ARCTIC
VOL. 44, NO. 4 (DECEMBER 1991) P. 275-278

Double Counts in Aerial Surveys to Estimate Polar Bear Numbers during the Ice-Free Period

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(Received 14 November 1990; accepted in revised form 14 February 1991)

ABSTRACT. The double-count technique in aerial surveys, a variant of the mark and recapture method, was tested over islands offshore northern Quebec to estimate the number of polar bears that retreated there in the summers of 1986 and 1987. One front observer and two lateral ones surveyed six areas from aboard a twin engine DC-3 aircraft, independently reporting the number of animals they saw to the crew navigator. Bears were classified as being seen both in front and on the side, in front only or on the side only, making it possible to estimate correction factors. Although the observed strip covered 1.75 km on each side of the aircraft, the bear visibility rate exceeded 60% for lateral observers; the low vegetation of the islands and the contrasting colour of bears explain this high visibility. Corrected bear density varied between 0.4 and 14.2 animals·100 km^{-2} according to year and area. The double-count technique could be used to estimate the size of bear populations retreating on the islands and the coasts of Hudson Bay during the ice-free period, but its costs would have to be evaluated and compared with current techniques before including this method in management programs.

Key words: polar bear, census, double count, Hudson Bay, Quebec, summer, *Ursus maritimus*

RÉSUMÉ. Une variante de la méthode de marquage-recapture, la technique des décomptes doubles en avion, a été expérimentée sur des îles au large du Québec nordique pour estimer le nombre d'ours blancs qui s'y étaient réfugiés à l'été de 1986 et de 1987. Un observateur avant et deux observateurs latéraux inventorièrent six endroits à bord d'un avion bimoteur DC-3, rapportant de façon indépendante au navigateur le nombre d'ours vus. Les animaux furent classés comme ayant été vus soit à l'avant et de côté, soit à l'avant seulement ou de côté seulement, ce qui permit de calculer des facteurs de correction. Bien que la bande observée de chaque côté de l'avion couvrait 1.75 km, le taux de visibilité des ours dépassait 60 pour cent pour les deux observateurs latéraux; la végétation rase des îles et la couleur contrastante des ours expliquent cette grande visibilité. La densité corrigée d'ours a varié entre 0.4 et 14.2 individus·100 km^{-2} selon l'année et l'endroit. La technique des décomptes doubles pourrait être utilisée pour estimer la taille des populations d'ours qui se réfugient sur les îles et les côtes de la Baie d'Hudson durant la période sans glace, mais il faudrait en évaluer les coûts et les comparer à ceux de la méthode en usage avant de la retenir pour les programmes de suivi.

Mots clés: Baie d'Hudson, été, décompte double, inventaire, Québec, ours blanc, *Ursus maritimus*

INTRODUCTION

Agencies responsible for wildlife management need indicators of population size to carry out their mandate of conservation and sustained use of harvested populations. With trend indicators, the population rate of change can be monitored (Caughley and Birch, 1971), and more detailed studies can be initiated for populations showing rapid decline or increase. While indices may suffice for unharvested species or conservative harvesting, population estimates are necessary for intensive harvesting or for vulnerable species.

Aerial census represents the most practical and widely used technique for estimating the population size of large mammals inhabiting vast and inaccessible areas (Caughley, 1977). Much research has been devoted in wildlife management to developing methods producing unbiased and precise population estimates. Visibility bias can be measured directly with known populations kept in enclosures (Leresche and Rausch, 1974) or with free-ranging radio-tagged or marked animals (Rice and Harder, 1977; Floyd *et al.*, 1979; Beasom *et al.*, 1986; Bartmann *et al.*, 1987; Crête *et al.*, 1986; Gasaway and Dubois, 1987; Samuel *et al.*, 1987; DeYoung *et al.*, 1989). The double-count technique, in which animals are recognized due to knowledge of their exact location, can also serve to estimate visibility bias (Magnusson *et al.*, 1978; Cook and Jacobson, 1979; Crête, 1979; Caughley and Grice, 1982; Estes and Jameson, 1988; Bayliss and Yeomans, 1989; Graham and Bell, 1989; Potvin *et al.*, 1991). However this technique may allow only partial correction, particularly when it is used with two independent observers sitting on the same aircraft: perception bias (potentially visible animals not seen) can be accounted for, but not availability bias (animals invisible to the observers due to visual obstacles) (Marsh and Sinclair, 1989).

For polar bears (*Ursus maritimus*), Prevett and Kolenosky (1982) developed an aerial trend estimate on the Ontario coast; elsewere in North America, population sizes have been generally estimated with multi-year mark and recapture models (Demaster *et al.*, 1980). Bears have been immobilized with drugs delivered from helicopter and marked with dye, ear tag and lip tattoo; they then have been recaptured in the same manner the same year or in subsequent years. Such estimates, albeit expensive, have often been imprecise due to small sample size and low probability of recapture (Derocher, 1987); furthermore, they could be biased because of the difficulty of random sampling over the sea ice. A permanent bone marker (tetracycline) has recently been tested to replace ear tags and tattoos in multi-year mark and recapture models; recapture data will be obtained by detecting the marker in jaws of bears harvested during hunting seasons (Taylor and Lee, 1990). On the other hand, Derocher (1987) successfully used the single-year mark and recapture method during the ice-free period in Manitoba. Two advantages arise from counting bears when they concentrate on islands and on the coasts of Hudson Bay in late summer and early autumn, the approach adopted by Derocher (1987): they are highly visible from the air in the absence of snow, and precision of estimates generally improves with density.

In this paper, we report on the use of the double-count technique with two independent observers in the same aircraft to derive corrected population estimates of polar bears on islands offshore Quebec during the ice-free period.

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METHODS

We selected as our study area six islands or groups of islands offshore northern Quebec known from previous reconnaissance flights to harbour polar bears during the ice-free period (Fig. 1). Parallel transect lines were drawn to ensure complete coverage, except for Mansel and Akpatok islands, too large for complete coverage given the flying time available. Each transect line was flown with a twin-engine DC-3 aircraft, cruising approximately at a speed of 200 km·h^{-1} and at an altitude of 200 m above the ground. The aircraft was equipped with a radar-altimeter. The survey was done in late August and early September in 1986 and 1987, except for Ottawa Islands the first year, which were censused in mid-October.

During the flight, a front observer stood in the cockpit, looking in front and on both sides of the aircraft; he reported to the navigator (the co-pilot) the number of polar bears seen. Two rear observers, seated on each side of the aircraft, also reported the number of animals they saw; they were not aware of the front observer's count. The location of each animal or group of bears was plotted on 1:250 000 topographic maps, and each observation was assigned to one of the three categories: seen in front only, in the rear only, both in front and in the rear. The pilot and co-pilot were asked not to assist the front observer, but their reaction may have helped to detect bears, particularly in the first year. This did not bias the results because the double-count technique does not assume equal visibility rate among observers. The rear observers were unaware of the observations made in the cockpit, ensuring independence between the two sets of observations. Two observers participated in the census both years, while one changed; the front observer was not the same person in the second year. The average width of the censused strip was estimated with a clinometer in 1988 over the tundra of northern Quebec, using the same aircraft operated under the same conditions. Ten readings were taken on both sides of the aircraft by each of the two observers who had participated in the 1987 flight.

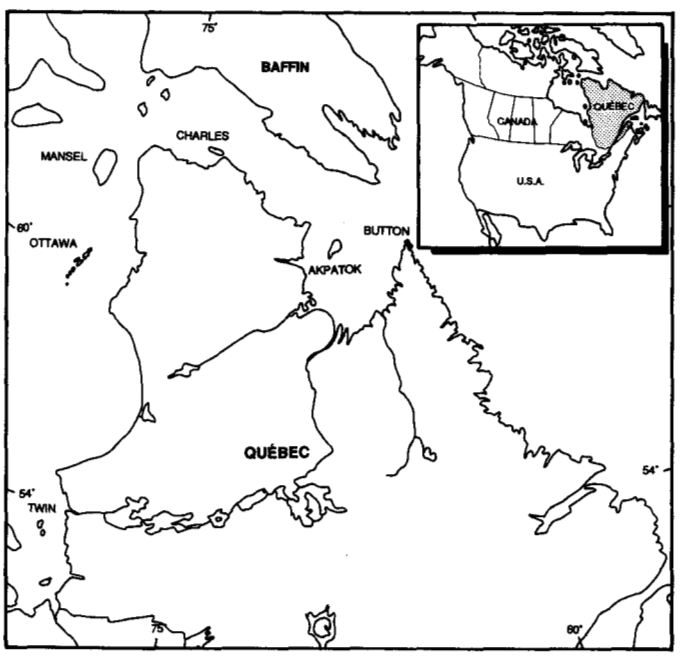

FIG. 1. Location of the six islands or groups of islands offshore Quebec where polar bears were censused during the ice-free period in 1986 and 1987.

As the sample size was often small, we estimated the visibility rate ($\hat{p}$) of bears and the corrected population size ($\hat{N}$) (and their variance) for the combined data each year. For the same reason, we did not discriminate between the left and right rear observer. $\hat{N}$, $\hat{p}$ and var ($\hat{N}$) were estimated according to Seber (1982). $\hat{N}$ was partitioned among islands according to the number of animals seen during the surveys to compare bear density among areas.

RESULTS

The width of the strip where bears were counted did not differ among observers ($t=0.51$; $P>0.5$); the angle made by the vertical of the aircraft and the outer limit of the strip averaged 83.6° (SE=0.4; n=20). As the aircraft flew at a mean altitude of 200 m, bears were counted within a 1.75 km strip on each side of the aircraft.

Polar bears were seen on each island but in varying numbers (Table 1); 52 different animals were counted in 1986, as compared to 79 the following year. The highest counts were made on the Twin Islands each summer and on Mansel Island in 1987.

The visibility rate of the rear observers was estimated at 0.62 in 1986, as compared to 0.71 in 1987; for the front observer, this rate was 0.72 and 0.36 the first and the second year respectively. The number of bears present in the whole surveyed area was estimated at 58 and 96 individuals during the first and the second year; these estimates differ statistically ($t=4.4$; $P<0.001$).

As transects were 3.5 km wide, complete coverage was possible everywhere except on Mansel and Akpatok islands. Corrected bear density varied greatly among islands, ranging from 0.4 to 14.2 individuals·100 km^{-2} (Table 2); density was above average on Button and Twin islands.

DISCUSSION

There are two categories of missed animals in aerial surveys: those that are potentially visible to observers but are not seen (perception bias), and those that are not available to observers because they are totally concealed by various obstacles (availability bias) (Marsh and Sinclair, 1989).

The availability bias must be null to completely correct population estimates derived using the double-count technique. On the tundra, the short vegetation does not impede the spotting of polar bears from an aircraft provided that the observation strip is narrow enough. But some animals use earth dens in summer refuges (Jonkel *et al.*, 1976), and they are invisible from the air when they are underground. However this behaviour seems uncommon, and we can assume that availability bias is marginal for polar bears around Hudson Bay during the snow-free period. The summer habitat used in Manitoba is also very open (Derocher, pers. comm. 1987).

Perception bias can be corrected with the double-count technique if the visibility rate exceeds 0.45-0.50 (Caughley and Grice, 1982; Graham and Bell, 1989). During our surveys, the visibility rate exceeded 0.60 for the rear observers in both years and for the front observer in 1986. With our experimental design, the front observer covered twice the area observed by each rear observer. The high visibility rate of the front observer during the first year can be explained either by

TABLE 1. Polar bears seen during the aerial census of islands offshore Quebec

	Number of bears seen by observers						Total number of bears seen		Corrected total number[a]	
	Front and rear		Front only		Rear only					
Island	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
Button[b]	3	0	1	0	1	3	5	3	6	4
Akpatok	1	3	4	5	0	3	5	11	6	13
Charles[c]	0	1	1	0	0	1	1	2	1	2
Mansel	4	13	3	3	0	14	7	30	8	36
Ottawa	3	2	0	0	0	6	3	8	3	10
Twin	15	6	7	2	9	17	31(9[d])	25(1)	34	30
Total	26	25	16	10	10	44	52	79	58(3.5[e])	96(7.8)

[a]Correction made for the overall total, i.e., 52 and 79; corrected numbers were weighted according to the number of bears seen on each island.
[b]≈80% of the ground visible due to fog (1987).
[c]≈30% of the ground visible due to fog (1987).
[d]Number of nine-month-old cubs among bears seen.
[e]Standard error of the estimate.

TABLE 2. Polar bear density during the ice-free period on islands offshore Quebec

Island	Transect length (km)	Total area (km^2)	Bear density (animals·100 km^{-2}) 1986	1987
Button	51	70	8.6	5.7
Akpatok	239	880	0.7	1.6
Charles	83	220	0.5	0.9
Mansel	559	3100	0.4	1.8
Ottawa	127	230	1.3	4.3
Twin	103	240	14.2	12.5

exceptional skill in detecting bears or by cues given by crew members. In both cases, the results remain valid because observations made in the front and the rear of the aircraft were independent. In Manitoba, Derocher (1987) estimated that the visibility rate varied between 0.76 and 0.82, using radio-tagged bears and a modification to the double-count technique. He restricted the transect width to 1 km on each side of the aircraft, as visibility dropped sharply beyond this distance.

The double-count technique in aerial surveys can be used to estimate the population size of polar bears around Hudson Bay. However our method should be improved. First, the transect width should be limited to 1 km on each side of the aircraft (Derocher, 1987) to keep the visibility rate high. Moreover, as twin-engine aircrafts are necessary for safety reasons, the arrangement and duties of the crew should be as advocated by Marsh and Sinclair (1989): there should be one tandem team of observers on each side of the airplane plus one survey leader sitting beside the pilot. However automatic recording of the observations is probably not necessary due to low bear density.

The double-count technique may certainly be used for the two bear populations that spend the ice-free period to the south of Hudson Bay — i.e., the Manitoba and Ontario populations (Derocher, 1987). It could probably also be used for the population retreating to northern Hudson Bay in summer. Everywhere that bears occupy vast areas the double-count technique should be applied in conjunction with a sampling plan (Marsh and Sinclair, 1989; Potvin *et al.*, 1991). There is generally an inverse relationship between animal density and the optimal size of sampling units (Crête and St-Hilaire, 1979; Crête *et al.*, 1987; Potvin *et al.*, 1987; unpubl. data). As bear density seems low (1-15 individuals·100 km^{-2}) and comparable to that of woodland caribou (*Rangifer tarandus*), for which we have made simulations, sampling units covering 100-200 km^2 should provide the best surface area to maximize the precision of estimates for a given budget. Ratio estimates (Cochran, 1977) could also be used if sampling units of varying size were necessary (Marsh and Sinclair, 1989). An unbiased statistical procedure was recently proposed to compute the variance of population estimates corrected with the double-count technique (Rivest *et al.*, 1991). Finally, sample sizes would depend on the desired precision.

But before deciding if the proposed technique should be incorporated into polar bear management programs around Hudson Bay, the cost of the double-count technique should be experimentally evaluated and compared with the cost and the precision of the multi-year mark and recapture method currently in use.

ACKNOWLEDGEMENTS

We thank the crew members belonging to the Service aérien du gouvernement du Québec for their great availability and professional work. We appreciated the interest shown by J. Adams, D. Le Hénaff and B. Picard, who acted as observers. Finally, J. Bouchard drew the figure and C. Coulombe and C. Picard typed the manuscript.

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