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Detection of American alligators in isolated, seasonal wetlands

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Abstract

Although the American alligator has been well-studied in coastal marshes and large reservoirs, very few studies have taken place in the isolated, seasonal wetlands that occur within the inland portion of the alligator's range. Understanding alligator populations in these systems is important because, although they are subject to the same management strategies and regulations as their more well-studied counterparts, they may have markedly different population dynamics and densities. Additionally, understanding patterns of alligator presence in isolated, seasonal wetlands is important to understanding how alligators may affect these critical habitats as ecosystem engineers. However, survey methods designed for large, open water systems may not work in these small, vegetated wetlands, and their efficacy in this habitat has yet to be documented. We conducted eyeshine surveys for alligators along walking transects through isolated, seasonal wetlands in southwest Georgia. We used a double-observer method with a Huggins closed capture analysis to determine the detection probability of this method, to model the effects of observer and wetland type on that parameter and to estimate abundance. We found that detection probability for eyeshine surveys under the best-supported model was 57%, between 2 and 5 times higher than documented in other habitats. We then compared eyeshine surveys with systematic trapping to ascertain which components of the population were more likely to be detected by each method. Both methods were effective in detecting a range of size classes in the wetlands; however, the two methods were most effective when used in concert. Wildlife biologists studying population trends and establishing harvest quotas can use this information to design surveys in the inland portion of the alligator's range.

Key words

Alligator mississippiensis, crocodilian populations, detection probability, double-observer eyeshine survey, Huggins closed capture design, seasonal wetland.

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Introduction

The American alligator (*Alligator mississippiensis*) is among the most frequently studied vertebrates in North America. However, these studies have been conducted almost exclusively in coastal marshes (McNease and Joanen, 1974; Mazzotti and Brandt, 1994; Wilkinson and Rhodes, 1997) and large reservoirs (Ruckel and Steele, 1984; Brandt, 1991). Although these habitats contain relatively dense populations of alligators, they constitute a small fraction of the total native range, which extends from central Texas to coastal North Carolina, and as far inland as Oklahoma (Conant and Collins, 1998). Despite evidence that inland populations differ from coastal populations in their ecology and population dynamics (Hayesodum et al., 1993; Ryberg et al., 2002; Lutterschmidt and Wasko, 2006), these populations have yet to be well-studied.

Understanding alligator populations in the isolated, seasonal wetlands that occur within the inland portion of their range is critical for two main reasons. First, statewide management plans are based on monitoring and research conducted primarily in coastal marshes and large reservoirs, where survey logistics are easier and alligator densities are highest. In Georgia, management plans are then applied equally across all habitats within a harvestable region (G. Waters, pers. comm.). If alligator populations in isolated, seasonal wetlands have lower abundance levels and distinctly different population dynamics than those in large reservoirs or marshes, then applying such broad-scale management strategies may lead to an over-harvesting of these populations (Ryberg et al., 2002). Second, the seasonal wetlands of the coastal plain constitute unique communities that provide critical habitat for a variety of threatened and endangered plants and animals (Gibbons, 2003; Semlitsch and Bodie, 2003; Sharitz, 2003). Because these wetlands dry nearly every year, they provide a low-predator environment for aquatic invertebrates and larval amphibians and are often important amphibian breeding sites. They are also used by a number of reptiles, as well as a suite of birds and some mammals, for foraging and habitat (Burke and Gibbons, 1995; Naugle et al., 2001; Roe et al., 2004). As alligators are large, aquatic predators known to heavily manipulate their environment through the construction of nest mounds and burrows (McIlhenny, 1935; Jones et al., 1994; Palmer and Mazzotti, 2004), their presence may play an important role in the dynamics of these small communities.

To obtain data on the presence and abundance of alligators in these systems, appropriate survey methods are required. However, the methods traditionally used for surveying and sampling populations are specifically designed for the large, open-water systems in which most historic studies have been conducted. Aerial nest counts, which are commonly used in coastal marshes, are inadequate in inland sites with heavy vegetative cover (Hayesodum et al., 1993). Eyeshine surveys, the most common method used for surveying alligator populations, are generally conducted in open water from a boat, which gives the observer the advantage of height, for increased visibility, and speed, to cover more ground. However isolated, seasonal wetlands are typically too shallow and vegetated to allow the use of watercraft. Furthermore, this method has been shown to vary in effectiveness based on a number of environmental factors (Woodward and Marion, 1978; Wood et al., 1985; Woodward et al., 1996). The primary sources of variation in counts were water temperature, which was positively correlated with alligator activity, and water level, as increasing water levels allowed alligators to access adjacent wetland areas not visible from the survey route.

Although eyeshine surveys are frequently used to survey alligator populations, the utility of such count data to indicate population trends is dependent on the assumption that detectability is constant across space and time (Burnham, 1981; Thompson, 2002). Eyeshine studies that have used mark-recapture or population modeling to estimate the average proportion of alligators detected have placed the detection probability at 9-25% (Taylor and Neal, 1984; Woodward et al., 1996). However, the effectiveness of this method in isolated, seasonal wetlands, in which eyeshine surveys must be conducted on foot, has not yet been documented. Use of a double-observer method during surveys is a cost-efficient approach that allows the estimation of detection probability and abundance (Nichols et al., 2000; Thompson, 2002; Bart et al., 2004). Additionally, the analysis of double-observer data within a Huggins closed capture model framework allows the use of grouping variables to test for habitat and observer effects on variation in the parameter estimates (Huggins, 1989). This method has been used to estimate detection probabilities for bat species (Duchamp et al., 2006) and whitetail deer (Collier et al., 2007), and it may provide a rigorous way to test the efficacy of eyeshine surveys for alligators as well.

Many capture methods that are traditionally used to sample alligator populations are similarly designed for open water systems (Chabreck, 1966). Researchers may use boats to approach an animal close enough to snare it, or large gill nets may be used to drag an area. However, the vegetative structure of small, seasonal wetlands makes the use of these methods impossible. To sample alligators in forested wetlands in east Texas, Ryberg and Cathey (2004) used box traps to capture alligators and had reasonably high trap success (12.5-21.5%).

Appropriate survey methods are needed to evaluate the occurrence, abundance, and subsequent ecological role of alligators in inland systems. The objectives of this study were (1) to evaluate the use of eyeshine surveys in two different types of seasonal wetlands in southwest Georgia (grassy marshes and cypress/gum swamps) using double observer surveys, and (2) to compare eyeshine surveys and systematic trapping in their utility for estimating alligator population size and demography in this system.

Study area

This study was conducted at Ichauway, the outdoor laboratory of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia. It is an 11,600 ha reserve predominantly composed of longleaf pine (*Pinus palustris*) and wiregrass (*Aristida beyrichiana*) uplands interspersed with more than 90 shallow, seasonal limesink wetlands. The site is also bisected by 25 km of the Ichawaynochaway Creek, and bordered by 20 km of the Flint River and a small section of the seasonally dry Big Cypress Creek.

There are three main types of wetlands on site (Kirkman et al., 2000): (1) cypress savannas, (2) grass-sedge marshes and (3) cypress-gum forests (*Taxodium ascendens* and *Nyssa biflora*, respectively). Cypress savannas are the smallest of the wetland types and also have the shortest hydroperiods (Kirkman et al., 2000; Liner, 2006), making them less conducive to alligator use. Grass-sedge marshes are generally the largest of the wetland types with an intermediate hydroperiod and cypress-gum forests generally have the longest hydroperiod, making these two wetland types most conducive to alligator use (Kirkman et al., 2000; Liner, 2006; Subalusky, 2007). We focused our study in 4 cypress-gum wetlands (4.69-12.18 ha) and 3 grass-sedge marshes (3.15-19.56 ha) that were known to have had alligators present within the 2 previous years.

Methods

Eyeshine surveys

We conducted eyeshine surveys along walking transects during three consecutive nights in each of seven isolated wetlands. We placed linear transects perpendicular to the longitudinal axis of the wetland at 100 m intervals to maximize our coverage of each wetland while minimizing the probability we would observe the same individual on multiple transects. The number of transects used in each wetland varied from 3-6, depending on the length of the wetland, and transect length varied from 75-350 m, depending on the width of each wetland. During daylight hours, we marked all transects with reflective flagging. We returned at night and used a 200,000 candlepower spotlight to walk the transects through the wetlands and search for alligator eyeshine.

All eyeshine surveys were conducted between 10 June and 28 June 2003. For each survey, we recorded the start and end time, weather condition (a categorical value where 0 = clear, 1 = 1-50% cloud cover, 2 = 51-100% cloud cover, 3 = rain), moon phase, and water and air temperatures. No surveys were conducted during weather conditions likely to adversely affect detectability of alligators, including high winds and heavy rain. We used a double-observer method for three consecutive nights at each wetland to allow us to calculate detection probability (Nichols et al., 2000; Thompson, 2002; Moore et al., 2004). We drew our two observers from a pool of six people, all of whom had some experience surveying for alligator eyeshine. To maintain independence of observations, each observer recorded their own data, and the secondary observer followed approximately 10 m behind the primary observer. Observers noted transect number and approximate distance from the transect centerline to the alligator, and animals were classified as juveniles <1.2 m (4 feet) total length, subadults of 1.2-1.8 m, adults >1.8 m (6 feet), or unknown (Chabreck, 1966). Using location and size information, we were able to determine which individuals were observed by both observers and which were only observed by either the first or second observer.

Eyeshine survey data analysis

We used a Huggins closed capture model to calculate detection probability using Program MARK (Huggins, 1989; White and Burnham, 1999; Collier et al., 2007). Huggins closed capture models treat the observations of primary and secondary observers as capture and recapture data and use maximum likelihood theory to estimate detection probability and abundance. These models also allow data to be grouped according to environmental or sampling variables, such as wetland type and observer in this case, in order to determine the effect of those variables on the derived parameters.

We developed a set of four candidate models to test the effect of wetland type and observer on detectability of alligators. Due to limited sample size, we were constrained in the number of variables we were able to include in our model. Because surveys were conducted in a relatively short time period during suitable weather conditions, we chose to incorporate observer and site differences likely to affect detectability rather than weather variables. Our models ranged from a constant model, $p(\cdot)$, in which capture probabilities were equal across habitat types and observers (number of parameters $= 1$) to a model $p(t^{*}g)$ in which detection varied across both observers (t) and wetland types (g) (number of parameters $= 4$). We evaluated the fit of each model using the quasi-likelihood Akaike's Information Criterion, corrected for overdispersion ($QAIC_c$; Burnham and Anderson, 2002), as computed by MARK (White and Burnham, 1999).

Trapping

Three weeks after eyeshine surveys were completed, we trapped alligators in six of the seven wetlands using baited trip-snare traps (Murphy and Fendley, 1974) and Tomahawk cage traps. We trapped three wetlands at a time over the course of two weeks, between July 15 and July 28. We used five traps of each type for four consecutive nights for a total of 40 trap-nights per wetland. We checked traps each morning and all captured animals were measured and marked. We took morphometric measurements including snout-vent length and tail length, noted sex and any injuries present, and marked animals using both a tail scute notching scheme (Mazzotti, 1983) and PIT tags (passive integrated transponders; Biomark, Inc., Boise, ID).

In characterizing the sizes of animals detected by eyeshine surveys and comparing those results to trapping data, we used data from the one night out of the three eyeshine surveys in which the maximum number of individuals was observed for each wetland. Using the maximum number observed on a single night allowed us to use the greatest amount of observations for a given wetland without the risk of biasing the data with repeated observations of the same individual. For trapping data, we used the sum total of individuals for each wetland, excluding recaptured animals.

Results

Eyeshine surveys

Average air temperature during eyeshine surveys was 25.2 ± 1.8 SD°C and average water temperature was 27.6 ± 3.8 SD°C. Double-observer eyeshine surveys resulted in 18 encounter histories of alligators, which were observed at an average distance of 35 m from the transect. Observations in forested (cypress-gum) wetlands accounted for 44.4% of observations and marsh (grass-sedge) wetland observations accounted for the remaining 55.6%. Each observer detected 72.2% of the alligators, but only 44.4% of individuals were detected by both observers. The most parsimonious model in this study was the model in which detection probability was held constant between both wetland types and both observers (table 1). The estimated detection probability of alligators in seasonal wetlands from this model was 0.57 (table 2).

Table 1.
Four models of detection probability of alligators using eyeshine surveys in inland wetland systems in Baker County, GA in 2003. Observer (t) and wetland type (g) are used as grouping variables. $\Delta QAIC_c = 0.000$ for the model most appropriate for the data set, and these values increase as parsimony decreases.

Model	Model description	Parameters	AIC_c	$\Delta QAIC_c$	$QAIC_c$ weight
$p(\cdot)$	Constant	1	237.335	0.000	0.459
$p(t)$	Obs. 1 ≠ Obs. 2	2	238.122	0.788	0.310
$p(g)$	Marsh ≠ Forested	2	239.181	1.846	0.182
$p(t^*g)$	Obs. 1≠ Obs. 2, Marsh ≠ Forest	4	241.835	4.500	0.048

Table 2.
Estimates of detection probability of alligators using eyeshine surveys in inland wetlands systems in Baker County, GA in 2003. The two most likely models are shown according to AIC model selection; $p(\cdot)$, the constant model, and $p(t)$, which accounts for differences between observers.

Model	Observer	Detection probability	Std. error	Lower 95% CI	Upper 95% CI
$p(\cdot)$	NA	0.570	0.048	0.47	0.66
$p(t)$	1	0.606	0.058	0.49	0.71
	2	0.538	0.056	0.43	0.64

Table 3.
Comparison of size classes of alligators detected by eyeshine surveys and trapping in inland wetlands in Baker County, GA in 2003.

		Forest		Marsh	
Size class	Size (m)	Eyeshine	Trapping	Eyeshine	Trapping
Juvenile	<1.2	2	5	1	2
Subadult	1.2-1.8	2	1	1	1
Adult	>1.8	0	3	3	0

The next most likely model was one that accounted for different detection probabilities between the first and second observer (table 1). Although the second observer had a lower detection probability (0.54 vs 0.61), the confidence intervals for these estimates overlapped widely indicating the difference was not significant (table 2). The model which accounted for different detection probabilities between the two wetland types had a fairly low $QAIC_c$ weight (table 1). Although this model indicated detection probability was higher in marsh wetlands, it was not well supported by the data.

Huggins closed capture models estimate abundance as a derived parameter which is calculated separately for each observer (Huggins, 1989). We used the abundance estimates derived from the constant model, which had the lowest $\Delta QAIC_c$ value. The derived abundance estimate for observer 1 was 110.5 ± 7.5 SE with a 95% confidence interval of 100.2-131.2. The data from observer 2 increased that estimate by 22.1 ± 2.5 SE, with a 95% confidence interval of 19.4-30.4.

In order to compare detection between eyeshine surveys and trapping, the following results are limited to the six wetlands (three forested and three marsh) where trapping also took place. There were eight observations in forested wetlands over three nights of surveys and 10 observations in marsh wetlands. The maximum number of alligators observed in a single wetland on one night ranged from 0-3, with a median value of 1. Using the survey night with the maximum number of observations for each wetland, four individuals in the juvenile and subadult size classes were observed in the three forested wetlands, and five individuals in the juvenile, subadult and adult size classes were observed in the three marsh wetlands (table 3). Although five out of the total 18 eyeshine observations were classified as unknown size, there were no animals in this category on the nights which were selected for comparison.

Trapping

Twelve alligators were captured, ranging in size from 43.0-147.5 cm snout-vent length, with an average of 72.1 cm SVL. Six (43.0-66.5 cm SVL) were captured in Tomahawk cage traps, and six (53.4-147.5 cm SVL) were captured in Murphy-

Fendley trip-snare traps. Only one alligator was recaptured during the sampling period, and it was caught in a trip-snare trap, at the same wetland, both times.

Alligators were captured at each of the three forested wetlands where they were trapped and only one of the marsh wetlands. A total of nine individuals were trapped in forested wetlands, ranging from 43.0-147.5 cm SVL with a mean of 77.7 ± 40.5 SD and a 95% confidence interval from 47-109 cm. Three individuals were captured in marsh wetlands, ranging from 44.0-66.5 cm SVL, a mean of 55.4 ± 11.3 SD and a 95% confidence interval from 27-83 cm. In the forested wetlands, trapping efforts detected animals in all three size class categories, while in marshes, trapping detected animals in the juvenile and subadult categories (table 3).

Discussion

Both eyeshine surveys and systematic trapping detected alligators in our inland wetland system. Eyeshine surveys were more effective than expected, with a detection probability of 57%. This estimate was 2-5 times higher than previously reported from studies in open-water systems (Taylor and Neal, 1984; Woodward et al., 1996). This result suggests eyeshine surveys are more effective in forested and emergent wetland systems than in open water systems, which is counter-intuitive given the dense vegetation structure of the wetlands. However, the small size of the wetlands in this study (3.15-19.56 ha) allowed fairly thorough coverage, which may have offset the effect of dense vegetation. Furthermore, the use of walking surveys eliminated the noise and turbulence disturbance of a boat motor, which may have further increased detectability.

The constant model, which modeled equal capture probabilities across observers and wetland type, was best supported by the data. This may have been a consequence of having only 18 encounter histories, as small sample sizes reduce the number of grouping variables one can model. However, the confidence intervals for the detection probability were relatively narrow, suggesting the sample size was sufficient to provide a robust estimate. The model which accounted for different detection probabilities between the first and second observer was weakly supported by the data, suggesting a higher detection probability for the first observer. As wariness has been well-documented in crocodilians, particularly adults, after initial exposure to spotlights or capture attempts, it is possible the first observer may have some detection advantage (Webb and Messel, 1979; Pacheco, 1996). However, in this study, both observers detected the same total number of individuals, detecting the same individuals only 44% of the time. The fact that both observers detected an equal number of individuals that the other missed may indicate the difficulty of detecting alligators in this habitat, as opposed to a disturbance-related bias against one observer or another. The model that accounted for different detection probabilities by wetland type was not very well-supported by the data, suggesting that dense emergent grasses had roughly the same effect on detection of eyeshine as dense stands of cypress and gum trees.

We obtained an abundance estimate of 133 alligators among all seven wetlands surveyed by adding together the derived abundance parameter for the first and second observer under the constant model $p(\cdot)$. Although narrow confidence intervals suggest the estimate is fairly precise, mark-recapture analysis will be needed to determine its accuracy. In order to have greater power to model the effect of grouping factors and to obtain a more precise abundance estimate, more surveys and more encounter histories are needed. Our limited sample size also did not allow us to account for weather and moon phase variables in our analyses; however, we accounted for that by conducting all surveys within a short time period during which environmental variables were fairly consistent and optimal for alligator activity.

We had 13 alligator captures over 240 trap*nights, for a total trap success of 5.4%. This success rate was much lower than Ryberg and Cathey (2004) achieved with box traps (12.5-21.5%). However, box traps large enough for adult alligators are more expensive to build and more difficult to carry through dense vegetation than trip-snare traps (Elsey and Trosclair, 2004). These factors limit their use on a large scale and resulted in our selection of the trip-snare design (Murphy and Fendley, 1974). The trip-snares and Tomahawk cage traps did catch animals of overlapping size classes, indicating that our trapping methods were sufficient to detect a wide and continuous range of sizes. Additionally, the smallest alligator we captured using a Tomahawk trap was 89.1 cm total length (TL), which was over 10 cm smaller than the smallest alligators captured in box traps (Ryberg and Cathey, 2004), indicating that we may have been more likely to detect smaller individuals with our trapping methods.

Eyeshine surveys and systematic trapping detected different size classes of alligators, although the trend was not consistent across wetland types. In forested wetlands, smaller individuals were detected by eyeshine surveys and larger ones by trapping. In marshes, the opposite trend occurred. Our data were not robust enough to draw definitive conclusions about how these survey methods vary by habitat type. Additionally, our ability to accurately estimate the size of animals observed using eyeshines is difficult to assess and could be responsible for some of this variation. However, judging from our experience working in these wetlands, it is also possible that the high degree of wariness in adult alligators in this system makes them difficult to detect by methods other than trapping. In isolated, seasonal wetland systems, use of multiple methods might be the best way to survey a broad cross-section of the population, which may be especially important due to low population numbers and subsequent low sample size.

In conclusion, our data suggest isolated, seasonal wetlands constitute an important yet under-studied habitat for alligators within the inland portion of their range. Double-observer eyeshine surveys indicate the detection probability of alligators in these systems is relatively high, and this method may be used with a Huggins closed capture analysis to derive abundance estimates as a function of grouping variables. This methodology is a cost-efficient way to calculate detection probabilities and derive abundance estimates from alligator eyeshine surveys, which are frequently employed yet limited in their usefulness. Wildlife managers could use this approach to estimate alligator abundance in inland habitats such as isolated, seasonal wetlands, which would aid in establishing harvest quotas applicable to the entire range of American alligator. The method should also be directly applicable to other crocodilian species that also occur in difficult-to-sample habitats. Results from these analyses can be tested using mark-recapture data. In seasonal wetland systems, use of both Tomahawk cage traps and trip-snare traps provide a cost-efficient method of sampling a wide range of size classes.

Use of both eyeshine surveys and systematic trapping gave us a more complete picture of the alligator population in this system. Understanding the patterns of alligator presence and abundance in isolated, seasonal wetlands is critical to developing appropriate management strategies for alligators in this habitat as well as to understanding the ecological role of alligators in these systems. However, the first step towards these goals is developing appropriate survey methods and evaluating their effectiveness.

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