Estimating Sighting Proportions of American Alligator Nests during Helicopter Survey

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Abstract: Proportions of American alligator *(Alligator mississippiensis)* nests sighted during aerial survey in Florida were estimated based upon multiple surveys by different observers. We compared sighting proportions across habitats, nesting seasons, and observer experience levels. The mean sighting proportion across all habitats and years was 0.736 (SE=0.024). Survey counts corrected by the mean sighting proportion reliably predicted total nest counts (R^2=0.933). Sighting proportions did not differ by habitat type (P=0.668) or year P=0.328). Experienced observers detected a greater proportion of nests (P<0.0001) than did either less experienced or inexperienced observers. Reliable estimates of nest abundance can be derived from aerial counts of alligator nests when corrected by the appropriate sighting proportion.

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Management of American alligator populations in the U.S. currently includes harvest of both early age-classes (eggs and/or hatchlings) and adults (Elsey et al. 1994, David 1996). In Florida, 50% of the total estimated annual production of nests is harvested. Harvest allocations have been based upon repeated nest counts on an area over the nesting season (Jennings et al. 1988). However, present alligator nest collection quotas in Florida rely upon a single survey. Presumably, all nests are not sighted in the course of an individual survey. Therefore, harvest levels are lower than

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50% for a given area and harvests may be conducted at less than maximum sustainable levels.

When conducting aerial surveys, the proportion of alligator nests sighted may differ due to interacting factors such as: habitat (e.g., open vs. closed canopies, terrain conditions); annual variation (e.g., habitat alterations, water level effects); weather (e.g., rain, shadows); observers (e.g., acuity, alertness, experience), and animal behavior (e.g., spatial distribution of nests, density of nests; Norton-Griffiths 1975, Heyer et al. 1994, Wilson et al. 1996). The combination of these factors produces sighting probabilities less than 1. In this study, sighting proportions are defined as the proportion of observable nests actually counted during aerial survey (Woodward et al. 1996). Adjustment of partial nest counts by this sighting proportion is essential to reduce bias associated with unknown or variable sighting probabilities.

Female alligators nest in diverse habitats in Florida. We predicted that nests would be more difficult to detect from the air in areas with substantial tree canopy. Accordingly, the proportion of nests sighted during aerial survey may differ among areas. Further, variations in nest sites over time due to varying water level and habitat conditions may affect the proportion of nests counted between years. Our objective was to determine the proportion of alligator nests sighted in two habitat types during aerial helicopter survey in Florida. Secondarily, we wanted to determine the impacts of habitat, annual variation, and observer experience on the proportion of nests sighted.

The Florida Game and Fresh Water Fish Commission (currently Florida Fish and Wildlife Conservation Commission) and the Florida Cooperative Fish and Wildlife Research Unit of the U.S. Fish and Wildlife Service (currently U.S. Geological Survey) provided funding and field personnel for this study. Alligator nest surveys were conducted by A. Brunnel, D. David, M, Jennings, A. Kinlaw, D. Osborne, P. Schulz, and J. Wrublik. J. Nichols developed the estimators for standard errors of sighting proportions. C. Moore assisted in the transformation of probabilities. This paper is contribution No. R-07832 of the Florida Agricultural Experiment Station Journal Series, Institute of Food and Agricultural Sciences, University of Florida.

Methods

Study areas were chosen that had a history of relatively dense nesting to provide an adequate sample size of nests during a 1.0 to 1.5 hour aerial survey. Study areas were grouped into 2 habitat types based on nesting habitat cover and logistical availability of areas for nesting survey. Cover designations were chosen by observation of the proportion of hatchling pods not associated with known nests observed during helicopter survey (Rice et al. 1999). Open marsh habitats were marshes with $<$20% canopy cover in nesting areas. Wooded habitats contained $>$20% canopy cover. Rice et al. (1999) during an unrelated study on the same study areas observed 1.4 $\pm$ 0.8 pods not associated with nests observed during aerial survey on open habitats and 25.4 $\pm$ 3.3 pods on wooded habitats.

Open marsh habitats examined in this study included lakes Okeechobee and Jesup. Lake Okeechobee was a shallow lake (191,223 ha) in south-central Florida in Okeechobee, Glades, Hendry, Palm Beach, and Martin counties. Vegetation consisted chiefly of giant reed *(Phragmites australis)*, cattail *(Typha domingensis)*, *Eleocharis cellulosa*, *Rhynchospora tracyi*, willow *(Salix caroliniana)*, giant bullrush *(Scirpus californicus)*, sawgrass *(Cladium jamaicense)*, and mixed grasses (Milleson 1987). Lake Jesup, in east-central Florida in Seminole County, was an eutrophic, alkaline, natural lake (4,805 ha; Canfield 1981). Sand cordgrass *(Spartina bakeri)* and *Phragmites australis* were the predominant vegetation types (Jennings et al. 1988).

Wooded habitats in this study were represented by Orange Lake and Lake Griffin. Orange Lake (5,254 ha) was located in north-central Florida in Alachua County and was characterized by an accumulation of peat, resulting in extensive floating islands of vegetation. Vegetation consisted primarily of *Sagittaria lancifolia*, *Salix spp.*, *Cladium jamaicense*, *Hydrocotyle umbellata*, *Myrica cerifera*, *Cephalanthus occidentalis*, and *Typha domingensis* (Deitz and Hines 1980). Lake Griffin was an eutrophic, hardwater natural lake (5,675 ha) in central Florida in Lake County (Canfield 1981). Vegetation consisted primarily of *Acer rubrum*, *Salix* spp., *Myrica cerifera*, *Sagittaria lancifolia*, and *Cladium jamaicense*.

Alligator Nest Surveys

Aerial surveys of nests were conducted from 2-seat, piston-engined helicopters during the alligator nesting seasons (late June and July) of 1989–1991 on each area. Portions of each survey were duplicated by 2 or more observers to estimate nest sighting proportions. An initial observer chosen randomly conducted a survey along the lakeshore or marsh in suitable nesting habitat. The survey continued until the observer had counted approximately 30 nests, with all nest flights lasting 1 to 1.5 hours. Surveys were conducted at 35–45 m altitude and 45–55 km/hour airspeed. The pilot was directed to follow the instructions of each observer except to insure that all subsequent observers remained within the area surveyed by the initial observer. Therefore, surveys could have differed in such factors as flight distance from open water and time spent searching in a given vegetation type. The pilot could adjust any factor for safety concerns. The same pilot was used for all surveys on a given day.

At each nest location, the pilot hovered the aircraft over the site at 30–35 m altitude to allow the observer to obtain a loran position and to record the location on 1":800' aerial photographs (Fla. Dep. Transportation, Tallahassee). On Lake Okeechobee, loran locations were used exclusively.

During the survey period, substantial nest construction occurred overnight. Therefore, all observers on a given survey conducted flights on the same day to alleviate estimation bias associated with open populations. Observer recorded information concerning nest appearance such as flooding, depredation, and false or incomplete nests. To insure similar visibility conditions in relation to fog, shadows, and thunderstorms, all flights were flown during 0900–1400 hours.

Calculation of Sighting Proportions

Nests were marked individually by mapping and by loran. The multiple observer approach allowed the use of closed population capture-recapture models to estimate the total number of nests on the surveyed area. Therefore, using notation from Magnusson et al. (1978), we noted those nests seen only by Observer 1 (S_1), those seen only by Observer 2 (S_2), and those seen by both Observers (B). Multiple surveys by 2 observers allowed for the use of a modified Peterson estimator (Chapman 1951) to estimate total number of nests:

$$\hat{N} = \frac{(S_1+B+1)(S_2+B+1)}{(B+1)} - 1$$

with variance

$$Var(\hat{N}) = \frac{S_1 S_2 (S_1+B+1)(S_2+B+1)}{(B+1)^2(B+2)}$$

where $\hat{N}$ is an estimate of total nests. When 3 or 4 independent observers were available for counts, an estimate of total nests was obtained using closed population capture-recapture estimators in Program Capture (Otis et al. 1978). Estimates of proportions of nests sighted by any observer ($\hat{p}_i$) were obtained by $n_i/\hat{N}$, where n_i was the count made by observer i and $\hat{N}$ was the total nest estimate based on either capture-recapture technique outlined above. The standard error of $\hat{p}_i$ was calculated by:

$$\hat{SE}(\hat{p}_i) = \sqrt{\left[\frac{n_i}{\hat{N}}\right]^2 \left[\frac{Var\hat{N}}{\hat{N}^2}\right] + \frac{\hat{p}_i(1-\hat{p}_i)}{\hat{N}}}$$

The calculated nest estimates obtained were compared to total counts of nests with simple linear regression techniques (SAS Inst. 1988). Total counts were established after repeated surveys during egg collection on the same day of the multiple-observer surveys (see Jennings et al. 1988).

Observer Experience

During several surveys on lakes Griffin, Jesup, and Okeechobee, we observed the difference in the proportion of nests sighted during aerial survey due to varying observer experience level. Observers were divided into groups delineated by experience level. "Experienced" observers were those with extensive (>2 years) survey background on a given study area. "Less experienced" observers were experienced with alligator nest surveys but unfamiliar with the particular study area. "Inexperienced" observers were biologists that were unacquainted with alligator nest surveys and had only minimal experience with alligator nesting biology.

Analysis

A 2-way analysis of variance procedure was used to test the difference in sighting proportions between the habitat and annual effects (SAS Inst. 1988). A 1-way analysis of variance procedure was used to examine the effects of observer experience level on nest sighting proportion (SAS Inst. 1988). Duncan's multiple range test

Table 1. Mean (SE) sighting proportions for alligator nests during aerial survey on 2 habitat types in central Florida during 1989–1991.

	Habitat type		
Year	Wooded	Open marsh	$\bar{x}$(SE)
1989	0.751 (0.037)	0.652 (0.062)	0.701 (0.038)
1990	0.849 (0.063)	0.722 (0.083)	0.743 (0.071)
1991	0.759 (0.037)	0.756 (0.049)	0.758 (0.028)
$\bar{x}$(SE)	0.764 (0.024)	0.714 (0.038)	0.736 (0.024)

was used to test for differences in mean sighting proportions in observer experience levels. Theoretical quantile-quantile plots were employed to compare the departures from normality of several methods of data transformation. These plots consisted of plotting the quantiles or ranks of the residuals of the transformed data against the corresponding quantiles of the normal distribution (Chambers et al. 1983). We were concerned with serious departures from the normal distribution and chose a transformation that best fulfilled the assumption of normality. We compared the standard transformation for proportional data (arcsine; Ott 1988), a weighted transformation (inverse of the variance), a combination of both the arcsine and weighted transformations, and untransformed proportions. After comparing quantile plots, we used a weighting function (inverse of the variance) to transform the sighting proportions for the comparison tests.

Results

The mean sighting proportion across all habitats and years was 0.736 (SE=0.024, Table 1). An analysis of variance procedure ($F_{3,21}=0.80$, $P=0.510$) found no differences in sighting proportions by habitat type ($F_{1,21}=0.19$, $P=0.668$) or year ($F_{2,21}=1.18$, $P=0.328$). Nest estimates from multiple surveys were similar to total nest counts after repeated surveys during egg collection ($F_{1,11}=129.89$, $P=0.0001$, $R^2=0.933$, Fig. 1).

Proportion of nests observed differed among experience levels ($F_{2,17}=22.34$, $P<0.0001$). Mean sighting proportions (SE) during aerial surveys were 0.777 (0.037) for experienced observers, 0.576 (0.059) for less experienced observers, and 0.449 (0.053) for inexperienced observers. Experienced observers counted a higher proportion of nests than did less experienced observers or inexperienced observers ($\alpha=0.05$, Duncan's Multiple Range Test). Less experienced observers counted a higher proportion of nests than inexperienced observers ($\alpha=0.05$, Duncan's Multiple Range Test).

Discussion

Aerial alligator nest surveys rarely account for all nests in the observation area. We estimated that experienced observers detected 77.7% of observable alligator

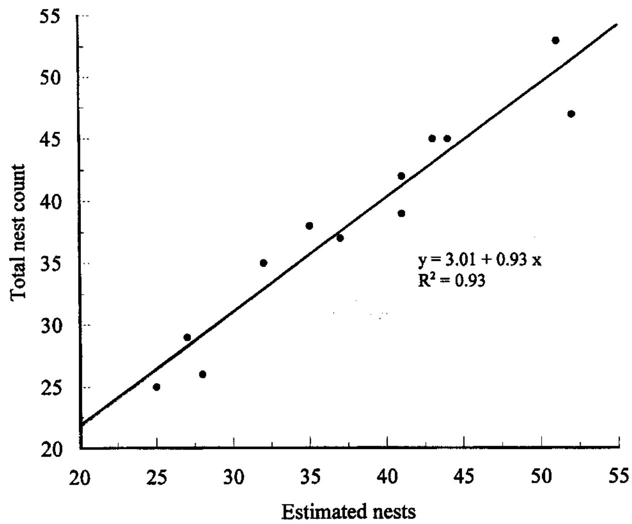

Figure 1. Comparison of numbers of alligator nests estimated from multiple aerial survey vs. total nests counted after repeated surveys by experienced observers on several Florida study areas during 1989–1991.

nests during helicopter surveys conducted at altitudes of 30–45 m and air speeds of 45–55 km/hour. Inexperienced observers and experienced observers with no prior familiarity with a survey area detected significantly fewer nests than did experienced observers who were familiar with alligator nesting on an area. Experience may allow observers to develop a search image for site-specific nest types or locations that improves their detection rate.

Alligator nesting occurs in diverse vegetation types, cover, and wetlands in Florida, but we did not find a difference in nest sighting proportion for the 2 habitats. We hypothesize that the population of alligator nests is composed of 2 components: those that have some modification of the surrounding habitat or occur in relatively open patches of habitat that can be sighted from the air; and those, due to obstructions such as canopy cover, that cannot. The sighting proportion, or correction factor, developed in this study only applies to nests with habitat alterations that make them observable from the air and not to those nests that are completely obstructed by vegetation or otherwise undetectable. For example, Rice et al. (1999) after repeated complete counts of nests found an average of 25.4 pods of hatchling alligators on Lake Griffin not associated with nests observed during aerial survey, compared to an average of only 1.4 on Lake Jesup. A substantial portion of the nesting area on Lake Griffin is covered in wooded swamp, whereas the nesting area on Lake Jesup is predominately emergent marsh. This suggests that the proportion of nests that are unobservable from the air may differ between habitats.

We suspected that vegetation distribution and density change due to water level variation and other environmental factors might influence sighting probabilities.

However, we did not find any annual variation in nest sighting proportions. Enhanced observability of nests due to modification of the immediate area surrounding a nesting site by female alligators may have offset any natural variation in habitat composition.

Management Considerations

Original early age class harvest quotas in Florida were determined using repeated nest counts throughout the nesting season (Jennings et al. 1988). These estimates compare well to a single count that has been corrected with a sighting proportion. This correction may be written simply as:

$$\hat{N}=\frac{C}{\hat{p}}$$

where C is the initial count from the nest survey, $\hat{p}$ is the estimate of sighting proportion (in our study, 0.736, SE=0.024), and $\hat{N}$ is the final nest estimate. Notably, the variance of the resultant population estimate increases by the variance of the sighting proportion. Using the mean sighting proportion developed in this study, for example, a count of 100 nests will yield a 95% CI around the total nest estimate of 127 to 146 nests.

Present alligator nesting estimates in Florida are based upon a single survey in some areas that is not corrected by this proportion and, presumably, is biased low. Mean sighting proportions from this study can be used to construct a correction factor for final population estimates involving alligator nest surveys in comparable habitats in Florida. However, caution should be exercised regarding the use of this value on new habitats and with changes in habitat across years. Sighting proportions developed annually or at least for new habitats would be most appropriate. The difference in sighting proportions among observer experience levels indicates that observers should be of similar experience level if comparisons of non-adjusted counts are used for trend analyses or nesting estimates.

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