GROWTH AND SURVIVAL RATES OF WILD AND REPATRIATED HATCHLING AMERICAN ALLIGATORS (*Alligator mississippiensis*) IN CENTRAL FLORIDA LAKES

BY

YOSAPONG TEMSIRIPONG

A THESIS PRESENTED TO THE GRADUATE SCHOOL
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Yosapong Temsiripong

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Egg harvests are implemented extensively by the Florida Fish and Wildlife Conservation Commission (FWC) for American alligators (*Alligator mississippiensis*). However, egg collection may influence population dynamics of alligators resulting in changes of growth and survival rates. Egg collection and incubation was conducted on Lake Apopka, Lake Griffin, and Orange Lake in summer, 1998. After hatching, 1,676 hatchlings were individually measured, weighed, marked, and released back at nest sites and in suitable habitats away from nests. Growth and survival rates of 10 month-old hatchlings were analyzed to investigate if there was a difference between wild and repatriated hatchling alligators. Growth increment of animals from different localities varied considerably among Lake Apopka, Lake Griffin, and Orange Lake ($P < 0.01$). Survival of tagged wild alligators (29.3%) was 41% greater than that of repatriated alligators (20.7%) ($P = 0.028$). Although the survival rate of repatriated hatchling

alligators was apparently less than that of wild alligators that were naturally hatched, this added mortality may have compensated for by increased survival of collected eggs by protecting them from flooding and depredation. Therefore, the net effect of egg collections with repatriation on the population dynamics of these alligator populations would be negligible.

INTRODUCTION

The American alligator (*Alligator mississippiensis*) exists in a wide range of aquatic habitats throughout the southeastern United States from North Carolina to Florida and west into Texas. In the wild, American alligator eggs are subject to flooding (Hines *et al*. 1968, Fogarty 1974, Jennings *et al.* 1988), depredation (Goodwin and Marion 1978, Deitz and Hines 1980), desiccation (Ferguson 1985), and disturbances by nesting turtles (Goodwin and Marion 1977, Deitz and Jackson 1979). It is a common practice around the world to remove crocodilian eggs and hatchlings from the wild for commercial use and restocking of endangered species. In Florida, a proportion of alligator eggs is collected and incubated in captivity for research purposes and the hatchlings released. A key question is whether this practice affects growth and survival rates of repatriated hatchlings.

Growth rates and changes in growth with age and size are important life-history characteristics. Growth rates of numerous reptiles including alligators are known to vary geographically as well as by habitat and individual (Andrews 1982). It is evident that different pods (groups of siblings) have different growth and survival rates, which could be due to many factors.

The logarithmic relationship between total length or snout-vent length and body mass is used to evaluate condition factors (Taylor 1979). Condition factors are an index of animal's health (Le Cren 1951). The factors have been used to make seasonal and habitat comparisons (Taylor 1979, Elsey *et al*. 1992).

Alligators are most susceptible to mortality, through natural causes and from predators, while embryonic in the nest or during the first few years of life. While in the nest, eggs are subject to fluctuations of environmental parameters and direct predation of egg-eating animals taking a heavy toll of unguarded clutches, both by day and night (Woodward *et al*. 1989).

Most of the generalities about crocodilians can be applied to alligators. Many species occupy densely vegetated or remote areas. They are behaviorally very sophisticated reptiles. An early work has demonstrated that crocodilians possess well-developed sensory abilities (Bellairs 1971), display repertoires and social systems (Modha 1967, Garrick and Lang 1977, Garrick *et al*, 1978), learning abilities (Northcutt and Heath 1971) and reproductive behaviors which include extensive parental care (Hunt 1975, Pooley 1977). McIlhenny (1935) described parental behaviors of alligators previously unreported for any crocodilian or, in fact, any reptile. Alligator nest guarding and nest opening behaviors were discussed, and Kushlan (1973) first described maternal duties from moving her fresh hatchlings to defending of groups of sibling (pods). Carr (1976) pointed out that most of McIlhenny's and Kushlan's observations were supported by subsequent investigations. Deitz (1979) was the first to provide quantitative data of these complex behaviors by finding that maternal presence, which involves regular maternal attendance or defense, was observed for 34% of all pods in central Florida lakes. This leads to the question of whether growth and survival of naturally hatched pods is different from that of repatriated pods. Adult alligators, presumably maternal females, were observed readopting the pods released at the nest site (Woodward, pers. comm.). Understanding the reasons of early age mortality will aid in the management and conservation of the species.

The objective of this study is, first, to determine if growth and survival of hatchling American alligators is different between wild and repatriated hatchlings across several locales in central Florida. Second, to find out whether hatchlings released at the nest site have a greater chance of survival and faster growth rate than those released at suitable habitat away from the nest site. This was accomplished by comparing relative growth rate, body condition factor, and survival rate between wild and repatriated pods.

REVIEW OF LITERATURE

Although only some alligators actively defend their nests against humans (Reese 1915, Joanen 1969, Cott 1971, Metzen 1978, Deitz 1979, Kushlan and Kushlan 1980, Hunt and Watanabe 1982), most if not all, tend their nests through the incubation period (Joanen 1969, Joanen and McNease 1970, Hunt and Watanabe 1982). Far from terminating maternal behavior, the post-hatching period seems to be a continuation of the complex relationship between mother and offspring. In 1976, Watanabe (1980) observed and photographed a female scraping her nest open with her forefeet and carrying some of the hatchlings to water in her mouth. Kushlan (1973) reported a mother carrying one of her vocalizing hatchlings from a roadbed where he had taken it. The amount and duration of parental care that pods receive is extremely variable in nature. Deitz (1979) pointed out that most protective females care for their pods from hatching to at least the onset of cold weather. Further some females remained in close association with their pods through the following spring. Woodward *et al*. (1987) reported that hatchlings remained together in pods for at least their 1st year and then began to disperse during their 2nd spring and summer.

Early conservation interest in the alligator beginning in the 1960's has led to many quantitative studies on growth (Hines *et al*. 1968, Chabreck and Joanen 1979, Brandt 1991, Magnusson 1995, Dalrymple 1996). Males grow faster than females in *Crocodylus niloticus* (Graham 1968) and *A. mississippiensis* (McIlhenny 1935, Deitz

1979). Differences in growth rates of Louisiana and Florida alligators are probably not significant until juveniles reach at least 60 cm SVL (Nichols *et al*. 1976). Deitz (1979) studied the mean yearly growth increment in north Florida (11.9-21.1 cm/yr), which is about the same as in Louisiana (22.0 cm/yr) reported by Chabreck and Joanen (1979). It was higher than that reported by Fuller (1981) in North Carolina (12.4 cm/yr) and Dalrymple (1996) in south Florida (13.6 cm/yr). However, most studies, based growth rates on small sample size, included animals of unknown age and of various size classes, and relied mainly on recaptures over short time intervals. These studies have shown great variability in growth rates and age at maturity of alligators from different geographic areas, and habitats, and among different ages, sizes, and sexes. Not all methods of age estimation are equally reliable for crocodilians (Magnusson and Sanaiotti 1995). Size frequency analyses are difficult to interpret because of large individual variation and the possibility that reproductive failure may mean that some year classes are missing. Because of this variability, population models (and harvest schedules based on these models) based on data from one area may not be applicable to other areas (Brandt 1991). Therefore, more detailed information on the extent and pattern of variability in growth rates within and among populations is needed.

Recent studies have indicated wide variation in survival rates of alligators. For example, Nichols *et al*. (1976) estimated that the average annual survival rate was 78.8% for alligators in the 1.2-1.5-m TL size class in southwestern Louisiana based on size class distribution. Taylor and Neal (1984) used a size class frequency distribution and found that 59.2% of alligators of the 1.2-m TL size class survive to the 1.5-m TL size class. Deitz (1979) found that 30% of a sample of lake alligators survived through their first year in Florida. Woodward *et al*. (1987) estimated 1-year survival of hatchling alligators in Orange Lake, Florida to be 41%. The wide range of estimates of survival rates is attributable in part to the differences between years and areas and also reflects biases due to different techniques (Chabreck *et al.* 1998).

Mortality explained earlier may be due to behavioral disturbances. Recently, Huchzermeyer (1997) found in captive breeding situations that *C. niloticus* hatchlings housed with a “substitute mother” made out of concrete slab or pipe had a lower level of stress. He proposed that stressed hatchlings had high plasma corticosterone levels, which lead to behavioral disturbances and appeared to be responsible for a large proportion of mortality in intensively reared crocodile hatchlings. Consequently, high levels of plasma corticosterone can cause slower growth rate. Elsey *et al*. (1990) found change in body weight was negatively correlated with plasma corticosterone; the lower the hormone levels, the faster the rate of growth.

Marking techniques have been used widely in fishery and wildlife management to obtain information on migration, behavior, population size, and stocking success (Emery and Wydoski 1987). Five marking techniques used for many of crocodilian studies were tagging, web-hole punching, toe-clipping, freeze branding, and scute-clipping. Jennings *et al*. (1991) had proved that these marking techniques have no effect on growth or survivorship of hatchling alligators. Even though scute-clipping appeared to be one of the best marking techniques, tagging was appropriate for this short-term study and also easy to apply in the field.

STUDY AREAS

Lake Apopka

Lake Apopka is the head water lake for the Ocklawaha Chain of Lakes (Figure 1). The lake is located in Orange and Lake counties, Florida, at Latitude 28° 37' N and Longitude 81° 38' W. The water surface of the lake is approximately 12,465 ha (Conrow *et al*., 1993), average depth is 1.65 m, average Trophic State Index (TSI) has varied from 82-91 (hypereutrophic condition), and the lake is considered the most severely polluted large Florida lake (U.S. EPA 1979). The lake water is well buffered, alkaline, highly turbid, and pea-green in color (Secchi transparency about 30 cm (12 in) or less). Consequently, the water quality of Lake Apopka is very poor. The biota of the community reflects its hypereutrophic chemical status. Blue-green algae dominate the water column throughout the year. The limited amount of emergent vegetation is predominantly cattails (*Typha* sp.), with some stands of bullrush (*Scirpus* sp.), and knotgrass, (*Paspalidium geminatum*) interspersed around the lake shoreline.

Alligator population sizes were estimated from annual night-light counts during 1995-1999 and adjusted for observability (Murphy 1977) by the Florida Fish and Wildlife Conservation Commission (FWC). Alligator surveys indicated that Lake Apopka alligator population density is 77.2 alligators/shoreline mile for juvenile less than 4 feet, and 20 alligators/shoreline mile for 4-foot and larger alligators. Juvenile population trend was increasing (B = 0.265, P = 0.01), but 4” and larger alligators had a stable population trend (B = -0.057, P = 0.16).

Lake Griffin

Lake Griffin is a large (6,679 ha) mesotrophic lake, with extensive marshy areas adjacent to northern portion of the lake and Oklawaha river (Florida LAKEWATCH 1996). The lake is located in Lake county, Florida at Latitude 28° 51’ 33” N and Longitude 81° 50’ 52” W (Figure 2). Trophic State Index (TSI) has varied from 80-90 (Walt Godwin, DWMP, pers. comm.). The lake is dominated by deeply weathered clayey sand and granular sand of the Hawthorne Formation (Florida LAKEWATCH 1996). The lake water is well buffered, alkaline, highly turbid, and pea-green in color (average Secchi transparency about 57.9 cm (Florida LAKEWATCH 1996)). Recent algal bloom affected the lakes in many ways, for example, there are more particles intercepting sunlight and heating up the water resulting in the warmer water temperature above average (Ross, pers. comm.). The temperature, then, dropped slower than that of Lake Apopka and Orange Lake during the onset of winter.

Alligator surveys by FWC in 1995-1999 indicated that Lake Griffin supports an alligator population comparable to Lake Apopka in density (76.1 3” and smaller alligators/shoreline mile and 50.2 4” and larger alligators/shoreline mile). Population trend for 3” and smaller alligators was stable (B = 0.135, P = 0.29), but it is increasing in 4” and larger alligators (B = 0.187, P = 0.01).

Orange Lake

Orange Lake is a large (5,330 ha) mesotrophic lake, with extensive marsh covering portions of the basin (Brezonik and Shannon, 1971). The lake is located in Alachua county, Florida, at Latitude 29° 27' 20" N and Longitude 82° 10' 20" W (Figure 3). Trophic State Index (TSI) is 59.6 and exhibits no significant long-term trend in water quality (Walt Godwin, DWMP unpublished data). Characteristic of marsh areas of this lake is a heavy buildup of peat. Gasses formed by decomposition bring large chunks of peat to the surface, resulting in floating islands and floating mats extending out from the lakeshore. Vegetational composition of these islands and fringe areas is largely *Sagittaria lancifolia, Cladium jamaicensis, Hydrocotyle umbellata, Panicum sp., Myrica cerifera, Cephalanthus occidentalis* and *Decodon verticillatus. Nupha lutem* and *Typha sp.* covers extensive portions of the open water margins, with *Eichornia crassipes, Limnobium spongia* and *Pistia stratiotes* common in more sheltered areas. In some areas, there is abundant submerged growth of *Hydrilla verticillata*, which is a suitable habitat for young American alligators.

FWC conducted alligator surveys in 1995-1999 indicating that Orange Lake alligator population density was 63.8 alligators/shoreline mile for juvenile less than 4 feet, and 52 alligators/shoreline mile for 4-foot and larger alligators. Both juvenile (B = 0.361, P = 0.03) and 4"and larger (B = 0.174, P = 0.01) alligator population trend was increasing.

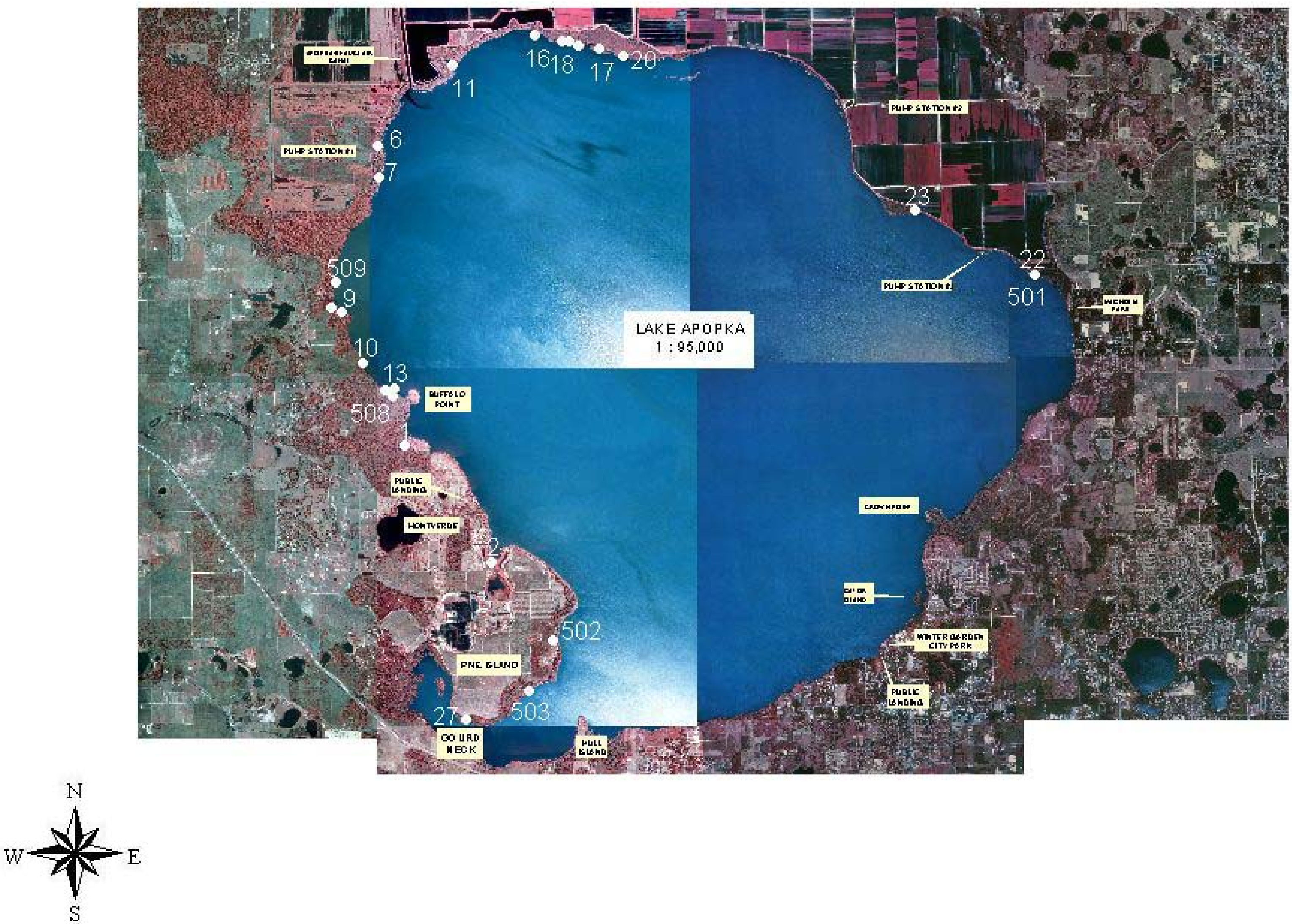

Figure1. Satellite imagery of Lake Apopka, Florida, with alligator pod number and location.

Figure 2. Satellite imagery of Lake Griffin, Florida with alligator pod number and location.

Figure 3. Satellite imagery of Orange Lake, Florida with alligator pod number and location.

MATERIALS AND METHODS

Egg Collection

Alligator eggs were collected as part of an ongoing Florida Fish and Wildlife Conservation Commission (FWC) clutch viability investigation from perimeter marshes and swamps on Lake Apopka, Lake Griffin, and Orange Lake in central Florida (Figures 1, 2, and 3). Entire clutches from a sample of accessible nests in each collection area were collected. Eggs were collected from 23 June to 6 July, 1998. A helicopter was used to locate nests and to direct airboat crews to nests by air-to-ground communications. Before removal, eggs were uncovered and marked on their upper axis, next to the opaque band (Ferguson 1985), with a waterproof-marking pen. Eggs were transferred to a 50×35×13-cm plastic pan lined with 5-7 cm of nest material. We were careful not to invert, rotate, or otherwise agitate eggs. If two layers of eggs were placed in a pan, a 1-cm-thick layer of nest material was used to separate layers.

A second layer of nest material was placed over the eggs to provide insulation and protection during transportation. Pans packed in this manner were hand-held and transported individually in a small airboat (3.6 m long) to a larger airboat (4.5 m), minimizing excessive motion and shocks from waves and uneven terrain. Inflated tire inner tubes were placed on the floor of the larger boat and covered with alternating sheets of 1.6-cm-thick plywood and 5-cm-thick foam rubber to separate and cushion layers of pans during transport. We used similar packing methods when transporting clutches by pick-up truck to incubators. Temperatures were monitored to ensure that the eggs were maintained between 28°C and 33°C from the time of collection until reaching the incubator at Wildlife Research Laboratory, Florida Fish and Wildlife Conservation Commission, Gainesville.

After the eggs were removed, we noted moisture content (dry, moist, or saturated) of the nesting material, presence and level of water in the egg cavity, evidence of previous flooding, % shade, measurement of the mound, and evidence of attendant alligators. Global Positioning System (GPS) coordinates were taken at the nest sites to assist navigation when returning back to release hatchlings. Coordinates of important map points such as boat ramp and waypoints were also recorded. We collected twenty-five clutches from Lake Apopka, thirty clutches from Lake Griffin, and forty-one clutches from Orange Lake (Table 1).

Egg Incubation

Alligator eggs were artificially incubated as described by Woodward *et al*. (1989) to examine inherent egg viability. A 1-room incubator was maintained at constant temperature (mean = 32.1°C, range 30.2°C-34.4°C) and humidity (mean = 92%, range 85%-94%). Egg fertility was determined by the presence of an opaque spot or band (Ferguson 1981, 1985; Webb *et al*. 1987). Embryo viability was determined by comparing the consistency of opaque bands among eggs in a clutch, egg odor, general color of eggs, and color of egg contents when transilluminated (Ferguson 1982). We removed all infertile eggs and eggs with dead embryos before incubation. A total of eighty-two clutches hatched from this artificial incubator (Table 1).

Table 1. Results of egg collection and incubation of American alligators from different locales in central Florida in 1998.

Lake	No. of clutch collected	No. of egg collected	Viability Rate[1]	Hatch Rate[2]	No. of clutches successfully hatching
Apopka	25	1,171	0.47	0.67	25
Griffin	30	1,457	0.29	0.54	16
Orange	41	1,448	0.63	0.85	41

Source: The Florida Fish and Wildlife Conservation Commission (FWC)
[1] Viability rate was the proportion of eggs successfully hatching from a total clutch of eggs (Woodward *et al.* 1993).
[2] Hatch rate of incubated eggs.

Tagging and Releasing

Each hatchling was tagged on the web of right-rear foot. The tag is in numerical series for each clutch so that it is convenient to recognize and verify in the field. Number 1 monel tags (Natl. Band and Tag Co., Newport, Ky.) were used to identify individual. All pods were measured TL (total length) and SVL (snout-vent length), weighed, tagged, and relocated into the wild following treatments described below. TL and SVL were measured to the nearest 0.1cm. Hatchlings remained in captivity for approximately 2 weeks before releasing due to the large number of clutches needed to be released. Only pods with at least 8 hatchlings were selected as experimental units. Therefore, the number of pods used in this study (Table 2) was smaller than the number of clutches produced in 1998 (Table 1)

Table 2. Sample sizes (number of pods) of hatchling alligators monitored for each lake and treatment.

Treatment	Lake			Total
	Apopka	Griffin	Orange	
Repatriated at nest site	10	6	9	25
Repatriated at suitable habitat	7	5	19	31
Wild	8	8	6	22
Total	25	19	34	78

Repatriated pods were released at known nest sites and in suitable habitat away from the nest site (Table 2). The word “Nest Site” defines the same site as egg collection site, while the word “Suitable Habitat” means an area that appeared to be suitable for hatchling alligators (Deitz 1979, Woodward *et al.* 1987) but separated from the nest site. Hatchlings released at nest sites were assumed to have associated maternal female alligators, whereas, hatchlings released in suitable habitats, were assumed to not be associated with maternal females. With this treatment design, differences in growth and survival could be influenced by the differences in treatments.

In addition, naturally hatched wild hatchlings were located and captured at night, measured TL and SVL, weighed, and tagged in the same fashion as repatriated hatchlings. Wild hatchling alligators were caught for tagging from airboats after locating eyeshines with a 200,000 c.p. spotlights and 15,000 c.p. head lamps. Alligators were caught by hand or by Pillstrom Tong (Pillstrom Tong Co., Ft. Smith, Ark.). The GPS position was also taken for later relocation. Locations of capture and recapture sites were ground-marked with bright colored flags and reflective nails for night detection.

Post-Hatching Observation

Hatchlings (groups of siblings) from one clutch are commonly referred as a “pod.” I conducted periodic observations of pods after releasing them to monitor pod movements. Each month during the study period, every pod was visited at least twice, once at night to capture one marked hatchling to verify pod identity and once during the daytime to observe the distance traveled and whether an adult alligator was present.

Recapture

Attempts to follow marked hatchlings were made every three months in October, January, and April to make sure they did not disperse a great distance. The last recapture was in May-July 1999 except for 3 Apopka pods that were checked in September 1999. I went back to the pod sites by following the coordinates from a GPS unit along with the satellite imageries and attribute data (pod location) on it (Figures 1, 2, and 3) and captured as many individuals as possible. Marked sites were revisited at night to capture marked hatchlings by searching the immediate area around the nest with a low intensity (15,000 c.p.) spotlight. If hatchlings could not be found, the search pattern was expanded for up to 200 m to cover accessible marsh and open water in the general vicinity of the nest. All pods were recaptured with the best and equal effort. Weather was one of the most important factors affecting hatchling capture. If wind and waves were too strong, hatchlings would climb up on land to avoid disturbances. Therefore, if the wind was too strong, it was extremely difficult to capture hatchlings. In such cases I returned and recaptured them again on a calm night. The number of nights I spent to recapture hatchlings varied across lakes. I spent 6, 5, and 9 nights in Lake Apopka, Lake Griffin, and Orange Lake respectively.

Hatchlings were captured by hand or with Pillstrom tongs. All animals were weighed, measured TL and SVL for analyses of growth rate and body condition. Individual data on capture-history used in the analysis, and estimates of the TL of attending alligators were also estimated if applicable. In addition, environmental conditions such as air and water temperature, water level, wind speed, and general habitat were noted. Recapture and data collection for each pod was accomplished as fast as possible to reduce stress and then all animals were released at the site of capture. Sex was identified by cloacal examination. Sexes were determined by comparing clitero-penis color and dimensions (Allsteadt and Lang 1995).

GIS Technology

The general approach combines the use of digitized topographic map layers of attributes (such as waterways, roads, vegetation type) and images (aerial photographs, satellite imagery, or digitized maps) supported by Florida Department of Environmental Protection (DEP). Application of geographic information system (GIS) technology to this project has had many additional benefits over more conventional mapping. The position of hatchling alligators and nest site were recorded via a GPS (Global Positioning System) in degrees and minutes of latitude and longitude which were then converted to decimal degrees for use in an Arcview 3.1 program (Figures 1, 2, and 3).

Data Analyses

Growth Rate

Growth rate was calculated as a total length (TL) change per growth day (cm/day). I used TL rather than SVL because there is greater standardization among researchers in the measurement of TL (Addison Jr. 1993 and Moler 1992). Growth days were referred to Deitz's thesis (1979) as the period prior to and after the cooler months when no growth occur. During no-growth period the water temperature dropped below 20°C (Coulson and Hernandez 1983). The length of this period is different across the lakes. Orange Lake had the shortest estimated growth period (365-120 = 245 days), whereas it was 265 and 285 days in Lake Apopka and Lake Griffin respectively (Table 3 and Figure 4). Log transformation was used to transform TL, SVL, and W to make them normally distributed. The total length change, then, was calculated by this equation.

$$\frac{TL_2 - TL_1}{\text{Growth days from capture}_1 \text{ to capture}_2}$$

Growth increment was also calculated using SVL to avoid problems resulting from tail tip loss. In order to find out the best index

$$\frac{SVL_2 - SVL_1}{\text{Growth days from capture}_1 \text{ to capture}_2}$$

Change in weight was calculated in a similar fashion to obtain the best indication of growth rate. This was a relative weight gain since it was compared to each other.

$$\frac{\text{Weight}_2 - \text{Weight}_1}{\text{Growth days from capture}_1 \text{ to capture}_2}$$

Condition factors (Le Cren 1951) are an index of the robustness of an animal and can be an indicator of well-being (Taylor 1979). Condition factors are derived from the relationship between length and weight in the population, $K = W \times L^{-b}$. K is a condition factor, W is mass (g), L can be either snout-vent length or total length (cm), and b is the slope of the regression of the natural log (ln) of TL on the natural log of mass. The constant "b" is dependent upon mean growth characteristics of individuals in the population and equals the slope of regression equation where lnTL is plotted against lnW. An individual relative condition factor (a_I) is then calculated as $a_I = W_I(L_I)^{-b}$ (Taylor 1979).

Table 3. Average water temperature in Lake Apopka, Lake Griffin, and Orange Lake during the study period.

Month	Lake Apopka (°C)	Lake Griffin (°C)	Orange Lake (°C)
7/98	29.7	30.6	28.5
8/98	30.2	29.0	30.0
9/98	26.0	28.4	26.7
10/98	25.6	26.3	26.2
11/98	23.7	24.2	23.3
12/98	20.1	21.9	18.0
1/99	19.0	19.3	17.0
2/99	14.3	18.6	17.5
3/99	19.1	17.7	18.5
4/99	24.0	26.7	22.7
5/99	25.5	23.1	23.9
6/99	27.9	27.5	27.3
Average	23.6	24.5	23.1
SD	4.9	4.3	4.7

Source: Department of Water Resources, SJRWMD

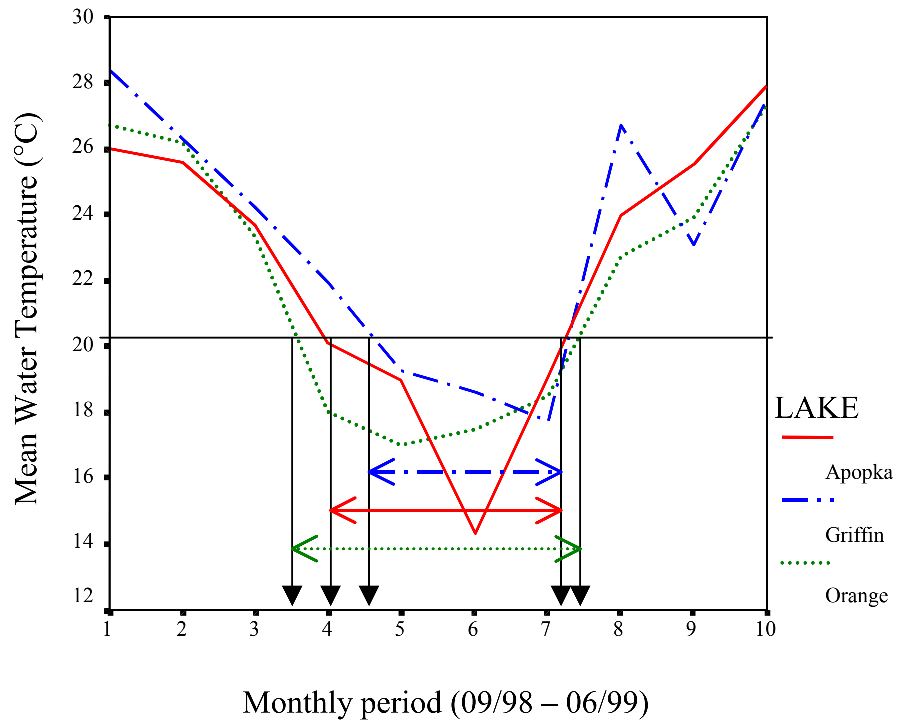

Figure 4. Water temperature of lakes in central Florida during study period. The minimum temperature for growth is 20°C (Deitz 1979). The four arrow lines depict the period of no growth days. The three double arrow lines indicate the period when no growth occurred for the three lakes.

Survival Rate

Survival rate was calculated by using Minimum-Known-Alive (MKA), which has been used extensively by crocodilian researchers because of its simplicity and for single recaptures. MKA survival rates represent the proportion of marked hatchlings known to survive to a certain age from an initial sample of marked animals. Even though MKA estimates are negatively biassed (Nichols and Pollock 1983), it is still qualified for this study because I was concerned more with relative rather than absolute survivorship of alligators.

Statistical Methods

All analyses of growth and survival rate were done by computer using SPSS versions 7.5 and 9.0 for Windows (Norusis 1991, Voelkl and Gerber 1999). My statistical design was a factorial analysis of variance to test effects of factors influencing growth and survival. It allowed for 2-way interactions between the effects of treatment and study areas on each response variable. This design was intended to test the following null-hypotheses. First, there was no difference in growth rate and survivorship among study areas. Second, there was no interaction among treatment and study area effects on growth and survival rates. Third, there was no difference in growth and survival rates between repatriated hatchlings at nest site and in suitable habitats. Finally, there is no difference in growth and survival between wild and repatriated hatchlings. The last hypothesis would be tested if there is no difference in growth and survival rates between repatriated hatchlings at nest site and in suitable habitat. If my hypotheses are valid, I should find differences in growth and survival rates between repatriated and wild pods in different locales in central Florida. Assumptions that have to be made are the following. First of all, pods are independent. Second, measurements are taken from normally distributed populations, which will be tested by Kolmorogov-Smirnoff Test. Last, the populations of growth and survival rates have equal variances tested by Levene's Test.

RESULTS

Egg collection was conducted on Lake Apopka, Lake Griffin, and Orange Lake in June and July 1998. After hatching, 1,676 hatchlings were marked and released. Repatriated hatchlings were released in September 1998, and recaptured in May-July 1999. Growth and survival data of hatchling alligators were collected from the marked-recaptured study.

Post-Hatching Observation

Post-Hatching observation was implemented to reveal where the pod would be after releasing. A total of 64 hours of daytime-observation was accomplished. Pod locations in Lake Apopka, Lake Griffin, and Orange Lake were digitally plotted in satellite images (Figures 1, 2, and 3 respectively). I found that hatchling American alligators moved little throughout the winter and were mostly inactive except on warm, sunny days. There was some tendency for pods to be extremely closely aggregated during cold weather. For example, on the cold night (16°C) of 5 December 1998, eighteen hatchlings were observed with more than ten 1-2 year old alligators near McCormick Island, Orange Lake. They stayed afloat very close to each other (less than 0.1 m). They were sluggish at this temperature, but were capable of coordinated movements and vocalized readily when captured. After hatching, American alligators formed pods and remained among aquatic vegetation. Hatchlings frequently vocalized while concealed in vegetation. From diurnal observation, adult alligators were occasionally observed near pods, but made no attempt to defend them, and I did not observe them responding to hatchling distress calls. Hatchlings were often observed foraging in non-vegetated shallows and occasionally lying on logs in open water.

Movement of hatchlings following their first winter was documented by monthly recaptures of one hatchling from each pod. Pods remained at nests for at least ten months. Most pods (77%) stayed at the original site even after the first winter. There were 3 Lake Apopka pods, 3 Lake Griffin pods, and 6 Orange Lake pods scattering along the shorelines, representing 15% of all tagged hatchling pods (Table 4). Average distance travel of these 12 pods from the three lakes was 83.5 m. Dispersed pods usually display a one-dimensional spreading along the lake or marsh fringe. Six repatriated pods (1 Lake Griffin and 5 Orange Lake pods) or 8% were not found (Table 4).

Sixty-four hours diurnal observation was not sufficient to draw a detailed conclusion on parental behavior. However, recapture at night gave additional opportunities to observe them. The size of all adult alligators observed near hatchlings fell in the range of adult female alligators. Seventy percent of female-sized alligators observed near nursery pond were very persistent (Table 5). Even though they submerged as the airboat approached, they resurfaced to observe us working up hatchlings. In presence of the female, non-distress grunting of hatchlings occurred in continuous and apparently random fashion. Hatchlings grunted frequently when searching for food or exploring their environment. Such behaviors happened more often in the presence of the female and this agrees with the findings of Deitz (1979).

Table 4. Movement summary during recapture of hatchling American alligators in central Florida lakes.

Lake	Pod No.	Original location	Last location	Dispersal (m)
Apopka	AP-508W	28’37.310”/81’41.070”	28’37.269”/81’41.067”	75.1
Apopka	AP-601W	28’40.770”/81’38.710”	28’40.771”/81’38.724”	25.1
Apopka	AP-12N	28’37.240”/81’41.010”	28’37.264”/81’40.979”	125.4
Griffin	GR-28N	28’55.870”/81’49.990”	28’55.844”/81’49.978”	26.5
Griffin	GR-21N	28’53.590”/81’49.560”	N/A	Missing pod
Griffin	GR-13S	28’53.400”/81’49.760”	28’53.365”/81’49.766”	52.9
Griffin	GR-34S	28’56.320”/81’49.730”	28’56.342”/81’49.745”	74.8
Orange	OR-506W	29’29.066”/82’10.580”	29’29.058”/82’10.603”	94.9
Orange	OR-510W	29’28.137”/82’10.069”	29’28.189”/82’10.056”	105.3
Orange	OR-6N	29’25.566”/82’11.140”	N/A	Missing pod
Orange	OR-20N	29’26.619”/82’07.896”	29’26.682”/82’07.936”	118.2
Orange	OR-44N	29’26.000”/82’08.580”	N/A	Missing pod
Orange	OR-106N	29’28.880”/82’10.100”	29’28.855”/82’10.039”	112.8
Orange	OR-9S	29’25.750”/82’11.610”	N/A	Missing pod
Orange	OR-13S	29’26.421”/82’09.026”	29’26.427”/82’09.035”	63.5
Orange	OR-36S	29’25.722”/82’10.667”	N/A	Missing pod
Orange	OR-38S	29’27.270”/82’11.970”	N/A	Missing pod
Orange	OR-110S	29’28.730”/82’10.010”	29’28.763”/82’09.970”	127.1

W = Wild hatchlings
N = Repatriated hatchlings at the nest site
S = Repatriated hatchlings into suitable habitat away from the nest site

Table 5. Behavioral summary of adult alligators observed at the pod sites.

Pod No.	Locale	Time	Adult alligator behavior
AP-20N	Apopka	0015	7’-8’ alligator at location, fled upon approach
GR-402W	Griffin	2210	7.5’ alligator stayed afloat all the time we were present
GR-10N	Griffin	0009	7’ alligator observed our activities 15 m away from airboat
OR-506W	Orange	2320	7’-8’ alligator submerged as we approached, kept 10 m observation distance
OR-45N	Orange	2345	7’ alligator submerged immediately as we approached
OR-126N	Orange	2125	7’ alligator submerged shortly after we shined light on her
OR-4S	Orange	0015	7.5’ alligator submerged as we approached, resurfaced briefly as we were working
OR-25S	Orange	2205	7’-8’ alligator observed our activities, responded to hatchling grunts
OR-27S	Orange	0015	7.5’ alligator submerged as we approached, resurfaced briefly as we were working
OR-117S	Orange	2250	7.5’ alligator in midst of pod, submerged promptly and resurfaced during work up

W = Wild hatchlings
N = Repatriated hatchlings at the nest site
S = Repatriated hatchlings into suitable habitat away from the nest site

Growth Rate

Of 1,676 wild and repatriated hatchling alligators from 78 clutches marked and released during the study, 372 (214 females, 157 males) or 22.2% were recaptured and used for growth analysis (Table 6). Mean hatchling alligator measurements of repatriated animals (n = 1,527) are as follows: SVL = 13.0 ± 0.5 cm (range = 10.3 to 14.1 cm); TL = 26.5 ± 1.0 cm (range = 20.5 to 29 cm); mass = 51.3 ± 5.3 g (range = 28.9 to 76.4 g). Mean hatchling alligator measurements of wild animals (n = 149) are as follows: SVL = 13.9 ± 1.3 cm (range = 10.5 to 16.6 cm); TL = 28.2 ± 2.6 cm (range = 20.5 to 33.5 cm); mass = 62.29 ± 10.9 g (range = 30 to 90 g).

Table 6. Recapture rates of hatchling American alligators on three central Florida lakes.

Lake	No. capture, tag and release	No. of recapture	Recapture rate
Apopka	525	119	0.23
Griffin	429	80	0.19
Orange	722	173	0.24
Overall	1,676	372	0.22

Change in total length (TL)

The sex ratio for 371 hatchlings was 1:1.36 (males:females). The difference in length gain was not detected ($P = 0.916$) between male ($n = 157$) and female hatchlings ($n = 214$). There was no correlation (Figure 7) between initial size of hatchlings and change in TL per day ($P = 0.213$). Similarly, growth rate was not correlated with clutch size ($P = 0.417$). Change in length did not correlate with the rate of survival ($P = 0.054$, $R^2 = 0.052$). No difference was detected between hatchlings released at nest site and in suitable habitat ($P = 0.226$). The difference in TL change/day between wild and repatriated hatchlings (Figure 5) was not significant ($P = 0.580$). However, growth rate differed among Lake Apopka, Lake Griffin, and Orange Lake ($P < 0.01$). There was no interaction among LAKE x TREATMENT effects ($P = 0.063$) on growth rate (Figure 6).

Table 7. Summary of ten-month growth increment in TL change and Change of TL per day for alligator hatchlings on central Florida lakes during 1998-1999.

					Repatriated hatchlings			
	Median		Wild hatchlings		Released at Nest site		Released in Suitable habitat	
Lake	recapture date	No. of pod	TL (cm)[1]	TL (cm/day)[2]	TL (cm)[1]	TL (cm/day)[2]	TL (cm)[1]	TL (cm/day)[2]
Apopka	June 25th	25	15.67	0.076 ± 0.02	15.24	0.075 ± 0.01	15.64	0.079 ± 0.01
Griffin	June 14th	19	19.88	0.081 ± 0.02	19.98	0.083 ± 0.01	18.99	0.080 ± 0.01
Orange	July 2nd	34	40.73**	0.159 ± 0.05**	19.41	0.103 ± 0.03	22.51	0.107 ± 0.04
Average			24.03	0.100 ± 0.05	17.65	0.086 ± 0.02	20.16	0.095 ± 0.03

** ($P < 0.01$)
[1] Average 10 month increase in total length (TL)
[2] Average 10 month increase in total length change per growth day

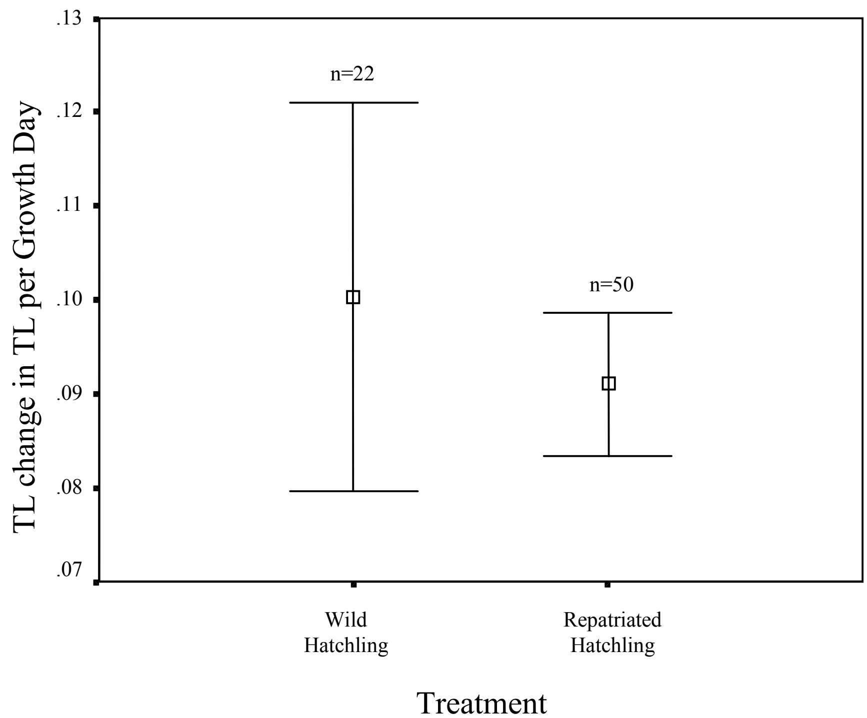

Figure 5. 95% Confidence Interval of total length (TL) change per growth day of wild and repatriated hatchling American alligators in central Florida lakes. The difference in TL change/day between wild and repatriated hatchlings is not significant (P = 0.580).

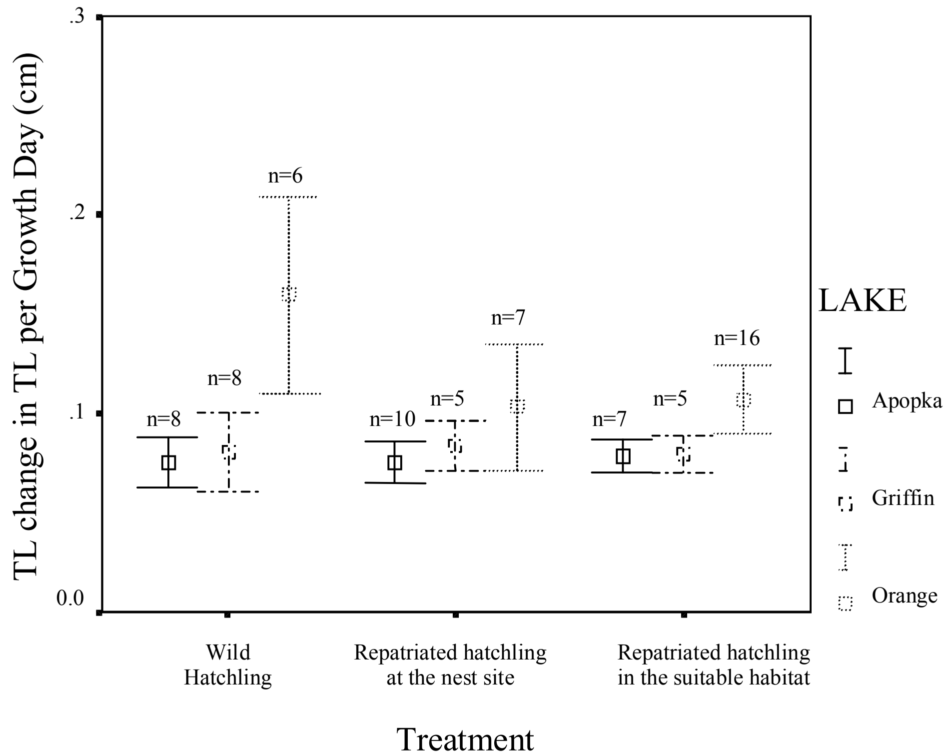

Figure 6. Differences in the variability of growth of hatchling American alligators among different lakes and different treatments. 95% Confidence Interval of total length (TL) change per growth day in central Florida lakes. There was no interaction among LAKE x TREATMENT effects (P = 0.063) on growth rate.

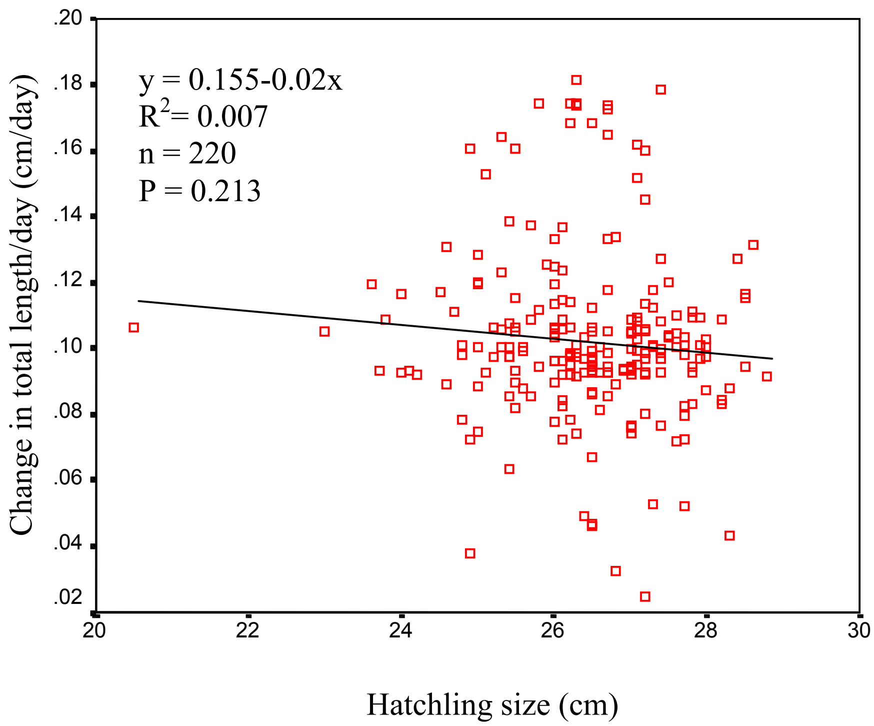

Figure 7. Relationship between hatching size and growth rate of hatchling alligators in central Florida lakes.

Change in Snout-vent Length (SVL)

There was no difference in SVL change/day between hatchlings released at the nest site and in suitable habitat away from the nest ($P = 0.118$). Therefore, SVL growth rates of all repatriated hatchling were compared with wild hatchlings. There was no difference in SVL change/day between wild and repatriated hatchlings ($P = 0.536$). Conversely, SVL differed among lakes ($P < 0.01$). LAKE x TREATMENT interaction ($P = 0.128$) was not detected indicating no difference in SVL change/day due to lakes and treatments.

Change in Weight (W)

There was no difference in weight gain between hatchlings released at the nest site and at suitable habitat away from the nest ($P = 0.207$). The gain in weight per day was not different between wild and repatriated hatchlings ($P = 0.047$). However, the difference in weight gain was highly significant across Lake Apopka, Lake Griffin, and Orange Lake ($P < 0.01$). LAKE x TREATMENT interaction ($P = 0.024$) was also detected indicating a difference in weight change/day due to lakes and treatments

Body Condition Factor (K)

As hatchlings grew they showed a slight but significant reduction in mass relative to length. When growth is isometric, the factor b will be equal to 3; therefore, the K factor for all animals can be calculated for each individual based on the equation $K = M \times 10^{2.69}/TL^{b}$ (Table 8). The condition factor (K) showed that Orange Lake alligators have a greater K (K = 2.78), meaning that alligators in Orange Lake have more mass relative to length than those in Lake Apopka (K = 2.48) and Lake Griffin (K = 2.38).

Table 8. Regression equations and standard error of the regression for predicting weight (W) from total length (TL) across three central Florida lakes.

Lake	Predictor	Estimated Value	Equation	R^2	SE
Overall	lnTL	lnW	Y = 2.693lnTL – 4.843	0.92*	0.09
Apopka	lnTL	lnW	Y = 2.481lnTL – 4.077	0.86*	0.08
Griffin	lnTL	lnW	Y = 2.381lnTL – 3.630	0.79*	0.10
Orange	lnTL	lnW	Y = 2.778lnTL – 5.167	0.95*	0.09

* (P < 0.0001)

Survival Rate

Survival rate was determined by the number of marked hatchlings that survived through the date of last recapture (Table 9). I recaptured at least 1 member of 92.3% of pods tagged and released (Table 10). Although 72 out of 78 pods were found after 10-month study periods, only 372 out of 1,676 hatchlings (22.2%) were actually recaptured (Table 6). The six missing pods were all repatriated pods even though the best efforts focused on every pod while recapturing. No difference in survivorship was detected ($P = 0.546$) between repatriated hatchlings released at nest site and in suitable habitat. Likewise, survivorship was not different ($P = 0.589$) across the three lakes (Figure 9). No LAKE x TREATMENT interaction ($P = 0.722$) was detected indicating that there was no difference in survival rate among treatments across lakes. No relation was detected between survival rate and clutch size ($P = 0.113$, $R^2 = 0.033$, $n = 78$) (Figure 10). Therefore, both repatriated treatments and all lake treatments were combined to test for difference between survivorship of wild vs. repatriated hatchlings. The survivorship of wild hatchlings pods (mean = 29.30, SD = 14.7, n = 22) was greater ($P = 0.028$) than repatriated pods (mean = 20.74, SD = 15.60, n = 56).

Table 9. Survival Rate of hatchling American alligators in central Florida lakes.

Lake	Wild hatchlings	Repatriated hatchlings released at		Overall mean
		Nest site	Suitable habitat	
Apopka	0.28 ± 0.14	0.27 ± 0.12	0.18 ± 0.12	0.25 ± 0.13
Griffin	0.31 ± 0.08	0.15 ± 0.11	0.14 ± 0.08	0.21 ± 0.12
Orange	0.29 ± 0.22	0.22 ± 0.17	0.22 ± 0.20	0.23 ± 0.19
Average	0.29 ± 0.14*	0.22 ± 0.14	0.20 ± 0.17	0.23 ± 0.16

* (P = 0.028)

Table 10. Proportion of pods from which at least 1 hatchling alligator was recaptured during a 9-month period on three central Florida lakes.

	Capture and Tag (pod)	Recapture (pod)	Recapture rates
Lake Apopka	25	25	1.0
Lake Griffin	19	18	0.95
Orange Lake	34	29	0.85
Overall	78	72	0.92

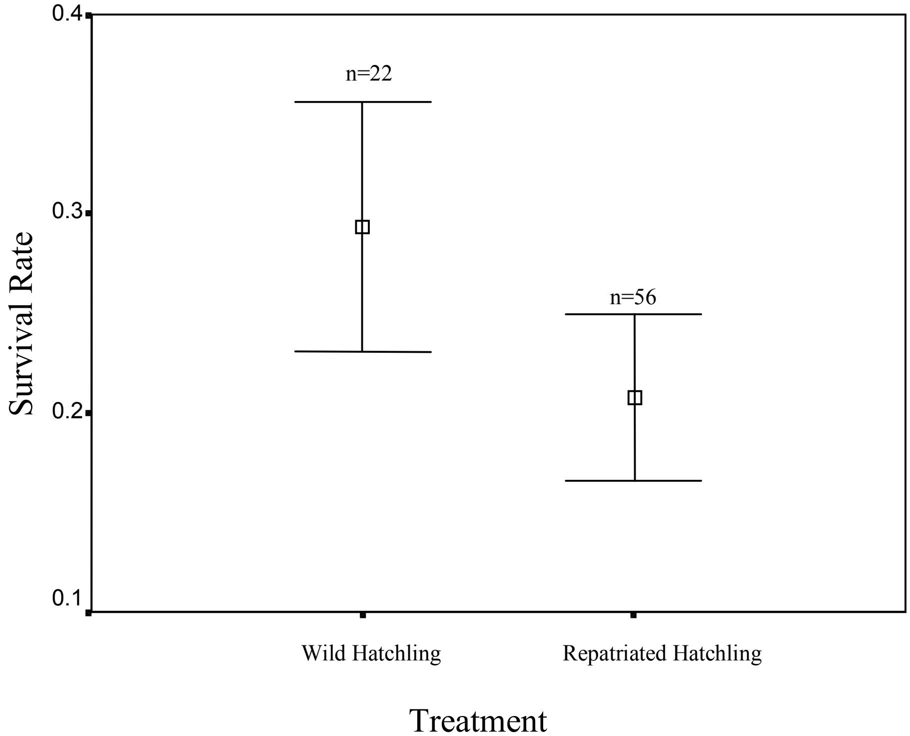

Figure 8. 95% Mean 9-month survival rate and confidence interval for wild and repatriated hatchling American alligators in central Florida lakes. Survival rate of wild hatchlings was greater (P = 0.028) than repatriated hatchlings.

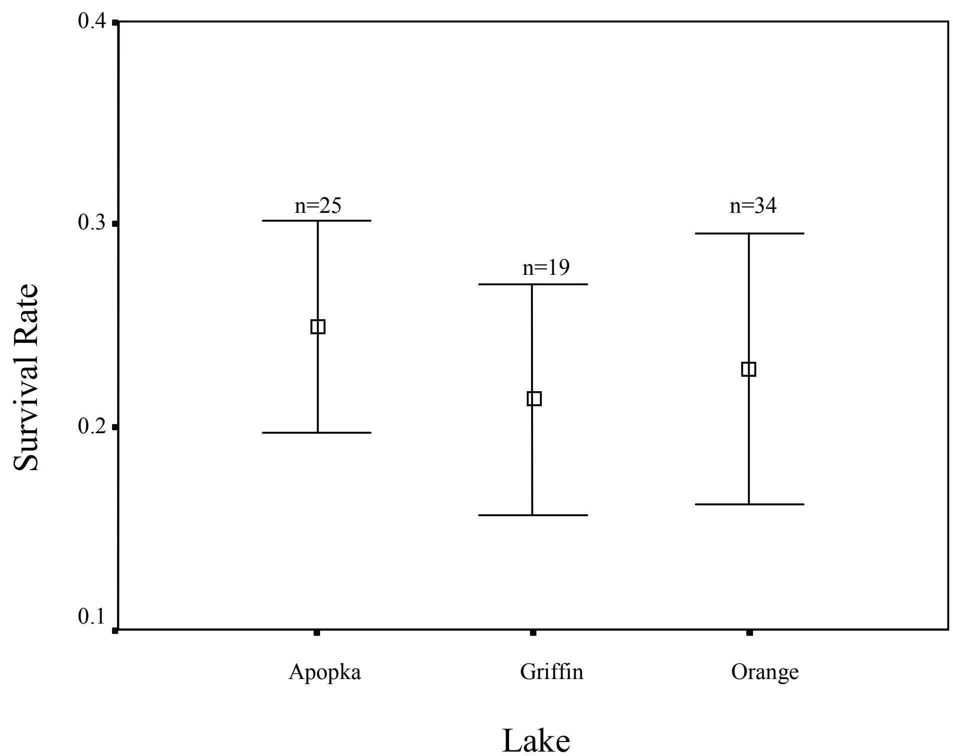

Figure 9. 95% Mean 9-month survival rate and confidence interval for wild and repatriated hatchling American alligators in central Florida lakes. Survivorship of was not different (P = 0.589) across the lakes.

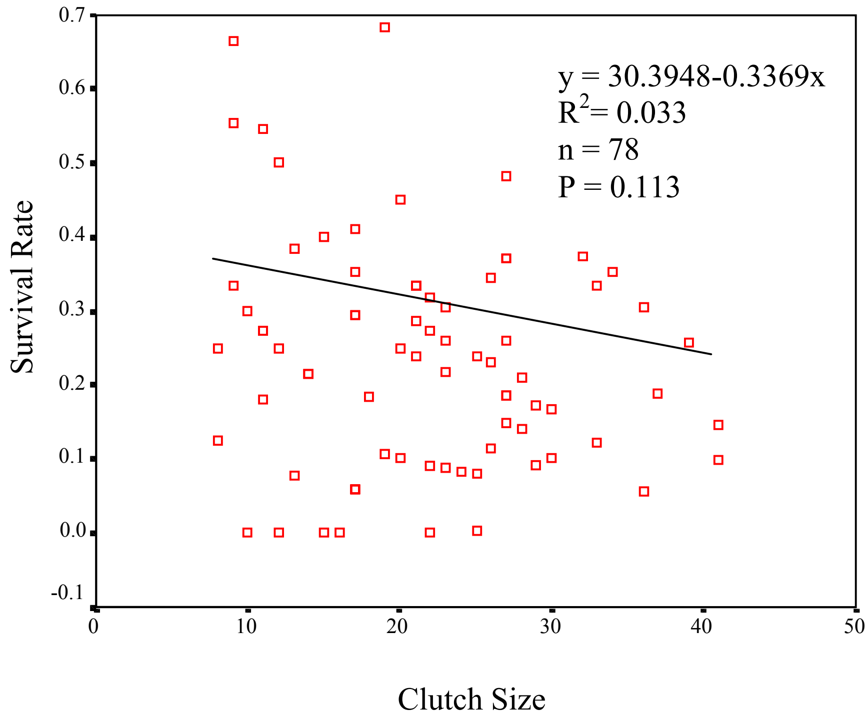

Figure 10. Relationship of survival rate of hatchling American alligators to clutch size in central Florida lakes.

DISCUSSION

Growth Rate

Repatriated hatchling alligators grew at rates similar to wild alligators but did not survive as well. In general, no difference was found between growth rates and survival rates of repatriated hatchlings released at nest sites or in suitable habitat. However growth rates and survival rates differed among study areas. The difference was not consistent and depended on treatment.

Growth rates were compared between wild and repatriated hatchlings across different locales in north central Florida. The gain in TL and SVL was different among lakes. The ten months growth increment of wild hatchlings was 24.03 cm which was higher than repatriated hatchlings at the nest site (17.65 cm) and at suitable habitat away from the nest (21.16 cm). Deitz (1979) studied the mean yearly growth increment in north Florida (11.9-21.1 cm/yr) about the same as in Louisiana (22.0 cm/yr) reported by Chabreck and Joanen (1979). However, it was higher than that reported by Fuller (1981) in North Carolina (12.4 cm/yr) and Dalrymple (1996) in south Florida (13.6 cm/yr).

It can be seen that the average length gain of repatriated and wild hatchlings differs across lakes. Growth in Orange Lake was significantly greater than the other lakes (Table 7). Because body condition factors can be used to make habitat comparisons (Taylor 1979, Elsey *et al.* 1992), the greatest body condition factor was found in alligators from Orange lake indicating that Orange Lake hatchlings were heavier than

Lake Apopka and Lake Griffin animals at the same size. Perhaps, one of the most important reasons for the difference is food availability because Orange Lake alligators not only grew at the faster pace, but they were heavier as well. The effects of habitat on growth rates of hatchling alligator were presumably related to food availability. Prey of hatchling alligators consists largely of macroinvertebrates and fish (Fogarty and Albury 1967, Chabreck 1971). The abundance and availability of these items varies considerably with water temperature, water depth and trophic state of the habitat. For example, alligators in Everglades National Park have an extremely low growth rate (Kushlan and Jacobsen 1990). Kushlan and Jacobsen suggested that the lower growth rate of Everglades alligators was due to seasonal shortages of food combined with the prolonged growing season with high ambient temperatures. The limited amount of emergent vegetation, predominantly cattails (*Typha* sp.), in Lake Apopka may limit insect biomass. The smallest growth rates of animals among the three lakes were found in Lake Apopka hatchlings, perhaps because of low food availability.

Differences in growth rates among study areas were determined primarily by differences in the thermoregulatory behavior of individuals, which appeared to be inherited (Sinervo 1990). Water temperatures differed among lakes and, thus, affected growth period. Therefore, differences in growth rate of hatchling alligators may be related to temperature differences. Nonetheless, the growth rate in this study (Table 7) was higher than that reported by Fuller (1981) in North Carolina (12.4 cm/yr) and Dalrymple (1996) in south Florida (13.6 cm/yr). Ambient temperature in North Carolina was very low compared to Florida. Consequently, the period of growth days was limited to six months while it is at least eight months in central Florida. In an earlier study on captive-reared hatchling alligators, growth rates of 0.2 cm/day for the first year were recorded (Joanen and McNease 1970).

This study showed that growth rates of males were not different from females. The difference in weight and length gain was not detected between sex during their first year of age. In Louisiana, differences in growth rates of alligators were not significant until juveniles reach 60 cm SVL (Nichols *et al*., 1976). As described in Deitz (1979), Wilkinson and Rhodes (1997), Brandt (1991), and Elsey *et al*. (1992), male and female hatchling alligators have equal growth rate in their early years. No correlation was obtained for initial hatchling size and % increase in body weight. The results indicated that size based dominance is not an important factor determining hatchling growth.

Because associated adult alligators were sighted with pods in all treatments and growth rates were not different between wild and repatriated pods, it can be inferred that all pods might have about the same level of stress associated with lack of associated maternal female alligators. This results in chronically elevated plasma corticosterone. Plasma corticosterone showed a strong negative correlation with change in body weight; the lower the hormone levels, the faster the rate of growth (Elsey *et al.* 1990).

Survival Rate

The survival rate shown in Table 9 was not as high as any other studies in Florida lakes (Deitz 1979, Woodward *et al.* 1987), possibly because losses of entire pods were also included in the mortality rate estimate. Survival estimates of 12 month-old wild hatchlings on Orange Lake was 41% (Woodward *et al*. 1987), and 30% (Deitz 1979). Most hatchling pods remained near nest sites for at least 10 months following hatching as described by (Deitz 1979). In this study, six missing pods were never found, although over 200 m around the original release location was intensively searched. All of the missing pods were repatriated pods although the best and equal effort was put on every pod during recapture attempts. Mark-recapture data indicated that survival rate of tagged wild alligators (29.3%) was 41% greater than that of repatriated alligators (20.74%).

It was possible that either emigration, or mortality, was responsible for the missing 6 pods. Note that all missing pods were from repatriated hatchlings: GR-21N, OR-9S, OR-36S, OR38-S, OR-6N, and OR-44N (Figures 2 and 3, Table 4). Though three out of the six were the pods released at nest sites, other extraneous factors might cause them to disperse; i.e., water level, habitat suitability, and food availability.

Droughts are thought to increase mortality of marsh alligators above that of lake alligators (Nichols *et al*. 1976). Twelve hatchling pods were observed travelling significant distances at the onset of winter season probably due to low water level. This behavior was viewed as increasing hatchling mortality because of desiccation and predation (Nichols *et al*. 1976). Fluctuating water levels concentrate alligator populations and increase social conflict with consequent injuries (Deitz 1979).

Different survival rates among lakes could be due to differences in population density, which may be regulated by intraspecific predation. Crocodilians have long been known to be cannibalistic. For example, in the first canal of Haines Creek, east of Lake Griffin, several 4-5 years old alligators were observed at the nest site of one missing pod (GR-21N) just after the first winter (Figure 2). Cannibalism was suspected as a cause of some mortality in juvenile alligators (Woodward *et al*. 1987). Similarly cannibalism may remove 7.4-10.1% of juvenile alligator population on Orange Lake annually (Delany *et al.* unpubl. data).

Since survival of tagged wild alligators was 41% greater than that of repatriated alligators, I hypothesized that parental association contributed to survival of hatchlings in their 1st year. Maternal behavior seems to be more likely during incubation and early post-hatching period. Female presence was observed either by chance or because she attempted to attend her young although it was difficult to estimate the size of big alligators as well as telling the gender. Besides, repatriated hatchlings remained in captivity for approximately 2 weeks, their survival skills such as searching behavior is thought to be affected resulting in greater chance of mortality.

Preliminary data in this study clearly indicate that it is feasible to release artificially hatched alligators back into the wild to supplement natural loss from embryonic death, and that repatriated alligators will grow as well as wild alligators, which presumably would enhance survivorship. Future studies should try to genetically match up mother and/or father alligator and their young to verify that an observed adult alligator is the parent of the pod. This work requires an extensive field experience to handle large alligators as well as knowledge in microsatellite techniques.

CONCLUSION

Growth rates can be experimentally manipulated fairly easily in laboratory determinations of growth dynamics, but in wild animals the factors, which determine access to food, and hence growth, can be very complex. Growth of hatchling alligators from different locales varied considerably. This study showed that repatriated hatchlings grow as well as wild alligators. This can be advantageous, as growth can greatly affect survivorship (Rootes 1989). Jacobsen and Kushlan (1989) suggest that if an alligator grows slower, it will take longer to reach sexual maturity, and increase its susceptibility to predation, disease and cannibalism.

This study showed that survival rate of repatriated hatchlings was lower than wild hatchlings. However, while significant, this difference is small and is unlikely to have any effect on the population dynamics of these alligators. Supplementing natural loss from embryonic death by restocking hatchlings appears to be a valuable management tool for Florida alligators. Although survivorship of naturally hatched alligators is greater than that of repatriated hatchlings, the initial number of repatriated hatchlings is more than wild hatchlings and equal growth rate may enhance survival of repatriated hatchlings to sexual maturity. This study also showed that repatriated hatchlings released at nest site and suitable habitat had similar growth and survival rates. Therefore, management of Florida alligators may adjust releasing procedures to be more practical by releasing hatchlings at suitable habitats. Continuation of this study plus genetic characterization to individuate alligator families over the next several years should provide data to further refine management practices, with emphasis on recommendations for techniques in selecting repatriating sites and optimum size at which to release juveniles.

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BIOGRAPHICAL SKETCH

Yosapong Temsiripong was born October 4, 1975, in Bangkok, Thailand. His family moved to the Sriracha district, a suburban area, where his admiration for wildlife started to develop. Favorite activities included camping, bird watching, fishing, and many out-door activities. His commitment to wildlife began when he joined the Environmental Conservation Organization. He made many trips to rain forests in Thailand.

Yos's interests remained constant through a high school, which led him to Kasetsart University, where he pursued a Bachelor of Science degree in zoology, graduating in 1996. Yos began investigating possible avenues to proceed with graduate studies. A year after his graduation, he was admitted to a Master of Science program in the Department of Wildlife Ecology and Conservation, University of Florida.

His present goals include continuing his education in any form available to him. With his working and training experiences both in his father's crocodile farm with Siamese crocodiles (*Crocodylus siamensis*) and at Wildlife Research Lab, Florida Fish and Wildlife Conservation Commission (FWC) with American alligators (*Alligator mississippiensis*), he should have sufficient knowledge to continue exploring the biological world. He also hopes to be able to share his love and appreciation for Florida's wildlife, especially American alligators, with his children, continuing a family tradition.