2012

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Recommended Citation

Conway, Warren C.; Calkins, Gary; and Saalfeld, David, "Nest Success and Hatchling Survival of American Alligators Within Inland Wetlands of East Texas" (2012). *Faculty Publications.* Paper 267.
http://scholarworks.sfasu.edu/forestry/267

The Journal of Wildlife Management 76(8):1568–1575; 2012; DOI: 10.1002/jwmg.413

Population Ecology

Nest Success and Hatchling Survival of American Alligators Within Inland Wetlands of East Texas

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ABSTRACT Because of liberalization of American alligator (*Alligator mississippiensis*) harvest management in Texas, estimates of nest success and hatchling survival for inland populations are essential for long-term, sustainable population and harvest management. To date, few studies have examined American alligator nest success and hatchling survival. We initiated a 3-year study from 2006 to 2008 to document alligator nest success and hatchling survival within several wetlands in east Texas. From June 2006 to August 2008, we located 30 nests from 3 wetlands within east Texas, where overall nest success was 44.2% (95% CI = 25.1–63.1%), irrespective of year. Nest circumference and day during the nesting season exerted the greatest influence on nest success. Additionally, from August 2006 to August 2008 we captured, marked, and released 271 hatchling alligators at Little Sandy National Wildlife Refuge, and recaptured an additional 192 hatchling alligators during this time. We estimated yearly apparent survival at 6.0% (95% CI = 2.0–14.6%) for hatchling alligators born in 2006 and 43.0% (95% CI = 28.4–57.8%) for those hatched in 2007. Variation in nest success and hatchling survival was likely attributed to fluctuating water levels and habitat management practices. Alligator harvest regulations need to account for variability in nest success and hatchling survival by including site-specific estimates of these metrics into harvest models. Failing to account for spatial and temporal variation in nest success and hatchling survival may result in unsustainable harvest and/or overharvest. © 2012 The Wildlife Society.

KEY WORDS *Alligator mississippiensis*, American alligator, harvest models, hatchling survival, nest success, Texas.

Nest success and hatchling survival are key drivers of population dynamics and important elements for modeling population stochasticity. American alligator (*Alligator mississippiensis*) nest success is used to estimate recruitment and monitor local population age and size structure (Nichols et al. 1976, McNease and Joanen 1978, Nichols 1987), where variability in nest success (46–74%; Joanen 1969, Deitz and Hines 1980, Ruckel and Steele 1984, Joanen and McNease 1989, Platt et al. 1995) is a function of several unpredictable factors. For example, alligator nest success may be influenced by predation rates (Goodwin and Marion 1978, Deitz and Hines 1980, Joanen and McNease 1989, Hunt and Ogden 1991, Platt et al. 1995), local habitat (Joanen 1969, Hayes-Odum et al. 1993), flooding (Joanen and McNease 1989, Platt et al. 1995), desiccation (Joanen and McNease 1989), female attendance (Kushlan and Kushlan 1980), and disturbance by nesting turtles (Goodwin and Marion 1978). Of these, predation by raccoons (*Procyon lotor*) and flooding have been cited as the main causes of alligator nest failure (Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Kushlan and Jacobsen 1990, Platt et al. 1995).

Beyond nest success, hatchling survival is a key metric in population modeling (Nichols 1987). Although adult alligator survival rates vary among size classes and habitats (Abercrombie 1989, Brandt 1989), few studies have estimated hatchling survival (Woodward et al. 1987), which is hypothesized to be extremely variable, both spatially and temporally, ranging from 12% to 63% (Deitz and Hines 1980, Woodward et al. 1987, Brandt 1989). Conservation concerns surrounding early age-class harvest in other regions have emphasized the importance of estimating juvenile survival rates throughout their range. The potential additive effects of increased harvest, along with poor hatchling and/or nest success could rapidly and drastically reduce alligator populations locally and/or regionally.

Nest success and hatchling survival rates are coarsely known or generally lacking for inland alligator populations (Deitz and Hines 1980, Nichols 1987, Brandt 1989). These elements directly affect population dynamics, and even in

Received: 18 March 2011; Accepted: 3 April 2012
Published: 23 July 2012

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regions where alligators have been extensively studied, large information gaps still exist (Nichols 1987). Estimates of relevant variables influencing nest success and hatchling survival are crucial for alligator conservation and management plan development, particularly in areas where little is known about alligator ecology. As nest success and hatchling survival are known to be variable among habitats and geographic regions, it is key to develop estimates for these population parameters within specific geographic areas (Ruckel and Steele 1984). Although alligator nesting ecology has been extensively studied throughout its range, no nesting ecology studies have been conducted in Texas and only a few studies have occurred within inland wetlands (Saalfeld 2010). Specifically, no estimates of nest success or hatchling survival have been developed for east Texas, the westernmost part of their geographic range. Regional alligator harvest management strategies may need to be adjusted based upon local hatchling survival, and nest success estimates. Our objectives for this study were to quantify nest success and estimate yearly hatchling survival of American alligators in east Texas wetlands.

STUDY AREA

This research was conducted at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (NWR) in east Texas (Fig. 1). Dam B WMA was a 5,113-ha area located within Jasper and Tyler counties at the confluence of the Angelina River, Neches River, and B. A. Steinhagen Reservoir. Dam B WMA was characterized by riverine, open lake, and shallow marsh habitats (Webb 2005, Webb et al. 2009). Dominant aquatic plants included water hyacinth (*Eichhornia crassipes*), common salvinia (*Salvinia minima*), giant salvinia (*Salvinia molesta*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticellata*), smartweeds (*Polygonum* spp.), and yellow pond lily (*Nuphar luteum*). Dominant woody species along wetland margins included baldcypress (*Taxodium distichum*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), Chinese tallow (*Triadica sebifera*), water oak (*Quercus nigra*), overcup oak (*Quercus lyrata*), water tupelo (*Nyssa aquatica*), and pine (*Pinus* spp.; Godfrey and Wooten 1981).

Kurth Lake was a 294-ha reservoir located in Angelina County, comprised of an abundance of deep (i.e., maximum depth of 12.2 m) open water habitat (>80% of lake is deep open water; D. T. Saalfeld, Stephen F. Austin State University, unpublished data) and a few shallow bays with isolated pockets of emergent marsh. Dominant aquatic species included American lotus (*Nelumbo lutea*), hydrilla, coontail (*Ceratophyllum demersum*), and yellow pond lily. Dominant woody species along wetland margins included buttonbush, black willow, Chinese tallow, water oak, overcup oak, and pine (Godfrey and Wooten 1981).

Little Sandy NWR consisted of 1,539 ha, of which approximately 1,100 ha were bottomland hardwood forest, located on the northern bank of the Sabine River in southern Wood County. Little Sandy NWR contained 4 main lentic bodies: Overton Lake, Brumley Lake, Bradford Lake, and Beaver Lake. Of these, we only used Overton Lake (an impoundment of Jim Ned Creek) and Brumley Lake (an impoundment of Little Sandy Creek) as study sites. Overton Lake was approximately 175 ha and Brumley Lake was

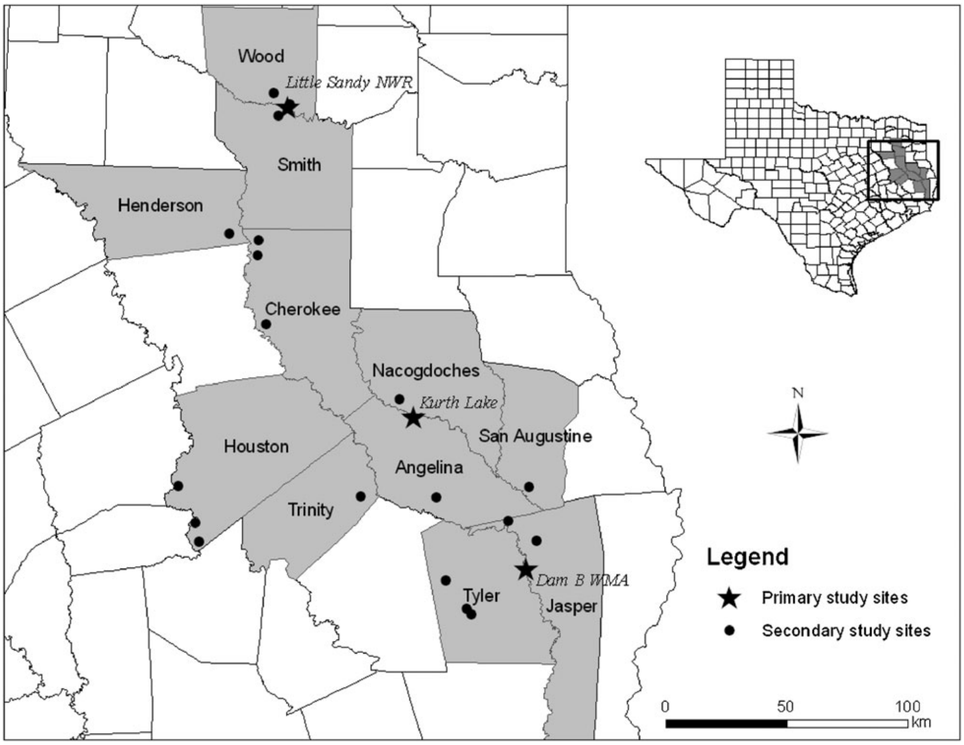

Figure 1. Location of counties and both primary and secondary study sites in east Texas used to study American alligator (*Alligator mississippiensis*) nest success and hatchling survival, 2006–2008.

approximately 200 ha. Both lakes were connected by several creeks and canals, essentially making these 2 lakes 1 large wetland. Hereafter, these 2 lakes will be referred to as Little Sandy NWR. Little Sandy NWR was characterized primarily by shallow marsh with little open water or creek channels. Dominant aquatic species included American frog-bit (*Limnobium spongia*), American lotus, Carolina fanwort (*Cabomba caroliniana*), coontail, cutgrass (*Zizaniopsis miliacea*), and yellow pond lily. Woody species included Chinese tallow, buttonbush, black willow, and southern wax myrtle (*Morella cerifera*; Godfrey and Wooten 1981).

We used an additional 25 permanent wetlands as secondary study sites for the nest success portion of this study (Fig. 1). We selected secondary study sites based upon presence of similar habitats (i.e., mosaic of open water, floating vegetation, and emergent vegetation) as the primary study sites (i.e., Little Sandy NWR and Dam B WMA). Secondary study sites were located using 1-m resolution, 2004 National Agriculture Imagery Program (NAIP) digital orthophoto quarter-quadrangle aerial photographs (DOQQ; Texas Natural Resources Information System, 2004) in ArcGIS 9.2 (ESRI, Redlands, CA). From an initial pool of >100 potentially available secondary study sites, inclusion of a particular wetland was ultimately dependent upon landowner permission and/or presence of alligators documented by Texas Parks and Wildlife spotlight surveys. These wetlands were scattered throughout east Texas and ranged in size from 10 ha to 150 ha.

METHODS

Data Collection

Nest survival.—We performed nest surveys at all 3 primary study sites (Dam B WMA, Kurth Lake, and Little Sandy NWR) from June 2006 to September 2008. Additionally, during June 2007 to September 2008, we surveyed secondary study sites a minimum of twice yearly to locate nests. We located nests by searching presumed appropriate habitats (i.e., areas close to the water's edge above the high water mark; Deitz and Hines 1980, Ruckel and Steele 1984, Hayes-Odum et al. 1993) by foot or boat, observing female behavior (i.e., occupying same area for several consecutive nights, exhibiting defensive postures), and searching areas with flattened shoreline herbaceous vegetation or with noticeable trails leading out of the water. Upon discovery, we obtained a Global Positioning System (GPS) point to relocate nests for monitoring and future nest habitat collection.

We monitored nests at least once weekly until nest fate was determined. Nests were considered successful if $\geq$1 egg hatched (Mayfield 1975). Successful nests showed no signs of predation (i.e., egg shells scattered about and/or nest excavated), a female had opened nest to allow hatchlings out, and/or hatchlings were sighted in close proximity to nest (Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Joanen and McNease 1989, Platt et al. 1995). If a nest showed signs of predation, we attempted to identify nest predators by searching for prints or tracks, fecal samples, hair, or other signs. To determine variables most influencing nest success, we measured or estimated the following variables for each nest after nest fate was determined: nest circumference (cm), true height above sea level (elevation; m), nest height (cm), canopy cover (%), basal area (m^2/ha), habitat type (i.e., levee, shoreline, or island), distance to water (m), and distance to nearest tree (m).

Hatchling survival.—To estimate hatchling survival (i.e., interval from hatching to first year), from 1 August 2006 to 1 August 2008, we captured, marked, and released hatchling American alligators at our 3 primary study sites using several capture techniques (i.e., snake tongs, hands, and dip nets). At night, we used spotlights affixed with red filters to locate alligators with a 4.9-m boat outfitted with a 20-horsepower mud motor. Upon capture, we restrained alligators with duct tape, and sexed each individual >50.0 cm in total length by cloacal examination (Chabreck 1963, Joanen and McNease 1978). Allsteadt and Lang (1995) developed a technique to sex alligators <50 cm through inspection of the genitalia (i.e., using a caliper and magnifying glass to inspect the size and shape of clitero-penis). However, because of small genitalia size and low light conditions, consistently and accurately obtaining these measurements was not possible; so we did not sex alligators <50 cm. For all captured individuals (regardless of size), we measured a suite of morphological features (see Saalfeld et al. 2008). We marked all hatchling alligators with a dorsal tail-scute removal (unique to each year) and a passive integrated transponder (PIT) tag to identify recaptured individuals. The Institutional Animal Care and Use Committee (Stephen F. Austin State University, TX; No. TECMW 09-20-06) approved all handling procedures.

During each sampling period (i.e., week), we sampled the entire study site at Little Sandy NWR and Kurth Lake by systematically traversing both wetlands and attempting to capture all alligators sighted. As Dam B WMA was larger, we were not able to sample the entire wetland; however, we selected a subsection of this wetland that we consistently sampled during each sampling period. We sampled during 16 periods each year and spent multiple days at each study site during a sampling period.

Data Analysis

Nest survival.—We calculated modified nest success estimates in Program Mark (Dinsmore et al. 2002) and examined the influence of variables on nest success. We used a 60-day incubation period (mean incubation period among alligator nests found during this study) to extrapolate daily survival rates to annual nest success estimates (Saalfeld 2010). Because nest success is a transformed variable, we used the delta method to estimate variance (Seber 1982). We modeled daily survival with a set of 23 a priori candidate models that included biologically relevant combinations of the following variables: year (coded 0 for 2006 and 1 for 2007), linear time trend (i.e., survival rates for each day following nest initiation were related in a linear trend over time), elevation, habitat type (i.e., levee, island, or shoreline), distance to water, distance to nearest tree, distance to shoreline, nest height, nest circumference, canopy cover, and basal area. As nests were located at only 3 wetlands that had similar habitat composition, vegetation, and proximity to other water bodies, we did not include wetland as a covariate in our analyses. We did not permit correlated variables ($P > 0.05$) to occur in the same model. We used Akaike's Information Criterion corrected for small sample size (AIC_c) to rank models; models were considered plausible if $\Delta AIC_c < 2$ (Burnham and Anderson 2002). Additionally, we calculated parameter likelihoods, estimates, and standard errors using model averaging.

Hatchling survival.—Using mark-recapture data of hatchling alligators, we estimated yearly and weekly apparent survival and the probability of recapture in Program Mark using Cormack–Jolly–Seber models (Cormack 1964, Jolly 1965, Seber 1965). We developed 16 a priori candidate models for hatchling survival that included combinations of apparent survival (φ) and recapture probability (p) that were allowed to vary over time (i.e., 15 parameters were entered into the model representing a separate estimate for apparent survival and/or recapture probability between sampling occasions) or remain constant (i.e., 1 parameter was entered into the model representing a constant estimate of apparent survival and/or recapture probability). In addition, we modeled apparent survival of hatchlings for 2 groups: hatched in 2006 and hatched in 2007. We obtained weekly estimates of apparent survival and probability of recapture by collapsing mark-recapture data into 1-week sampling periods; we collapsed several nights of sampling within a week (typically 2–3 nights per wetland) into 1 measure of whether or not an individual was captured during the week-long sampling period. However, as we did not sample every week, we adjusted time intervals between sampling periods in Program Mark to account for gaps in sampling effort. For example, we did not sample during winter; therefore, we adjusted the time interval between sampling periods by the number of weeks that sampling did not occur. We used AIC_c to rank models as described above. We performed a goodness-of-fit test in Program RELEASE (Burnham et al. 1987) to determine if the global model fit the data well and to check for data overdispersion.

RESULTS

Nest Survival

From 27 June 2006 to 21 September 2008, we discovered and monitored 30 American alligator nests (10 in 2006, 17 in 2007, and 3 in 2008), the majority (60%) of which were located from 18 July to 2 August (Fig. 2). Most nests occurred at Little Sandy NWR (26 nests; 10 in 2006, 13 in 2007, and 3 in 2008), with only 2 nests discovered at both Murchison Lake (secondary study site) and Dam B WMA (all discovered in 2007). Alligator nests hatched 27 August to 21 September, with most nests (63%) hatching during the first week of September (Fig. 2).

Among all years, 16 nests were successful (2 in 2006, 11 in 2007, and 3 in 2008). Of the 14 unsuccessful nests, 5 were depredated by raccoons (all in 2006), 2 were depredated by feral hogs (*Sus scrofa*; both in 2006), and 7 were inundated (1 in 2006 and 6 in 2007) and never hatched. Overall estimate of nest success was 44.2% (95% CI = 25.1–63.1%) using a 60-day incubation period. The estimate of nest success was 19.9% for 2006 (95% CI = 0.0–42.3%) and 61.1% for 2007 (95% CI = 37.1–85.2%). We did not calculate an estimate for 2008 because of limited sample size ($n = 3$).

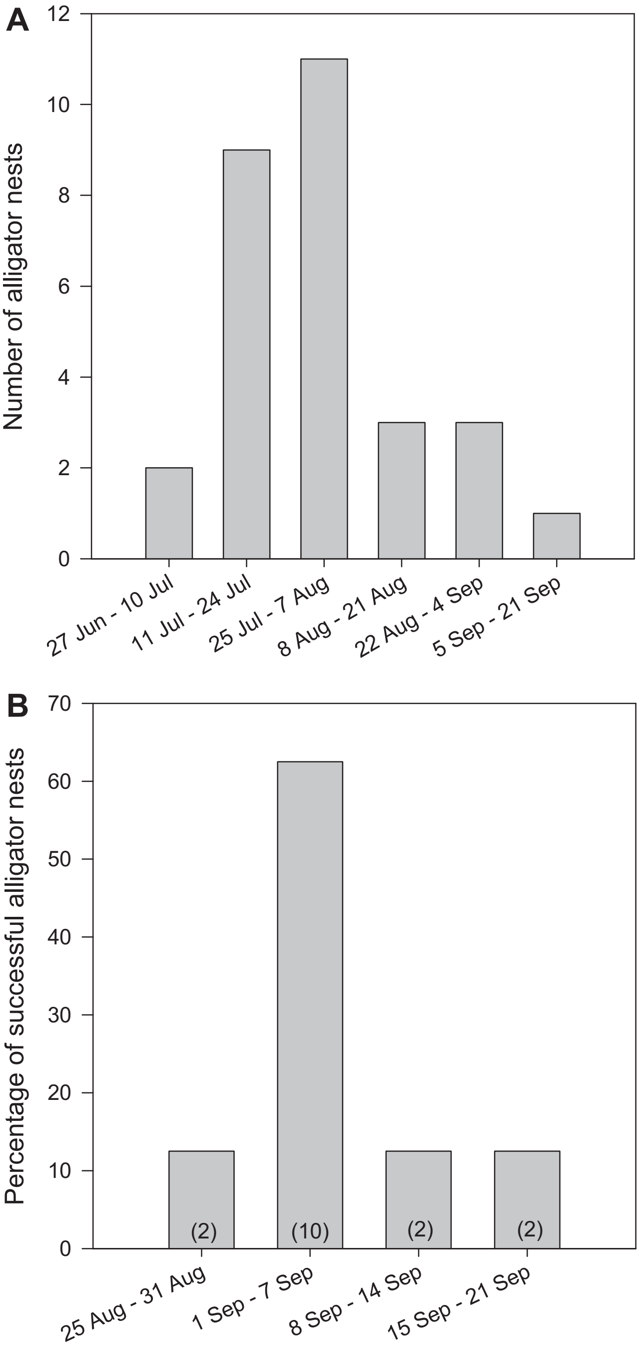

Figure 2. Number of American alligator (*Alligator mississippiensis*) nests (A) and percentage of successful American alligator nests (B) located within east Texas wetlands, 2006–2008 by hatching date. Numbers in parentheses correspond to number of successful alligator nests hatched within each time period.

From the nest success analysis in Program Mark (Dinsmore et al. 2002), the first 2 models should be considered plausible (i.e., $\Delta \mathrm{AIC}_c < 2$; Burnham and Anderson 2002). The top-ranked model (AIC_c relative weight [w_i] = 0.44) was the additive model of the linear time trend and nest circumference (Table 1). The second-ranked model ($\Delta \mathrm{AIC}_c = 1.86$, $w_i = 0.18$) was the additive model of the linear time trend, year, and nest circumference (Table 1). Parameter likelihoods illustrated that the linear time trend (likelihood = 0.99; estimate = − 0.09, SE = 0.04) and nest circumference (likelihood = 0.85; estimate = 0.01, SE = 0.01) were the most influential parameters to be included in the top-ranked model. Although year (likelihood = 0.32; estimate = 0.15, SE = 0.26) was included in the second-ranked model, year was likely an uninformative parameter and insignificant to alligator nest success (Arnold 2010). From both models, nest success declined as day during the nesting season (i.e., linear time trend) increased, as nest circumference decreased, and was greater in 2007 than 2006.

Hatchling Survival

From 2006 to 2008, at Little Sandy NWR, we captured 271 unique hatchlings; with 192 recapture events comprised of 118 unique individuals. In 2006, we captured 62 hatchlings with 39 recaptures, and in 2007, we captured 209 hatchlings with 153 recaptures. We captured hatchling alligators from 19 different pods, where number of individuals captured per pod ranged from 2 to 24 hatchlings. Although we attempted to capture hatchlings at all primary study sites, we were unable to capture enough hatchlings from Dam B WMA (53 hatchlings over 5 years) and Kurth Lake (80 hatchlings over 3 years) to warrant inclusion in any subsequent survival models. Among 16 models, the top-ranked hatchling survival model included constant survival for each year and probability of recapture varying over time for each year (Fig. 3 and Table 2). From this model, we estimated cumulative yearly survival to be 6% for hatchlings born in 2006 and 43% for hatchlings born in 2007. The estimate of overdispersion ($\hat{c}$) from Program RELEASE (test 2 + test 3) was 0.70 ($\chi^2 = 44.23$, $P = 0.965$) indicating the model fit the data well.

DISCUSSION

Nest Survival

Alligator nest success (44%) estimated in this study is well within the range of previous estimates, albeit slightly lower than coastal Louisiana (68%; Joanen 1969) and north-central Florida (62–67%; Goodwin and Marion 1978, Deitz and Hines 1980), but similar to southern Georgia (48–74%; Ruckel and Steele 1984) and southeastern Louisiana (46%; Platt et al. 1995). Based on the similarity in nest success estimates from other regions, nest success may potentially vary more temporally than spatially. For example, in this study, nest success varied from 20% in 2006 to 61% in 2007, with water levels varying dramatically between years. Although this study had limited sample sizes, both nest success and the number of nests located increased in 2007 when water levels were highest. Additionally, in 2006 when water levels were lowest, more nests were unsuccessful (8 out of 10 nests were unsuccessful in 2006 and only 6 out of 17 were unsuccessful in 2007) with most being depredated by raccoons and feral hogs.

Similar to previous studies (Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Kushlan and

Table 1. Model results from nest survival (*S*) analysis of American alligator (*Alligator mississippiensis*) nests within east Texas wetlands, 2006–2007.

Model	No. of parameters	$\Delta \mathrm{AIC}_c$[a]	w_i[b]
S (linear time trend + nest circumference)	3	0.00	0.44
S (linear time trend + year + nest circumference)	4	1.86	0.18
S (linear time trend + nest circumference + distance to water)	4	2.02	0.16
S (linear time trend + year + nest circumference + distance to water)	5	3.83	0.07
S (linear time trend + year)	3	4.07	0.06
S (linear time trend)	2	5.22	0.03
S (linear time trend + distance to water)	3	5.23	0.03
S (linear time trend + year + distance to water)	4	6.05	0.02
S (nest circumference)	2	10.45	0.00
S (year + nest circumference)	3	11.85	0.00
S (year)	2	11.91	0.00
S (year × nest circumference)	4	12.55	0.00
S (year × distance to water)	4	13.31	0.00
S (distance to water)	2	13.79	0.00
S (year + distance to water)	3	13.85	0.00
S (.)[c]	1	14.72	0.00
S (distance to nearest tree)	2	15.29	0.00
S (nest height)	2	15.71	0.00
S (% canopy cover)	2	15.93	0.00
S (distance to shoreline)	2	16.28	0.00
S (elevation)	2	16.34	0.00
S (habitat type)	3	29.02	0.00
S (basal area)	2	27.86	0.00

[a] Difference between model's Akaike's Information Criterion corrected for small sample size (AIC_c) and the lowest AIC_c value.

[b] AIC_c relative weight attributed to model.

[c] Model of no effects on nest survival (constant survival).

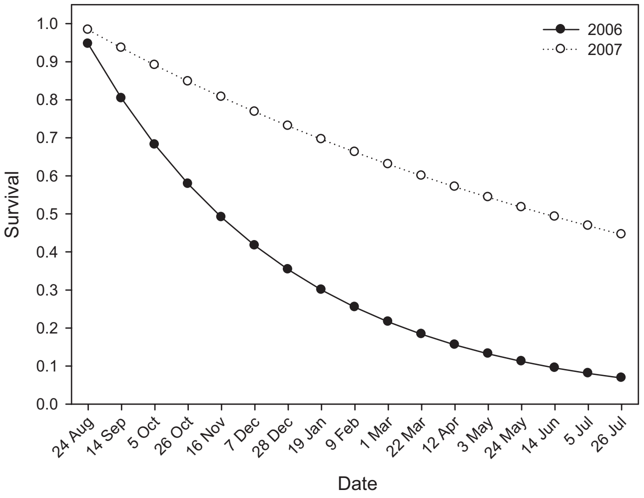

Figure 3. Cumulative weekly estimates of survival rates and 95% confidence intervals for American alligators (*Alligator mississippiensis*) hatched in 2006 and 2007 at Little Sandy National Wildlife Refuge, Texas.

Jacobsen 1990, Platt et al. 1995), the 2 primary causes of alligator nest failures were depredation by raccoons and flooding. Raccoons are hypothesized to be the primary predator of alligator nests (Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Joanen and McNease 1989, Platt et al. 1995), where predation frequency increases during drought years (Fleming et al. 1976, Joanen and McNease 1989). For example, in 2006 (i.e., the driest year of this study), 50% of nests were depredated, presumably by raccoons, whereas, in 2007, when water levels were higher, no nests were known to be depredated. As water levels declined in 2006, access to islands (i.e., where most nests were located in 2006) potentially improved (i.e., shorter distance to islands) for predators such as raccoons. In years with higher water levels, alligator nests located on islands may be more difficult to access (i.e., longer distance to swim) and the relative cost to predators of potential nest predation exceeds benefits when other food sources (e.g., fish, amphibians, invertebrates) are likely more readily available (Joanen 1969, Fleming et al. 1976).

Similar to other regions (i.e., southern Georgia and coastal Louisiana; Joanen 1969, Goodwin and Marion 1978), most nest failure or predation occurred during the later stages of incubation (i.e., after the seventh week) and nest success declined later in the nesting season. In 2006, predation rates may have been elevated during later stages of incubation as infertile eggs began to rot, fertile eggs began to crack, and/or declining water levels exposed alligator nests to predators (Joanen 1969, Joanen and McNease 1989). In 2007, most nests failed because of a rain event (>25 cm in 7 days; National Weather Service precipitation data) atypical for east Texas in summer (i.e., late Jul). During this event, the Sabine River rose to levels that breached the levees surrounding Little Sandy NWR, inundating islands where most nests were located. Many of these islands were primarily composed of decomposing vegetation that barely rose above typical water levels, making these island nests more susceptible to high water events than elevated levees. During the same rain event, water levels within Steinhagen Reservoir (i.e., Dam B WMA) also rose to levels that inundated several alligator nests constructed close to the water's edge.

In most years, the benefits of nesting close to the water's edge on islands outweigh risks of an unpredictable late summer flood. For example, islands provide protection from predators, minimize distance hatchlings have to travel from nest to water after hatching, and allow for better defense by attending females of nests from predators. As water levels rarely naturally rise during the nesting season, placing nests close to water on islands will likely improve

Table 2. Cormack–Jolly–Seber models for apparent survival (φ) and probability of recapture (p) of hatchling American alligators (*Alligator mississippiensis*) captured at Little Sandy National Wildlife Refuge, Texas, 2006–2008.

Model structure[a]		**Model statistics**		
φ	p	**No. of parameters**	$\Delta\mathrm{AIC}_c$[b]	w_i[c]
grp	grp × t	32	0.00	0.99
grp	t	17	8.71	0.01
c	t	16	16.83	0.00
c	grp × t	31	17.99	0.00
t	t	30	31.85	0.00
grp × t	t	45	34.02	0.00
t	grp × t	45	36.01	0.00
grp × t	grp × t	60	48.25	0.00
grp	grp	4	58.22	0.00
grp	c	3	66.60	0.00
c	c	2	75.50	0.00
c	grp	3	75.84	0.00
grp × t	grp	32	77.61	0.00
t	c	16	78.63	0.00
t	grp	17	79.89	0.00
grp × t	c	31	80.91	0.00

[a] Model factors included: $c = \varphi$ or p remain constant among sampling intervals, $t = \varphi$ and p vary among sampling intervals, and grp = group, where each year's cohort (i.e., 2006 and 2007) was coded as a separate group.

[b] Difference between model's Akaike's Information Criterion (AIC_c) corrected for small sample size and the lowest AIC_c value.

[c] AIC_c relative weight attributed to model.

nest success in most years. However, the relative risks of inundation in east Texas could be a factor of water level management, an element for which alligators may have little or no response. For example, water levels at Little Sandy NWR are managed to allow natural fluctuations based upon run-off from rain events and evaporation and transpiration. However, at Dam B WMA, water levels within the reservoir are managed by the United States Army Corps of Engineers, where multiple use water management goals (e.g., flood control, drinking water downstream, electricity, and recreation) result in fluctuating water levels, with little or no consideration for nesting alligators. Therefore, the high water mark at Dam B WMA is unpredictable, making alligator nests potentially more susceptible to flooding.

Hatchling Survival

Analogous to nest success, hatchling survival can be influenced by habitat, female attendance, alligator density, nest microclimate, food availability, and/or weather (Nichols 1987, Woodward et al. 1987, Brandt 1989); all of which often vary spatiotemporally. For example, annual apparent survival rates ranged from 12% to 41% in northcentral Florida (12–31% using minimum known alive, Deitz and Hines 1980, 41% using Cormack–Jolly–Seber models, Woodward et al. 1987), to 63% in South Carolina (using minimum known alive models; Brandt 1989), and to 35% in Louisiana (interpretation from population size structure; Nichols et al. 1976). Similarly, in this study, yearly survival for hatchling American alligators varied temporally, where annual apparent survival rates varied from 6% (lower than previous studies) for alligators hatched in 2006, to 43% (within range of previous studies) for those hatched in 2007. However, Cormack–Jolly–Seber estimates combine mortality and emigration. As such, true survival rates may be greater, although hatchling emigration within their first year is unlikely.

Dramatic differences in annual survival rates observed in this study are likely because of a 1-time event occurring during winter and spring of 2006–2007 at Little Sandy NWR. A mechanical harvester was used to remove aquatic vegetation, and during this process, several (i.e., minimally 30 alligators) 30–100 cm alligators were killed by the blades. By harvesting aquatic vegetation in shallow marsh areas during winter when hatchling alligators are typically inactive and cannot escape, the mechanical harvester directly affected this cohort's survival. With the removal of vegetative cover by the mechanical harvester, hatchling mortality may have also increased because of decreased vegetative cover to conceal them from predators or larger conspecifics. Overall, the mechanical harvester added both direct and indirect sources of mortality for hatchling alligators at Little Sandy NWR that is not typical for most wetlands and likely caused lower survival rates for the 2006 cohort. Although such vegetation control affects water quality and habitat management in east Texas water bodies, adjusting timing and location of such operations will be important to minimize impacts on juvenile alligators (any time during Aug to Jun in shallow marsh habitats) and sluggish adults (if executed during winter). Although this 1-time event was probably the main influence on mortality in 2006, differences in hatchling survival between years could also have been because of environmental factors. For example, in 2007, more hatchlings likely survived because of higher water levels, which potentially provided additional habitat and created refugia (e.g., flooded cut grass stands or flooded vegetated islands that are too dense for predators to effectively locate hatchlings) from predators.

MANAGEMENT IMPLICATIONS

Alligator harvest regulations should accommodate variability in nest success and hatchling survival by including site-specific estimates into harvest models. Not accounting for spatial and temporal variation in nest success and hatchling survival could potentially result in unsustainable harvest and/or overharvest. For example, at Dam B WMA, alligators have been studied extensively since 2003, and during this time span, <10 nests and <60 hatchlings have been documented. Conversely, >38 nests and >250 hatchlings were documented in 3 years at Little Sandy NWR. Additionally, 211 alligators have been harvested from Dam B WMA since 1997 (approx. 17 alligators/year); however, <15 alligators (approx. 1 alligator/year) were harvested at Little Sandy NWR during the same time frame. Therefore, the additive effects of poor recruitment, poor hatchling survival, few successful nests, and greater hunting pressure (compared to Little Sandy NWR) may lead to unsustainable harvest at Dam B WMA. However, obtaining yearly or site-specific estimates of nest success remains unlikely, difficult, time consuming, and expensive. As such, spotlight surveys of pods could provide the next best index of nest success. By modifying spotlight counts currently being conducted to set harvest restrictions to include shallow marsh habitats, pods could easily be counted and used to establish harvest models. Therefore, to sustainably harvest American alligators, annual water levels and hatchling abundance (as determined from pod counts) should be included into harvest models, from which, harvest quotas can be modified on a yearly basis to account for annual variation in nest success and hatchling survival.

ACKNOWLEDGMENTS

Financial, logistical, and technical support was provided in part by the Texas Parks and Wildlife Department (Scientific Permit SPR-0804-009) through the Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University (Animal Care and Use Committee Approval No. TECMW 09-20-06). Special appreciation to the staff of Martin Dies Jr. State Park, U.S. Fish and Wildlife Service, J. Neal, and Abitibi Consolidated Industries, for additional logistical, financial, and technical support. We thank R. White, A. Rainey, B. Koerth, J. Staton, A. Wadyko, M. Buckingham, J. Rustin, B. McNeill, and S. Saalfeld for assisting with data collection for this study. We thank 2 anonymous reviewers for comments that improved the manuscript.

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Associate Editor: John Maerz.