Application of a double-count line transect method to estimate density of brown bears in arctic Alaska.

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Abstract: We used a double-count aerial line transect method to estimate grizzly bear (Ursus arctos) densities in the mountains of the Brooks Range in northern Alaska. The technique used tandem 2-place aircraft flying transects at about 100 m above ground level with the pilot and passenger as observers. A pilot study in 1999 showed that observational efficiency declined when observers searched both sides of transects. As a result, pilots and passengers recorded bear observations from the same side of the aircraft, on one side of the transect only. We truncated the northern edge of the study area at 300 m elevation as bear densities were very low on the arctic coastal plain. Transect searches also did not include habitat above 1220 m. In 2000 and 2001, we flew a total of 821 35-km transect lines and observed 143 bear groups. The most distant groups were eliminated from the data set and 137 bear groups were used in the analysis. Line transect models that produced detection functions estimated the probability of observers detecting a bear at various distances for a given set of covariates (group size, type, activity, percent cover). The sum of group size divided by the probability of detection gave an estimate of population size. We estimated grizzly bear densities to be 17.6 bears/1000 km^2 (95%CI = 13.7) in the 20,720 km^2 area surveyed in 2000 and 2001. In 2003, we completed another 134 transects and observed an additional 29 bear-groups that was used to increase the precision of the estimate. Using data from all 3 years, we estimated grizzly bear densities to be 18.3 bears/1000 km^2 (95% CI = 12.3). Observations of at least 160 bear groups are desirable for this technique to be effective. This technique does not require marking or radiocollaring bears. It is useful for surveying remote rugged areas and can be spread over more than one year to reduce annual costs and logistics.

Introduction

Measures of animal density can be difficult and costly to obtain in remote regions of rugged habitat. Aerial surveys of wildlife populations are a cost-effective way to determine population status with species that are highly visible from the air. But the problem of visibility bias (Pollock and Kendall 1987) must be overcome and a valid sample design must be used to expand the estimator into unsampled areas and to estimate the sampling variance. Sightability among animals along transects may vary due to activity, group size and other factors and requires the use of covariates to better estimate differences in the probability of detection (Quang and Becker 1996). Quang and Becker (1999) developed a double count procedure for collecting line-transect data in mountainous terrain by flying contour transects. The object of this paper is to describe preliminary results of the use of this technique to obtain a density estimate of grizzly bears (*Ursus arctos*) in mountainous terrain in northern Alaska.

Study Area

The study area was located in north-central Alaska from the crest of the Brooks Range (68° 15') north to the edge of the arctic coastal plain (69° 15') and from the headwaters of the Canning River in the Arctic National Wildlife Refuge (145°) west to the Anatuvik River in Gates of the Arctic National Park (151°) (Fig. 1) Rugged mountains and narrow mountain valleys characterize the terrain. Land cover was arctic or alpine tundra with low growing plants or barren rock or soil.

Methods

Study design: We identified a set of transects by randomly selecting transect midpoints using GIS-generated topographic maps and expanding the transects to a total length of 35 km along the elevation contours associated with the midpoint. In 1999, we conducted a pilot study to determine if both sides of the aircraft could be searched and if bear densities in the coastal plain portion of the study area were high enough to allow application of the technique. In 2000 and 2001 we surveyed 366 transects and 495 transects, respectively. We flew an additional 134 transects in 2003 to improved the precision of the density estimate calculated in 2001. The 1999 feasibility study found that coastal plain habitat below 300 m comprised 45% of the transects surveyed but only 10% of the bear observations. As a result, we truncated the northern edge of the study area at 300 m elevation in 2000, 2001 and 2003. Transect searches also did not include habitat above 1220 m, where past experience in the area indicated that bear density would be so low that effort expended would not be efficient.

Survey techniques: Two observers (1 pilot and 1 observer) were used in this double count study. We used 3 - 5 small 2-person search aircraft during survey flights each day. The passenger was seated directly behind the pilot and a screen separated the 2 observers to ensure independence of the observations

(Fig. 2). Transects were flown at about 100 m AGL. Flights took place on June 10-17 in 2000 , June 8-20 in 2001 and June 6-9 in 2003. The pilot study indicated that observational efficiency declined when observers searched both sides of transect lines at the same time. In 2000, 2001 and 2003, both observers searched the same side of the aircraft. Geolink™ software tracked the flight path of the aircraft from a laptop computer operated by the rear observer. Programmed key-button functions were used to input information into this database. Information included start of transect, transect identification number, off and on transect marks, switch-side marks, end of transect marks, maximum sightability and bear location marks. To insure the independence of the observations, sightings of bears were not immediately disclosed but were indicated by the observers by turning on a shielded light. If both observers turned on their lights, the airplane left the transect to obtain the location of the bear by flying over it. If only 1 observer switched on a light, the flight path continued to search along the transect until the second observer was unlikely to see the bear (3-5 seconds after passing the bear). At that time, the sighting was revealed and the airplane made a low level pass over the bear to obtain the location. We used Global Positioning System (GPS) receivers in each aircraft to determine the latitude and longitude of each bear group. Group size, activity, percent vegetation cover, group type, and search distance were recorded for each bear group. We defined the term "bear group" as any sighting of a single bear or a group of bears including females with offspring and breeding pairs.

Data analysis: We calculated the distance from each bear group to the closest point on the transect line. We used a stem and leaf diagram (Hoaglin et al. 1985) to find natural break points close to the 95 percentile. Observations at distances beyond this were eliminated from the analysis. We used AIC criteria (Buckland et al. 1993) to fit 2 separate line transect models using the observations from the pilot-observer and from the passenger-observer. Each line transect model produced a detection function that estimated a probability curve for that observer detecting a group of bears for various distances along the transect, for a given set of covariates. Using both observers' detection functions and assuming that their observations were independent, we estimated the probability that both observers together observed a given bear group (inclusion probability, *p*). Group (S) was divided by the inclusion probability (p) for each observation and these values were summed using the Horvitz-Thompson formula (Borchers et al. 1988) to calculate an estimate of population size (N). To obtain a density estimate, we used calculated the transect area surveyed and divided the estimated number of bears by this area. We used bootstrapping (Effron 1982) to calculate variances and confidence intervals for density estimates and expressed confidence limits as a plus or minus percentage of the point estimate.

Results

During the pilot study in 1999, few bears were seen on the coastal plain (Fig. 3) and the study area was truncated to elevations above 300 m during surveys in 2000, 2001 and 2003.

In June 2000 we observed 60 bear groups along 366 transects with a total length of 12952.5 km (Fig.3). In June 2001, we surveyed 495 transects with a total length of 17,694 km. 6 and 83 bears (Fig 4). During these 2 years combined, pilots saw 32 bears, passengers saw 45 bears and both observers together saw 66 bears. Bear sightings tended to be highest in the western third of the study area (58 sightings) compared with 39 sightings in the central third and 46 sightings in the eastern third. Bear distances from transect ranged from 28 m to 1490 m. Because 95% of the observations fell within 880 m from the transect, the data was truncated at that distance and we used only 137 of the 43 bear groups to calculate the detection models from the 2000 and 2001 data.

In 2003, additional sampling in 2003 added 29 bear groups along 134 transects with a total length of 4690 km (Fig. 5). During all 3 years combined, 172 bear groups were seen (Table 1). O these, 166 bear groups were used to calculate the detection models, the density estimate and confidence intervals for the estimate using data from all 3 years combined.

Detection curves: The pilots and passengers had different detection models based on AIC criteria. We estimated that the maximum detection for the pilot-observer as 0.802 with a negative slope for bear activity (detection becomes more difficult as the bear is more active) and a positive slope for type of group (other groups (breeding pairs and subadult groups) are more detectable than single bears. We estimated the maximum detection curve for the passenger-observers to be 1.0. The negative coefficient for running bears indicates that running bears are more likely to be seen near the transect. The positive coefficient for the adult group parameter indicates that detection of adult bears is better. A comparison of the pilots' and the passengers' detection curves indicated that passengers had better detection than pilots near the apex of the curves, but that the pilots out-performed the passengers at distances approximately 150 meters or more from the apex .

Population estimate:
For the area surveyed in 2000 and 2001, we estimated a density of 17.6 bears per 1000 km^2 (95% CI = 13.6) (Table 2). With addition of 29 bear groups in 2003, the density estimate was recalculated to be 18.3 bears per 1000 km^2 (95% CI = 12.3).

Discussion and conclusions

We had hoped that the density estimate for grizzly bears in north-central Alaska would be more precise. Although a minimum of 150 bear groups was our goal for the first 2 years combined, we saw only 143 groups in 2000 and 2001. Of these, 137 groups were used in the analysis. In 2003, we flew an additional 134 transects and observed 29 bear groups. The resulting total of 166 bear groups improved the precision of the density estimate: the width of the confidence interval was less (12.3) compared to the confidence interval calculated for the 2000 and 2001 combined data (13.6). Based on our experience we recommend that a minimum of 163 bear groups need to be located for this technique to be effective. We predict that this level of sampling would result in a 90% confidence interval whose limits are plus or minus 15-20% of the point estimate.

This technique requires the use of several small aircraft for several days to complete a survey of a large area (>20,000 km^2 in this case), but does not need animals to be marked or radiocollared. The technique is particularly suitable for remote areas of rugged terrain that are difficult and costly to survey. Because the data from several years can be combined to calculate the detection functions, the work can be spaced over multiple years, reducing annual costs and logistics.

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Table 1. Number of bear groups observed along random contour transects during density estimate surveys in north-central Alaska, June 2000, 2001 and 2003.

Year	Number of transects flown	Length of all Transects combined (km)	Number of bear groups seen
2000	366	12952	60
2001	495	17695	83
2003	134	4690	29
2000 +2001	861	30647	143
All years	995	35337	172

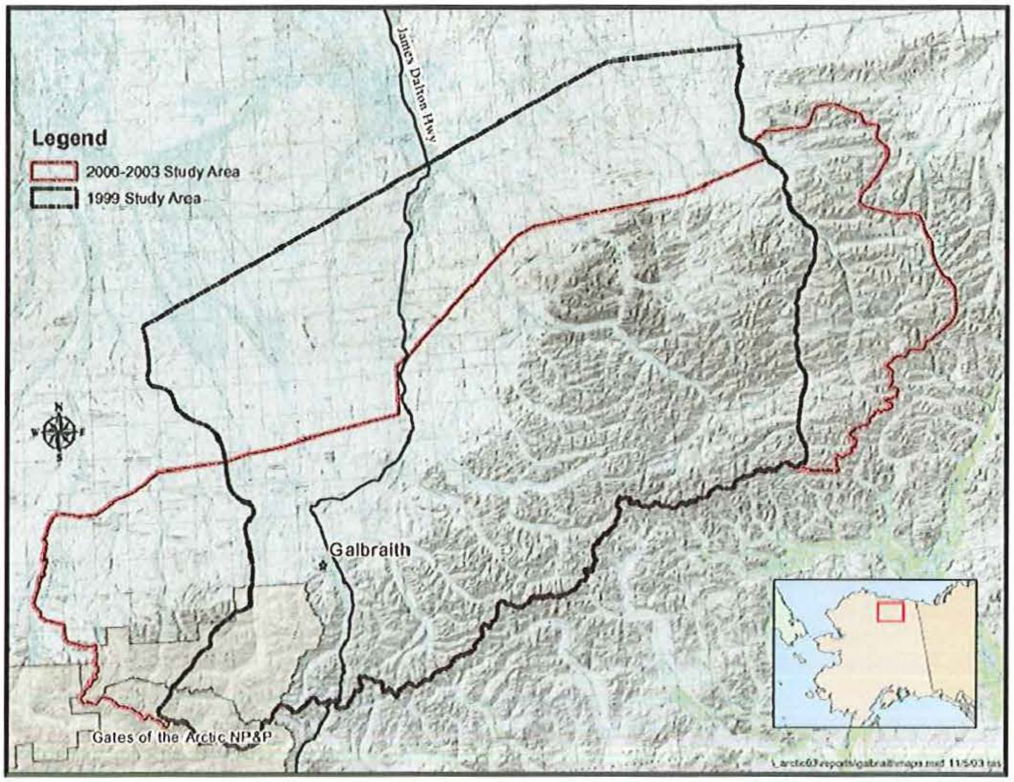

Fig. 1. Study area in northern Alaska flown in grizzly bear density study. After a pilot study in 1999, the survey area was expanded northeast and southwest and the coastal plain segment was eliminated because few bears occupied this region.

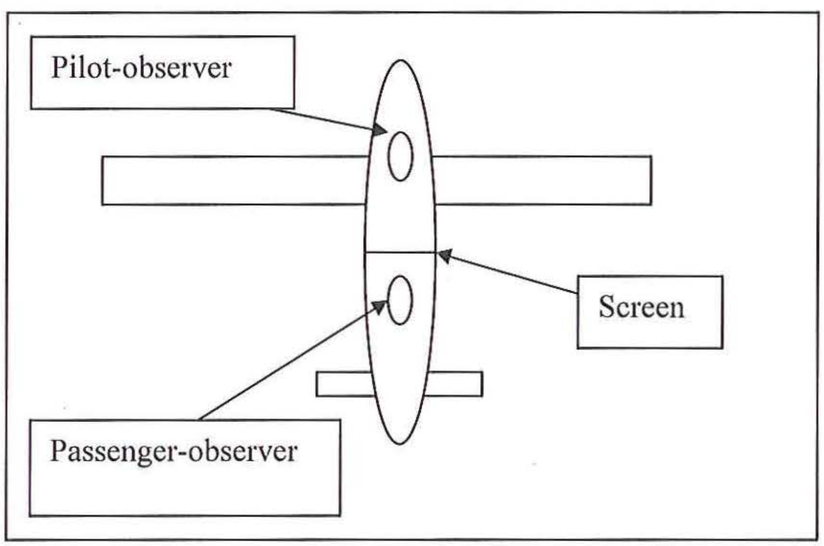

Fig. 2. Configuration of observers in two-passenger aircraft used in bear density estimation in north-central Alaska, 1999-2003.

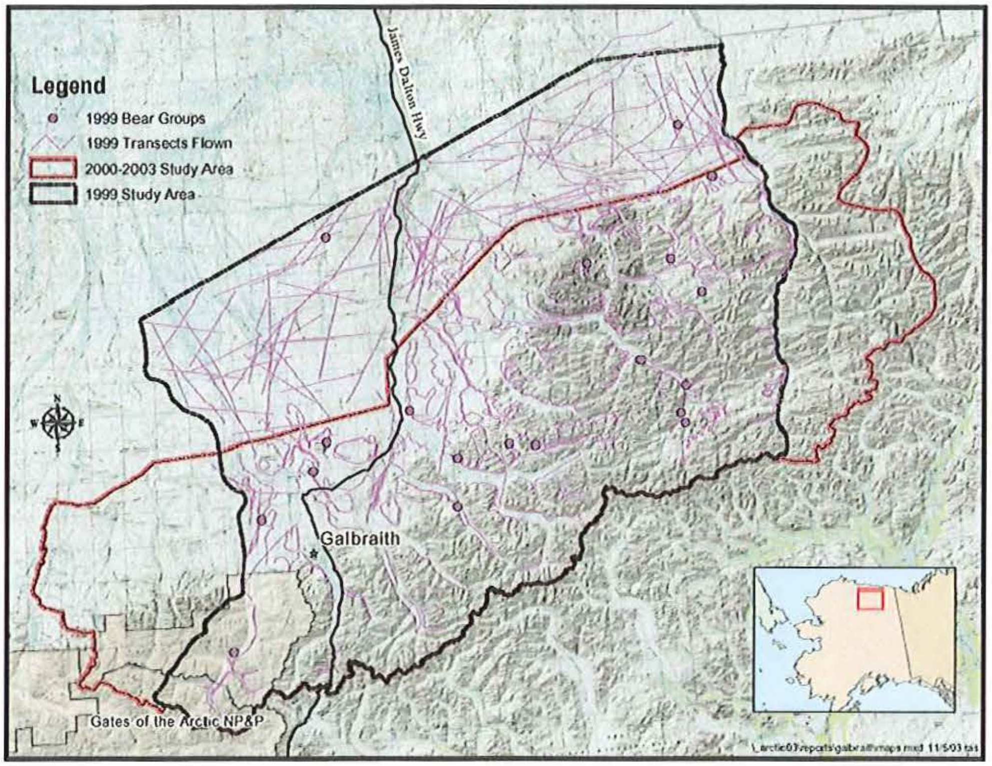

Fig. 3 Transects flown and bear groups observed during density estimate pilot study in north-central Alaska, June 1999.

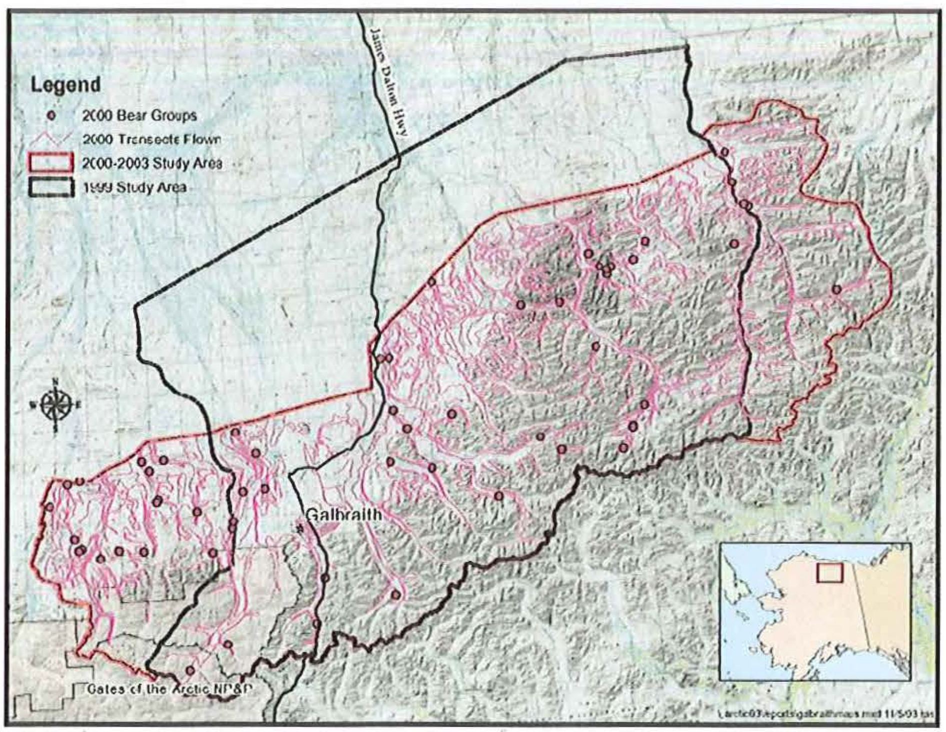

Fig. 4. Transects flown and bear groups observed during density estimate surveys in north-central Alaska, June 2000.

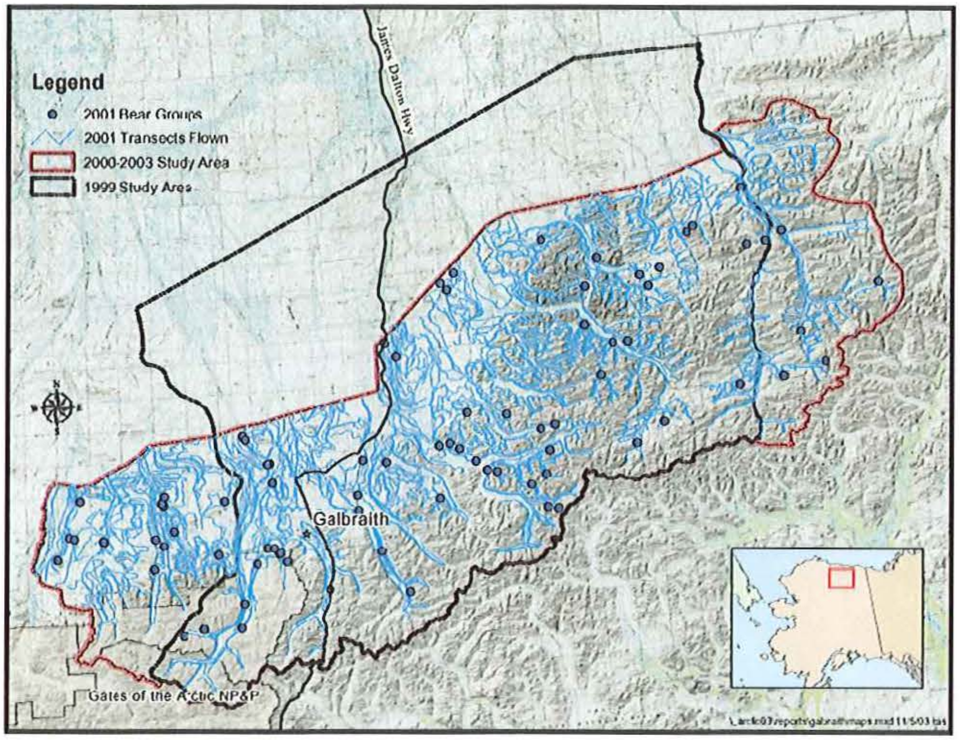

Fig. 5. Transects flown and bear groups observed during density estimate surveys in north-central Alaska, June 2001

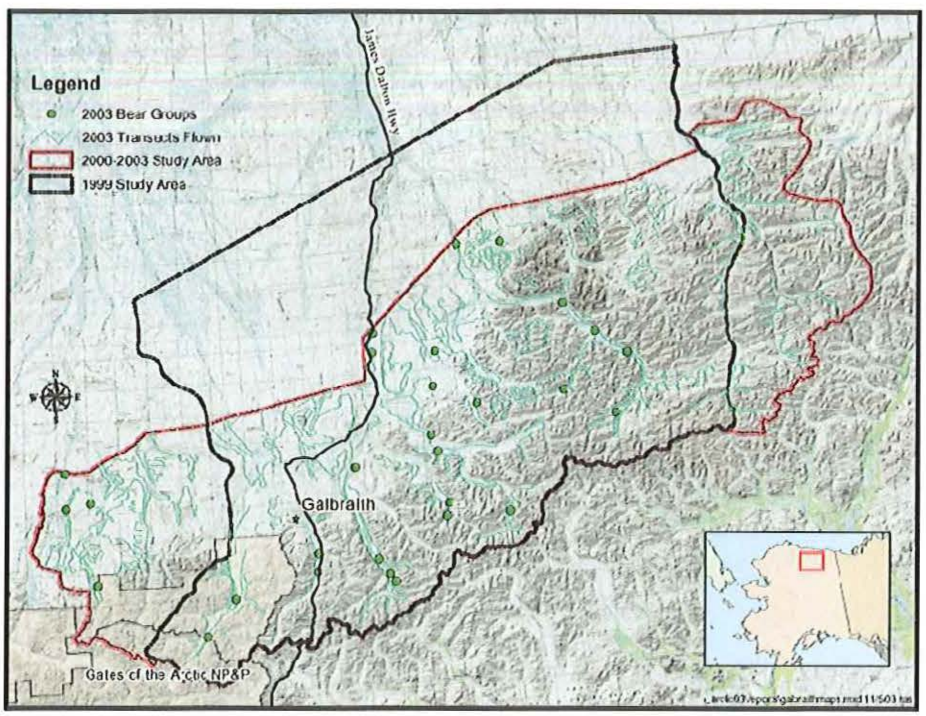

Fig. 6. Transects flown and bear groups observed during density estimate surveys in north-central Alaska, June 2004.