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NESTING OF ALLIGATORS AT THE ARTHUR R. MARSHALL LOXAHATCHEE NATIONAL WILDLIFE REFUGE

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The American alligator (*Alligator mississippiensis*) is a keystone species within the Everglades landscape. It shapes the landscape by constructing nests and maintaining alligator holes (Craighead 1968), and it is influenced by the hydrologic conditions within the landscape. The location and height above water that an alligator builds its nest depends on water levels immediately prior to and during nesting (Kushlan and Jacobsen 1990). Hatching success also can be influenced by water levels, for example, a rapid rise in water level during the nesting period can flood the egg cavity, leading to embryonic mortality (Joanen and McNease 1980).

Alligators, because of their linkage to hydrological conditions, have been selected as an indicator species for efforts to restore appropriate hydrology to the Everglades. Currently, efforts are underway to construct population and individually based models for alligators as part of the USGS Across Trophic Level Spatial Simulation (ATLSS) effort. This program seeks to build models for evaluation of possible effects of alternative water management plans on higher trophic levels in the greater Everglades region. It is necessary for these efforts to have information on reproductive characteristics (nesting habitat, clutch size, egg viability, nesting success, probability of flooding, etc.) of alligators across different habitats throughout south Florida. Published data on nesting and clutch characteristics can be found for numerous locations throughout Florida, including Lake Okeechobee (Woodward et al. 1993, Masson 1995), Water Conservation Areas 2 & 3 (Masson 1995), and Everglades National Park (Kushlan and Jacobsen 1990). No published data are available for alligator nesting in Water Conservation Area 1, which is part of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (hereinafter Loxahatchee). This paper reports the results of a pilot study on nesting characteristics of alligators in Loxahatchee during 1999.

Loxahatchee is a 57,234 ha remnant of northern Everglades wetland. The interior of the refuge is completely surrounded by canals and levees, and hydrologic conditions are determined by local rainfall and water management. Water levels are regulated by the Army Corps of Engineers with water control structures in the north and south to match a prescribed schedule designed to keep the water between 4.27 and 5.18 m National Vertical Geodetic Datum (NVGD) depending on season. Unlike many areas of the Everglades, where there is little substrate overlaying the bedrock, Loxahatchee has a relatively deep peat base ranging from 1.25 m to over 4.5 m in depth (Stephens and Jones 1951, Stephens 1984). The peat surface topography influences the distribution of vegetation communities (Pope 1991) which include a mosaic of sawgrass (*Cladium jamaicense*) marsh, wet prairie, slough, and tree islands. This mosaic of habitats, combined with the high productivity associated with the deep peat soils results in a marsh system that contains high densities of potential alligator food items such as invertebrates, small and large fish, amphibians, and turtles. In addition, there are numerous habitat options for alligators, ranging from areas with tree islands that provide high ground for nesting to sloughs and alligator holes that provide refugia during droughts.

In addition to the interior marsh the refuge has a series of impoundments that have been or are managed for wildlife, primarily wading birds and shore birds. These impoundments are separated from each other by levees and contain various vegetation communities, including sawgrass, cattail (*Typha domingensis*), willow (*Salix caroliniana*), and pickerelweed (*Pontederia cordata*). Water levels in the impoundments are managed by refuge personnel. Alligators of all sizes are regularly observed in the interior and the impoundments.

We located alligator nests by searching likely areas by airboat (interior), truck (impoundments) and on foot (both) on six days between the end of June and the end of July 1999. We spent approximately 20 hours searching for nests primarily in areas along existing airboat trails, in areas where pods of young had been observed, and around alligator holes identified during other field work.

After locating a nest, we took a geographic coordinate using a geographical positioning system (GPS), and looked for an attendant alligator. If a female alligator was present, we attempted to capture it using a self-locking wire snare attached to a PVC pipe; if not, we approached the nest cautiously. We recorded habitat (tree island, sawgrass, levee, impoundment), nesting material, nest height (distance from the top of the nest to the ground surface to the nearest 0.5 cm), nest length and width (nearest 5 cm), distance to water, and amount of standing water at the nest (nearest 1 cm) for each nest. We opened nests, carefully removed all eggs, and placed the eggs in a plastic container, making sure to maintain the original egg orientation. We recorded clutch depth (distance to the nearest 0.5 cm from the top of the nest to the first egg), distance to the bottom of the clutch, and the presence of other eggs (primarily turtle); we counted eggs and measured the length and width of each to the nearest 0.01 cm using vernier calipers. We measured egg mass to the nearest 0.5 g using a 100 g pesola spring scale, and examined eggs for banding to determine if they had been fertilized. After returning all eggs to the nest and reburying them, we revisited all nests in September to determine if the eggs had hatched.

We coded each alligator nest as: (1) female aggressively defended nest, (2) female was present and visible but did not actively defend the nest, (3) female known to be present (bubbles, movement in the water) but was not visible (submerged), or (4) no sign of female at the nest. We measured mass, snout vent length, total length, and tail girth, determined the sex by probing the cloaca, and marked each captured animal by clipping scutes and by placing a web tag in the right rear foot. We released animals after collecting nest and egg data.

Of the 21 nests that we found, 14 were located in the interior of the refuge and 7 within the impoundments and headquarters area. Nests in the interior were located on small tree islands ($n = 10$; these often were wedged between tree trunks), on floating peat mat ($n = 1$), and in sawgrass ($n = 3$). Nests in the impoundments were found primarily along the levees, although one nest was located in the interior of an impoundment.

Nest height ranged from 30 to 83 cm (x = 61.3 cm ± 19.1). The bottom of the clutch, measured on the date the nests were located, averaged 27.8 ± 17.9 cm below the ground surface (range 4-53 cm) and 37.0 ± 19.3 cm above the water surface (range 16.5-78.0 cm). Nest length ranged from 90 to 350 cm (x = 166.9 ± 56.2 cm), and nest width ranged from 85 to 270 cm (x = 144.4 ± 47.9 cm). Nests were composed of nearby vegetation: leaf litter, sawgrass, and ferns on tree islands, and impoundment nests were made of grass from the levees and contained more dirt than did those in the interior.

Five alligator nests had eggs of other species, including American anole (*Anolis carolinensis*) and turtle (*Pseudemys nelsoni* and/or *Apalone ferox*) eggs. One nest in the interior had ants (*Cremastogaster* sp.) when it was opened, and we observed fire ants (*Solenopsis invicta*) at two levee nests during hatching. All nests produced at least 1 hatchling, but ants caused mortality in some nests.

We counted and measured eggs in 15 of the 21 nests. Three false nests (two in the interior and one in the impoundments) contained no eggs. Clutch size (CS) averaged 31 ± 9 eggs (range = 17-43) and clutch mass (CM) averaged 2287 g ± 542 (range = 1414-

3142 g). Egg mass, length, and width averaged 74.5 ± 13.1 g (range 33-128 g), 7.2 ± 6.0 (range 5.0-10.0), and 4.2 ± 0.3 (range 3.3-4.8) respectively. Clutch fertilization rate, as determined by banding of all of the eggs in eight nests and 98% of all eggs, ranged from 91 to 100%. There was a significant linear relationship between clutch size and clutch mass (CM = 49.2[CS] + 774.7; $P = 0.0007$; $r^2 = 0.60$) and between female size (SVL) and clutch size (CS = SVL[1.02] - 75; $P = 0.001$; $r^2 = 0.89$). We did not find a significant relationship between female size and clutch mass.

Mean clutch size in Loxahatchee was similar to values reported for other areas in south Florida (x = 24.2, Morea unpubl. data for Everglades National Park; x = 35.6 in WCA 2 and WCA 3, Masson 1995). In this study, clutch size showed a significant linear relationship to female size, but clutch mass did not, although sample size is small ($n = 7$). Relationships between female size, clutch size, and clutch mass in other studies are variable. Deitz and Hines (1980) saw no significant relationship between clutch size and female size in north central Florida ($n = 14$), but both mean egg weight and clutch mass increased with female size ($n = 7$). Joanen (1969) also found no significant correlation between clutch size and female size. Hall (1991) found a positive relationship between clutch mass and female size ($n = 11$) from various sites in north-central Florida; and Wilkinson (1984) found a positive relationship between average clutch size, clutch volume, and female size.

Egg fertilization rate can influence the potential reproductive output of a species and may vary with location. Low egg fertility can be an indicator of poor habitat conditions (e.g., low water), low population density, or an unknown environmental stress. Based on banding, 98% of the eggs in this study appeared to be fertile, which is relatively high. Deitz and Hines (1980) reported 0-77% unbanded eggs with an average of 10.9% ($n = 29$). Kushlan and Jacobsen 1990 reported 4.7% unbanded eggs for nests in Everglades National Park; and Percival et al. (unpubl. data) reported banding rates of 70-89% (unbanded—30-11%) for alligators in north central Florida.

Approaching a nest resulted in four outcomes: (1) a female aggressively defended nest ($n = 8$); (2) a female was present and visible but did not actively defend the nest ($n = 6$); or (3) a female known to be present (bubbles, movement in the water) but was not visible ($n = 3$); or (4) no sign of female at the nest ($n = 4$). Six females ranging in size from 1.96-2.27 m TL were captured at nests. The 38% of females that vigorously defended their nests against humans in this study is higher than values reported by Joanen (1969) in Louisiana (9.2%), Metzen (1977) in Okefenokee (18.7%), Deitz and Hines (1980) in Paynes Prairie (14.9%) or Kushlan and Kushlan (1979) in Everglades National Park (22%). This higher rate of defense in our study may be related to the fact that alligators at Loxahatchee either rarely encounter people (interior) or have non-threatening encounters (impoundments), as suggested by Kushlan and Kushlan (1980).

None of the nests in this study was depredated. The low rate of loss to predators may be a result of the combination of habitat, nest defense, and low numbers of predators. Racoons (*Procyon lotor*) and otters (*Lutra canadensis*) are present both in the interior and in the impoundments, but are not abundant. Additionally, no nests were flooded. The water levels in Loxahatchee are managed based on a regulation schedule that determines maximum and minimum water levels at different times during the year. The schedule dictates that the water levels during the June through August period stay between 4.80 and 5.12 m NVGD. Generally water levels fluctuate less than 0.3 m (1 ft) during this period. Water levels in 1999 fluctuated 0.84 m (2.75 ft) and were lowest in the first part of June, but rose rapidly throughout June due to heavy rains. The highest nesting season water levels occurred during the last week in June and the first week of July corresponding to the major period when eggs were laid. Nest cavities were generally high (averaging 28 cm above ground and 37 cm above standing water) probably as a result of the relatively high water levels during nesting. Kushlan and Jacobsen (1990) showed that the height above the marsh floor that eggs were placed was correlated with water level at the time of nesting.

The number of nests located in a fairly short period of time and the number of additional nests and pods of young located outside of this study indicate that nesting effort is fairly high in Loxahatchee. Our data also indicate that egg fertilization rate was high and vulnerability to predation and flooding was low in 1999. Observations of pods of young and juvenile animals suggest that this pattern of high reproductive output may occur frequently, but additional information on distribution of nests, impacts of water management, and temporal variation in clutch characteristics (size, egg mass, and egg fertility) will be needed to evaluate the success of Everglades restoration.

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