independent bears, and all (n = 10) family groups present during 6 surveys, but they misclassified 3 of 5 subadults as lone adults, 1 of 7 lone adults as a subadult, and a female with 3 yearlings as 4 lone adults. Further, aerial observers sighted 89% of all bears (n = 55) and 79% of independent bears (n = 28) that used moth sites on the days that surveys were conducted. Classification of family groups and lone bears did not significantly differ between ground and aerial counts, but further stratification of lone bears indicated significant (P = 0.03) under-representation of subadults and over-representation of lone adults from the air. Low sightability of subadults (56%) and misclassification of family groups also contributed to these errors. Aerial observers sighted and accurately classified all 5 adult females with cubs present during the aerial surveys, and no yearlings were misclassified as cubs. However, using other data collected from the ground, we found that aerial observers sighted only 82% of all females with cubs because 2 of 11 family groups observed to use study sites were not present during aerial surveys. Nevertheless, aerial sightability and classification of females with cubs and estimates of litter size at moth sites seemed reliable.

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Key words: aerial survey, army cutworm moth, classification, *Euxoa auxiliaris*, grizzly bear, moth aggregation sites, sightability, *Ursus arctos*, Yellowstone National Park.

The composition of various populations of brown bears has been estimated using capture samples (Craighead et al. 1995, Miller et al. 1997), harvest data (Miller and Miller 1990, Sellers 1994), and direct observation (Atwell et al. 1980, Reynolds 1993). Because mark–recapture is often expensive and highly intrusive (Miller and Nelson 1993, Eberhardt et al. 1994), aerial surveys are being relied upon more often by managers to detect trends in bear populations. Aerial surveys were found to be an inexpensive and efficient way to monitor bear populations in alpine areas during early summer on Admiralty Island, Alaska (Schoen and Beier 1990), and, when standardized, on salmon (*Oncorhynchus* spp.) streams on the Alaska Peninsula (Sellers 1994).

Despite heavy reliance by managers on data from aerial surveys, little effort has been made to evaluate the accuracy of classification of sex, age, and litter size by aerial observers. Estimates of bias in classification (Miller and Nelson 1993) and sightability (Barnes 1986, Miller et al. 1987, Barnes et al. 1988, Miller 1990, Miller and Sellers 1992, Miller and Nelson 1993, Barnes and Smith 1995, Miller et al. 1997) for brown bears typically have been a secondary objective. Although some investigators have evaluated aerial counts of brown bears using simultaneous ground counts (Erickson and Siniff 1963, Dean 1987, Barnes 1994, French et al. 1994), non-simultaneous ground counts (Atwell et al. 1980, French et al. 1994, Sellers 1994), and productivity and recruitment data (Schoen and Beier 1990), most investigators only attempted to minimize bias by standardizing survey methodology. Only 2 studies have been specifically designed to measure bias in aerial counts, and both used simultaneous ground counts to verify (Erickson and Siniff 1963) or calibrate (Dean 1987) results. Time of day, observer experience, and wind velocity all affected results of aerial surveys of brown bears on salmon streams on the Alaskan Peninsula (Erickson and Siniff 1963). In Denali National Park, Alaska, vegetation and topography (slope, aspect) affected estimates of sighting efficiency (Dean 1987).

Aerial surveys are used by the IGBST to estimate trends in the grizzly bear population in the Greater Yellowstone Ecosystem (Eberhardt et al. 1994). Trends are estimated from (1) reproduction and survival of radiocollared bears (Eberhardt et al. 1994) and (2) the annual and 6-year running average count of unduplicated females with cubs observed from the ground or air (U.S. Fish and Wildl. Serv. 1993, Knight et al. 1995). Although Knight et al.

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(1995) concluded that the use of the former method was more reliable than the latter to estimate trends, they felt the general agreement between the 2 methods was encouraging because both were subject to various biases and each provided unique advantages.

Aerial surveys of moth aggregation sites (MAS) are essential for monitoring the GYE grizzly population because moth sites attract large numbers of bears (Klaver et al. 1986, Mattson et al. 1991*b*), thus functioning as ecocenters, much like the garbage dumps of Yellowstone National Park prior to 1973 (Craighead et al. 1995). We estimated that ≤66% of known, unduplicated females with cubs in the GYE aggregate at these alpine talus fields each summer to forage on concentrations of army cutworm moths (O'Brien and Lindzey 1994).

Since determinations regarding the recovery of the GYE grizzly population are based partly on aerial observations and derived indices, there is a need to evaluate the effectiveness of aerial surveys in various habitats and especially at moth sites. Concerns about potential biases of aerial surveys include (1) under-counting females with cubs not present during infrequent surveys, (2) sightability of females with cubs present during surveys, and (3) the ability of aerial observers to correctly classify family groups and sight all offspring in each litter observed. Knight et al. (1995) assumed that all cubs in a family group were sighted by aerial observers. It is important that this assumption be tested. The goals of our study were as follows: (1) to evaluate how well observers could sight and classify bears at moth sites during aerial surveys and (2) to estimate the proportion of females with cubs that used moth sites but were not sighted by aerial observers because they were not present during surveys.

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STUDY AREA

Study sites were located in the northern and central portions of the Absaroka Mountains. The Absarokas are a northwest to southeast trending mountain range about 250 km long, located to the east and southeast of Yellowstone National Park primarily in the Shoshone National Forest in northwestern Wyoming (Fig. 1). The Absaroka mountains were formed by a series of volcanic eruptions during the early Eocene, late Pleistocene, and Quaternary periods (Sundell 1993). Subsequent glaciation and natural erosion carved out the present topography, which is characterized by spine-like ridgelines and prominent mountain massifs that are often capped by remanent expanses of alpine plateau.

Moth aggregation sites typically consisted of colluvial talus fans beneath chutes in cirque cliffs and above the cliffs on less steep portions of the massif. Moth sites were associated with permanent snowfields, glacial cirques, and hanging valleys. Moth sites that were heavily used by grizzly bears were located in alpine areas at elevations between 3,250–3,650 m and on all but northerly aspects (91–314°) and most often on southern aspects (136–221°; O'Brien and Lindzey 1994). Al-

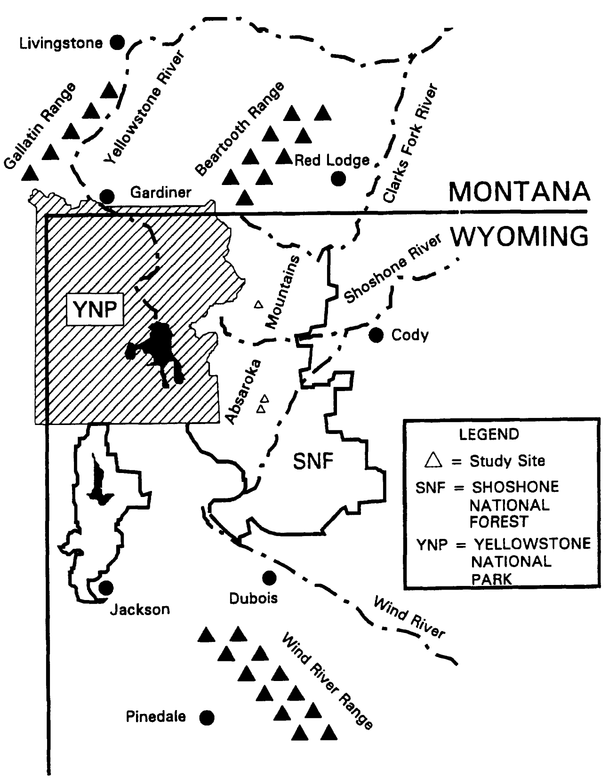

Fig. 1. Study areas within the Absaroka Mountains, Wyoming, 1991–92.

pine vegetation commonly found at moth sites was described by Thilenius and Smith (1985). Daytime temperatures at our alpine study sites during July and August of 1992 ranged between -2–25 C, and daily highs were often between 16–25 C (O'Brien and Lindzey 1994). Winds were often strong (20–30 km/hr; Thilenius and Smith 1985) and usually from the southwest (O'Brien and Lindzey 1994).

METHODS

Ground Observation

We observed bears at 4 moth sites within 3 MAS complexes (massifs with multiple moth sites) during the summers of 1991–92. We selected observation sites that enabled unobstructed views where we did not disturb bears at or traveling to the moth sites. Observation sites were typically downwind, on an opposing massif, about 1.5–2.5 km from the moth site. We used high power (50–80X) telescopes (Questar Corporation, P.O. Box 59, New Hope, PA 18938) to observe bears at 15-minute intervals during daylight hours (0600–2100 hr) for 5–12 days/visit. We also counted and classified bears present during each aerial survey.

Aerial Observation

The IGBST used 2 types of aerial surveys in the GYE. Telemetry flights were used to locate radiocollared bears, a few of which used our study sites. They also used aerial surveys to specifically count and classify bears (especially females with cubs) at moth aggregation sites. Six aerial surveys were conducted simultaneously with ground counts between 29 July–6 September in 1991 and 1992. Twelve additional aerial surveys (16 Jul–19 Sep 1991–92) were conducted while ground observers were not present (i.e., non-simultaneous data) at the sites. Aerial surveys were conducted by the Gallatin Flying Service (D. Stradley, Belgrade, Mont.) using a Piper Supercub and by Western Air Research Inc. (F. Reed, Driggs, Id.) using a Maule M5-235C. All aerial observers (n = 3) and pilots (n = 2) conducted surveys in teams of 2 except in 1 survey which used only 1 pilot-observer. All pilots and observers were experienced at sighting and classifying bears at moth sites, and each had conducted surveys for several years prior this study.

Simultaneous ground and aerial surveys were conducted during favorable weather conditions. Flight altitudes ranged between 60–180 m (typically 120 m). Pilots flew circular patterns around moth sites until both the pilot and observer were satisfied that all bears were detected and correctly classified. Aerial observers recorded the locations of either single or groups of bears using UTM (universal transverse mercator) coordinates or occasionally by township, range, and section. When groups of independent bears were near one another, aerial observers often recorded the position (up or downslope) or direction of each bear relative to other bears nearby. Ground observers often communicated by radio with aerial observers after the survey to determine which bears were detected and how they were classified.

Classification

Aerial and ground observers used the same criteria to classify bears. We used structural characteristics detailed by Blanchard (1987) and sex–age groupings similar to Stonorov and Stokes (1972) and Egbert and Stokes (1976) except we grouped adolescent adults (which we were unable to identify) with adults. We used adult females with cubs that were present during 5 of 6 aerial surveys as our primary reference for age class determination. We also used as a reference 2 radiocollared bears, a 3.5-year old subadult male (1991) and an adult female that was alone in 1991 and with 3 cubs in 1992. We defined subadults as smaller than and lone adults as equal to or larger than an adult female with young. Size determination and thus classification was simplified because it occurred in mid-summer prior to fall hyperphagia (Mattson et al. 1991*a*) and weight gain (Blanchard 1987). Classification of all bears from the ground was agreed upon by 2 observers. Also, because we had several hours and often several days prior to aerial surveys to observe, compare, and classify bears, the likelihood of misclassifying a bear was low. The primary author participated in all ground observations.

We classified independent bears as lone adults (LA), subadults (SA), and adult females with young (F). Independent bears were enumerated in terms of bear units (BU). Dean (1987) defined a bear unit as a solitary bear or a group of bears including family groups, mating pairs, or groups of subadults. We excluded the latter 2 groups because mating season (June) was over and no groups of subadults were observed during simultaneous counts. We were unable to determine the sex of lone bears.

We classified offspring as cubs (C), yearlings (Y1), and 2.5-year olds (Y2). Criteria used for assigning age to offspring included size comparison to the parent and other family groups, facial development, and behavior. We determined the age of offspring when they stood close behind the flanks of the adult female preferably on level ground where we could directly compare height between offspring and parent. We also used behavioral responses to environmental stimuli (Atwell et al. 1980) to help differentiate between cubs and yearlings. Cubs commonly ran and hid after being struck by talus dislodged by their mother, whereas yearlings were less fearful and often moved aside. Nursing behavior and spatial distances among bears during foraging bouts also helped indicate offspring age.

Statistical Analysis

We used chi-square tests (Zar 1984) to compare composition of bears seen by ground and aerial observers. First, we compared the number of family groups and lone bears. Second, we compared the number of lone adults and subadults. We used an $\alpha = 0.1$ for all tests to reduce the potential for type II error (i.e., concluding that ground and aerial observers had good correspondence when they did not). Chi-square tests were appropriate because aerial and ground classifications of bears were independent, and we used bear units instead of individual bears as sample units (i.e., for tests of heterogeneity).

RESULTS

Sightability during Simultaneous Aerial and Ground Observations

During 6 surveys, aerial observers sighted 92% (49 of 53) of all bears and 85% (22 of 26 BU) of the independent bears seen during simultaneous ground observations at moth aggregation sites. However, the number of independent bears tabulated from the air (n = 25 BU) was nearly the same as ground counts (Table 1) despite aerial observers not sighting several bears and misclassifying others (discussed below). No additional bears were sighted from the ground or air during 3 additional surveys. Aerial observers sighted all 10 females with young present during the surveys, but 1 adult female with 3 yearlings, which were foraging >100 m apart during surveys, were misclassified as 4 lone adult bears. We adjusted the results to correct for this error, thus avoiding the misinterpretation that misclassified bears were not sighted and to better compare lone adult and subadult classification. After this adjustment, observers sighted and correctly counted all family groups (Table 1). All of the 4 bears not sighted by aerial surveys were subadults. Aerial observers sighted all lone adults, 56% of subadults, and 75% of lone bears (Table 1).

Classification during Simultaneous Aerial and Ground Observation

No significant differences existed between ground and aerial classification of family groups and lone bears ($\chi^2 = 0.03$, 1 df, $P = 0.86$). Only 1 family group was misclassified by aerial observers at moth aggregation sites. However, among lone bears, subadults were under-represented and lone adults were over-represented by aerial observers ($\chi^2 = 4.80$, 1 df, $P = 0.03$), even adjusting for the 1 known misclassification ($\chi^2 = 2.73$, 1 df, $P = 0.10$) and despite another known misclassification of a lone adult as a subadult. When aerial observers sighted (truly) lone bears, they correctly classified lone adults 6 of 7 times (86%) and subadults 2 of 5 times (40%). Overall, only 2 of 9 (22%) subadults present during surveys were sighted and correctly classified by aerial observers.

Under-representation of subadults by aerial surveys was due not only to misclassification bias, but to lower sightability of subadults as indicated above. When the 4 (unseen) subadults were removed from the ground sample, under-representation of subadults became non-significant ($\chi^2 = 1.76$, 1 df, $P = 0.18$).

Aerial and Ground Comparisons Using Non-simultaneous Data

Based on combined records of all aerial and ground counts, 11 females with cubs used the 2 MAS complexes under study during the summers of 1991–92, of which 2 (18%) were not present during aerial surveys and 3 were not observed during ground surveys (2 used other sites within the MAS complexes, and the other was not present during our visits). Although the 1 female with 2.5-year olds was correctly classified by aerial observers during simultaneous ground counts, aerial observers appeared to misclassify another female with two 2.5-year olds. We observed this family group leaving our observation area to forage on moths at an adjacent site; minutes later, they were observed by an aerial survey, foraging >100 m apart and classified as a lone adult and 2 subadults.

In total, ground observers tallied 55 bears during the 6 days that aerial surveys were conducted including bears (n = 2) present when survey planes were not. Aerial observers saw 49 or 89% of all bears and 22 or 79% of independent bears (n = 28) that visited moth sites on the survey days. They also sighted and correctly classified only 3 of 10 (30%) subadult bears observed to use moth sites on those days.

Table 1. Simultaneous ground and aerial counts ($n = 6$) of grizzly bears at moth aggregation sites in the Absaroka Mountains, Wyoming, 1991–92. Independent bears (i.e., bear units, BU) included females with young (F), lone adults (LA), and subadults (SA). Dependent offspring included cubs (C), yearlings (Y1), and 2.5-year olds (Y2).

Date and start time of survey	Family groups				Lone bears		Totals	
Survey type	F	C	Y1	Y2	LA	SA	*n*	BU
29 Jul 1991 0730 hr								
Ground	2	3	4	0	1	2	12	5
Air	2	3	4	0	2	0	11	4
8 Aug 1991 0920 hr								
Ground	1	3	0	0	3	1	8	5
Air	1	3	0	0	2	2	8	5
6 Sep 1991 1008 hr								
Ground	0	0	0	0	1	0	1	1
Air	0	0	0	0	1	0	1	1
30 Jul 1992 0935 hr								
Ground	2	2	3	0	1	2	10	5
Air	2	2	3	0	2	0	9	4
13 Aug 1992 0936 hr								
Ground	2	2	3	0	0	2	9	4
Air	2	2	3	0	1	0	8	3
14 Aug 1992 0759 hr								
Ground	3	2	3	2	1	2	13	6
Air	2	2	0	2	5	1	12	8
Total ground	10	12	13	2	7	9	53	26
Total air	9	12	10	2	13[a]	3[b]	49	25
Total air adjusted[c]	10	12	13	2	9[a]	3[b]	49	22
Total ground, entire days[d]	10	12	13	2	8	10	55	28

[a] Includes 3 misclassified subadults.
[b] Includes 1 misclassified lone adult.
[c] Corrected for aerial misclassification of adult female with 3 yearlings as 4 lone adults.
[d] Ground counts for the entire days that aerial surveys were conducted including times of day when survey planes were not present.

DISCUSSION

Overall, aerial observers sighted (92%, 85% BU) and correctly classified most grizzly bears that used moth aggregation sites during aerial surveys. They also documented most of the bear use (89%, 79% BU) on (entire) days that surveys were conducted. Most bears sighted in talus areas were easily seen from the air, even at great distances (L. Roop, Wyo. Game and Fish Dep., Cody, pers. commun., 1995). Nevertheless, aerial observers reported that some bears hid and fled from aircraft. For example, despite aerial observers receiving radio signals from a female with cubs near our study site (when we were not present), the aerial observers did not see her. We had more difficulty sighting bears at moth sites (especially those not included in analysis) that contained greater numbers of large boulders, rock outcrops, and cliffs, all of which caused proportionately more shadows and blindspots. This may have contributed to the lower aerial sightability estimate (59%) observed by French et al. (1994), who conducted 4 simultaneous air-ground counts at a nearby MAS complex in Wyoming. Their lower estimate also might be explained by fewer aerial surveys, the number of sites surveyed, survey conditions (turbulence, altitudes), or whether bears were all in talus areas. French et al.'s (1994) sightability estimate was similar to those in more heavily vegetated habitats in Alaska.

In the GYE, IGBST observation flights only surveyed open areas and woodland edges for bears because aerial surveys of wooded areas were not considered cost-effective (Knight et al. 1987). In Alaska, aerial sightability of brown bears was affected by habitat, terrain, time of year (e.g., leaf-out), and reproductive status rather than individual bear behavior (Barnes and Smith 1995). In grass–shrub habitats of coastal Alaska, sightability ranged between 30–53% (Erickson and Siniff 1963, Barnes et al. 1988, Miller and Sellers 1992, Barnes and Smith 1995). In one area it decreased from 40% to 26% as leaf-out progressed (Barnes et al. 1988). Even when exact locations of bears were determined using radiotelemetry, aerial observers sighted only 59–68% of all bears (Miller and Sellers 1992, Sellers 1994). In shrub habitats of south-central Alaska, sightability for independent bears >2-years old was only 24–47% (Miller et al. 1987, Miller 1990). Many of these Alaskan studies also suggest, however, that higher sightability would occur in areas of less cover. Barnes (1994) reported that the mean number of bears observed on salmon streams compared favorably between simultaneous ground and aerial counts. Further, although Erickson and Siniff (1963) reported 47% sightability near salmon streams, their results were also highly variable (range = 0–88%), depending on vegetation (Dean 1987).

In our study, aerial observers sighted and correctly classified all females with cubs present at moth sites probably due to the open habitat. Aerial surveys were conducted between 0700–1000 hours, and during this time, 90% of females with cubs were observed on open talus scree (O'Brien and Lindzey 1994). Also, we observed no additional females with cubs at moth sites for the remainder of the days that aerial surveys were conducted, indicating that early mornings were a good time to conduct aerial surveys for this age group.

For open alpine habitats, our results support Knight et al's. (1995) assumption that all cubs in each litter were sighted by aerial observers. Aerial observers also had little or no difficulty classifying adult females with cubs through the end of August. In tundra–shrub habitats near Nome, Alaska, all cubs in 10 litters were sighted (S.D. Miller, Alas. Dep. Fish and Game, Anchorage, pers. commun., 1995) and were correctly classified by aerial observers (Miller and Nelson 1993).

Some caution is warranted in applying these results, however, as 2 (18%) females with cubs that were known to use 2 MAS complexes during our study were not present and thus not tabulated during aerial surveys. Also, because 1 of these females with cubs was the same color and had the same number of cubs as another (sighted) family group that used this site, both families would have had to have been sighted on the same aerial survey to have been recorded as 2 separate groups (Knight et al. 1995).

Our high sightability of females with cubs also may have been due, in part, to aerial surveys being conducted late in the year (after 16 Jul) when cubs were more mobile and independent compared to many Alaskan studies that were often conducted earlier in the year. During late spring (21 May–16 Jun) in Alaska, females with cubs were less sightable than females with yearlings from the air because females with cubs exited dens later and thus were less active and used more remote, steep, high altitude habitats (denning areas) where sightability was difficult (Miller et al. 1987, Barnes et al. 1988, Miller and Nelson 1993, and Barnes and Smith 1995). Sightability for females with cubs was 30% for 5 families in tundra–shrub habitat (Miller and Nelson 1993) and 18% in mountainous terrain on Kodiak Island (Barnes and Smith 1995).

Repeated aerial surveys at moth sites also may lead to greater sightability of females with cubs because bears appeared to habituate to low-flying aircraft. During 2 aerial surveys conducted on successive days, a female with cubs fled and attempted to hide from the survey plane during the first survey, but on the second survey, although clearly nervous, she did not flee which suggests mothers may transfer tolerant behavior to their offspring. Aerial observers in the GYE reported that many adult female grizzlies often appeared to tolerate or ignore aircraft disturbance despite panic by their offspring (L. Roop, pers. commun.). McLellan and Schackleton (1989) also reported that bears can habituate to aircraft and are less likely to react to aircraft that fly at altitudes >150 m.

Aerial sightability was also high for females with yearling and 2.5-year old young at moth sites, whereas in Alaska, investigators had more difficulty sighting these age classes. Sightability for females with older young (≥1-year old) in Alaska was 40% for 5 family groups in tundra–shrub habitats near Nome (Miller and Nelson 1993) and 68% (the highest of any age group) on Kodiak Island (Barnes and Smith 1995). Also on Kodiak Island, sightability of females with young (0.5–2.5-year olds) ranged between 58–71% (Barnes 1986). In Denali National Park, Dean (1987) estimated that, at most, 75% of females with young were sighted by aerial observers.

In our study, aerial observers had more difficulty classifying females with older young than those with cubs, which was due in part to spatial separation between the parent and offspring. The older the offspring, the more independent they became and further away they fed from their mother, making judgement of size more difficult. One yearling and apparently several 2.5-year old litters (as identified by non-simultaneous ground and aerial counts, observation flight reports, and aerial observers) were misclassified as subadults and less often as lone adults, thus the age (size) of offspring tended to be overestimated. In these instances, the mother bears were misclassified as lone adults. Aerial misclassification of these age groups, especially 2.5-year olds, resulted in under-representation. We suspect, however, that the majority (if not most) of yearling litters sighted in the GYE during surveys were correctly identified by aerial observers throughout the summer.

Analysis of IGBST observations during telemetry flights (1974–92) suggested that misclassification of yearlings as cubs was probably more common than the reverse in the GYE (C. Pease, Univ. of Texas at Austin, unpubl. data). Despite aerial observers having some prior knowledge of the age and status of offspring they were tracking, 6% of the family groups (n = 583) composed mostly of yearling and 2.5-year old litters were either misclassified, the term cub was incorrectly used to include all ages of young, or both. Cub litters were misclassified as yearlings only once (n = 449).

Aerial observers in our study seemed to have less difficulty classifying females with older young, especially those with yearling litters, than did investigators in Alaska. Most (75%) yearling litters (n = 4) using moth sites were correctly classified, and when 2.5-year olds were misclassified, their age was overestimated. In comparison, females with litters of cubs, yearlings, 2.5-year olds, and 3.5-year olds sighted near Nome, Alaska, were correctly classified by aerial observers 100% (n = 10), 30% (n = 10), 50% (n = 2), and 50% (n = 2) of the time, respectively (Miller and Nelson 1993). Yearlings were misclassified as 2.5-year olds 70% of the time, and 2.5–3.5-year olds were sometimes misclassified as a year younger. Erickson and Siniff (1963) reported that litters of ≥1-year old offspring were pooled because aerial classification was unreliable. Sellers (Alaska Dep. Fish and Game, King Salmon, pers. commun., 1995) stated that only cubs seen from the air prior to September can be correctly classified >90% of the time, and differentiating ≥1-year-old offspring was reliable only in the spring. As in our study, aerial observers on Kodiak Island, Alaska, also misclassified a female with 3 yearlings as a lone adult because they failed to sight her offspring during the survey (Barnes 1986). We suspect that the lower availability of hyperphagic foods found in the GYE during the summer (Mattson et al. 1991*a*) moderates annual fluctuation in bear (offspring) growth patterns, thereby making it easier for aerial observers to classify bears (offspring) in the GYE.

In our study, aerial observers had the most difficulty sighting and assessing the age of solitary subadults. Although all (solitary) lone adults were sighted and most (86%) were correctly classified, subadults were both difficult to sight (56%) and correctly classify (40%), which led to the misinterpretation that subadults were under-represented. Aerial observers often overestimated the size of subadults and misclassified them as lone adults thereby inflating counts in that age class. Their misclassification of 1 lone adult as a subadult and the near agreement between aerial and ground counts of independent bears (i.e., despite not sighting or misclassifying some bears from the air) indicates that some error is also compensatory. Using data from aerial surveys of bears at moth aggregation sites in Wyoming, Mattson et al. (1991*b*) suggested that subadults were under-represented because they may have been less detectable. Using *non-simultaneous* ground counts for comparison, French et al. (1994) also reported that aerial counts seemed to significantly under-represent subadults at moth sites because it appeared that aerial observers could not adequately differentiate between single adult and subadult bears. They did not indicate, however, whether subadult or lone adult age classes had differing sightabilities, nor if it affected their (overall) sightability estimate. Our findings were similar to those reported in Alaska where sightability of subadult bears was 48% on Kodiak Island (Barnes and Smith 1995).

Aerial sightability of lone adults at moth aggregation sites was high, whereas in Alaska, sightability was much lower: 48–50% for lone adult males and females on Kodiak Island (Barnes and Smith 1995) and 22% for 2 lone males and 50% for 3 lone females in tundra–shrub habitats near Nome (Miller and Nelson 1993). Even though aerial observers sighted all lone adults during surveys in our study, total counts of bears among surveys were not possible because aerial observers were unable to individually identify unmarked, solitary bears. O'Brien and Lindzey (1994) reported that 3 of 10 (30%) lone adults used moth sites irregularly (≤1 day), and some were possibly transients. These bears were not likely to be sighted by aerial observers because they were seldom present and because aerial surveys were infrequent. Similarly, at Kodiak Island, Alaska, Barnes (1986) found that 3 of 11 (27%) lone bears that used salmon streams were not sighted at least once during 6 aerial surveys.

MANAGEMENT IMPLICATIONS

Aerial counts of females with cubs in the GYE are not only used by the IGBST to monitor population trends, but will likely play a prominent role in future efforts to delist the grizzly bear. Our limited data indicate that aerial surveys are effective in that experienced aerial observers can accurately classify females with cubs that use moth aggregation sites through the end of August, and they sight all cubs in each litter observed. Further, sightability of family groups in talus areas is high, likely due to a lack of vegetative cover and to timing of aerial surveys (0700–1000 hr) during peak use by females with cubs (O'Brien and Lindzey 1994). The frequency of aerial counts (about 6 flights, 1 every 7–10 days, 16 Jul–15 Sep), however, likely yielded low estimates of the number of females with cubs because some (18%) were not present during surveys and because indistinguishable family groups would have needed to be seen on the same survey to be counted as separate groups. Further study is needed to assess the costs and benefits of conducting more flights. Since use of moth aggregation sites by females with cubs apparently decreases in late summer (Mattson et al. 1991*b*), it may be better to focus most additional effort during the early summer (before 14 Aug).

Although aerial observers in this and most other studies did not misclassify yearlings as cubs, all studies had small sample sizes, and most Alaskan studies reported classification of yearlings to be somewhat unreliable (Erickson and Siniff 1963, Miller and Nelson 1993, R. Sellers, pers. commun.). If yearlings are sometimes misclassified as cubs in the GYE (C. Pease, Univ. of Texas, Austin, pers. commun., 1995), counts of females with cubs could be overestimated. This might be a particular concern in areas like coastal Alaska, which has had large annual fluctuations in bear food resources and disparate rates of offspring growth (R. Sellers, pers. commun.).

Misclassification and lower sightability of subadult bears by aerial observers suggests that the subadult and lone adult age groups should (for now) be combined during analysis. However, until more is known, aerial observers should continue to document these age groups separately to avoid a premature loss of information (e.g., the knowledge that at least some subadults use each site is still valuable information).

More study is needed to better evaluate the ability of aerial observers to sight and classify family groups and solitary bears, to sight offspring in various habitat types, and to evaluate the effect of fluctuating food resources over time on offspring classification. Further, it would also be worthwhile to determine whether aerial observers could accurately classify family groups during hyperphagia (fall) because some females with young used moth sites until early October in some years (O'Brien and Lindzey 1994). Because many studies are ongoing, it is currently possible to collect and pool some of these data by using ground counts to test results of aerial surveys (as in this study), by using uninformed aerial observers and known-aged bears (Miller and Nelson 1993), or by having aerial observers estimate age and sex of bears just prior to capture (I. Stirling, Can. Wildl. Serv., Edmonton, Alta., pers. commun., 1995).

Standardization of aerial survey methodology and data recording procedures is needed. In our study, data recording (sex–age group, weight, location, and relative position to other bears) varied by observer and agency. Offspring notation should be unambiguous and specific (cub-of-year, yearling, 2.5-year old, or 3.5-year old), and observations of suspected family groups that appear spatially separated should be clearly documented. Furthermore, we suggest using only UTM coordinates (versus section numbers) to document bear locations and verifying the coordinates after the flight.

We recommend avoiding west aspects for simultaneous aerial and ground counts because dark shadows and glare make it difficult for observers to detect bears in the mornings. We also recommend that aerial surveys cover adjacent MAS complexes on the same day, as family groups can travel between adjacent areas. Also, because (intra) seasonal movements between adjacent MAS complexes are possible (T. Ryder, Wyoming Game and Fish Dep., Lander, pers. commun., 1995), more studies on bear movements between adjacent areas are needed to assess whether some family groups might be counted twice.

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