Assessing ground-based counts of nestling bald eagles in northeastern Minnesota

Mark R. Fuller, Jeff S. Hatfield, and Edward L. Lindquist

Abstract We present evidence that the bald eagle (*Haliaeetus leucocephalus*) productivity survey in the Boundary Waters Canoe Area Wilderness of northeastern Minnesota may have underestimated the number of nestlings during 1986–1988. Recommendations are provided to achieve more accurate ground-based counts. By conducting ground-based observations for up to 1 hour/nest, an accurate count of the number of bald eagle nestlings can be obtained. If nests are only observed for up to 30 minutes/nest, an accurate determination of nest success can be made. The effort that managers put into counts should be based on the intended use of the productivity data. If small changes in mean productivity would trigger management action, the less accurate ground-based counts should be conducted with caution. Prior to implementing ground-based counts, a study like ours should estimate bias associated with different survey procedures and the observation time needed to achieve accurate results.

Key words bald eagle, count, *Haliaeetus leucocephalus*, nestling, Superior National Forest, survey

Considerable effort is expended on surveys of bald eagles (*Haliaeetus leucocephalus*) because they are classified as threatened in much of their range, are protected by the Bald Eagle Protection Act of 1974 (16 USC 668-668c), and receive special consideration in many states and provinces (e.g., Henny and Anthony 1989; Nickerson 1989; Frenzel 1991*a*). The U.S. Department of Agriculture Forest Service (USFS) regularly locates, marks, and manages nest trees and nest areas (USFS, Eastern Reg., Land and Resource Management Plan, Superior National Forest, 1986), surveys occupied nests, and counts nestling bald eagles. U.S. Department of Interior Fish and Wildlife Service (USFWS) recovery plans for threatened bald eagle populations rely on nest counts and productivity estimates to assess recovery (e.g., 1 criterion for progress is ≥1 nestling/occupied nest; USFWS 1983). Counts and estimates of occupancy and productivity commonly are used to assess the general status of bald eagles (Gerrard et al. 1983; Grubb et al. 1983; Henny and Anthony 1989; Nickerson 1989). These data also are used for ecological and management studies of habitat selection and quality (e.g., Whitfield et al. 1974; McEwen and Hirth 1979) and for studies of how bald eagle populations are affected by contaminants (Wiemeyer et al. 1984) and disturbances (Fraser et al. 1985).

Bald eagle nests are typically surveyed from boats and aircraft along transects or shorelines stratified on potential nest habitat or on results of previous surveys in an area (Grier 1977; Grier et al. 1981; Hodges et al. 1984; Frenzel 1991*b*). Factors that influence the timing and conduct of aerial counts of nests and nestlings (Fraser et al. 1983) and errors associated with the counts (Fraser et al. 1984) have also been studied. However, some surveys (or portions of surveys) must be conducted from the ground or water because of limited aircraft availability, flying costs, weather conditions, and other factors (Weekes 1974; Whitfield et al. 1974; Stocek and Pearce 1978; Hodges and Robards 1982; Gerrard et al. 1983). Mansell (1965) recognized that nestlings often were obscured from the view of an observer on the ground because of the structure of the bald eagles' large stick

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nests. Since 1985 counts of nestlings in the Boundary Waters Canoe Area Wilderness (BWCAW) in the Superior National Forest (SNF) in Minnesota, have been conducted from the ground or water because of regulations prohibiting low-level aerial surveys that disturb recreation in wilderness areas (U.S. Congress, Public Law 95-495, The Boundary Waters Canoe Area Wilderness Act of 1978). These counts henceforth are called ground-based counts, although some are conducted from water.

Our objectives were to (1) test for bias in nestling bald eagle counts in the BWCAW by conducting ground-based and aerial counts on a sample of nests and (2) estimate the time needed to observe nests to obtain accurate ground-based counts. This study addressed the perception of lower productivity in the BWCAW since 1985, when the ground-based count method was initiated. The results are important because BWCAW nests constitute about 50% of the SNF total, and SNF nests constitute about 6.4% of the nests in areas referenced by the Northern States Bald Eagle Recovery Plan (USFWS 1983). Further, bald eagle populations in the BWCAW are of management interest because the wilderness area habitat is unique in the region and USFS management of resources in the BWCAW differs from management of nonwilderness public lands.

Study area and methods

We studied eagles in the western end of the Superior National Forest (about 16,317 km^2) and on adjacent private lands in northeastern Minnesota (Fig. 1). About a third of the SNF comprises the BWCAW, and the study area was located in the La Croix and Kiwishiwi ranger districts of the SNF. The landscape consisted of slight relief and nearly continuous forest interspersed with palustrine, lacustrine, and riverine wetlands. Forest vegetation included species from boreal and temperate deciduous forests. Common upland coniferous trees were jack pine (*Pinus banksiana*), eastern white pine (*P. strobus*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*). Upland deciduous trees were dominated by quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), and paper birch (*Betula papyrifera*). Forested

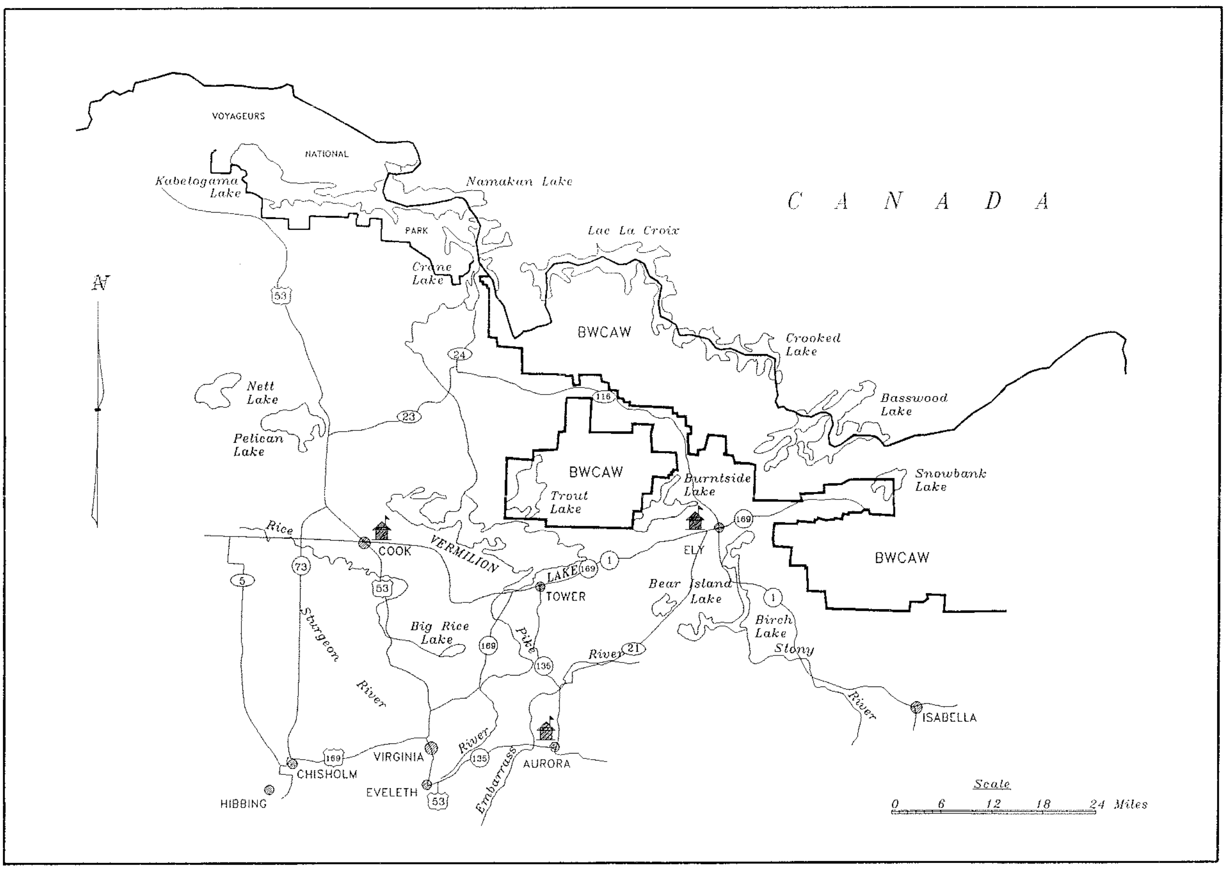

Fig. 1. Northeastern Minnesota study area for assessing bald eagle productivity counts including the western portion of the Superior National Forest and portions of the Boundary Waters Canoe Area Wilderness (BWCAW), 1980–1989.

wetlands were dominated by black spruce (*Picea mariana*), northern white-cedar (*Thuja occidentalis*), and black ash (*Fraxinus nigra*). More detailed descriptions of these vegetation communities can be found elsewhere (Peek et al. 1976; Ohmann and Grigal 1979; Rogers 1987).

There were about 60 bald eagle nests inside the BWCAW and about 50 throughout the remainder of the SNF and adjacent private lands. We performed ground-based and aerial counts at 12 nests in 1988 and 11 nests in 1989 located outside the BWCAW. These nests were selected because they were in the regular SNF bald eagle survey and were relatively convenient to access with surface transportation, primarily by boat. We conducted ground-based counts in 1988 (Lindquist and Hatfield) and 1989 (Fuller and Hatfield) with SNF staff that participated in the regular survey; all we knew about each nest was that it was successful and contained ≥1 nestling. We also participated in the occupancy survey conducted each year from aircraft and visited nests sites in the BWCAW to familiarize ourselves with the regular survey.

The regular survey (since 1985) included (1) aerial counts (helicopter and fixed-wing aircraft) of nests associated with adult bald eagles (i.e., occupancy of nests) in all of SNF and adjacent lands, (2) aerial counts of nestlings (i.e., productivity) for all occupied nests outside the BWCAW, and (3) ground-based nestling counts from a boat or land of most occupied nests within the BWCAW. The counts were conducted from about 5 April–25 April for occupancy and from 20 June–5 July for productivity. The productivity survey occurred when the nestlings were generally 5–9 weeks old. Occupied nests were plotted on topographic maps and aerial photographs. The aircraft circled each nest to accurately detect any young present (Fraser et al. 1983, 1984). Aerial and some ground-based counts were made by SNF staff; volunteers and collaborators from the Audubon Center of the Northwoods in Sandstone, Minnesota, performed many of the ground-based counts.

In 1988 we used procedures that were followed by staff and volunteers for ground-based counts of nestlings in the BWCAW during 1986–1987. We generally spent about 15 minutes observing each nest. In 1989 we spent up to 1 hour at each nest to achieve more accurate counts and to assess the effect of observation length on productivity estimates. We went to the area with the best view of the nest, regardless of its location. We recorded the time that each observation began, the total time at each nest, and in 1989, the time that each nestling was first observed in each nest. When 2 separate nestlings were observed in a nest, both observation times were recorded.

We used Fisher's exact test (Lehmann 1975) to test for differences in productivity of nests in the BWCAW and the SNF outside the BWCAW. Fisher's exact test is nonparametric and was used because of the small sample sizes in some years. One-tailed tests were performed to test for lower productivity in the BWCAW. Productivity was compared between the aerial nestling counts of the SNF and BWCAW for each of the years 1980–1984 and between the aerial counts of the SNF and ground-based counts of the BWCAW for each of 1985–1989. Only successful nests were used in the statistical analyses because some occupied nests, as defined by the USFS, might represent the same breeding territory because breeding pairs of bald eagles often have >1 nest/territory. Nests with 2 or 3 nestlings were combined into 1 category because nests with 3 nestlings were rare and their inclusion as a separate category would have adversely affected the results of Fisher's exact tests.

For the experimental portion of our study, Fisher's exact test also was used to investigate bias. Bias at a nest was defined as the ground-based count minus the aerial count and always took the value 0 or −1. One-tailed tests were used for 1988 and 1989 to determine if nests with 2 nestlings had more bias than nests with 1 nestling. In addition, a 1-tailed test was used to determine if nests with 2 nestlings had more bias in 1988 than in 1989.

To estimate observation time needed for accurate ground-based counts, survival analyses (Lawless 1982, Blackwood 1991) were used. Survival analysis is more commonly used to estimate the time until a "failure" occurs, but we used it to estimate the time needed for ground-based observation of ≥1 nestling and 2 nestlings. We used the product-limit nonparametric estimate of the failure function. The product-limit method used observation times at each nest to estimate the probability of detecting ≥1 nestling and 2 nestlings versus the amount of observation time and to produce standard errors (SAS Inst., Inc. 1985). In addition, starting time at each nest was used as a covariate to test for the effect of time of day on the probability of detection. However, small sample sizes may affect the power and reliability of this covariate test. Only 1989 data were used for survival analyses because the appropriate times were not measured for all the 1988 nests and because many of the 1988 ground-based counts were biased when compared to the aerial counts (i.e., right-censored observations in survival analysis terminology).

Table 1. Bald eagle productivity (nestlings/successful nest) from 1980–1989 in the Boundary Waters Canoe Area Wilderness (BWCAW) and the Superior National Forest (SNF) outside the BWCAW, Minnesota.

	BWCAW			SNF outside BWCAW			
Year	Mean	*n*	SE	Mean	*n*	SE	*P*[a]
1980	1.50	16	0.13	1.88	8	0.13	0.09
1981	1.43	14	0.14	1.33	9	0.17	0.81
1982	1.43	14	0.14	1.60	10	0.16	0.34
1983	1.55	20	0.11	1.58	12	0.23	0.86
1984	1.50	14	0.14	1.73	15	0.12	0.18
1985	1.50	2	0.50	1.67	12	0.19	0.69
1986	1.31	16	0.15	1.56	18	0.12	0.05[b]
1987	1.33	15	0.13	1.70	23	0.10	0.03[b]
1988	1.29	17	0.11	1.69	33	0.09	0.02[b]
1989	1.56	27	0.10	1.68	25	0.11	0.37

[a] Fisher's exact test, 1-tailed, tested each year if mean productivity was greater on the SNF outside the BWCAW than within the BWCAW.

[b] Statistically significant at $P \leq 0.05$.

Results

Summary statistics (mean, SE, sample size) of productivity in BWCAW and SNF and the *P*-values for the Fisher's exact tests revealed differences ($P \leq 0.05$) between productivity of the BWCAW and SNF for the years 1986, 1987, and 1988 (Table 1). These results indicated that ground-based counts in the BWCAW after 1985 could have resulted in the lower productivity reported for those nests. The lack of a difference in 1989 probably reflected increased observation effort prompted by the results of our 1988 experimental counts.

In 1988, 2 of 2 nests with 1 nestling were unbiased when observed from the ground. However, 3 of 10 nests with 2 nestlings had a bias of −1 because of an undetected nestling. Fisher's exact test yielded $P = 0.15$ for testing if 2-nestling nests were more biased. The mean bias was −0.58 (Table 2), and the mean observation time on the ground was 20.8 minutes (SE = 2.9) for the 12 nests observed in 1988. In 1989, 3 of three 1-nestling nests and 6 of eight 2-nestling nests were unbiased for ground-based counts. The mean bias in 1989 was −0.18. The mean observation time for the 11 nests counted from the ground in 1989 was 44.6 minutes (SE = 6.0) and Fisher's exact test ($P = 0.51$) indicated no difference between the bias in 1- and 2-nestling nests in 1989. However, comparing 2-nestling nests in 1988 with 1989 yielded $P = 0.08$ for Fisher's 1-tailed exact test.

We graphed probability of detection versus ground-based observation time from the survival analyses for 1989 (Fig. 2). We included the 11 nests observed for bias and 7 additional nests in the BWCAW that we observed using similar methods. The increments in the curves are not always equal because some nests had identical observation times (e.g, 10 of 18 nests had ≥1 nestling observed after 0 elapsed minutes upon starting observations). No observations were censored for nest success (i.e., ≥1 nestling was observed in every nest). Also, the curve for the probability of detecting ≥1 nestling assumes that the proportions of 1- and 2-nestling nests in our sample are unbiased estimates of the true population proportions. For estimating the probability of detecting 2 nestlings, $n = 15$ because the 3 1-nestling nests could not be included. In 2 of these 15 nests, the second nestling was not observed before the observation period ended. However, the product-limit estimator used this censored information because we knew from the aerial counts that these nests had 2 nestlings and we observed these nests from the ground for 38 and 63 minutes, respectively. For the 7 BWCAW nests, none were censored because 2 nestlings were observed in each nest from the ground or water.

Starting time of observations was not a significant covariate in predicting the probability of detection ($\chi^2 = 0.49$, 1 df, $P = 0.49$ for ≥1 nestling; $\chi^2 = 1.31$, 1 df, $P = 0.25$ for 2 nestlings). Thus, nestling detection was not influenced by time of day. Confidence intervals can be obtained from Figure 2 in the standard way (Lawless 1982). If ground-based observers remain at a nest >24 minutes, they would be about 95% confident of having a 90% probability of detecting ≥1 nestling given that the nest was successful. On average, however, observing for >24 minutes would yield >98% probability of detecting ≥1 nestling given that the nest was successful. Similarly, if ground-based

Table 2. Bald eagle productivity (nestlings/successful nest) in a sample of nests from the Superior National Forest, Minnesota, surveyed in 1988 and 1989 using ground-based and aerial counting methods.

		Ground-based[a]		Aerial		Bias[b]	
Year	*n*	Mean	SE	Mean	SE	Mean	SE
1988	12	1.25	0.13	1.83	0.11	−0.58	0.15
1989	11	1.55	0.16	1.73	0.14	−0.18	0.12

[a] Ground-based observation time of nests averaged 20.8 minutes (SE = 2.9) in 1988 and 44.6 minutes (SE = 6.0) in 1989.

[b] The bias at each nest was the ground-based count minus the aerial count and was 0 (equal aerial and ground-based count) or −1 (undercounted from the ground by 1 nestling) for individual nests.

observers remain at a nest >61 minutes, they would be about 95% confident of having a 90% probability of detecting 2 nestlings given that the nest contained 2 nestlings. On average, observing for >61 minutes would yield >99% probability of detecting 2 nestlings given that 2 nestlings were present.

Discussion and recommendations

Our analyses revealed a difference in productivity counts in the SNF and BWCAW during 1986–1988. Moreover, our experiment suggested that the change to ground-based counts in BWCAW might be responsible for the lower counts of productivity obtained on the BWCAW during this period. Counting from the ground or water might undercount nestlings as they are less readily visible from below the nest. Vegetation and nest structure can obscure nestlings. Spending more time observing nests and positioning for the best view of a nest should reduce bias in ground-based counts.

Our 1988 and 1989 ground-based versus aerial counts further illustrated discrepancy in estimates. In 1988 we observed each nest for an average of 21 minutes and correctly determined the success of each of the 12 nests but had a bias of −0.58 nestlings/nest in the mean productivity estimate. In 1989 we lengthened our average observation to 45 minutes/nest. Again, we correctly determined the success of all 11 nests while decreasing the bias to −0.18 nestlings/nest, considerably less than in 1988.

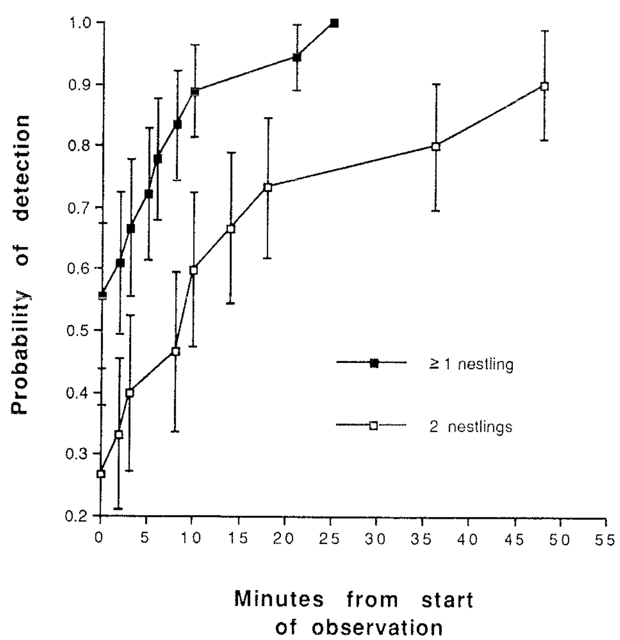

Fig. 2. Probability of detection for ground-based counts of bald eagle nestlings in northeastern Minnesota, 1989, as a function of time observing the nest from a position that afforded a clear view of the nest from the ground or from a boat. Error bars indicate ±1 SE.

Based on the confidence intervals derived, we can estimate the time required to observe nests from the ground or water to get an accurate count. If the objective of the survey is to estimate nest success, ground-based observers should observe each nest for up to 30 minutes to have a high probability of accurately determining if the nest is successful. Observers should leave the area as soon as they see a nestling; they do not need to remain longer than 30 minutes if no nestlings are observed. If the objective is to estimate nest productivity, ground-based observers should observe each nest for up to 1 hour to have a high probability of accurately determining if there are 0–2 nestlings present. Observers should leave the area after seeing 2 nestlings; they do not need to remain longer than 1 hour if 0 or 1 nestling is observed. These recommendations assume that ground-based observation conditions (e.g., weather) are similar to those encountered in this study, that the best view of the nest is obtained, and that nestlings are similar in age to the nestlings observed in this study. We make no recommendations about 3-nestling nests because none were included in the experimental portion of our study. However, as very few nests have 3 nestlings, recommendations to observe up to 3 nestlings in a nest would greatly increase the observation time/nest to achieve a very small increase in accuracy of the productivity estimate.

Acknowledgments. We accompanied A. Dietz, D. Chassen, N. Hunze, D. Potter, and D. Watt on ground-based surveys and flew with pilots D. Bowman and C. Palombi on aerial surveys. We thank the other staff and volunteers of the SNF and Audubon Center of the Northwoods for conducting counts. D. Frenzel, J. Mathisen, and R. Radtke provided much insight into survey procedures and use of results. T. Nicholls helped initiate this project and provided partial support through the USFS North Central Forest Experiment Station. C. Henny, W. Link, J. Ramsey, and M. Munson-McGee provided helpful reviews of earlier versions of this manuscript.

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Received 6 August 1993.
Accepted 27 June 1994.
Associate Editor: Thompson.