QUADRAT SAMPLING OF A NESTING POPULATION OF BALD EAGLES

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Abstract: An aerial stratified random sample survey of nesting bald eagles (*Haliaeetus leucocephalus*) was conducted during 1974 on 173,900 km² of northwestern Ontario and southeastern Manitoba, Canada I sampled less than the total (target) area to reduce cost and to avoid a search bias in areas previously visited. Fifty-three 100 km² quadrats provided estimates of 428 ± 158 (37%) eagles, excluding nestlings, and 291 ± 88 (30%) breeding areas for the sampled area and 579 ± 165 breeding areas for the entire area Stratification reduced the variance of the means by roughly 22 percent for breeding areas in the entire area A real visibility bias requires rigorously standardized techniques and, unless measured, limits the usefulness of estimates of actual numbers The techniques should be feasible for a larger region and repeated sampling would provide a measure of trends in the status of this species of eagle

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Claims that bald eagle populations have declined or not are based largely on reproductive information (Braun et al. 1975, Broley 1958, Gerrard 1973, Grier 1974, Laycock 1973, Sprunt 1966, 1969, Sprunt et al 1973, U.S. Dept. of Interior 1974). The lack of simultaneous information on age-specific mortality and age of first breeding precludes the modeling of bald eagle population dynamics (Brown 1974, Brown and Cade 1972, Henny et al 1970, Mertz 1971, Whitfield et al 1974, Young 1968). Lack of adequate census data also hinders the determination of population status based upon changes in numbers of individuals. Counts of eagles on wintering areas (Fawks 1961 plus yearly updates, Hancock 1974, Higby 1975, Lint 1975, Southern 1963, 1964, Wrakestraw 1973) or during migrations (McClelland 1973, Spofford 1969, U.S. Dept. of Interior 1971) are of limited value because they reflect annual variations in weather and food availability. Furthermore, it is difficult to ascertain the source of eagles observed on migration or wintering areas. The National Audubon Society, U.S. Fish and Wildlife Service, and others have attempted to determine the total number of nesting bald eagles in the 48 contiguous states (Braun et al 1975, Laycock 1973, Sprunt 1966, U.S. Dept of Interior 1974). The majority of nesting birds, however, are found in Alaska and Canada, where only scattered attempts have been made to assess the eagle populations (Davis 1966, Gerrard 1973, Gerrard and Whitfield 1967, Grier 1967, 1969, King et al 1972, Mansell 1965, Whitfield et al 1974). All that is clear from the numbers of birds seen nesting in Alaska and Canada, and on wintering areas in the contiguous United States is that the present population of bald eagles in North America must be relatively large (Braun et al 1975) Reliable censuses are needed to determine the status of the continental breeding population for management purposes.

King et al. (1972) conducted a quadrat sample survey of bald eagles in southeastern Alaska. In searching for a technique to gain information on bald eagle numbers in Canada's boreal forest, in northwestern Ontario and southeastern Manitoba, I conducted a similar survey during 1974. The results of that survey as reported herein were encouraging and, with some modification, the techniques can provide useful trend information in future years.

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Table 1 Classification and distribution of quadrats in the study area Eleven quadrats with much human activity (towns, mines) and considered unsuitable for eagles were excluded from consideration

Stratum	Previously surveyed	Quadrats sampled (1974)	Not surveyed	Total
(1) estimated 25–75% water with minimum resident human activity	97	17	153	267
(2) estimated 25–75% water with moderate resident human activity	47	12	43	102
(3) estimated 10–25% or 75–90% water	91	24	260	375
(4) estimated water area less than 10%, over 90% or in bodies of less than 12 km perimeter	56	0	928	984
Total	291	53	1,384	1,728

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STUDY AREA AND METHODS

The study area extended from 92° to 96° West Longitude and from 49° to 55° North Latitude. Characteristics of the area have been described previously (Grier 1969). This area was divided into 1,739 quadrats, each 100 km^2, by using the Universal Transverse Mercator Grid which is conveniently printed on 1:250,000 scale topographical maps. Bald eagle nests in this region are found almost exclusively along the shorelines of rivers and larger lakes (Gerrard et al. 1975). The area of water and length of shoreline within quadrats is highly variable. There is so much shoreline that it is impractical to measure but the proportion of water to land surface area in quadrats can be used as a rough index of the amount of shoreline.

At this point it is important to distinguish between *target* and *sampled* populations (Cochran 1963:6). The target population involved the entire 1,739 quadrat study area. But because of 2 problems the chosen sampled area was less than the target area. The first problem involved several years of my previous experience in parts of the region; I felt that my knowledge of birds and nests in those areas could seriously bias any search for additional breeding areas. Previous experience consisted of 2 types: 1) non-random sampling in which eagle nests were reported by other persons or accidentally found by me during travel in the area and 2) an aborted random sample survey in 1973. The latter involved quadrats of 20 by 20 minutes of latitude and longitude which were found to be too large logistically and ecologically. A total of 291 quadrats with my previous experience were excluded from the sampled area.

The second problem in choosing the sample area involved cost. Experience with the aborted survey of 1973 showed that areas with too little shoreline were too sparsely inhabited by eagles to justify the cost of aerial searches. Thus, after the quadrats were classified into strata (see below and Table 1), these low-density areas were excluded from the sampled areas. This amounted to 928 quadrats with less than 10 or greater than 90 percent water, or in which the water was in small bodies with a shoreline estimated to be less than 12 km (cf. Gerrard et al. 1975). In addition, 11 quadrats containing high resident human use (towns and mines) were eliminated from the sampled area.

The remaining 509 quadrats, the sampled population, were classified and stratified into 2 groups by amount of water area present: 225 quadrats with 25–75 percent of the surface area water in one group and 284 quadrats with 10–25 or 75–90 percent water in the other. The first group included 55 quadrats with moderate levels of resident human activity and 170 quadrats with little or no such human presence. Because of a

Table 2 Observations of bald eagles and breeding areas in sampled quadrats. Sixteen young eagles on nests were excluded see text. The total number of birds consisted of 36 adults and 10 (22%) subadults

	Stratum[a]			
	1	2	3	Totals
Total quadrats	170	55	284	509
Sample quadrats	17	12	24	53
Bald eagles				
Total observed	16	12	18	46
mean/quadrat	0.94	1.00	0.75	
variance	1.18	2.18	1.24	
Breeding areas				
Total observed	14	7	10	31
mean/quadrat	0.82	0.58	0.42	
variance	0.65	0.63	0.25	

[a] See text and Table 1.

possible human disturbance effect, these were divided and considered as separate strata. Few quadrats in the 10–25 or 75–90 percent water group were near resident human activity so this group was not subdivided.

Because previous estimates of variance were not available to help determine sample sizes, I arbitrarily chose to survey 10 percent of the quadrats in strata 1 and 3 (see Table 1). A few of the quadrats in stratum 3 were later eliminated because smoke from nearby forest fires prevented us from traveling to them. More than 10 percent of the quadrats were included in stratum 2 because the stratum was small and I felt that 10 percent would be too few. Stratum 4 was not surveyed because of the cost, as described previously. The classification and distribution of all quadrats is shown in Table 1.

Quadrats were selected at random and the shoreline in each was searched for birds and nests. Eagles commonly return to the same areas to breed each year and may build more than 1 nest in that area. Because the nests are stationary, semi-permanent and often more visible than the birds, the breeding areas identified by the presence of 1 or more nests serve as a good index to the numbers of breeding adults. For further discussion see Grier (1974:470).

The aerial searches were conducted between 1 July and 15 July 1974 using a Piper J3 aircraft equipped with pontoons, and flown by an experienced pilot. We cruised at a speed of 112 to 130 km/hr (70 to 80 miles/hr) at a height of 20 to 100 m above the tree tops. Following the shoreline as closely as possible, usually within 100 m, we surveyed quadrats from 2 hours after sunrise to 2 hours before sunset, when it was not raining, and in wind from 0 to 24 km/hr. Both the pilot and I continuously searched for eagles and nests. Young eagles on nests were not counted in the aerial census because they were associated with, and thus seen with, the nests.

Osprey (*Pandion haliaetus*) nests were occasionally encountered in the same regions as bald eagles. However, nests with birds present, whether adults or nestlings, are easily identified. Empty osprey nests can nearly always be identified by an experienced observer on the basis of smaller size and the position in the top of the tree. Eagles occasionally construct nests at the top of the tree, in osprey fashion, but that is rare. In this survey out of 37 total nests observed for both species, none was questioned as to species.

RESULTS AND DISCUSSION

From the observations in sampled quadrats (Table 2) and using standard assumptions and models based on the normal distribution (Cochran 1963), I estimated the number of eagles for the sampled population to be 428 ± 158 birds, excluding young on the nests, and the number of breeding areas to be 291 ± 88, at the 95 percent confidence intervals (Table 3).

If one relaxes the restrictions on estimates as applying to just the sampled area (see Cochran 1963:6), estimates can be made for

Table 3. Estimated bald eagle population and breeding area parameters calculated from stratification. The following formulas from Cochran (1963) were used: 5.1, 5.12, 5.14, 5.15 and 5A.27.

	Sampled population		Target population
	Eagles	Breeding areas	Breeding areas
Mean number/quadrat	0.84	0.57	0.34
Standard error	0.15	0.09	0.05
Effective degrees of freedom	43	40	74
Estimated total population	428 ± 158 (37%)	291 ± 88 (30%)	579 ± 165 (29%)
Percent reduction in estimated variance ($\bar{Y}_{st}$)	−6[a]	2	22

[a] Negative reduction = increase in variance.

the entire target area. Additionally I took the liberty to borrow information from the aborted 1973 survey to add stratum 4 (see Table 1) to the estimate. I consider the observations for breeding areas to be more reliable than counts of birds (see below) so I performed the exercise just for breeding areas. Of the 56 previously sampled quadrats in stratum 4, 48 were included in those 20 by 20 minute latitude–longitude quadrats in which surveys were completed in 1973. Of those 48, 7 contained 1 bald eagle breeding area apiece for a mean and sample variance, respectively, of 0.15 and 0.13. By hypothetically considering these 48 as having been "sampled" along with the 53 quadrats actually sampled in 1974, and by considering that the quadrats surveyed had been drawn from the entire 1,728 quadrat target area, estimates were obtained for the entire area (Table 3). Stratification did not help much in the area actually sampled (Table 3), apparently because the low density stratum was not included. But if that stratum is considered, as it probably should be in future surveys, then it appears that stratification would be important and useful.

It is possible that the use of the normal distribution is not justified (discussed in Cochran 1963:38–44) and that another, such as Poisson or negative binomial, should be used in the construction of confidence intervals. I fitted the observed frequency distributions to a variety of discrete distributions (Gates and Ethridge 1972) but the sample size was simply too small to permit valid comparisons of the fits. Alternatively, the results of different surveys could be compared by nonparametric tests (Conover 1971).

Estimates of actual numbers of birds or breeding areas are conservative at best and of only limited value, however, because it became obvious that some birds and breeding areas were not being seen. Additional breeding areas have been found by flying along the shoreline more than once in previously censused areas. Evidence that we overlooked birds, or that they were out of the quadrat (least likely), was that in 5 quadrats with nestlings present we saw only 1 adult while we were flying; and estimates of the number of adults expected from the number of breeding areas believed to be occupied are higher than numbers estimated from observations of birds. This visibility bias is common and may be unavoidable in aerial censuses (Caughley 1974, LeResche and Rausch 1974). If too large and unless it can be measured, such bias may render estimates of actual numbers useless (Cochran 1963). An additional source of bias is that some adult eagles are seen on or near nests, with the nest possibly affecting the chance of seeing the birds. The

adults' behavior at different parts of the nesting cycle would also affect their presence at nests. In view of these problems an index of breeding birds based on breeding areas may be more reliable than a count of the birds themselves.

The visibility biases for both nests and birds should be less if the survey is conducted before the trees develop leaves. An earlier census would also yield better estimates of initial nesting activity by the eagles, as recommended by Postupalsky (1974). In spite of the bias, however, if it can be held constant then valid comparisons among surveys over a period of years can be performed. This requires that the type of aircraft, flying conditions, number of observers, experience of observers and time of year all be kept as constant as possible.

The quadrat size was ideal logistically. To sample the 53 quadrats we logged approximately 73 hours of aircraft engine time (1.38 hr/quadrat) of which a mean of 0.36 hr/quadrat was spent searching suitable shoreline. We spent a maximum of 48 minutes to survey a quadrat. The remaining, nearly 75 percent, of the time was spent going to and from quadrats and covering areas that did not contain shoreline within quadrats. The travel time to and from quadrats could be reduced by cluster sampling.

Excluding the Atlantic and Pacific seacoasts which provide habitat for many bald eagles and which are roughly comparable to the area surveyed by King et al. (1972), I estimate from maps that Canada contains approximately 1.7 million km^2 of boreal forests, lakes, and rivers similar to the habitat that I surveyed. Quadrat sampling of the entire area would be logistically possible and would help assess current population levels of the bald eagle in the interior of Canada. More importantly, resampling at regular intervals could indicate the population trend of this species of eagle.

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