THE EFFECT OF LIGHTNING FIRES ON HATCHABILITY OF ALLIGATOR EGGS

Ruth M. Elsey
Louisiana Department of Wildlife and Fisheries, Rockefeller Wildlife Refuge, 5476 Grand Chenier Highway, Grand Chenier, Louisiana 70643, USA
Email: elsey_rm@wlf.state.la.us

E. Barry Moser
Louisiana State University Agricultural Center, Department of Experimental Statistics, Baton Rouge, Louisiana 70803, USA
Email: bmoser@lsu.edu

Abstract. Lightning fires burned over 2400 ha of American alligator (Alligator mississippiensis) nesting habitat on Rockefeller Refuge in August 1998. Thirty-seven alligator nests were located in the burned areas after the wildfires ceased. Nests were damaged to varying extent, and the hatchability of the remaining alligator eggs was inversely related to the depth to which the nests were burned. A trend analysis indicated that the log of odds of hatching could be modeled as a linear decreasing trend with nest grade ($\chi^2 = 24.8$, df = 1, $P < 0.0001$). Uncontrolled wildfires can be an important mortality factor limiting alligator egg hatching success.

Key Words. Alligator mississippiensis; Alligator nest; Hatchability; Lightning fire; Louisiana; Marsh.

Nesting success of the American alligator (Alligator mississippiensis) is adversely affected by numerous environmental factors, including flooding, drought, and predation (Elsey 1996; Joanen 1969). A recent study evaluated the effects of summer wildfires on the structure of alligator nests (Elsey 1996). Most of the eggs from those nests had previously been collected for various research projects, thus it was not possible to determine hatchability of alligator eggs from nests affected by wildfires in that study. In August 1998, thunderstorms ignited several lightning fires on Rockefeller Refuge, some of which occurred in dense alligator nesting habitat. Eggs in the affected areas had not yet been collected; this provided the opportunity to evaluate the effect of wildfires on hatch rates of alligator eggs in nests burned by uncontrolled fires.

MATERIALS AND METHODS

Study Area

This study was conducted on portions of the Louisiana Department of Wildlife and Fisheries’ Rockefeller Refuge. The refuge is a 32,000 ha coastal marsh in Cameron and Vermilion parishes in southwestern Louisiana. The predominant vegetation and refuge boundaries were described by Joanen (1969).

Research Nest Surveys

Rockefeller Refuge has a widespread alligator population and has been the site of extensive research on alligator culture. This has led to the development of a statewide alligator farming and egg ranching program (Joanen and McNease 1991). Approximately 15,000 alligator eggs are produced annually on Rockefeller, many of which are collected for research and ranching programs. Nest density on the refuge is very high and can be as much as 1 nest per 5 ha under optimum environmental conditions (Joanen and McNease 1989). Much of the area is usually prescription burned approximately every other winter. Numerous bayous, ponds, and lakes act as natural firebreaks, resulting in a mosaic pattern of incomplete burns. The alligator study areas had not been control burned in the prior two winters to minimize impacts on a separate ongoing research project.

We surveyed portions of the refuge for alligator nests on 11 June 1998 and 25 June 1998. Intensive nest surveys are done annually on Rockefeller on an 810 ha nesting study site. Attempts are made to
determine the total nest count on this area, located south of impoundment unit 13. Nests were marked with 3.05-m (10-foot) PVC pipes and plotted on an aerial map to aid ground crews in relocating the nests by airboat. In 1998, 41 of the nests in this area had Optic Stowaway® temperature recorders (Onset Computer Corporation, Pocasset, Massachusetts) placed in the egg cavity early in incubation, as part of another study on temperature dependent sex determination of hatching alligators.

Another area (unit number 6) was not surveyed intensely for alligator nests in June, although it contains excellent habitat. However, eight nests at specific locations were marked on the June 11 flight as a follow up to a genetics study initiated the previous year. This area generally produces 100–350 nests annually; however we only marked specific nests in very close proximity to a nest site from the prior year.

The third area studied (west of Little Constance Bayou, 360 ha) was not surveyed by helicopter, thus nests were not marked by PVC pipes.

Wildfires

Several wildfires occurred on Rockefeller Refuge in the first week of August 1998. They were presumably ignited by lightning strikes. The refuge was surveyed by fixed-wing aircraft on 13 August 1998 and over 6000 ha were estimated to have burned. The three burned areas considered to be excellent alligator habitat in the Superior Canal system encompassed some 2400 ha.

Nest Searches

On 10 August 1998, nests in the area south of impoundment 13 were visited by airboat to collect eggs from the 41 nests in which temperature recorders had been placed in late June. It was necessary for the temperature dependent sex determination project to collect the eggs late in incubation (after the temperature sensitive period for sex determination) but prior to hatching, so that all resulting hatchlings could be evaluated for sex ratio. During the course of egg collections and retrieval of the temperature recorders on 10–12 August 1998, we discovered lightning fires had affected some of the nests in the area where recorders had been placed.

In the area south of impoundment 13, approximately 140 ha burned. Seven nests were located in the burned portion. While collecting these nests, we noted additional ongoing burning in marshes located further to the south in Unit number 6. We made trips to this area on 17, 18, and 19 August 1998. Of the eight nests marked earlier in Unit 6, six were within the burned area, which covered approximately 1900 ha. We intensively searched the area by airboat and found a total of 30 nests in this region.
We next attempted to locate any remaining alligator nests in the 360 ha burned area west of Little Constance Bayou. No alligator nests were found in this area.

As in our prior study (Elsey 1996) alligator nests were readily seen and exposed on the burned areas due to loss of surrounding vegetation. Some nests were located by the PVC nest markers, despite the fact that many pipes were melted or burned due to the intensity of the fire. All nests were located in the marsh proper; none were on levees. All were constructed predominantly of wiregrass (*Spartina patens*), occasionally with some overgrowth of deerpea (*Vigna luteola*).

**Egg Incubation**

Eggs collected from the burned areas were examined and incubated at the laboratory as described by Joannen and McNease (1987) if viable. Hatch rates were calculated as the number of live hatchlings obtained divided by the number of fertile eggs incubated (excluding infertile eggs and those known to have died early in development).

**Statistical Analyses**

Hatching success data were analyzed using a quasi-likelihood logistic analysis (McCullagh and Nelder 1989) treating egg hatching success as a binomial response. Since eggs collected from the same nest are not likely to be independent, the Williams (1982) method for adjusting for overdispersion of binomial data was applied using the PROC LOGISTIC procedure of SAS version 8.1. Likelihood ratio tests (LRT) were used to test for a nest grade effect and confidence intervals were constructed using the profile likelihood method. Odds ratios are reported so as to compare hatching success of the nest grades 1, 2, and 3 to the grade 0 level.

**RESULTS**

Thirty-seven nests were located in areas affected by lightning fires. Nine were classified as Grade 0 (24.32%), eight were Grade 1 (21.62%), and there were ten each classified as Grade 2 or 3 (27.03% each category). In 11 cases, no viable eggs were remaining which could be collected for incubation.
Often only a few remnants of eggshells remained. It could not be determined if the eggs burned entirely, hatched, or possibly had been removed by a predator before or after the burn. At a Grade 1 nest we observed a single live hatchling near the nest, indicating at least partial nest success.

The remaining 26 clutches were incubated at the Rockefeller laboratory facility as previously described (Joanen and McNease 1987). Unfortunately a valve problem in one incubator led to seven of these nests being flooded. Hatch rates were determined for the remaining 19 clutches. Hatch rates were inversely related to the extent nests were burned (Table 1). Eggs from Grade 0 nests had a 90.1% hatch rate, and Grade 1 nests had a 79.9% hatch. The hatch rate for Grade 2 nests was 57.1%. Two Grade 3 nests produced a total of only 14 hatchlings from 74 eggs (18.9% hatch).

The deviance divided by the degrees of freedom from the logistic model fit without the Williams (1982) adjustment was large (dev/df = 4.1, P < 0.0001) and indicated a poor fit of the model. Therefore, the Williams adjustment was applied to account for the model overdispersion. There were considerable differences in the hatchability of the eggs among nest grades (LRT $\chi^2 = 37.3, df = 3, P < 0.0001$), with the odds of hatching at nest Grade 1 being 43.5% (95% CI: 11.6, 152.9) of that at grade 0, odds of hatching at nest Grade 2 being 14.6% (95% CI: 4.4, 40.4) of that at grade 0, and the odds of hatching at nest Grade 3 being 2.6% (95% CI: 0.5, 10.2) of that of Grade 0. The predicted probabilities of egg hatching (with 95% prediction intervals) at Grades 0–3 are 88.8% (76.8, 95.0), 77.4% (61.9, 87.8), 56.6% (42.6, 69.4), and 18.9% (6.6, 43.6), respectively (Fig. 3). A trend analysis indicated that the log odds of hatching could be modeled as a linear decreasing trend with nest grade ($\chi^2 = 24.8, df = 1, P < 0.0001$, Lack of Fit $\chi^2 = 1.1, df = 2, P = 0.5749$), and is presented here as a curvilinear trend with percent hatch.

Figure 3. Relationship between alligator nest grade classification and predicted hatching success. A trend analysis indicated that the log odds of hatching could be modeled as a linear decreasing trend with nest grade ($\chi^2 = 24.8, df = 1, P < 0.0001$, Lack of Fit $\chi^2 = 1.1, df = 2, P = 0.5749$), and is presented here as a curvilinear trend with percent hatch.

egg remaining, which were blackened, some with embryonic fluids leaking. None were viable. The hatch rate for these five Grade 3 nests with eggs would have been less than 10%, if it was assumed the three completely non-viable nests had contained a conservative estimate of 35 eggs each. A prior study found the average clutch size for alligators on Rockefeller was 38.9 eggs ($n = 315$ nests; Joanen 1969). Five other nests (with no remaining eggs) were classified as Grade 3 nests. Minimal remnants of a few eggshells remained; in contrast to successfully hatched nests wherein numerous shells and inner eggshell membranes (and the presence of live hatchlings) suggest nest success. These nests could have been lost to predators prior to or after the fire. Our data suggest the ten Grade 3 nests led to the production of only 14 live hatchlings.

Serendipitously, two of the Grade 3 nests in the area south of impoundment 13 contained temperature

<table>
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<th>Nest Grade</th>
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<th>Hatch Rate (%)</th>
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<td>2</td>
<td>14</td>
<td>74</td>
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loggers programmed to record the temperature every 15 min. The temperature recorders had been placed in the nests in late June, and were positioned approximately in the center of the nest cavity. In both cases, the surface of the nest was burned away, such that the upper layer of eggs was visible from a distance when the nest was approached by airboat (Fig. 4). In one nest, the temperature exceeded the upper range of the recorder (75°C) and caused it to malfunction. In the other nest, the recorded temperatures were stable prior to the fire, and between 31 and 32°C. At 1321 h on 7 August, the temperature was 31.9°C. At 1336 h, the temperature in the nest cavity had risen to 36.1°C, and 15 min later had reached 49.3°C (Fig. 5). Subsequently a gradual decline was noted, presumably as the fire passed through the area. Approximately 10 h later the temperature in the nest had returned to a nearly normal level around 32°C.

**DISCUSSION**

This study clearly documents that summer lightning fires can adversely impact hatching success of alligator eggs. Alligator nests are usually constructed in June, with hatching occurring late August and early September (Joanen 1969). Thus, wildfires occurring during the egg incubation period can be a substantial mortality factor for alligator eggs. Of the Grade 3 nests located which still contained any intact eggs, only 14 hatchlings were produced (eight of 42 eggs in one nest, and six of 32 eggs in the other). The egg cavity was exposed when the upper surface of the nest was burned away. Had we not collected the eggs soon after the fire, these could have more easily fallen prey to predators than if the eggs had remained concealed in an undisturbed nest cavity. Thus, hatch rates of these nests may have been even lower had we not collected the eggs for incubation at the laboratory.

Over half (54.1%) of the nests in this study were classified as either Grade 2 or 3, and had very low hatch rates. The hatch rate for the nests affected by the fire (grades 1, 2, and 3) was 57.6% (238 hatchlings from 413 eggs). This is much lower than hatch rates for unburned nests reported by Joanen (1969), wherein 68.3% of nests hatched successfully, plus an additional 7.3% classified as “partially infertile” which “in some cases produced live young” (Joanen 1969). Viability may have been affected by temperature extremes or oxygen depletion during the fire. At temperatures greater than 36°C, alligator embryos fail to develop beyond stage 18 (a developmental stage reached at 25 d of incubation at 30°C), and at incubation temperatures of 35°C, embryonic survival is only 11% (Lang and Andrews 1994). Normal incubation temperatures for alligator eggs are approximately 30.0–32.5°C. Only 24.3% of the nests (grade 0) in the study areas were unaffected by the burn, because surrounding water limited fire damage.
Alligator nest losses in this study were probably more severe than reported earlier (Elsey 1996) due to drought conditions in the year of the present study. In 1995, rainfall from 1 March–31 May on Rockefeller Refuge totaled 50.0 cm. During the same period in 1998, rainfall totaled 26.1 cm, with only 0.28 cm precipitation during May 1998, immediately prior to alligator nest construction. In the area west of Little Constance Bayou, we were unable to find remains or evidence of any alligator nests. It is uncertain if no nests were initially constructed due to drought conditions, or if any nests in the area were completely destroyed by the fire, or if damage was so severe any remaining nests were unrecognizable.

To our knowledge, this is the first documentation of the adverse effects of wildfires on hatching rates of eggs in alligator nests. Louisiana's extensive alligator farming/ranching program has made alligator nesting/egg availability an important part of land management goals in coastal marshes (Elsey 1996; Joanen and McNease 1991). Thousands (250,000–350,000) of alligator eggs are collected annually in Louisiana by alligator farmers and land managers. The economic revenue from this resource encourages landowners to preserve their wetlands and maintain quality alligator habitat (Joanen et al. 1997; Perry et al. 1993), which benefits other species as well.

As previously noted (Elsey 1996), many land managers attempt to control water levels in their marshes to enhance alligator nest production (Joanen and McNease 1989). Under drought conditions, it is particularly important to maintain adequate water levels to minimize damage from lightning strikes. As mentioned, this is likely why losses seen in the 1998 burn were more extensive than those seen in 1995, when water levels were normal. Alligator nest and egg losses could be significant if wildfires were widespread; 54.1% of the nests in our study were deeply burned (grade 2 or 3).

It can be advantageous for alligator ranchers to collect alligator eggs early in incubation to avoid later flooding, predation, and desiccation (Elsey 1996). This study suggests significant alligator egg mortality can occur as a result of summer lightning fires, providing another reason alligator egg collections should be scheduled early after oviposition. However, egg collections should be timed to avoid the sensitive period when mechanical damage due to transport is likely (Joanen and McNease 1987).

Although not as common as predation nor as deleterious as major flood events, uncontrolled wildfires can be an important mortality factor limiting alligator egg hatching success, due to significantly reduced hatch rates seen in moderately and severely burned nests.

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**LITERATURE CITED**


