AMERICAN ALLIGATOR (*ALLIGATOR MISSISSIPPIENSIS*) ECOLOGY IN INLAND WETLANDS OF EAST TEXAS

By

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ABSTRACT

Although few studies have focused upon home ranges, movements, nest success, nest site selection, hatchling survival, growth rates, body condition, and diet of American alligators (*Alligator mississippiensis*), there is considerable variation among studies. Several factors contribute to this variation including habitat, prey availability, population density, and water level. Geographic differences in these variables make it challenging to establish broad-scale or regional conservation, management, or harvest recommendations. As such, the goals of this research were to estimate home range size, daily movements, home range overlap, nest success, nest site selection, hatchling survival, hatchling abundance, growth rates, body condition, and food habits of American alligators in east Texas wetlands.

Home range and movement data were collected from 2006 – 2008, where 31 sexually mature alligators (total length > 1.6 m) were captured and fitted with transmitters. Alligator home range size and daily movements were most affected by sex, season, size, and year, but alligators used smaller home ranges and executed shorter movements than most other estimates throughout the alligator's geographic range. Alligators in inland wetlands may be more constrained than coastal individuals (occupying larger, relatively contiguous coastal marshes), as inland alligator home ranges and movements were restricted by overall wetland size, water level fluctuations, high population densities, and/or exotic invasive aquatic plants.

As part of this study, 30 nests were monitored. Overall, alligator nest success (Mayfield estimate) was 49.5%, irrespective of year. Also, 271 hatchling alligators were captured (an additional 192 hatchling alligators were recaptured), where yearly apparent survival was estimated as 6.0% for hatchling alligators born in 2006 and 43.0% for those born in 2007. Nest circumference, year, and time during incubation exerted the greatest influence on nest survival. Most habitat variables were consistent throughout and within study sites, where alligators tended to select nest sites near (< 5 m) a large tree, far (> 150 m) from open water, and within areas with (> 50%) shallow marsh habitat. Variation in nest success, nest site selection, and hatchling survival are likely attributable to fluctuating water levels and habitat management practices.

Growth rates and condition were also estimated through an intensive mark-recapture study from 2003 – 2008, where 1064 alligators, ranging in size from 20.9 cm to 363.5 cm (total length), were captured, and 472 alligators were recaptured, ranging in size from 25.4 cm to 292.1 cm. Mean growth rate for recaptured alligators was 32.5 cm/yr (SE = 1.0), irrespective of size, wetland, and sex. Growth rates varied among wetlands and size classes, with growth rates decreasing as size increased. Estimated time to maturity (i.e., > 1.8 m total length) was 9 years, estimated from a modified von Bertalanffy growth curve (L_∞ = 388.1 cm; k =0.0003). Mean condition for all size classes, sexes, and wetlands combined was 2.16 (SE = 0.0). Similar to growth rates, condition varied among wetlands and size classes, however condition improved as alligator size increased. Overall, alligators exhibited faster growth rates, but were in poorer body condition than reported throughout their range. This trade-off may be a factor of increased number of vacant breeding territories after harvest of large individuals, high population densities, food availability, and/or habitat conditions.

In 2006 – 2008, 62 alligator diet samples were obtained from alligators ranging in size from 94.7 cm to 386.0 cm (total length). A total of 33 different prey items and 1 parasite were identified to the lowest possible taxon, comprising 670 individual prey items (excluding parasites). Irrespective of size class, sex, and wetland, > 85% of individual prey items were invertebrates. Food habits varied among wetlands where alligators at Little Sandy National Wildlife Refuge consumed more fish and wading birds as compared to Angelina-Neches/Dam B Wildlife Management Area where more mammals were consumed. Nearly all diet samples contained some sort of organic by-catch and/or non-food items (i.e., woody debris, aquatic plants, seeds, rocks, fishing tackle, etc.). Alligators had similar diets between sexes, however, non-breeding size (< 1.83 m in total length) alligators consumed more invertebrate prey items by weight and percent occurrence than breeding size alligators. Alligators apparently forage opportunistically, and any possible geographic differences in food habits among populations are most likely influenced by food availability.

Several key components influencing alligator populations (i.e., nest success, hatchling survival, home ranges, movements, diet, body condition, and growth rates) can

be affected by specific habitat characteristics such as water levels, extent of available habitat, and presence of exotic invasive plants. More specifically, removal of exotic invasive plants should be encouraged in order to provide important habitat for alligators. Two common techniques for the removal of aquatic vegetation are spraying with herbicides and mechanically harvesting, both of which need to be properly timed and at the right intensity. In addition, to promote better nest success and hatchling survival, water levels within reservoirs should remain consistent during the nesting season (i.e., July – September). By keeping water at constant levels, female alligators can safely select nest sites above high water marks and shallow marsh habitat for hatchlings will remain available. Although water levels can be maintained by varying rates of discharge, this may not be possible in every year or at every wetland containing alligators. Therefore, it remains important to understand the relationship between water levels, nest success, and hatchling survival and to incorporate water levels into population and harvest models for American alligators.

Due to the geographic variability in numerous factors observed in this study, regional management regulations and harvest models should be modified; developed with regionially specific parameters. For example, specific regional metrics such as nest success, hatchling survival, population density, food availability, growth rates, body condition, and movement patterns need to be considered or incorporated into regional harvest regulations. Combined with small home ranges, poor hatchling survival, few successful nests, and poor body condition, current non-selective harvest techniques (removal of many large, presumably dominant, individuals) may dramatically influence age, size, and sex structure of alligator populations. Therefore, harvest within these wetlands needs to be more selective, where intermediate size classes (e.g., 1.2 – 1.8 m) are targeted to reduce higher density portions of the population and to lessen pressure on dominant individuals.

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CHAPTER I

HOME RANGE AND MOVEMENTS OF AMERICAN ALLIGATORS IN INLAND WETLANDS OF EAST TEXAS

INTRODUCTION

Although the exact definition of a home range is still debated, it is generally accepted to be the area in which an individual performs its normal activities (i.e., food gathering, mating, and caring for young; Burt 1943). A home range does not include occasional departures outside the area that are perhaps exploratory in nature (Burt 1943, White and Garrott 1990). However, many research projects require temporal boundaries, where home ranges are defined as the extent of area with a specific probability of the focal animal's occurrence, during a specified time period (Kernohan et al. 2001). Home ranges are usually modeled from discrete observations (e.g., through radio, GPS, and/or satellite telemetry, or direct resighting) using utilization distributions (Kernohan et al. 2001). A utilization distribution describes the relative frequency distribution for location data over a specific time period, which provides estimates of an animal's probability of occurrence at each point in space (Kernohan et al. 2001). However, utilization distributions (i.e., methods based on location densities) are not the only method for modeling home ranges. Estimates can also be calculated using minimum distances among locations (e.g., minimum convex polygon; White and Garrott 1990, Kernohan et al. 2001). Along with modeling home ranges, discrete individual observations can also provide estimates of daily movement, habitat use, population demographics, distribution, biotic potential, and other life history traits (Morea 1999).

Home range is an important parameter to estimate because it can provide insight into basic population processes (Hutton 1989, Kernohan et al. 2001). For example, estimates of resource requirements, metabolic costs, spacing patterns within the environment, core activity areas, and territoriality may be estimated or inferred using home range data (Morea 1999, Percival et al. 2000). Moreover, home range size, shape, and location may have adaptive significance, by indicating habitat conditions and environmental influences (e.g., local climate and water levels; Morea 1999). Home range characteristics can also reflect variation in important population and/or community characteristics such as size, distribution, and territoriality (Schoener 1981), and life-history strategies such as growth and survival (Hutton 1989). For example, home range size is considered an important, predictable aspect of an animal's feeding strategy and has been related to food density, metabolic needs, and the efficiency of movement (Schoener 1971, Simon 1975). Additionally, home range size is frequently inversely correlated with population density (Schoener 1968, Brown 1969, Krebs 1971), home range exclusiveness can indicate significant inter-specific competition (Orians and Willson 1964), and spatial configuration (e.g., degree of overlap among home ranges can provide an estimate of territoriality) of coexisting individuals' home ranges can provide insight into social system structuring (Brown 1964). Along with providing insight into basic ecology, estimating daily movements and home ranges can facilitate development of management strategies for regional populations of species of interest such as American alligators (*Alligator mississippiensis*).

The American alligator, once listed as an endangered species in 1967, has made a dramatic recovery and is now one of the few crocodilians not currently in danger of extinction (Groombridge 1987). In the mid-20th Century, American alligator populations were severely depleted due to overharvesting, persecution, and habitat loss (McIlhenny 1935, Groombridge 1987, Brandt 1989). By 1987 alligators were deemed fully recovered across their entire range and were removed from the Endangered Species List. This dramatic range-wide population increase was attributed to protective legislation and research on basic alligator biology throughout the 1970s and 1980s, that aided in the establishment of appropriate recovery, conservation, and management plans throughout its geographic range (see Brisbin et al. 1986).

Refining alligator conservation and management strategies is key for viable, long term management. This is especially true for a species that was recently endangered, but is now legally harvested throughout most of its range (Groombridge 1987). Daily movement and home range estimates can provide valuable insight into basic population processes and facilitate development of regionally specific alligator management strategies. Such movement and home range studies have been conducted on alligators in Louisiana (Joanen and McNease 1970;1972, McNease and Joanen 1974, Taylor 1984, Rootes and Chabreck 1993), South Carolina (Murphy 1977), Arkansas (Roth 2003), North Carolina (Hagan 1982), and Florida (Goodwin and Marion 1979, Morea 1999), but never in Texas. These studies have provided valuable information on the spatiotemporal variability in home range size and daily movements, as related to variation in geographic location, sex, habitat, water levels, temperature, salinity, food supply, season, reproductive class, and size (Chabreck 1965, Morea 1999). Although these studies are useful within their specific region, the magnitude of variation in home range size and daily movements among geographic locations (a) complicates comparisons at regional scales and (b) magnifies the need for locally/regionally specific data for alligator management and conservation.

Texas alligator populations are stable or increasing, with the greatest concentrations occurring on the mid to upper coast; however, expanding inland populations exist along major river drainages, impoundments, and reservoirs (Johnson et al. 1985, Saalfeld et al. 2008, Webb et al. 2009). Although few studies have focused upon inland alligator populations in Texas, several elements (e.g., growth rates, body condition, and habitat use) of alligator ecology clearly deviate from established coastal Texas estimates (Ryberg *et al.* 2002, Webb 2005, Webb *et al.* 2009). Nevertheless, current population and harvest management strategies for inland alligators are based upon models and data collected from coastal (Louisiana) populations (Thompson et al. 1984, Newsom et al. 1987) and do not account for any regional variability. Consequently, inland alligator management is, at best, coarse. To fill this information gap and further examine regional and geographic variation in alligator ecology, a three year study was initiated to estimate home range size and daily movement of alligators in three wetlands in east Texas. Specifically, the objectives of this research were to estimate home range, daily movements, and home range overlap between sexes, and among years, study areas, size classes, and seasons.

METHODS

Study Area

This research was conducted at three wetlands in east Texas (Angelina-Neches/Dam B Wildlife Management Area [Dam B WMA], Kurth Lake, and Little Sandy National Wildlife Refuge [NWR]; Figure 1.1). Dam B WMA is 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 (Figure 1.2). Dam B WMA is characterized by riverine, open lake, and shallow marsh habitats (Webb 2005, Webb et al. 2009). Dominant aquatic plants include water hyacinth (*Eichhornia crassipes*), common salvinia (*Salvinia minima*), giant salvinia (*S. molesta*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticellata*), smartweeds (*Polygonum* spp.), and yellow pond lily (*Nuphar luteum*). Dominant woody species along wetland margins are baldcypress (*Taxodium distichum*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), Chinese tallow (*Triadica sebifera*), water oak (*Quercus nigra*), overcup oak (*Q. lyrata*), water tupelo (*Nyssa aquatica*), and pine (*Pinus* spp.; Godfrey and Wooten 1981).

Kurth Lake is 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; Saalfeld et al., unpublished data) and a few shallow bays with isolated pockets of emergent marsh (Figure 1.3). Dominant aquatic species are American lotus (*Nelumbo lutea*), hydrilla, coontail (*Ceratophyllum demersum*), and yellow pond lily. Dominant woody species along wetland margins are buttonbush, black willow, Chinese tallow, water oak, overcup oak, and pine (Godfrey and Wooten 1981).

Little Sandy NWR consists of 1,539 ha, of which ≈ 1100 ha are bottomland hardwood forest, located on the northern bank of the Sabine River in southern Wood County. Little Sandy NWR contains four main lentic bodies: Overton Lake, Brumley Lake, Bradford Lake, and Beaver Lake. Of these, only Overton Lake (an impoundment of Jim Ned Creek) and Brumley Lake (an impoundment of Little Sandy Creek) were used as study sites. Overton Lake is approximately 175 ha and Brumley Lake is approximately 200 ha. Both lakes are connected by several creeks and canals, essentially making these two lakes one large wetland. Hereafter, these two lakes will be referred to as Little Sandy NWR. Little Sandy NWR is characterized primarily by shallow marsh with little open water or creek channels (Figure 1.4). Dominant aquatic species are American frog-bit (*Limnobium spongia*), American lotus, Carolina fanwort (*Cabomba caroliniana*), coontail, cutgrass (*Zizaniopsis miliacea*), and yellow pond lily. Woody species include Chinese tallow, buttonbush, black willow, and southern wax myrtle (*Morella cerifera*; Godfrey and Wooten 1981).

Capture and Handling

From 1 April – 31 October 2006, 2007, and 2008, American alligators were captured, uniquely marked, and released at Dam B WMA, Kurth Lake, and Little Sandy NWR using several capture techniques (i.e., snake tongs, pole snares, hands, and swim in live traps; see Webb 2005 for complete capture descriptions). During capture sessions, efforts were made to capture all individuals sighted resulting in equal capture effort for successive captures (Deitz 1979). At night, spotlights affixed with red filters were used to locate alligators with a 4.9 m Go-Devil® boat outfitted with a 20 hp Go-Devil® mud motor. Alligators < 125 cm were captured using snares, tongs, or hands, while swim-in live traps (Ryberg and Cathey 2004) were used to capture larger alligators (> 1.6 m). Traps, baited with chicken or fish, were deployed in areas where alligators had been observed, set during afternoon or evening, and left open for at least a 24-hour period. Each trap was checked at 0000 h and by 1000 h the following morning.

Upon capture, alligators were restrained with duct tape, and each individual > 50.0 cm in total length was sexed 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, due to small genitalia size and low light conditions it was not possible to consistently and accurately obtain these measurements; so alligators < 50 cm were not sexed. For all captured individuals (regardless of size), the following morphological features were measured: total length (cm; ventral tip of snout to tip of tail), snout-vent length (cm; ventral tip of snout to proximal tip of vent), eye to nare length (cm), total head length (cm; dorsal tip of snout to distal part of head scute), tail girth (cm; circumference of tail directly behind rear legs), right hind leg length (cm), chest girth (cm; circumference of chest directly behind front legs), and mass (g; only obtained for individuals < 50 kg). All length measurements were obtained using a flexible tape measure and mass was obtained using a Pesola® hanging scale (Baar, Switzerland) for individuals > 50 cm or an Ohaus Scout® Pro digital scale (Pine Brook, NJ) for those < 50 cm. All alligators were uniquely marked by at least two of the following: dorsal tail-scute removal, numbered Monel tags (#681 Monel tags for alligators > 152 cm; #1 Monel tags for alligators < 152 cm), or passive integrated transponder (PIT) tags. In addition, a GPS location was obtained using a Garmin eTrex Legend Cx (Olathe, KS) for each capture/recapture.

Custom built external VHF transmitters (Advanced Telemetry Systems, Isanti, MN) were attached to alligators > 1.6 m in total length. These transmitters (3-stage, pulse rate = 40 ppm, warranty battery life = 799 days, theoretical battery life = 1598 days, and mass = 130 g) could withstand being submerged for long time periods, and had split rings built into the transmitter to aid in attachment (Figure 1.5). Transmitters were attached to the nuchal scutes by drilling holes through the base and running cables through the scutes and the split rings (modified from Kay 2004). Additionally, Loctite

Fixmaster Underwater Repair Epoxy (Avon, OH) was used to keep transmitters firmly attached.

Relocations

For transmittered individuals, locations were obtained at random times throughout the day at least twice weekly during spring and summer (April 1 – October 31) and biweekly during fall and winter (November 1 – March 31) in each year. Locations were obtained through direct resighting of individuals or through triangulation of transmittered individuals. Triangulation was primarily used to estimate the location of transmittered individuals because alligators typically inhabited inaccessible areas with abundant shallow emergent vegetation, making direct resighting of specific animals difficult. When animals were triangulated, a minimum of three bearings were obtained within 15 min using an Advanced Telemetry Systems receiver (model #: R2000, Isanti, MN) and 3 element folding Yagi antenna. Locations were verified in the field using Locate III (Nams 2006) to ensure bearing convergence and the degree of error area ellipse associated with each estimate. If estimates did not converge or if estimates converged, but had a high error area ellipse (e.g., > 10,000 m^2), a new set of bearings was obtained. All locations were estimated in Locate III using maximum likelihood estimators. For non-transmittered individuals, locations used in movement analyses corresponded to locations where uniquely marked alligators were recaptured (i.e., recapture location).

DATA ANALYSIS

Home Range Estimation for Transmittered Alligators

Locations were categorized for each individual by year (2006, 2007, and 2008) and season; with a minimum of 25 locations per grouping (e.g., spring 2006, spring 2007, spring 2008, etc.). Seasons were classified as spring/breeding season (April – June), summer/nesting and brooding season (July – September), and winter (January – March). Individual 95% fixed kernel home ranges were estimated within each season and year (Seaman and Powell 1996), for each transmittered alligator, using Home Range Analysis Tools (Rodgers and Carr 1998) in ArcGIS 9.2 (ESRI, Redlands, CA), with least squares cross validation used to estimate bandwidth (Jones et al. 1996, Seaman and Powell 1996). To estimate core home range, 50% fixed kernel estimates were calculated for each individual within each season and year. In addition to kernel home range estimates, 100% and 95% minimum convex polygon (MCP; Row and Blouin-Demers 2006) home ranges were also estimated using Home Range Analysis Tools (Rodgers and Carr 1998) in ArcGIS 9.2 (ESRI, Redlands, CA) for each individual within each season and year.

Home Range Overlap Estimation

Home range overlap was calculated for transmittered alligators using 95% and 50% fixed kernel home ranges in ArcGIS 9.2 (ESRI, Redlands, CA). Euclidean distances (m) between alligators were estimated for each day transmitter locations were obtained, using Hawth's Analysis Tools (Beyer 2004) in ArcGIS 9.2 (ESRI, Redlands, CA). Euclidean distances provide an estimate of how close alligators are at any given point in time regardless of home range overlap. Both overlap and distance calculations were constrained to transmittered individuals from Little Sandy NWR due to sample size constraints at other study site wetlands (i.e., Kurth Lake and Dam B WMA).

Daily Movement Estimation

To calculate mean minimum linear distance an alligator traveled in a 24 h period, each location for an individual alligator (either a transmitter location or a recapture location; Powell et al. 2000) was treated as a point, and the distance (m) between successive points was calculated using Hawth's Analysis Tools (Beyer 2004) in ArcGIS 9.2 (ESRI, Redlands, CA). Because transmittered alligators were not located every day, total distance (m) traveled was divided by number of days between successive locations to obtain a minimum distance traveled per 24 h (m/day; Taylor and Neal 1984, Rootes and Chabreck 1993), where successive locations were on average 24 hours apart. As time between individual recaptures for non-transmittered alligators was variable, recaptures occurring $\geq$ 14 days apart (maximum time between two successive transmitter locations) were excluded from these analyses.

Statistical Analyses

Differences in home range size were examined between sexes and among years (2006, 2007, and 2008), seasons (spring, summer, and winter), and wetlands (Kurth Lake, Little Sandy NWR, and Dam B WMA) using repeated measures Analysis of Variance (ANOVA; PROC MIXED; SAS Institute 1999), repeated among capture events or transmitter locations with a compound symmetric covariance structure. Home range size was not compared among size classes as all transmittered individuals were > 1.6 m. Home range overlap, number of individuals whose home ranges overlap, and distance between transmittered alligators was also examined between sexes and years (2007 and 2008 only), and among seasons and wetlands using repeated measures ANOVA (PROC MIXED; SAS Institute 1999) with the same methodology as above. Similarly, differences in minimum daily movements were examined between sexes and among seasons, years, and wetlands, using repeated measures ANOVA (PROC MIXED; SAS Institute 1999) with the same methodology as above. When comparing minimum daily movements, data from transmittered individuals and non-transmittered recaptured individuals were not used in the same analyses. For all significant tests, least squared means separation was used to examine differences ($P < 0.05$).

RESULTS

From 1 April 2006 – 31 October 2008, 774 unique alligators ranging in size from 20.9 – 363.5 cm (total length) were captured, measured, marked, and released at Little Sandy NWR, Kurth Lake, and Dam B WMA (Table 1.1). During the same period there were 400 recapture events (268 individuals) ranging in size from 25.4 – 261.7 cm (Table 1.1). The number of days between capture events for a unique alligator ranged from 1 to 455 days ($\bar{x}$ = 64.1 days). Additionally, 150 recapture events occurred within 14 days of each other and were used in movement analyses of non-transmittered individuals.

A total of 31 alligators (161.6 – 363.5 cm) were fitted with transmitters (24 females [6 in 2006; 11 in 2007; 7 in 2008] and 5 males [2 in 2007; 3 in 2008] from Little Sandy NWR and 1 female and 1 male [2007] from Dam B WMA). All transmittered alligators, except one individual (transmitter failure or dispersed one week after capture), were tracked for a minimum of one year, with transmitter retention time averaging 573 days (not accounting for individuals still transmittered in March 2009). An average of 60 locations per alligator was used to estimate each home range (including home range estimates that were broken up by season and year), with no home range estimate calculated with < 25 locations.

Home Ranges of Transmittered Individuals

Mean 95% fixed kernel home range size was 49.8 ha (SE = 4.4), irrespective of year, sex, wetland, and season. Irrespective of sex, season, and year, alligators had similar home range sizes between wetlands ($F_{1, 28} = 0.08$; $P = 0.775$). Therefore, subsequent analyses of home range size of transmittered individuals were performed with wetlands combined. There were no year * season * sex ($F_{1, 7} = 4.56$; $P = 0.070$), year * sex ($F_{1, 20} = 2.00$; $P = 0.173$), or season * sex ($F_{2, 32} = 1.60$; $P = 0.217$) interactions for alligator home range size, however, a year * season ($F_{1, 7} = 9.59$; $P = 0.017$) interaction occurred, where alligator home range size was largest in summer 2007. Additionally, home range size was similar between sexes ($F_{1, 28} = 0.01$; $P = 0.926$), and among seasons ($F_{2, 32} = 1.22$; $P = 0.310$) and years ($F_{2, 20} = 0.81$; $P = 0.460$; Table 1.2).

Results from 100% MCP, 95% MCP, and 50% fixed kernel had similar trends in which variables (e.g., wetland, season, sex, and year) were significant as those detected for 95% fixed kernel, therefore, only the results for 95% fixed kernel were reported. Means, standard errors, and ANOVA results for 100% MCP, 95% MCP, and 50% fixed kernel are reported in Appendices A – C, to provide comparisons with previous and future studies.

Home Range Overlap

Due to limited numbers of transmittered alligators at Kurth Lake and Dam B WMA, home range overlap was only calculated for transmittered alligators at Little Sandy NWR. At Little Sandy NWR, home range overlap was only estimated for 2007 and 2008 due to the limited number of transmittered alligators in 2006. From April – October 2007 and 2008, > 86% of an individual alligator's 95% fixed kernel home range overlapped with other transmittered alligators (Figure 1.6 and 1.7). Additionally, from April – October 2007 and 2008, > 72% of an individual alligator's 50% fixed kernel home range (i.e., core area) overlapped with other transmittered alligators (Figure 1.8 – 1.13). Alligators at Little Sandy NWR had similar home range overlap between sexes ($F_{1, 27} = 0.00$; $P = 0.951$), years ($F_{1, 16} = 0.27$; $P = 0.610$), and among seasons ($F_{1, 21} = 0.10$; $P = 0.758$). There were no year * season * sex ($F_{1, 7} = 0.34$; $P = 0.579$), year * sex ($F_{1, 16} = 0.28$; $P = 0.604$), season * sex ($F_{1, 21} = 0.37$; $P = 0.549$), or season * year ($F_{1, 7} = 0.72$; $P = 0.425$) interactions for alligator home range size (Table 1.3). Although a large percentage of each transmittered alligator's home range overlapped with other alligators, on any given day, alligators were on average 815 m (SE = 4.9) away from each other. Euclidean distances varied among sexes ($F_{2, 24} = 45.74$; $P < 0.001$), where distances between females to other females ($\bar{x}$ = 843 m) was greater than distances between females and males ($\bar{x}$ = 743 m) and males to males ($\bar{x}$ = 561 m).

Daily Movements of Transmittered Individuals

Alligator mean minimum daily movement was 103.5 m/day (SE = 4.3), irrespective of year, wetland, sex, and season. Irrespective of sex, season, and year, alligators traveled similar distances among wetlands ($F_{1, 28} = 1.99$; $P = 0.169$). Therefore, subsequent analyses of daily movements of transmittered individuals were performed with wetlands combined. There were no year * season * sex ($F_{2, 22} = 0.59$; $P = 0.564$), year * season ($F_{3, 22} = 1.04$; $P = 0.393$), nor season * sex ($F_{2, 50} = 1.63$; $P = 0.206$) interactions for alligator daily movements. However, a year * sex ($F_{1, 23} = 4.29$; $P = 0.049$) interaction occurred. Both male and female alligators traveled similar distances ($F_{1, 28} = 1.40$; $P = 0.248$). However, alligator daily movements did vary among years ($F_{2, 24} = 6.14$; $P = 0.007$) and seasons ($F_{2, 52} = 22.05$; $P < 0.001$), where alligators moved greater distances in 2007 and 2008 than 2006 and moved greater distances in spring and summer than winter (Table 1.4).

Daily Movements of Non-transmittered Individuals

Although no formal tests were included with transmittered and non-transmittered data combined, when pooled, alligator mean daily movements increased as total length increased (Figure 1.14). All alligators captured/recaptured within 14 days were < 118.1 cm in total length (i.e., subadults or juveniles) and their mean minimum daily movement was 11.8 m (SE = 1.8), irrespective of year, wetland, sex, and season. Non-transmittered alligators traveled similar distances between wetlands ($F_{2, 115} = 0.34$; $P = 0.711$), seasons ($F_{1, 4} = 0.68$; $P = 0.457$), and sexes ($F_{1, 67} = 1.64$; $P = 0.205$). Due to insufficient sample sizes, interactions and daily movement comparisons among years were not performed on non-transmittered alligators (Table 1.5).

DISCUSSION

Although few studies have focused upon home ranges and movements of American alligators, there appears to be considerable variation in results among studies (Joanen and McNease 1970;1972, Goodwin and Marion 1979, Hagan 1982, Taylor 1984, Rootes and Chabreck 1993, Morea 1999). Several factors could contribute to this variation including habitat condition, prey availability, and water levels; factors known influence American alligator home range size and to vary geographically (Chabreck 1965, Goodwin and Marion 1979, Rootes and Chabreck 1993). Home range sizes within this study were considerably lower than previous studies, especially among breeding size (i.e., individuals > 1.6 m in total length) males (Table 1.6). Although home ranges and movements of breeding size female alligators were within reported ranges, they too were lower than most other studies (Table 1.6). Shorter movements and smaller home ranges observed in this study could be the result of several competing factors acting singularly, or concomitantly, such as wetland characteristics (i.e., habitat composition [amount of shallow marsh, open water, deep marsh, etc.], amount and extent of available habitat, and alligator population density.

In general, home range size is thought to be inversely proportional to habitat quality (estimated by prey availably and abundance), where individuals within quality habitats may neither travel long distances nor require large home ranges to breed, find food, or locate other resources (e.g., basking spots and den sights; McLoughlin et al. 2000). As habitat quality is directly related to specific wetland characteristics, such as habitat composition and water depth (Morea 1999), these factors can potentially affect home ranges of American alligators. Alligators within east Texas use habitats with a mosaic of open water, floating vegetation, and emergent vegetation (Webb et al. 2009), where regionally suitable alligator habitat has been described as 20 – 40% open water, < 20% open water > 1.2 m deep, high interspersion, and ponded water < 15 cm deep (Newsom et al. 1987, Webb et al. 2009). Although absolute habitat quality is coarsely understood, based upon percent habitat composition, both Little Sandy NWR and Dam B WMA (Webb 2005, Webb et al. 2009) contain suitable alligator habitat (see Appendix D and E). Although Little Sandy NWR and Dam B WMA contained suitable alligator habitat, previous studies in Louisiana (Taylor 1984) and north-central Florida (Goodwin and Marion 1979) also likely contained similar habitat, but alligator home ranges were much larger. For example, in a region with similar habitat composition to east Texas (i.e., forested wetland in northern Louisiana), Taylor (1984) estimated female home ranges to be 56 ha; > 65% larger than mean home range size of adult female alligators at Little Sandy NWR. Therefore, smaller home ranges and shorter movements documented in this study may be more influenced by other factors such as extent of available habitat and population density rather than habitat characteristics (i.e., habitat quality or suitability).

Beyond presence of potentially suitable and/or quality habitat, extent of available habitat may also dramatically affect home range sizes of American alligators. For example, wetland systems with greater available habitat may allow alligators to occupy larger home ranges as they may be able to move greater distances and occupy/defend a larger area (Morea 1999). Conversely, in smaller wetland systems, alligator movements and home range sizes are likely constrained by extent of available habitat in which they can travel and/or occupy (Morea 1999, Roth 2003). Although Little Sandy NWR contains suitable alligator habitat, it is much smaller (375 ha) than wetlands used in previous studies (600 – 35,000 ha; Chabreck 1965, Joanen and McNease 1970;1972, McNease and Joanen 1974, Goodwin and Marion 1979, Hagan 1982, Taylor 1984, Rootes and Chabreck 1993). As such, alligators in confined areas, due to less available space, should not be able to occupy/defend comparably sized home ranges or move as far as they might in other larger wetlands. However, such area related restrictions did not influence home range size or movements in this study, as both metrics remained similar among wetlands of different sizes. For example, home ranges and movements at Dam B WMA were similar to Little Sandy NWR, even though Dam B WMA is > 12 times larger. Although small sample sizes at Dam B WMA may preclude detection of larger home range sizes, similarity in home range size and movement patterns among wetlands indicate that wetland area may not limit alligator home ranges and movements in east Texas.

However, extent of available habitat and subsequently home range size and movements are not only influenced by size of a wetland, but can also be limited by amount of emergent and floating vegetation and water levels. For example, home range size and movements may be negatively influenced by exotic invasive aquatic plants (i.e., water hyacinth and giant salvinia) that form large mats and potentially limit truly available habitat, restrict movements, and reduce home range size. Such reductions have been reported in natural marshes in coastal Louisiana (McNease and Joanen 1974) and Florida Everglades (Morea 1999) due to native vegetation limiting movements. Additionally, home range size and movements can be directly tied to water levels (Chabreck 1965, Hines et al. 1968, Joanen and McNease 1970, Morea 1999). Low water levels in 2006 and 2007 at Dam B WMA (repairs to Town Bluff Dam), created irregular conditions that may have contributed to restricted movements and smaller home ranges. Additionally, larger home ranges and greater movements occurred during 2007, when high summer water levels (United States Geological Survey gauges at Big Sandy Creek and Sabine River near Hawkins, TX) simultaneously increased available habitat and reduced obstacles (i.e., emergent vegetation, islands, and/or levees). Even though Dam B WMA is 12 times larger than Little Sandy NWR, low water conditions existing during a drawdown in 2006 and subsequent expansion of exotic invasive aquatic plants made this wetland functionally smaller. Although alligator home ranges and movements in this study may be limited by availability of suitable habitat and/or extent of available habitat, factors responsible for the similarity in home range size and movements between study sites are complicated by other factors such as water fluctuations and exotic invasive aquatic plants, which combine to dramatically alter both habitat availability and physical space within these wetlands.

Beyond habitat related issues, home ranges and movements may be ultimately limited by alligator population density. Home range size is typically negatively related to population density, due to greater competition and territoriality, where individuals theoretically move shorter distances to avoid such interactions (Trewhella et al. 1988, McLoughlin et al. 2000). High population density can also result in extensive home range overlap, even in territorial species, due to necessity of resource sharing (McLoughlin et al. 2000). Previous studies at Dam B WMA suggest alligator densities are lower than other geographic regions (Webb et al. 2009). However, current population density estimates within Little Sandy NWR (0.4 ha/alligator, ~893 alligators within wetland) are greater than reported at Dam B WMA (3.8 ha/alligator, ~1360 alligators within wetland; Saalfeld et al. unpublished). Higher densities at Little Sandy NWR may force alligators to occupy smaller home ranges and use shorter movements. As alligators are considered territorial (Joanen and McNease 1970;1972, Rootes and Chabreck 1993, Morea 1999), home range overlap is more likely a result of high population density. Territories in American alligators are thought to be defended by breeding size individuals in order to maintain access to feeding, breeding, and/or nesting areas (Chabreck 1965). However, when population densities are high, alligators may be forced to share the same habitat, with territoriality being replaced with temporal avoidance.

Movements of smaller alligators increase as they approach breeding size, after which, daily movements decline (Chabreck 1965). After younger alligators (i.e., 0 – 2 years old) are forced to disperse (Chabreck 1965), movements continually increase to take advantage of larger food items and establish territories. As alligators increase in size, they become better equipped to defend preferred core areas and are less likely to be forced into marginal habitats, theoretically resulting in both reduced movements and home range size (Morea 1999). However, movements did not decline for larger size classes in this study. Perhaps the inconsistent movement patterns were due to fewer large/dominant individuals (e.g., only 3 alligators > 2.5 m were transmittered) existing within these wetlands. For example, at both Dam B WMA and Little Sandy NWR > 75% of transmittered alligators were 1.6 – 2.1 m. Such small breeding size alligators (i.e., 1.6 – 2.1 m) may not be large enough to effectively defend a smaller territory with sufficient quality resources, precluding predicted detection of decreasing movements after breeding size is obtained.

MANAGEMENT IMPLICATIONS

Geographic differences in home ranges and movements make it challenging to establish broad-scale or even regional conservation, management, or harvest recommendations. Therefore, obtaining site specific data are key for proper management. For example, shorter movements and smaller home ranges within this study were likely influenced by extent of available habitat, where increasing extent of available habitat could theoretically elevate carrying capacity, minimize competition, and increase food availability. However, extent of available habitat can be influenced by numerous factors including water level fluctuations and exotic invasive plants. For example, at Dam B WMA, salvinia, alligatorweed, and water hyacinth have formed large mats, reducing the amount of habitat for alligators and potentially negatively impacting prey densities and food availability (see Chapter IV). Therefore, exotic plant control and management may be key to increase the extent of habitat available. Exotic invasive plant removal may be achieved by herbicide application and/or mechanically harvesting. However, either approach, if not properly timed or executed at the proper intensity could negatively influence alligator populations (see Chapter II and IV).   For example, at Dam B WMA, removal of exotic invasive plants is done exclusively by spraying herbicides. However, large mats of decomposing plant material can lead to sharp decreases in dissolved oxygen levels, especially in shallow water, leading to fish kills and decreased prey abundances. Therefore, control of aquatic invasive species should be done early in the season (e.g., spring) when temperatures are lower and the impact on dissolved oxygen levels would be less severe. However, if spraying is to occur in warmer, summer months, spraying smaller patches to create channels in shallow water habitat may be more effective. By spraying small patches, dissolved oxygen levels may not decline as severely and patches may be opened for alligators to access foraging areas. Additionally, removal of exotic invasive plants can be accomplished with the aid of a mechanical harvester. However, use of this technique should only be applied during the warmer months when alligators have enough energy to avoid mortality inflicted from the harvester (see Chapter II). Additionally, mechanical harvesters should be used only in deeper water, away from shoreline and islands, so additional disturbance or mortality is not inflicted to nesting females and hatchlings.

Water level fluctuations can also dramatically impact extent of available habitat, either naturally (based upon precipitation patterns) or anthropogenically (through water manipulation on reservoirs). For example, at Dam B WMA water levels are manipulated based upon varying management goals (e.g., electricity, drinking water, recreation, and flood control), with little if any consideration for alligators occurring therein. During periods of low water levels at Dam B WMA, alligators of all size classes congregated in open water areas, which provided little cover for small alligators, who were exposed to greater risks of predation and cannibalism (see Chapter IV). In order to alleviate these problems, water levels during the alligator growing season (i.e., April – October), should be maintained at consistent levels, to maintain reliable/predictable habitat conditions throughout the nesting cycle and reduce potential competition.

Although no studies have evaluated impacts harvest has on alligator home range size or movements, alligator harvest is predicted to continue to increase in east Texas. It is unknown how the additive effects of harvest and smaller home ranges and shorter movements might impact these populations. Alligators at the three study sites have been subjected to harvest for at least the past 15 years, resulting in many of the large (most likely dominant) individuals being removed from the population (Texas Parks and Wildlife Department unpublished, Saalfeld et al. unpublished). Current non-selective harvest (e.g., hook and line techniques used on Dam B WMA and Little Sandy) combined with small home ranges may result in unsustainable harvest. By removing large, presumably dominant, individuals from the population, smaller alligators are no longer inhibited from breeding, potentially leading to decreased clutch size, hatchling survival, growth rates, and nest success. Although, current harvest strategies are non-selective and size structure of harvested alligators should reflect the natural size distribution, hunters place baits high enough such that only larger alligators are targeted. Harvest within these wetlands needs to be more selective, where intermediate size classes (e.g., 1.2 – 1.8 m) are targeted to reduce higher density portions of the population and to lessen pressure on dominant individuals. Therefore, harvest of intermediate size classes could potentially lessen the additive impact of small home range sizes and removal of dominant individuals and potentially promote sustainable harvest.

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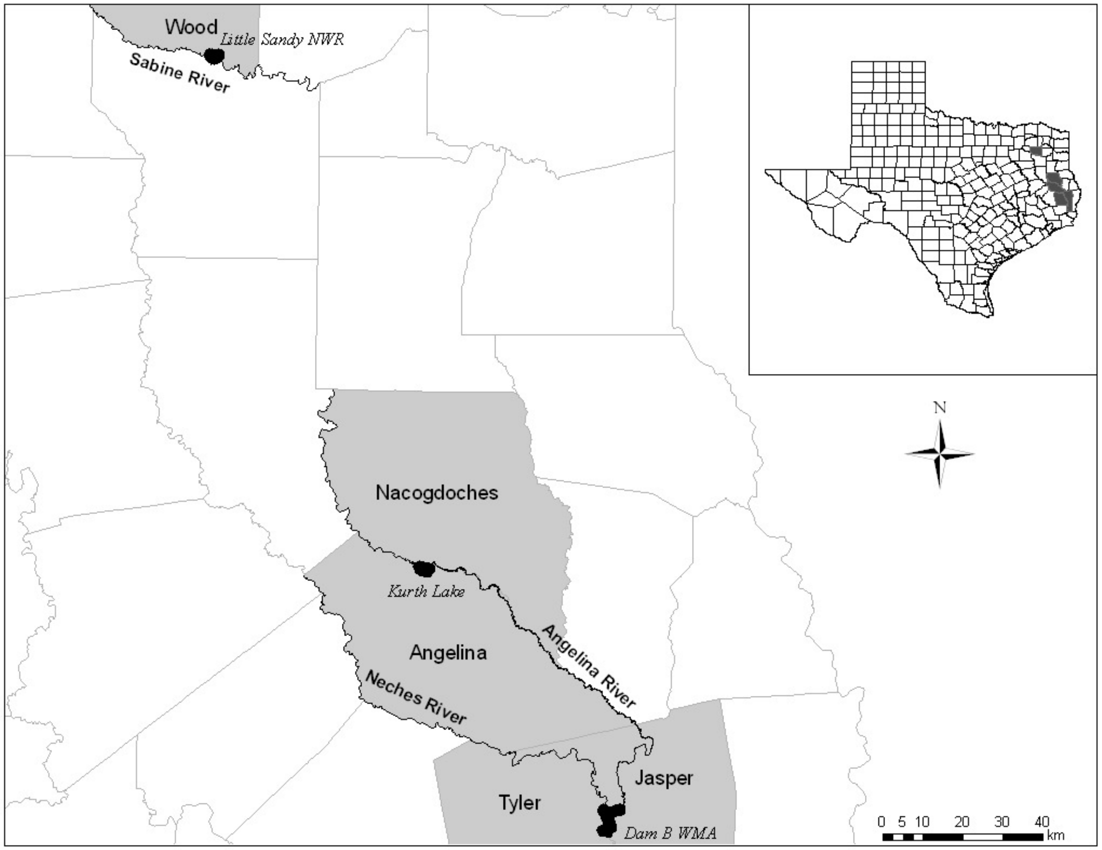

Figure 1.1. Location of counties and study sites in east Texas used to study American alligators (*Alligator mississippiensis*), 2006 – 2008.

Figure 1.2. Aerial photograph of Angelina-Neches/Dam B Wildlife Management Area (Jasper and Tyler counties, Texas) from 1 m resolution, 2004 National Agriculture Imagery Program digital orthophoto quarter-quadrangle aerial photographs (Texas Natural Resources Information System 2004).

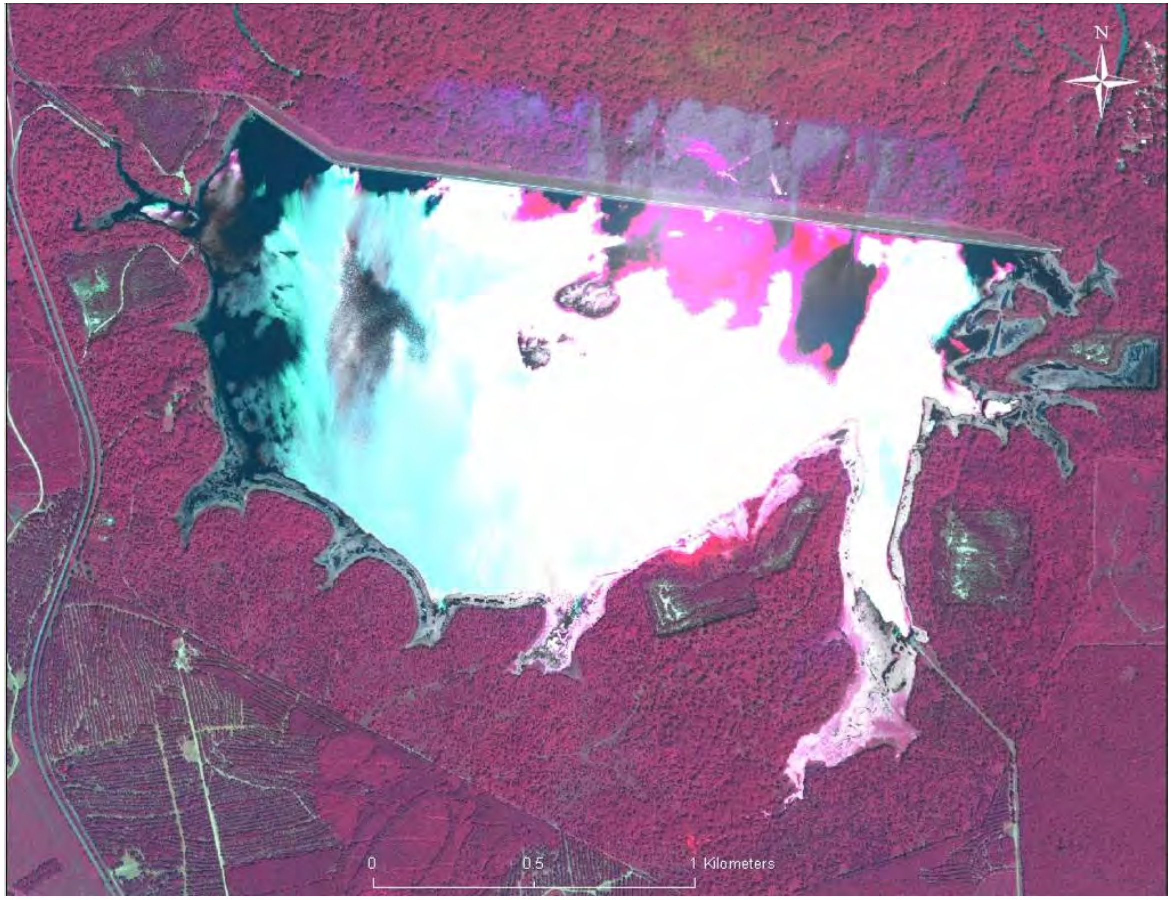

Figure 1.3. Aerial photograph of Kurth Lake (Angelina County, Texas) from 1 m resolution, 2004 National Agriculture Imagery Program digital orthophoto quarter-quadrangle aerial photographs (Texas Natural Resources Information System 2004).

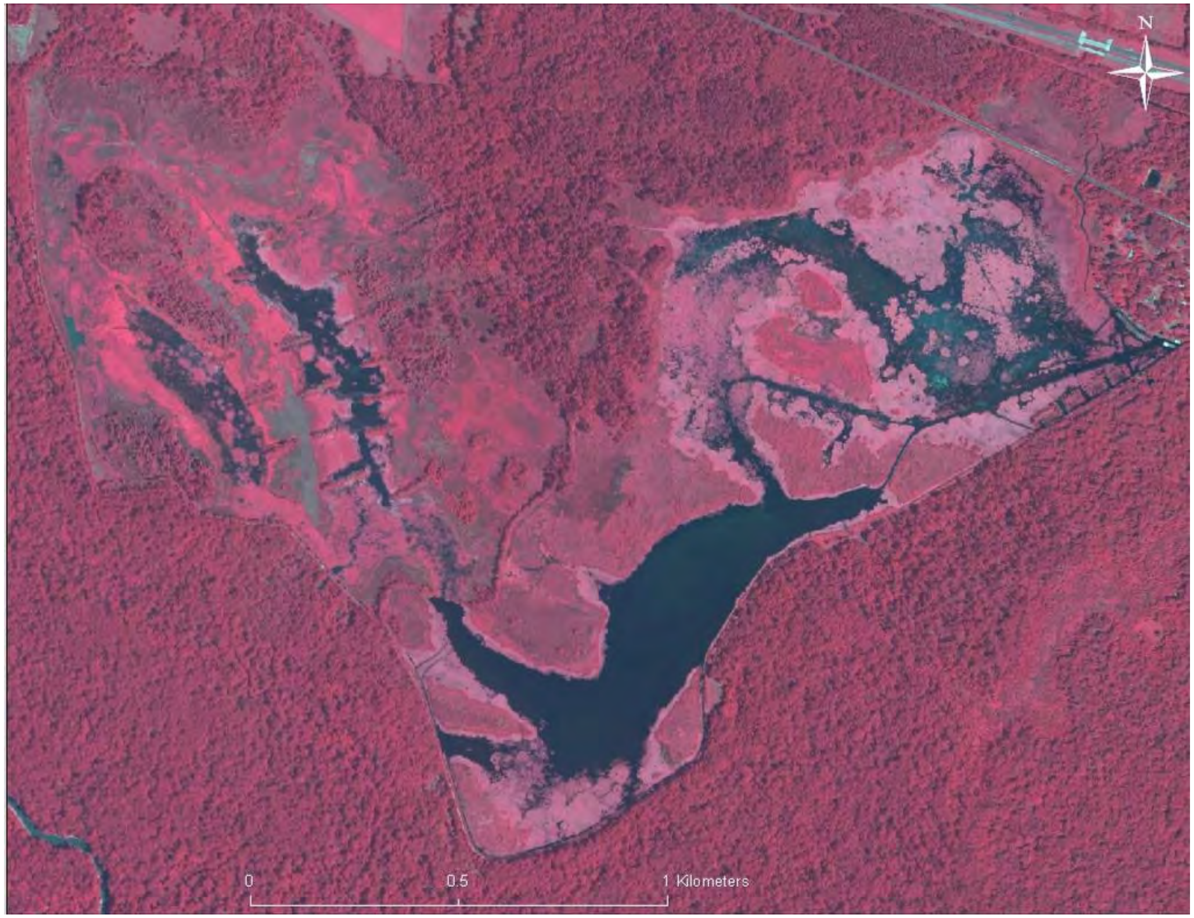

Figure 1.4. Aerial photograph of Little Sandy National Wildlife Refuge (Wood County, Texas) from 1 m resolution, 2004 National Agriculture Imagery Program digital orthophoto quarter-quadrangle aerial photographs (Texas Natural Resources Information System 2004).

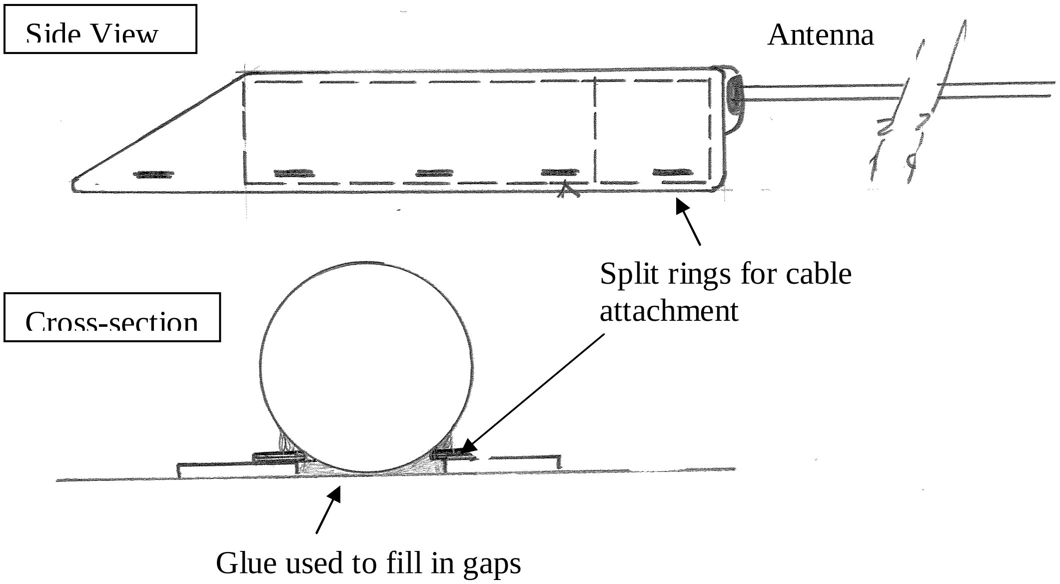

Figure 1.5. Schematic of custom built external transmitters (Advanced Telemetry Systems, Isanti, MN) attached to American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

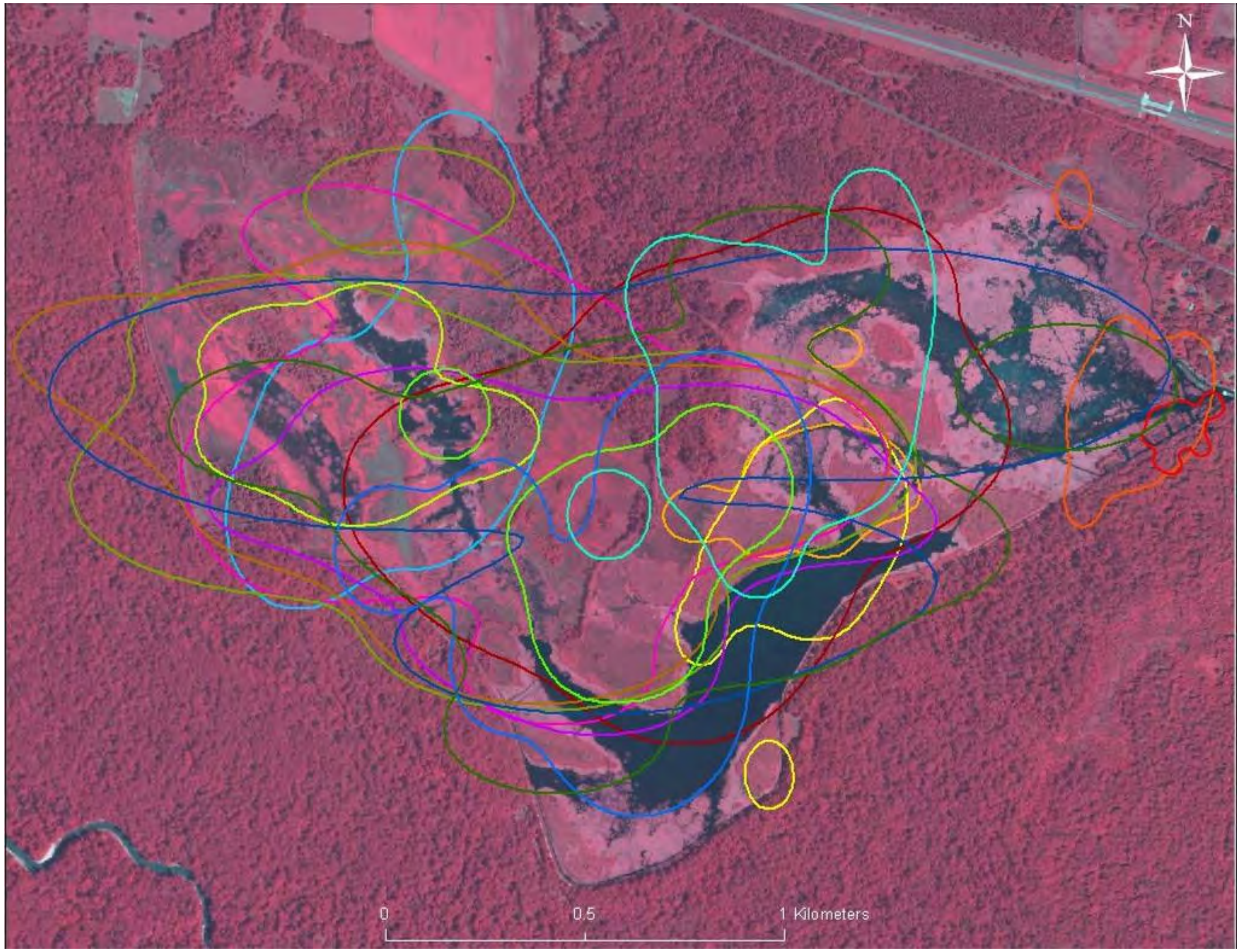

Figure 1.6. Fixed kernel (95%) annual home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2007, illustrating degree of home range overlap.

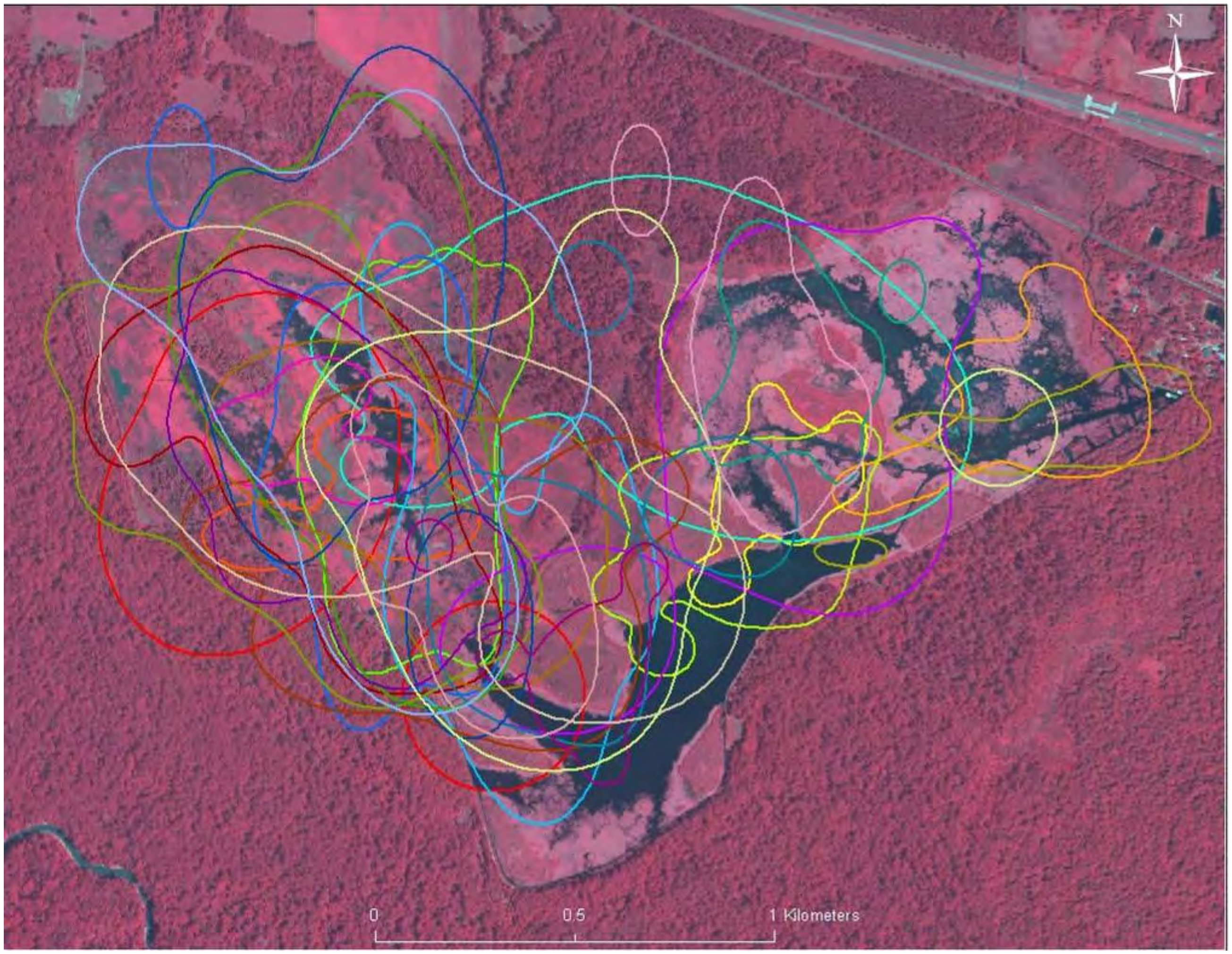

Figure 1.7. Fixed kernel (95%) annual home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2008, illustrating degree of home range overlap.

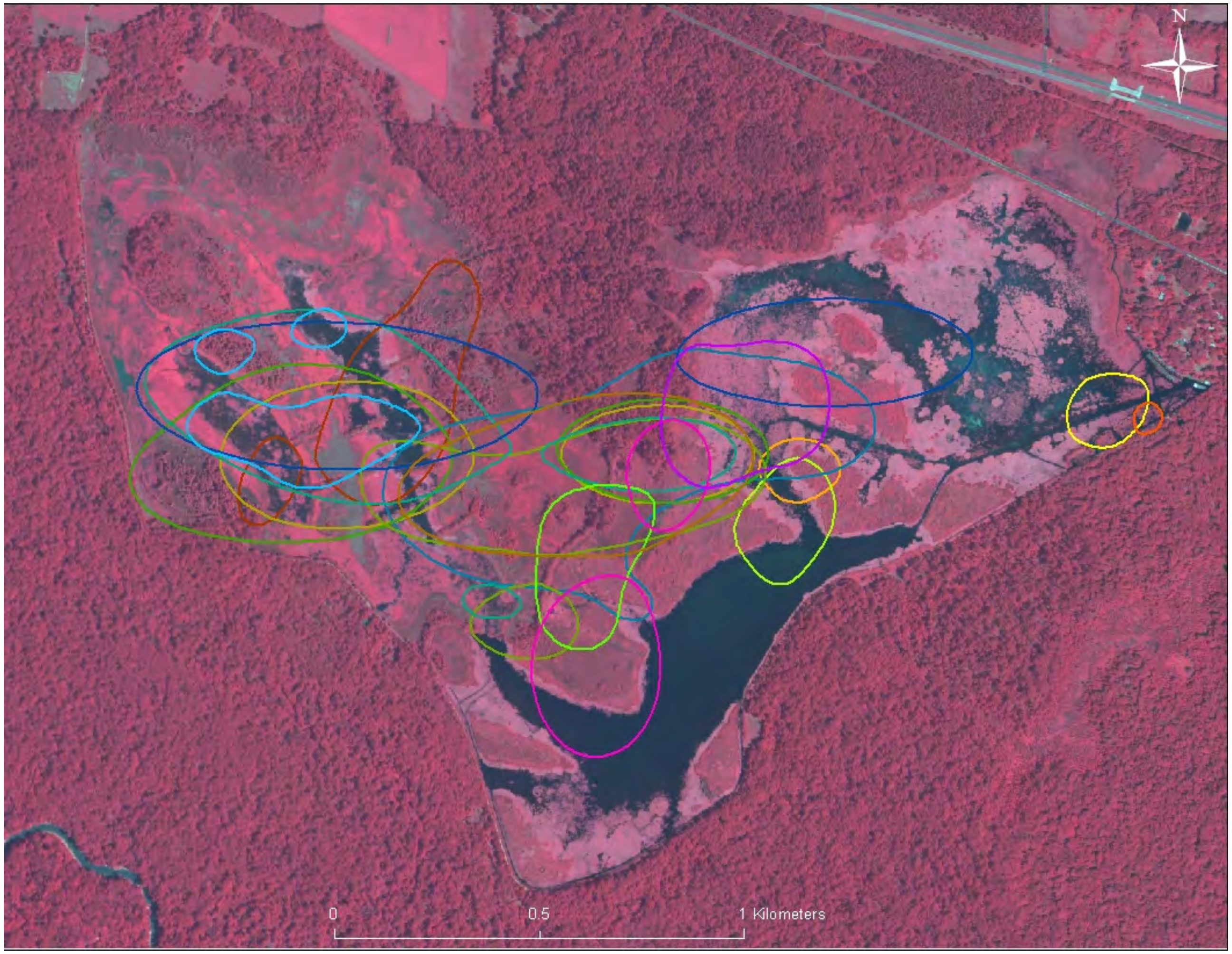

Figure 1.8. Fixed kernel (50%) annual home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2007, illustrating degree of core home range overlap.

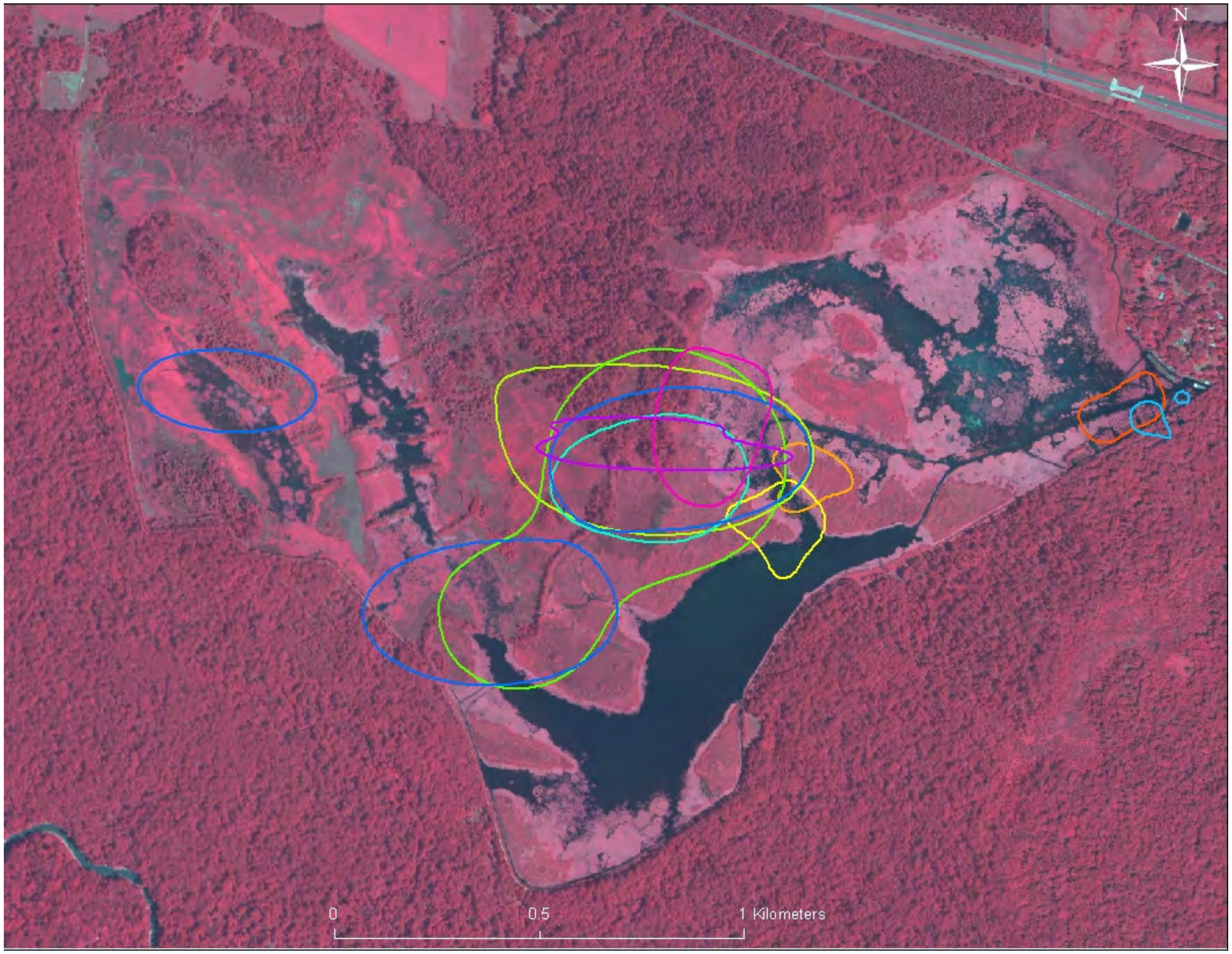

Figure 1.9. Fixed kernel (50%) home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas during spring 2007, illustrating degree of core home range overlap.

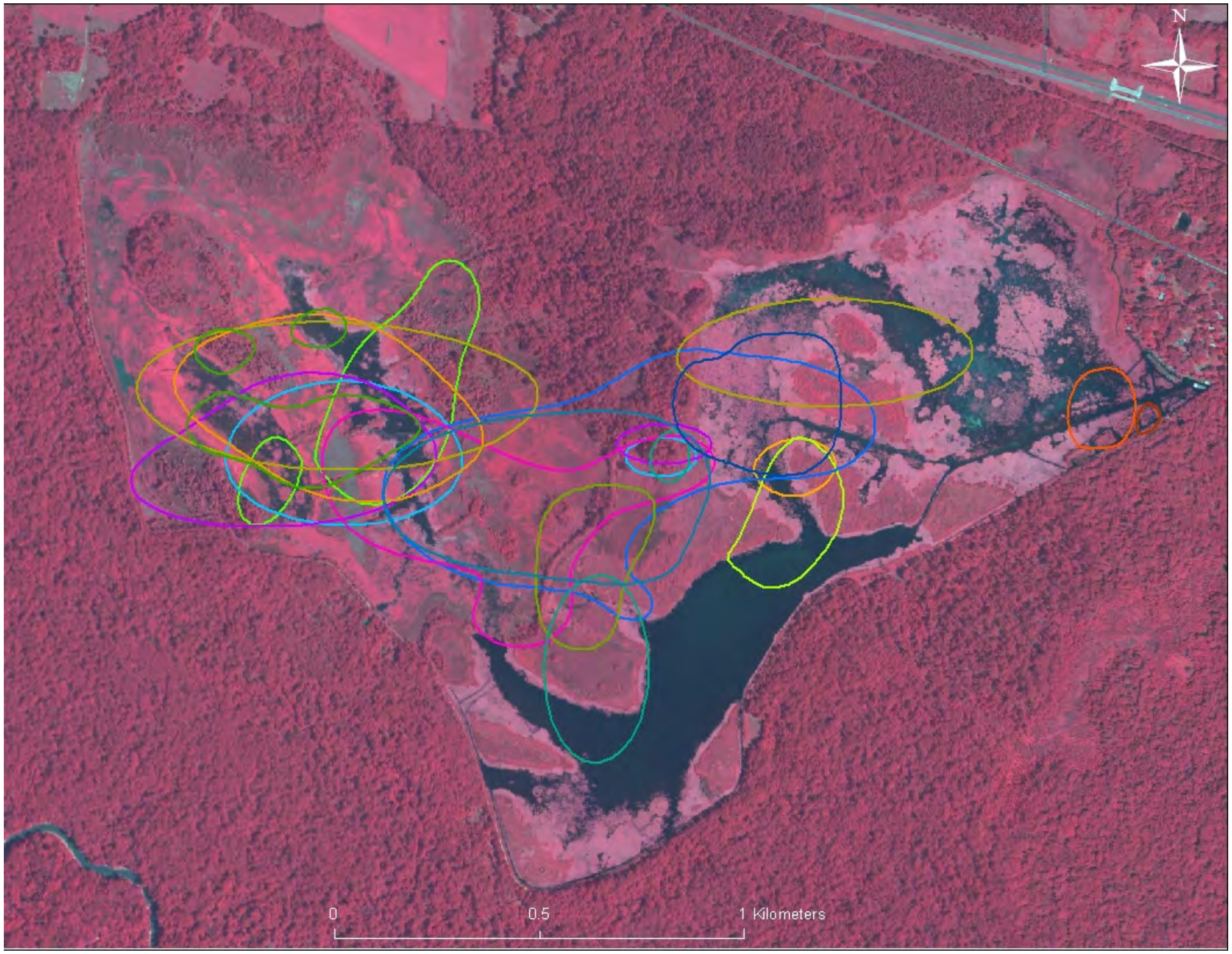

Figure 1.10. Fixed kernel (50%) home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas during summer 2007, illustrating degree of core home range overlap.

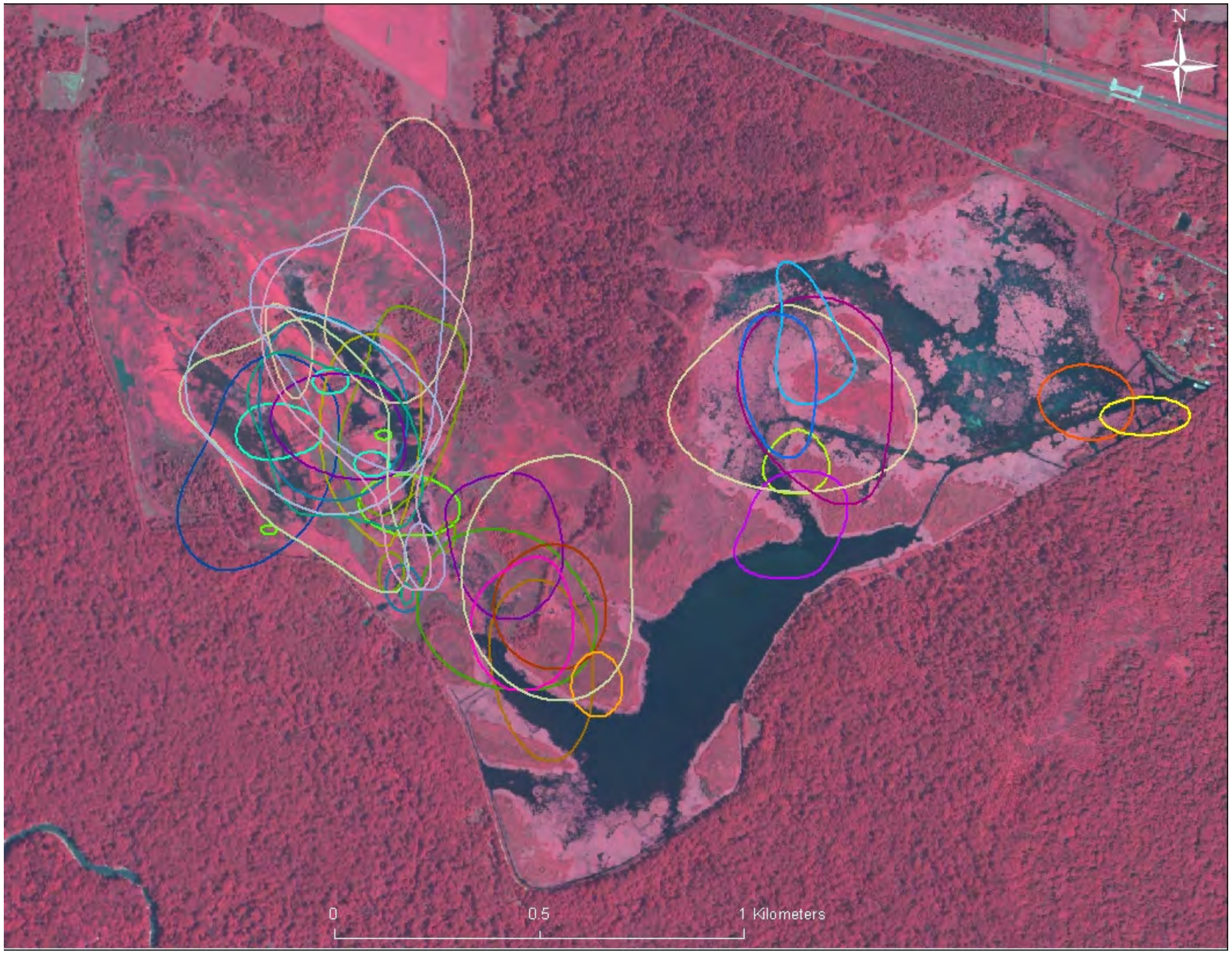

Figure 1.11. Fixed kernel (50%) home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2008, illustrating degree of core home range overlap.

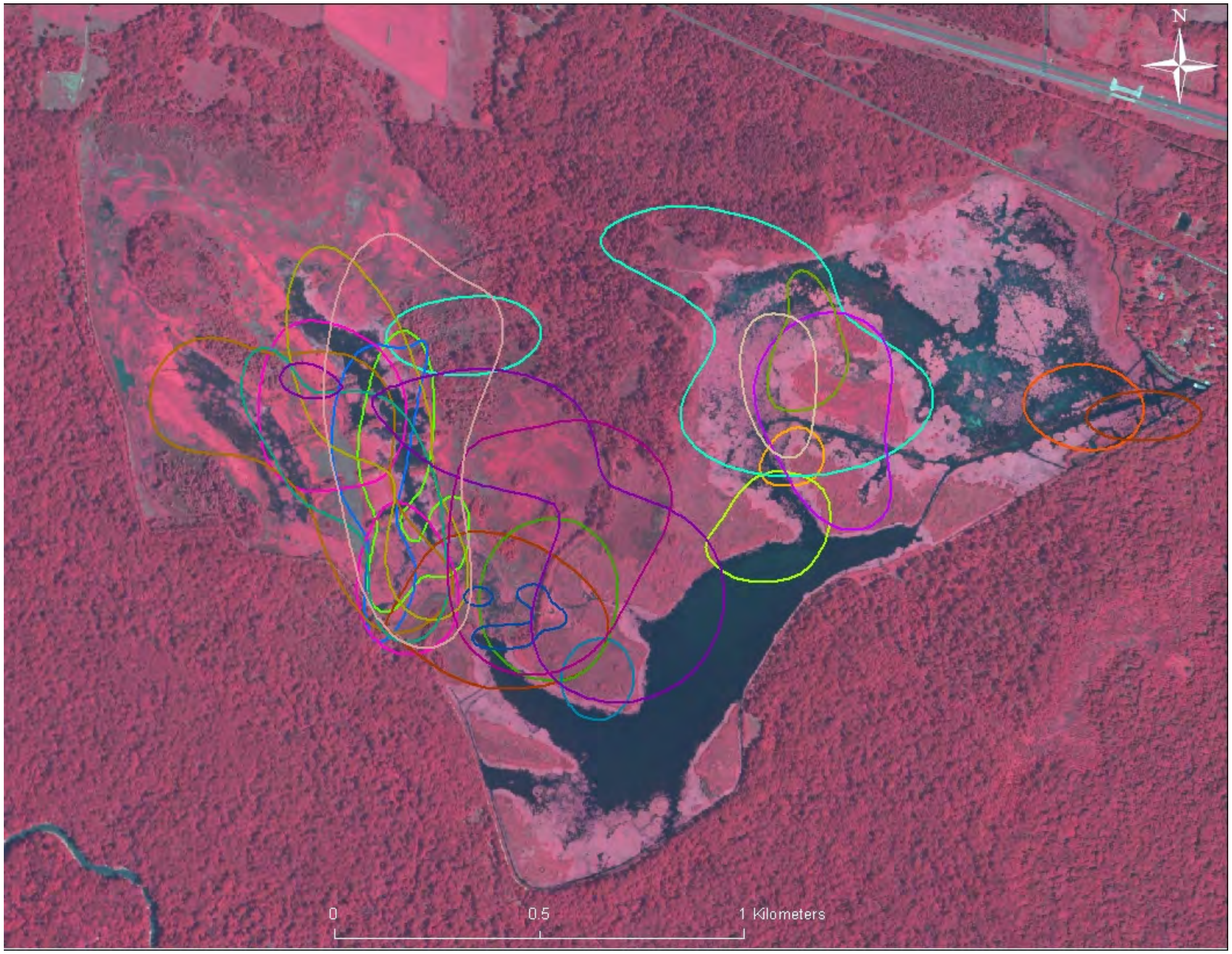

Figure 1.12. Fixed kernel (50%) home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas during spring 2008, illustrating degree of core home range overlap.

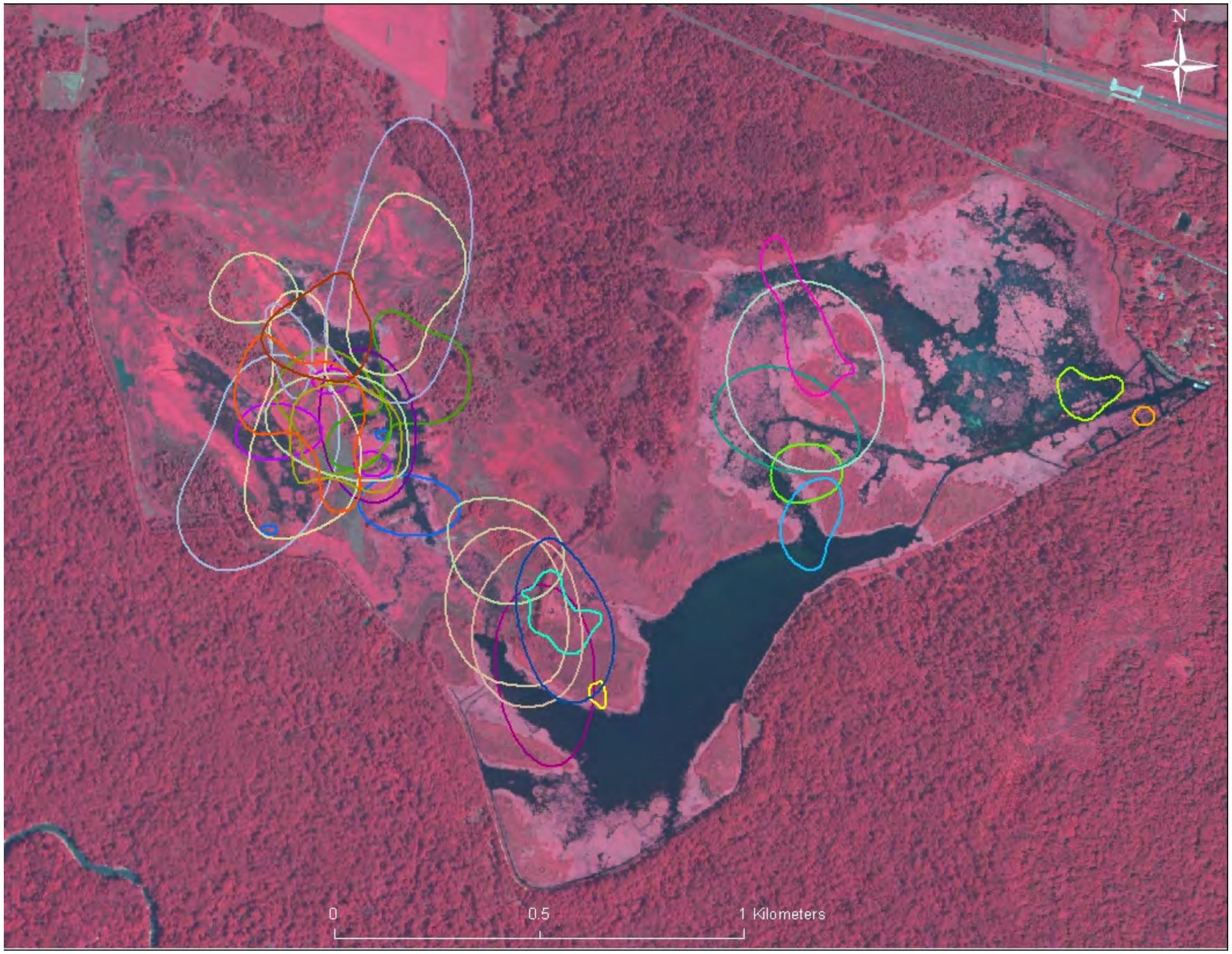

Figure 1.13. Fixed kernel (50%) home ranges of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas during summer 2008, illustrating degree of core home range overlap.

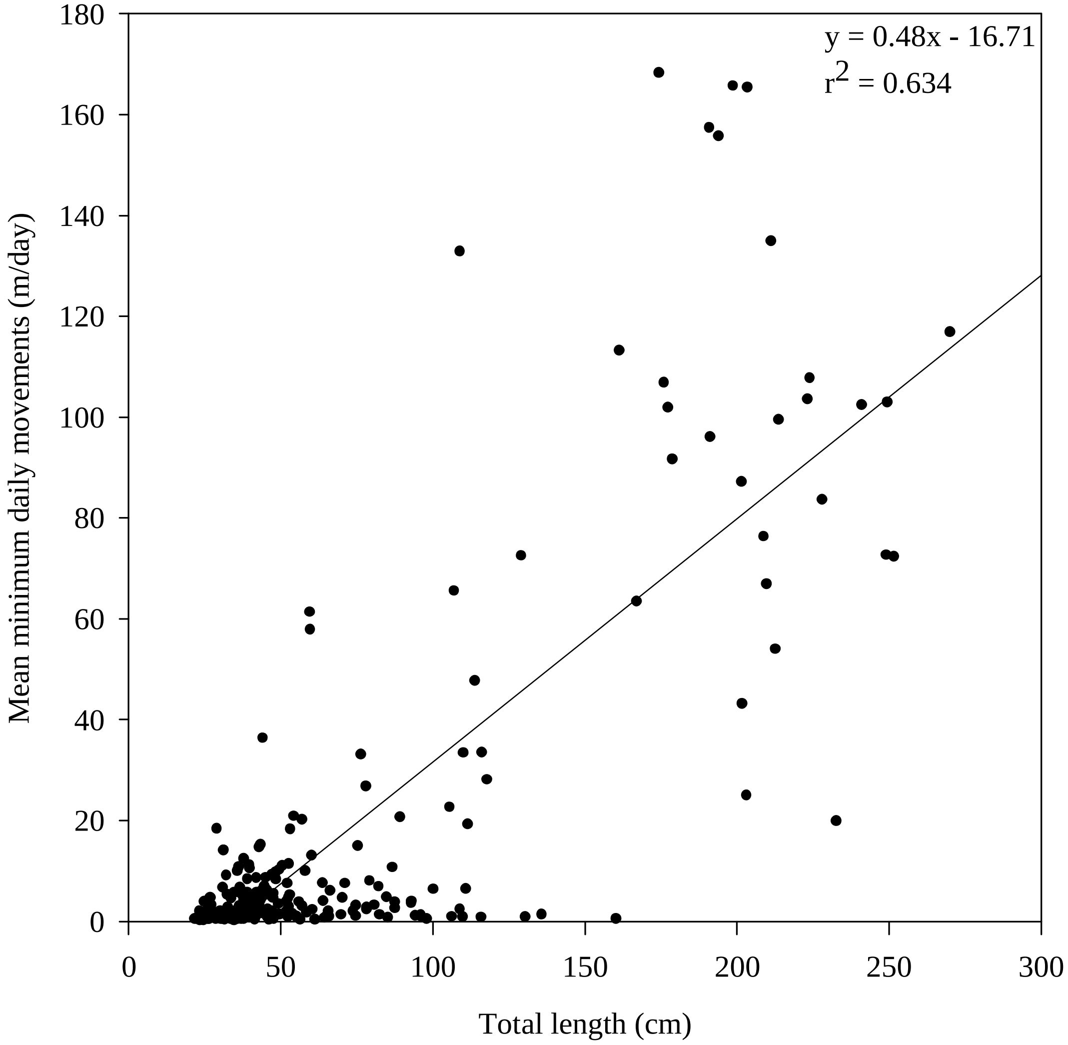

Figure 1.14. Mean minimum daily movements (m/day) by total length for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

Table 1.1. Total number of captures, recaptures and number, size range, and sex (male, female, and undetermined [individuals < 50.0 cm in total length that could not be sexed accurately]) of American alligators (*Alligator mississippiensis*) captured at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2006 – 2008.

Study Area	Captures (*n*)	Recaptures (*n*)	Size range (cm)	Male (*n*)	Females (*n*)	Undetermined (*n*)
Dam B WMA	141	22	25.1 – 363.5	73	50	18
Kurth Lake	112	53	25.6 – 263.4	26	15	38
LSNWR	521	325	20.9 – 270.3	154	118	249

Table 1.2. Means ($\bar{x}$) and standard errors(SE) of 95% fixed kernel home ranges (ha) for transmittered American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA) and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	8	44.9 a	11.2
LSNWR	Combined	Combined	Combined	90	50.2 a	4.7
Combined	Female	Combined	Combined	78	48.5 *a*	5.0
Combined	Male	Combined	Combined	20	55.0 *a*	9.8
Combined	Combined	2006	Combined	5	21.5 a	12.8
Combined	Combined	2007	Combined	28	71.6 a	11.1
Combined	Combined	2008	Combined	65	42.6 a	4.0
Combined	Combined	Combined	Spring	33	60.1 *a*	8.4
Combined	Combined	Combined	Summer	51	47.2 *a*	6.0
Combined	Combined	Combined	Winter	14	35.0 *a*	7.6

Table 1.2. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Female	2006	Combined	5	21.5 A	12.8
Combined	Female	2007	Combined	24	70.7 A	12.2
Combined	Female	2008	Combined	49	40.3 A	4.3
Combined	Male	2007	Combined	4	76.7 A	28.4
Combined	Male	2008	Combined	16	49.6 A	10.0
Combined	Female	Combined	Spring	28	59.9 *A*	9.3
Combined	Female	Combined	Summer	42	45.0 *A*	6.5
Combined	Female	Combined	Winter	8	26.3 *A*	5.4
Combined	Male	Combined	Spring	5	61.4 *A*	22.7
Combined	Male	Combined	Summer	9	57.1 *A*	15.7
Combined	Male	Combined	Winter	6	46.6 *A*	15.8
Combined	Combined	2006	Summer	5	21.5[e]	12.8
Combined	Combined	2007	Spring	10	64.9 BC	21.7
Combined	Combined	2007	Summer	18	75.3 A	12.7
Combined	Combined	2008	Spring	23	58.1 AC	8.0

Table 1.2. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Combined	2008	Summer	28	33.7 C	4.7
Combined	Combined	2008	Winter	14	35.0 AC	7.6
Combined	Female	2006	Summer	5	21.5 A	12.8
Combined	Female	2007	Spring	9	69.4 A	23.8
Combined	Female	2007	Summer	15	71.5 A	14.1
Combined	Female	2008	Spring	19	55.4 A	8.2
Combined	Female	2008	Summer	22	32.3 A	4.8
Combined	Female	2008	Winter	8	26.3 A	5.4
Combined	Male	2007	Spring	2	24.7 A	5.8
Combined	Male	2007	Summer	3	94.1 A	31.7
Combined	Male	2008	Spring	4	70.6 A	26.8
Combined	Male	2008	Summer	6	38.6 A	13.6

Table 1.2. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Combined	Male	2008	Winter	6	46.6 *A*	15.8

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

Table 1.3. Means ($\bar{x}$) and standard errors(SE) for percent overlap of 95% fixed kernel home ranges for transmittered American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge (NWR), Texas, 2007 – 2008.

Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (%)[c]	SE
Female	Combined[d]	Combined	65	87.4 *a*	2.5
Male	Combined	Combined	14	85.1 *a*	6.3
Combined	2007	Combined	28	86.8 a	3.5
Combined	2008	Combined	51	87.1 a	3.1
Combined	Combined	Spring	33	87.5 *a*	3.5
Combined	Combined	Summer	46	86.6 *a*	3.2
Female	2007	Combined	24	86.6 A	4.0
Female	2008	Combined	41	87.9 A	3.3
Male	2007	Combined	4	88.1 A	7.7
Male	2008	Combined	10	83.9 A	8.5
Female	Combined	Spring	28	87.2 *A*	3.9

Table 1.3. Continued.

Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (%)[c]	SE
Female	Combined	Summer	37	87.6 *A*	3.3
Male	Combined	Spring	5	89.3 *A*	8.2
Male	Combined	Summer	9	82.9 *A*	8.9
Combined	2007	Spring	10	82.2 A	7.7
Combined	2007	Summer	18	89.4 A	3.5
Combined	2008	Spring	23	89.9 A	3.5
Combined	2008	Summer	28	84.9 A	4.7
Female	2007	Spring	9	80.2 *A*	8.4
Female	2007	Summer	15	90.5 *A*	3.8
Female	2008	Spring	19	90.5 *A*	4.1
Female	2008	Summer	22	85.6 *A*	5.0
Male	2007	Summer	3	84.1 *A*	9.2
Male	2008	Spring	4	86.8 *A*	10.0

Table 1.3. Continued.

Sex	Year	Season[a]	n[b]	$\bar{x}$ (%)[c]	SE
Male	2008	Summer	6	82.1 $\underline{A}$	13.2

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

Table 1.4. Means ($\bar{x}$) and standard errors(SE) of daily movements (m/day) for transmittered American alligator (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA) and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (m/day)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	42	56.7 a	14.1
LSNWR	Combined	Combined	Combined	1358	105.0 a	4.4
Combined	Female	Combined	Combined	1198	101.7 *a*	4.4
Combined	Male	Combined	Combined	202	114.4 *a*	13.9
Combined	Combined	2006	Combined	57	13.8 b	2.6
Combined	Combined	2007	Combined	529	108.3 a	7.8
Combined	Combined	2008	Combined	814	106.8 a	5.2
Combined	Combined	Combined	Spring	519	135.5 *a*	8.2
Combined	Combined	Combined	Summer	754	96.6 *b*	5.3
Combined	Combined	Combined	Winter	127	14.3 *c*	1.6

Table 1.4. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (m/day)[c]	SE
Combined	Female	2006	Combined	57	13.8 C	2.6
Combined	Female	2007	Combined	457	100.9 AB	7.6
Combined	Male	2007	Combined	72	155.1 A	30.4
Combined	Male	2008	Combined	130	91.9 BC	13.3
Combined	Female	Combined	Spring	458	131.7 *A*	8.3
Combined	Female	Combined	Summer	641	94.2 *A*	5.4
Combined	Female	Combined	Winter	99	11.9 *A*	1.5
Combined	Male	Combined	Spring	61	163.9 *A*	31.1
Combined	Male	Combined	Summer	113	110.5 *A*	17.6
Combined	Male	Combined	Winter	28	22.3 *A*	4.5
Combined	Combined	2006	Summer	45	17.0 A	3.1
Combined	Combined	2006	Winter	12	1.7 A	0.5
Combined	Combined	2007	Spring	113	142.9 A	21.3
Combined	Combined	2007	Summer	358	112.7 A	9.1
Combined	Combined	2007	Winter	58	13.6 A	1.9

Table 1.4. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (m/day)[c]	SE
Combined	Combined	2008	Spring	406	133.4 A	8.7
Combined	Combined	2008	Summer	351	90.4 A	6.3
Combined	Combined	2008	Winter	57	17.6 A	2.8
Combined	Female	2006	Summer	45	17.0 *A*	3.1
Combined	Female	2006	Winter	12	1.7 *A*	0.5
Combined	Female	2007	Spring	102	129.1 *A*	20.3
Combined	Female	2007	Summer	305	105.9 *A*	8.9
Combined	Female	2007	Winter	50	12.7 *A*	2.1
Combined	Female	2008	Spring	356	132.4 *A*	9.0
Combined	Female	2008	Summer	291	93.8 *A*	7.0
Combined	Female	2008	Winter	37	14.3 *A*	2.8
Combined	Male	2007	Spring	11	270.2 *A*	109.1
Combined	Male	2007	Summer	53	151.8 *A*	33.6
Combined	Male	2007	Winter	8	19.1 *A*	4.8
Combined	Male	2008	Spring	50	140.6 *A*	29.1
Combined	Male	2008	Summer	60	74.1 *A*	13.7

Table 1.4. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (m/day)[c]	SE
Combined	Male	2008	Winter	20	23.6 $\underline{A}$	6.0

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

Table 1.5. Means ($\bar{x}$) and standard errors(SE) of daily movements (m/day) for non-transmittered American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (m/day)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	8	6.6 a	1.6
Kurth Lake	Combined	Combined	Combined	13	14.9 a	8.1
LSNWR	Combined	Combined	Combined	129	11.8 a	2.0
Combined	Female	Combined	Combined	41	10.5 *a*	3.1
Combined	Male	Combined	Combined	55	17.7 *a*	4.1
Combined	Combined	2006	Combined	44	15.2[e]	4.2
Combined	Combined	2007	Combined	42	16.1[e]	4.1
Combined	Combined	2008	Combined	64	6.6[e]	1.4
Combined	Combined	Combined	Spring	76	10.2 A	2.5

Table 1.5. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (m/day)[c]	SE
Combined	Combined	Combined	Summer	74	13.4 A	2.7

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

Table 1.6. Summary of previous studies documenting home ranges and movements of American alligators (*Alligator mississippiensis*).

Author	Location	Sex	Movements (m/day)	Home Range (ha)[a]
Joanen and McNease 1970	coastal Louisiana	F	24	9
Joanen and McNease 1972	coastal Louisiana	M	735	375
Goodwin and Marion 1979	north-central Florida	M	720	176
		F	430	11
Hagan 1982	coastal North Carolina	M	440	441
		F	345	54

Table 1.6. Continued.

Author	Location	Sex	Movements (m/day)	Home Range (ha)[a]
Taylor 1984	inland Louisiana	F	20	56
Rootes and Chabreck 1993	coastal Louisiana	F	.	36
Morea 1999	Florida Everglades	M	167	181
		F	70	59
This study	inland Texas	M	114	19
		F	101	19

[a] Home range values from previous studies were all estimated using minimum convex polygon.

CHAPTER II

NEST SUCCESS, NEST SITE SELECTION, AND HATCHLING SURVIVAL OF AMERICAN ALLIGATORS WITHIN INLAND WETLANDS OF EAST TEXAS

INTRODUCTION

American alligator (*Alligator mississippiensis*) nesting ecology has been studied extensively throughout its range (Joanen 1969, Goodwin and Marion 1978, Deitz and Hines 1980, Platt et al. 1995, Reagan 2000, Elsey et al. 2008); however, factors that influence nest site selection and construction are complex and poorly understood (Platt et al. 1995). Many studies have described specific elements of alligator nest site selection, such as spatial patterning (Woodward et al. 1984, Jennings et al. 1987, Reagan 2000), nest site fidelity (Elsey et al. 2008), nest temperature variation (Chabreck 1973, Deeming and Ferguson 1989b, Rhodes and Lang 1996), and maternal behavior (Kushlan 1973, Hunt and Watanabe 1982, Hunt 1987). However, the influence of local and landscape habitat features on nest site selection has been coarsely examined (Joanen 1969, Wilkinson and Rhodes 1992, Platt et al. 1995, Reagan 2000), where alligators nest on elevated spoil banks in floating/emergent marshes in southeastern Louisiana (Platt et al. 1995), natural freshwater marshes in coastal Louisiana (Joanen 1969), and managed impoundments in coastal South Carolina (Wilkinson and Rhodes 1992).

At finer scales, nest site selection may also be a function of substrate/habitat availability within a female's home range (Schulte and Chabreck 1990) and proximity to her den (Joanen 1969). For example, nest site selection may be thermally influenced, as females may select nest sites close to open water (at certain heights above water level) and shade for sanctuary during daytime (Ferguson 1985, Jennings et al. 1987). However, such fine scale nest site features are poorly described and no universal patterns of nest site selection have been described for alligators in any region.

Variables relevant to, and influencing, alligator nest site selection may be strong drivers of fecundity, abundance, and demographic characteristics within a population (Kolbe and Janzen 2002, Gjerdrum et al. 2005). Alligator nest microenvironment directly influences growth rates, sex, body mass, and egg yolk mass, (Ferguson and Joanen 1983, Webb and Cooper-Preston 1989), as nest-incubation temperatures drive alligator sex determination and development after egg deposition within the nest (Ferguson and Joanen 1982, Joanen et al. 1987, Deeming and Ferguson 1989a, Allsteadt and Lang 1995a, Congdon et al. 1995). As such, decision making processes employed by female alligators during nest site selection arguably may be more consequential than in other non-temperature dependent sex determined species.

Regardless of reproductive or physiological pathway and related nest site selection processes employed by nesting species, nest success and subsequent hatchling survival are key drivers of population dynamics and important elements for modeling population stochasticity. Alligator 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), and variable nest success (46 – 74%; Joanen 1969, Goodwin and Marion 1978, 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, nest success will be directly influenced by predation rates (Fleming et al. 1976, Metzen 1977, 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 nest failure (Fleming et al. 1976, 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. For example, hatchling survival varies spatially and temporally, ranging from 12 – 41% in northcentral Florida (12 – 31% using minimum known alive; Deitz and Hines 1980, 41% using Jolly-Seber models; Woodward et al. 1987), 63% in South Carolina (using minimum known alive models; Brandt 1989), and 35% in Louisiana (interpretation using population size structures; Nichols et al. 1976). Increasing conservation concerns focused upon early age-class harvest in other regions have emphasized the importance of estimating juvenile survival rates throughout their range. Potentially additive effects of increased harvest, along with poor hatchling and/or nest success could rapidly and drastically reduce alligator populations locally and/or regionally.

Female reproductive effort, nest site selection, nest success, and adult and hatchling survival rates (Deitz and Hines 1980, Nichols 1987, Brandt 1989); are all coarsely known or generally lacking for inland alligator populations. All of these elements directly affect population dynamics, and even in regions where alligators have been extensively studied, there are still large information gaps (Nichols 1987). Estimates of relevant variables influencing nest site selection, 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 these 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. Specifically, no characterization of nest site selection processes, or any estimates of nest success, hatchling abundance, and hatchling survival have ever been developed for east Texas, the western most part of their geographic range. Regional alligator management strategies may need to be adjusted based upon local hatchling abundance and survival estimates, local nest success estimates, and characterization of nest site selection. The objectives of this study were to examine inland American alligator nesting ecology by quantifying nest success, determining factors influencing nest site selection at multiple spatial scales, and estimate yearly hatchling survival and hatchling abundance of American alligators in east Texas wetlands.

METHODS

Study Area

This research was conducted at three wetlands in east Texas (Angelina-Neches/Dam B Wildlife Management Area [Dam B WMA], Kurth Lake, and Little Sandy National Wildlife Refuge [NWR]; Figure 1.1). Dam B WMA is 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 (Figure 1.2). Dam B WMA is characterized by riverine, open lake, and shallow marsh habitats (Webb 2005, Webb et al. 2009). Dominant aquatic plants include water hyacinth (*Eichhornia crassipes*), common salvinia (*Salvinia minima*), giant salvinia (*S. molesta*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticellata*), smartweeds (*Polygonum* spp.), and yellow pond lily (*Nuphar luteum*). Dominant woody species along wetland margins are baldcypress (*Taxodium distichum*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), Chinese tallow (*Triadica sebifera*), water oak (*Quercus nigra*), overcup oak (*Q. lyrata*), water tupelo (*Nyssa aquatica*), and pine (*Pinus* spp.; Godfrey and Wooten 1981).

Kurth Lake is 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; Saalfeld et al., unpublished data) and a few shallow bays with isolated pockets of emergent marsh (Figure 1.3). Dominant aquatic species are American lotus (*Nelumbo lutea*), hydrilla, coontail (*Ceratophyllum demersum*), and yellow pond lily. Dominant woody species along wetland margins are buttonbush, black willow, Chinese tallow, water oak, overcup oak, and pine (Godfrey and Wooten 1981).

Little Sandy NWR consists of 1,539 ha, of which ≈ 1100 ha are bottomland hardwood forest, located on the northern bank of the Sabine River in southern Wood County. Little Sandy NWR contains four main lentic bodies: Overton Lake, Brumley Lake, Bradford Lake, and Beaver Lake. Of these, only Overton Lake (an impoundment of Jim Ned Creek) and Brumley Lake (an impoundment of Little Sandy Creek) were used as study sites. Overton Lake is approximately 175 ha and Brumley Lake is approximately 200 ha. Both lakes are connected by several creeks and canals, essentially making these two lakes one large wetland. Hereafter, these two lakes will be referred to as Little Sandy NWR. Little Sandy NWR is characterized primarily by shallow marsh with little open water or creek channels (Figure 1.4). Dominant aquatic species are American frog-bit (*Limnobium spongia*), American lotus, Carolina fanwort (*Cabomba caroliniana*), coontail, cutgrass (*Zizaniopsis miliacea*), and yellow pond lily. Woody species include Chinese tallow, buttonbush, black willow, and southern wax myrtle (*Morella cerifera*; Godfrey and Wooten 1981).

An additional 25 wetlands were selected as secondary study sites for the nest site selection and nest success portion of this study. Secondary study sites were selected 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 the pool of available secondary study sites, inclusion of a particular wetland was ultimately dependant 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 – 150 ha (Figure 2.1).

Nest Success

Nests surveys were performed at all three primary study sites from June – September, 2006 – 2008. Additionally, during June – September, 2007 – 2008, secondary study sites were surveyed a minimum of twice a year in order to locate nests. Nests were located 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, etc.), and searching areas with flattened shoreline herbaceous vegetation or with noticeable trails leading out of the water. Upon discovery, a global positioning system (GPS; Garmin eTrex Legend Cx, Olathe, KS) point was obtained in order to relocate nests for future measurements.

Nests were monitored at least once weekly until nest fate was determined. Nests were considered successful if ≥ 1 egg hatched (i.e., at least one 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 (Joanen 1969, 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, attempts were made to identify nest predators by searching for prints/tracks, fecal samples, hair, and/or other signs.

To determine variables most influencing nest success, the following variables were measured or estimated for each nest after nest fate was determined: nest circumference (cm), true height above sea level (elevation), 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). Nest circumference was measured around the base of nest and nest height (i.e., distance from the base of nest to highest point) was measured at several points around nest to provide an average nest height estimate (Ruckel and Steele 1984). Distances to water (i.e., distance between nest and water's edge when nest was located) and nearest tree were measured from the base of the nest at a point nearest the water or tree. Nest elevation was obtained from the GPS unit. Basal area was estimated using a prism angle gauge with a basal area factor of 10.

Nest Site Selection

To compare nest sites with available habitat, an equal number of random sites were generated for each year and study site. Random locations were obtained using Hawth's Analysis Tools (Beyer 2004) random point generator, where random points were restricted to be < 3 m from the permanent water's edge and > 10 m apart from each other or a nest. At nests (after failure or hatching) and at random sites, microhabitat characteristics were measured and consisted of true height above sea level (elevation), canopy cover (%), basal area (m^2/ha), habitat type (i.e., levee, shoreline, or island), distance to water (cm; distance between nest and water's edge when nest was located), distance to nearest tree (m), and distance to potential feeding areas (i.e., shallow marsh, deep marsh, etc; Jennings et al. 1987). In addition, all vegetation within a 1/100 ha plot centered on each nest and associated random point was identified to species and percent composition of herbaceous plants, woody plants, bare ground, and water was estimated.

Macrohabitat around each nest and random point were also measured. Large scale habitat variables were estimated using a combination of field measurements (i.e., water depth and % vegetated cover) and satellite images. Five wetland categories (i.e., island, shallow marsh [comprised of > 90% emergent vegetation and < 1 m in depth], deep marsh [comprised of > 50% emergent and submergent vegetation and 1 – 3 m in depth], shoreline, and open water [comprised of < 25% submergent vegetation and > 3 m in depth]) were digitized using 1 m resolution, 2008 NAIP DOQQ aerial photographs (Texas Natural Resources Information System 2004). Classifications were then ground truthed during fieldwork conducted at the three primary study sites (i.e., Little Sandy NWR, Dam B WMA, and Kurth Lake). For each alligator capture/recapture event (see Chapter I), a GPS location was obtained using a Garmin eTrex Legend Cx (Olathe, KS). At these locations, water depth (m), % emergent vegetation, % submergent vegetation, and % open water were estimated. These field measurements were overlaid with digitized habitat classifications using ArcGIS 9.2 (ESRI, Redlands, CA). Discrepancies between field measurements and digitized wetland classifications were then rectified in accordance to field measurements. To quantify macrohabitat characteristics, a 100m diameter circular plot (i.e., furthest distance hatchlings were found from nests within their first 6 months; Saalfeld et al., unpublished data) centered on nests or random points was created using ArcGIS 9.2 (ESRI, Redlands, CA). Within each plot, composition (%) of all habitat types (i.e., shallow marsh, deep marsh, open water, shoreline, and island) was estimated.

Hatchling Survival and Abundance

From 1 August 2006 – 1 August 2008, hatchling American alligators were captured, marked, and released at Little Sandy NWR using several capture techniques (i.e., snake tongs, hands, and nets). Although Allsteadt and Lang (1995b) 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], due to small genitalia size and low light conditions it was not possible to consistently and accurately obtain these measurements; so alligators < 50 cm were not sexed. For all captured individuals (regardless of size), the following morphological features were measured: total length (cm; ventral tip of snout to tip of tail), snout-vent length (cm; ventral tip of snout to proximal tip of vent), eye to nare length (cm), total head length (cm; dorsal tip of snout to distal part of head scute), tail girth (cm, circumference of tail directly behind rear legs), right hind leg length (cm), chest girth (cm; circumference of chest directly behind front legs), and mass (g; only obtained for individuals < 50 kg). All length measurements were obtained using a flexible tape measure and mass was obtained using a Pesola® hanging scale (Baar, Switzerland) for individuals > 50 cm or an Ohaus Scout® Pro digital scale (Pine Brook, NJ) for those < 50 cm. All alligators were uniquely marked by at least two of the following: dorsal tail-scute removal, numbered Monel tags (#681 Monel tags for alligators > 152 cm; #1 Monel tags for alligators < 152 cm), or passive integrated transponder (PIT) tags.

DATA ANALYSIS

Nest Success

Raw nest success was estimated using a standard proportion (i.e., number of successful nests divided by total number of nests) for each study site and year. In addition, the Mayfield Method (Mayfield 1975) in Program Mark (Dinsmore et al. 2002) was used to calculate modified nest success and variables influencing nest success. A 60 day incubation period (mean incubation period among alligator nests found during this study) was used to extrapolate daily survival rates to nest success estimates. Because nest success is a transformed variable (i.e., daily nest survival extrapolated to a 60 day incubation period), in order to obtain variance estimates, the delta method was used (Seber 1982). Daily survival was modeled with an *a priori* candidate set of 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. Correlated variables ($P > 0.05$) were not permitted to occur in the same model. Akaike's Information Criterion corrected for small sample size (AICc) was used to rank the model(s), where models were considered plausible if ΔAICc < 2 (Burnham and Anderson 2002). Additionally, parameter likelihoods, estimates, and standard errors were calculated using model averaging.

Nest Site Selection

Logistic regression (PROC LOGISTIC; SAS Institute 1999) was used to determine habitat (i.e., both micro and macro) variables most predictive of nest sites. A set of *a priori* candidate models was developed that included biologically relevant combinations of the following habitat variables: surrounding vegetation (i.e., percent composition of herbaceous plants, woody plants, bare ground, and water), elevation, canopy cover, basal area, distances to water, nearest tree, habitat type (i.e., open water, shoreline, or island), distance to potential feeding areas (i.e., shallow marsh, and deep marsh), and percent composition of surrounding habitat (i.e., % island, % shallow marsh, % deep marsh, % shoreline, and % open water). Correlated variables were not permitted in the same models ($P > 0.05$). Akaike's Information Criterion corrected for small sample size (AIC_c) was used to rank the model(s). Models were considered plausible if ΔAICc < 2 (Burnham and Anderson 2002). Additionally, parameter likelihoods, estimates, and standard errors were calculated using model averaging. Hosmer and Lemeshow goodness-of-fit statistic (PROC LOGISTIC; SAS Institute 1999) was used to test model fit.

Hatchling Abundance and Survival

From mark-recapture data of hatchling alligators, hatchling abundance in 2006 and 2007 at Little Sandy NWR was estimated using a modified Jolly-Seber model (i.e., POPAN; Jolly 1965, Seber 1965, Schwarz and Arnason 1996) in Program Mark. Candidate models for hatchling abundance included combinations of apparent survival (φ), recapture probability (p), and probability of entrance (*pent*) that were allowed to vary over time (i.e., 15 parameters were entered into the model representing a separate estimate for apparent survival, recapture probability, and/or probability of entrance between sampling occasions) or remain constant (i.e., one parameter was entered into the model representing a constant estimate of apparent survival, recapture probability, and/or probability of entrance over all sampling occasions). Weekly estimates of apparent survival, probability of recapture, and probability of entrance were obtained by collapsing mark/recapture data into one-week sampling periods (i.e., several nights of sampling within a week were collapsed into one measure of whether or not an individual was captured during the week-long sampling period). However, because not every week was sampled, time intervals between sampling periods were adjusted in Program Mark. For example, alligators were not captured from the end of October until April. Therefore, the time interval between these sampling periods was adjusted to 32 (i.e., 32 weeks between sampling periods), and this time interval was used in Program Mark to provide weekly estimates of apparent survival and probability of recapture. Akaike's Information Criterion corrected for small sample size (AICc) was used to rank the model(s). Models were considered plausible if ΔAICc < 2 (Burnham and Anderson 2002). Goodness-of-fit was performed in Program RELEASE to determine if the global model fit the data well and to check for data overdispersion (Burnham et al. 1987). Overdispersion was estimated using $\hat{c}$, where $\hat{c} = \chi^2$ / degrees of freedom from Program RELEASE (Burnham et al. 1987).

Yearly and weekly apparent survival and the probability of recapture were estimated in Program Mark using Cormack-Jolly-Seber models (Cormack 1964, Jolly 1965, Seber 1965). Candidate models for apparent survival were run separately for each year and included combinations of φ and 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 over all sampling occasions). Weekly estimates of apparent survival and probability of recapture were obtained by collapsing mark/recapture data into one week sampling periods similar to above. Akaike's Information Criterion corrected for small sample size (AICc) was used to rank the model(s). Models were considered plausible if ΔAICc < 2 (Burnham and Anderson 2002). Goodness-of-fit was performed in Program RELEASE (Burnham et al. 1987) to determine if the global model fit the data well and to check for data overdispersion.

Overdispersion was estimated using $\hat{c}$, where $\hat{c} = \chi^2$ / degrees of freedom from Program RELEASE (Burnham et al. 1987).

RESULTS

Nest Success

From 27 June – 21 September 2006 – 2008, a total of 30 American alligator nests (10 in 2006, 17 in 2007, and 3 in 2008) were discovered (Figure 2.2), majority (60%) of which were located from 18 July – 2 August. Most nests were discovered at Little Sandy NWR (26 nests), with only 2 nests discovered at both Murchison Lake (secondary study site) and Dam B WMA. An additional 18 successful nests (5 at Kurth Lake [1 in 2006 and 4 in 2007] and 13 at Little Sandy [6 in 2006 and 7 in 2007]) were found after hatching (i.e., found by locating pods). Because these nest locations were found later in the year (i.e., late September – October), they were not included in the microhabitat analysis due to potential changes in vegetation and water levels. However, these nests were included in the macrohabitat analysis.

Alligator nests were documented to hatch from 27 August – 21 September, with most nests (63%) hatching the first week of September (Figure 2.3). Overall, raw nest success was 53.3% combined among all years (20.0% for 2006, 71.4% for 2007, and 100% for 2008; however, only 3 nests were located in 2008). Of the 14 unsuccessful nests, 5 were predated by raccoons, 2 were predated by feral hogs (*Sus scrofa*), and 7 inundated and never hatched. Overall Mayfield estimate of nest success was 44.2%

(95% CI = 25.1 – 63.1%) using a 60 day incubation period. The Mayfield 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%). A Mayfield estimate could not be calculated for 2008 due to limited sample size ($n = 3$). On average, nests were observed for 46 days (range 13 – 70 days). Not all nests were discovered upon initiation, but nests discovered early during incubation were incubated for an average of 60 days (longest a successful nest incubated was 64 days).

Successful nests had larger nest circumferences, were closer to water, were further from trees, and had less canopy cover than unsuccessful nests (Table 2.1). From the nest success analysis in Program Mark (Dinsmore et al. 2002), among the 23 models, the first two models should be considered plausible (i.e., ΔAICc < 2; Burnham and Anderson, 2002). The top model (AIC_c relative wt [AIC_w] = 0.444) was the additive model of the linear time trend and nest circumference (Table 2.2; Figure 2.4). The second-best model ($\Delta AIC_c = 1.86$, $AIC_w = 0.18$) was the additive model of the linear time trend, year, and nest circumference (Table 2.2; Figure 2.5 – 2.6). Parameter likelihoods illustrated that the linear time trend (likelihood = 0.99; estimate = -0.09, SE = 0.04), year (likelihood = 0.32; estimate = 0.15, SE = 0.26), and nest circumference (likelihood = 0.85; estimate = 0.01, SE = 0.01) were the most important parameters to be included in the top model. From both models, nest success declined as time during incubation increased, as nest circumference decreased, and was higher in 2007 than 2006 (Figures 2.4 – 2.6).

Nest Site Selection

Alligators selected nest sites that were located on islands, had few large trees (i.e., counted in basal area calculation), and were further from open water and in close proximity to shallow marsh habitat than random sites (Table 2.3). Among the population of 24 models developed using logistic regression, the best model ($AIC_w = 0.870$) was the additive model of % shallow water, distance to open water, and distance to nearest tree (Table 2.4). The parameter likelihoods illustrated that % shallow water (likelihood = 0.910; estimate = 0.079, SE = 2.649), distance to nearest tree (likelihood = 0.966; estimate = -0.012, SE = 2.782), and distance to open water (likelihood = 0.959; estimate = 0.015, SE = 2.767) were the most important parameters to be included in the top model. The top model (i.e., y = -0.619 + 0.032 [% shallow water] – 0.002 [distance to nearest tree] + 0.004 [distance to open water]) indicated that probability of a nest increased as % shallow marsh vegetation increased, distance from open water habitat increased, and distance to nearest tree decreased. Hosmer and Lemeshow goodness-of-fit statistic ($\hat{c} = 0.76$, $\chi^2 = 6.07$, $P = 0.639$) indicated a good fit.

Hatchling Survival and Abundance

A total of 271 unique hatchlings were caught at Little Sandy NWR from 2006 – 2008, with 192 recaptures events comprised of 118 different individuals. In 2006, 62 hatchlings were captured with 39 recaptures, and in 2007, 209 hatchlings were captured with 153 recaptures. Hatchling alligators were caught from 19 different pods with number of individuals caught per pod ranging from 2 – 24 hatchlings. Among four Cormack-Jolly-Seber models, the top hatchling survival model was the same for 2006 and 2007. In both years, the top model included constant survival but probability of recapture varying over time (Table 2.5 and Figure 2.7). From these, apparent weekly survival was estimated to be 0.95 for 2006 and 0.98 for 2007 and probability of recapture ranged from 0.08 – 0.63 for 2006 and 0.02 – 0.22 for 2007 (Table 2.6). Therefore, cumulative yearly survival was estimated to be 6% for hatchlings born in 2006 and 43% for hatchlings born in 2007. Estimates of $\hat{c}$ from Program RELEASE (Test 2 + Test 3) were 0.59 for 2006 ($\chi^2 = 10.01$, $P = 0.900$) and 0.74 for 2007 ($\chi^2 = 34.22$, $P = 0.900$), indicating good fit.

Among four Jolly-Seber models, the top model for estimating hatchling abundance was the same in 2006 and 2007. In both years, the top model of hatchling abundance included constant survival and recapture rates and probability of entrance varying across time (Table 2.7). From these, estimated hatchling abundances at Little Sandy NWR were 278 (95% CI = 151 – 585 hatchlings) in 2006 and 418 (95% CI = 345 – 529 hatchlings) in 2007, apparent weekly survival was estimated to be 0.93 for 2006 and 0.98 for 2007, and probability of recapture ranged from 0.08 – 0.37 for 2006 and 0.04 – 0.23 for 2007 (Table 2.8). Because hatchling alligators enter the population at approximately the same time and few if any move between populations, probability of entrance was only estimated for the first time interval with a value of 0.95 for 2006 and 0.95 for 2007 (Table 2.8). Estimates of $\hat{c}$ from Program RELEASE (Test 2 + Test 3) were 0.59 for 2006 ($\chi^2 = 10.01$, $P = 0.900$) and 0.74 for 2007 ($\chi^2 = 34.22$, $P = 0.900$), indicating a good fit.

DISCUSSION

Alligator nest success is directly influenced, either singly or in combination, by predation (Fleming et al. 1976, Metzen 1977, Goodwin and Marion 1978, Deitz and Hines 1980, Joanen and McNease 1989, Hunt and Ogden 1991, Platt et al. 1995), local habitat conditions (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). The magnitude and/or importance of all of these factors will vary among geographic regions and wetlands, as nest success varies spatiotemporally from 46 – 74% (Joanen 1969, Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Joanen and McNease 1989, Platt et al. 1995). Nest success (53%) estimated in this study is well within the range of previous estimates, albeit slightly lower than coastal Louisiana (68.3%; Joanen, 1969) and north-central Florida (62.0% – 67.9%; Goodwin and Marion 1978, Deitz and Hines 1980), but similar to southern Georgia (48.3% – 74.2%; Ruckel and Steele 1984) and southeastern Louisiana (46.6%; Platt et al. 1995).

Similar to previous studies (Fleming et al. 1976, Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Kushlan and Jacobsen 1990, Platt et al. 1995), the two primary causes of alligator nest failures were predation 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 predated, presumably by raccoons. Conversely, in 2007, when water levels were higher, more nests were discovered and no nests were known to be predated. As water levels declined in 2006, access to islands (i.e., where most nests were located in 2006) theoretically 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, etc.) 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), nest failure or predation occurred during the later stages of incubation (i.e., after the seventh week). Nest success declined as time during the nesting season progressed (Figure 2.4 – 2.6). 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 due to a rain event (> 25 cm in 7 days; National Weather Service precipitation data) atypical for east Texas in summer (i.e., late July). 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 decomposing vegetation that barely rose above typical water levels, making nests located on these islands 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 a 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 of nests from predators. As water levels rarely rise naturally during the nesting season, placing nests close to water on islands will likely increase 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/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. Finally, water removal during the nesting season may reduce shallow marsh habitat, decreasing the amount of safe foraging grounds for hatchlings and increasing the risk of predation or cannibalism for hatchlings from nests that successfully hatch.

Several studies (Metzen 1977, Deitz and Hines 1980, Hunt and Ogden 1991) reported hatching success for undefended nests was lower than defended nests in which females aggressively defended and attended (Joanen 1969, Joanen and McNease 1970, Metzen 1977, Deitz and Hines 1980, Kushlan and Kushlan 1980, Hunt and Ogden 1991). For example, Hunt (1987) estimated predation to be 88% on unguarded nests and 17% on guarded nests in Okefenokee Swamp, Georgia. In this study, only casual observations of alligator nest attendance and defense were made, and as nests were typically approached by boat, nest attendance and defense may be underestimated. Nonetheless, aggressive female displays were still documented at 13% of nests (with 50% hatching) and female attendance (including defended nests) occurred at 40% of nests (with > 67% hatching). Female attendance and defense could be an important factor in nest success and may warrant more specific attention in future work.

Factors that influence alligator nest site selection and construction are complex and poorly understood. Social interactions with conspecifics, vegetation type at nest site, temperature, proximity of site to water, exposure to sunlight, and height above water level have been hypothesized to influence nest site selection (Ferguson 1985). In this study, alligators selected nest sites on heavily vegetated islands, close to trees (< 4 m), further (> 150 m) from open water, and in areas with a high percentage of shallow marsh habitat (~ 50%). Use of islands, as opposed to shoreline or levees, has been previously documented in Texas (Hayes-Odum et al. 1993), and may provide nesting alligators with increased protection from potential predation (Fleming et al. 1976, Hayes-Odum et al. 1993) and convenient access to feeding areas for both hatchlings and attending adults. Islands were often located near adult feeding areas (e.g., wading bird rookeries), and attending females may remain close to their nest while foraging and simultaneously providing adequate nest defense and protection. Moreover, islands are typically surrounded by shallow marsh habitat, where their physical location may reduce human disturbance and provide greater cover for hatchlings, increase hatchling feeding efficiency, and increase hatchling survival due to infrequent use of shallow marsh by larger alligators (Chabreck 1965, Goodwin and Marion 1979, Woodward et al. 1987, Delany 1990). Nest sites located further from open water with abundant shallow marsh may help protect hatchling alligators from larger male alligators occurring in open water habitat, and reduce the risk of cannibalism (Nichols et al. 1976, Goodwin and Marion 1979).

Avoidance of flooding is also likely a key component to alligator nest site selection, where nests are typically placed above the high water mark and range from 3.8 m from the water’s edge in Okefenokee Swamp, Georgia (Hunt 1987), to 2.1 – 11.5 m in southern Georgia (Ruckel and Steele 1984), to 4.8 m in southeastern Louisiana (Platt et al. 1995), and to 3.4 m in northcentral Florida (Goodwin and Marion 1978). However, nests in this study were located < 1 m from the water’s edge; much closer than any previous estimates. Although nests placed close to water may be more protected from predators and minimize distance hatchlings must travel to the water after hatching, risks of inundation during high water events are elevated (Jennings et al. 1987, Joanen and McNease 1989, Platt et al. 1995). For example, nearly 25% of nest failures were due to flooding, and female nest attendance/defense cannot improve success or reduce risks of failure due to random flooding events. Water levels in east Texas wetlands are usually at their peak during spring and typically decline throughout the summer. Therefore, alligators may place nests close to water as levels are at their highest during the time of nest construction and perhaps due to the low perceived risk of inundation in most years. However, alligators are unable to ameliorate the effects of high water events (i.e., by placing nests further from the water's edges), making nests more susceptible to flooding (Platt et al. 1995).

Alligator nest site selection may also be related to microclimate for egg development. Sex determination in all crocodilians, including American alligators, is dependant upon egg incubation temperature prior to hatching (Ferguson and Joanen 1982, Lang and Andrews 1994), with the range of viable incubation temperatures occurring between 28 – 35°C (Rhodes and Lang 1996). In alligators, the temperature dependent sex determination pattern for alligators is female-male-female (Rhodes and Lang 1996). For example, cooler (≤ 31.5°C) and warmer (≥ 35.0°C) incubation temperatures exclusively produce females, while intermediate temperatures (32.5°C – 33.0°C) produce exclusively males (Allsteadt and Lang 1995a), and transitional temperatures result in mixed sex ratios (Lang and Andrews 1994). Nest temperatures are affected by habitat, rainfall, air temperature, decomposition heat, nest composition, time of nesting, and metabolic embryo heat (Chabreck 1973, Magnusson 1979, Ferguson and Joanen 1983, Webb et al. 1983, Hutton 1987, Lang et al. 1989, Schulte and Chabreck 1990, Hayes 1992, Campos 1993). Therefore, nest locations with a large shade tree as found in this study could aid in temperature regulation of nests and eggs as well as thermoregulation of attending females (Jennings et al. 1987). For example, Campos (1993) found yacare caiman (*Caiman crocodilus yacare*) nests located in forested habitats were much better insolated from temperature changes than nests on floating grass mats. Although nest temperatures were not measured in this study, a shaded nest is likely more protected from desiccation and lethal egg temperatures (i.e., > 35°C), benefits that are exacerbated in east Texas, where ambient temperatures are often > 37°C in non-forested areas. Beyond gender, nest temperatures influence hatchling size, body mass, growth rates, and yolk mass due to site specific variability in incubation temperatures (Ferguson and Joanen 1983, Joanen et al. 1987, Webb and Cooper-Preston 1989, Allsteadt and Lang 1995a). As nest microclimate is a key element of alligator nest success, sex ratios, and hatchling survival; availability and quality of appropriate nesting habitat are key elements to maintain population structure.

Analogous to nest success and nest site selection, 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, widely ranging annual apparent survival rates ranged from 12 – 41% in northcentral Florida (12 – 31% using minimum known alive, Deitz and Hines 1980, 41% using 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 born in 2006, to 43% (within range of previous studies) for those born in 2007. However, it should be noted that Jolly-Seber estimates combine mortality and emigration. As such, true survival rates may be higher, although hatchling emigration within their first year is unlikely. Dramatic differences in annual survival rates observed in this study are likely due to a one time event occurring during winter and spring of 2006 – 2007 at Little Sandy NWR. A mechanical harvester (i.e., a large boat with rotating saw-like blades) was used to remove aquatic vegetation, and during this process, several (i.e., ~ 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 impacted this cohort's survival. With the removal of vegetative cover by the mechanical harvester, hatchling mortality may have also increased due to decreased vegetative cover to conceal them from predators. 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 is important for water quality and habitat management in east Texas water bodies, adjusting timing of such operations will be important to minimize impacts on juvenile alligators (any time during the annual cycle) and sluggish adults (if executed during winter).

MANAGEMENT IMPLICATIONS

Within east Texas wetlands, nest success and hatchling survival (excluding 2006) estimates were comparable to other geographic regions (Joanen 1969, Goodwin and Marion 1978, Deitz and Hines 1980, Ruckel and Steele 1984, Woodward et al. 1987, Joanen and McNease 1989, Platt et al. 1995). Number of nests located, number of successful nests, and hatchling survival were variable among years, where such variation could impact age and size structure of local alligator populations. Therefore, alligator management within east Texas wetlands should address nesting habitat enhancement, water level management, and development/modification of harvest regulations that account for temporal variation in hatchling survival and nest success.

Historically, a majority of the islands and riparian zones surrounding east Texas wetlands were suitable habitat for nesting alligators, where alligators nest on vegetated islands or elevated levees surrounded by shallow marsh habitat. Such habitats are declining regionally, replaced by manicured wetland edges, trails encircling lakes, river channelization, and elimination of oxbows and backwater areas. Most of the vegetated islands at Little Sandy NWR and Dam B WMA are dominated by dense stands of Chinese tallow, effectively limiting physical space for nesting alligators. Moreover, most nesting islands at Dam B WMA are surrounded by exotic invasive aquatic plants such as salvinia, alligatorweed, and water hyacinth, all of which combine to reduce available nesting habitat and limit shallow water habitats critical for hatchling survival. Removal of exotic invasive plants should be encouraged in order provide important habitat for nesting alligators and hatchlings.

Two common techniques for the removal aquatic vegetation are spraying with herbicides and mechanically harvesting, both of which if not properly timed or at the right intensity can negatively impact alligator populations. For example, at Dam B WMA, removal of exotic invasive plants is done exclusively by spraying herbicides. However, large mats of decomposing plant material can lead to sharp decreases in dissolved oxygen levels, especially in shallow water, leading to fish kills and decreased prey abundances. Therefore, control of aquatic invasive species should be done early in the season (e.g., spring) when temperatures are lower and the impact on dissolved oxygen levels would be less severe. However, if spraying is to occur in warmer, summer months, spraying smaller patches to create channels in shallow water habitat may be more effective. By spraying small patches, dissolved oxygen levels may not decline as severely and patches may be opened for alligators to access foraging areas. Additionally, removal of exotic invasive plants can be accomplished with the aid of a mechanical harvester. However, use of this technique should only be applied during the warmer months when alligators have enough energy to avoid mortality inflicted from the harvester. Additionally, mechanical harvesters should be used only in deeper water, away from shoreline and islands, so additional disturbance or mortality is not inflicted to nesting females and hatchlings.

Alligators cannot *a priori* account for unseasonable floods during the nesting season, which often result in nest failures. In reservoirs like Dam B WMA, water levels fluctuate based upon management goals rather than precipitation. Such fluctuations can negatively impact both alligator nests and hatchlings. If water levels drop, shallow marsh habitat may become reduced, thereby, exposing nests and/or hatchling alligators to increased risks of predation and/or cannibalism. Conversely, if water levels stay high for extended periods of time, nests could be flooded. To promote better nest success and hatchling survival, water levels within reservoirs should remain consistent during the nesting season (i.e., July – September). By keeping water at constant levels, female alligators can safely select nest sites above high water marks and shallow marsh habitat for hatchlings will remain available. Although water levels can be maintained by varying rates of discharge, this may not be possible in every year or at every wetland containing alligators. Therefore, it remains important to understand the relationship between water levels, nest success, and hatchling survival and to incorporate water levels into population and harvest models for American alligators.

Alligators harvest regulations need to accommodate variability in nest success by including site specific yearly estimates of nest success into harvest models. Not accounting for spatial and temporal variation in nest success could result in unsustainable and/or over-harvest. 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 D WMA since 1997 (~ 17 alligators/year), however, < 15 alligators (~ 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 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. For example, in years when few pods are located and/or water levels rise dramatically during the nesting season, a more conservative quota can be set.

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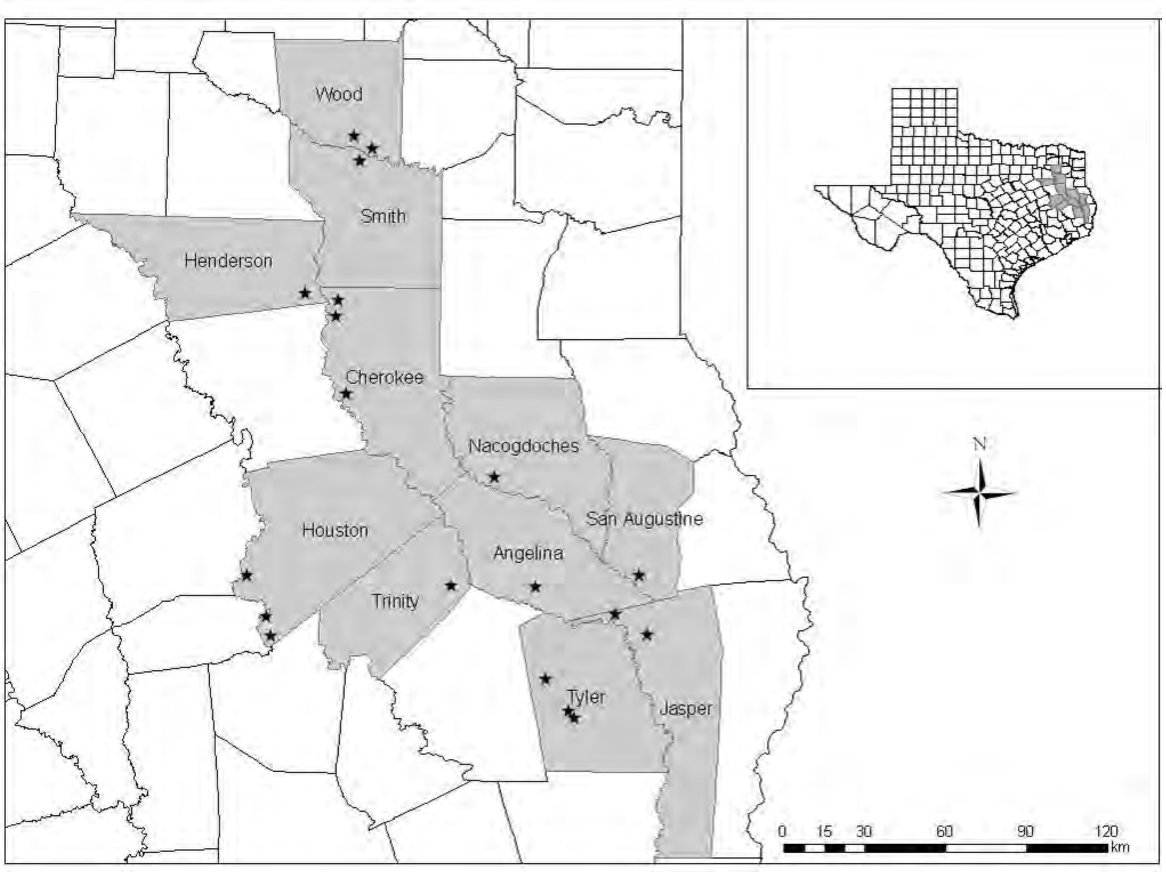

Figure 2.1. Counties and secondary study site locations (indicated by star) within east Texas where American alligator (*Alligator mississippiensis*) nest surveys were conducted in 2007 – 2008.

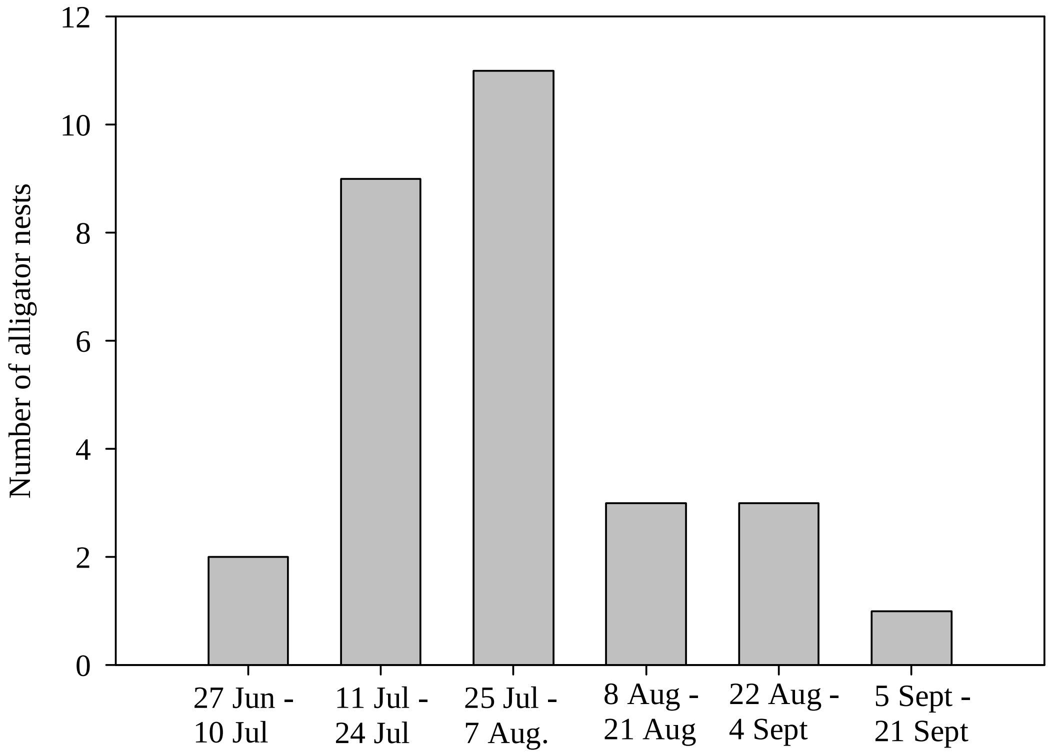

Figure 2.2. Number of American alligator (*Alligator mississippiensis*) nests located within wetlands of east Texas, 2006 – 2008.

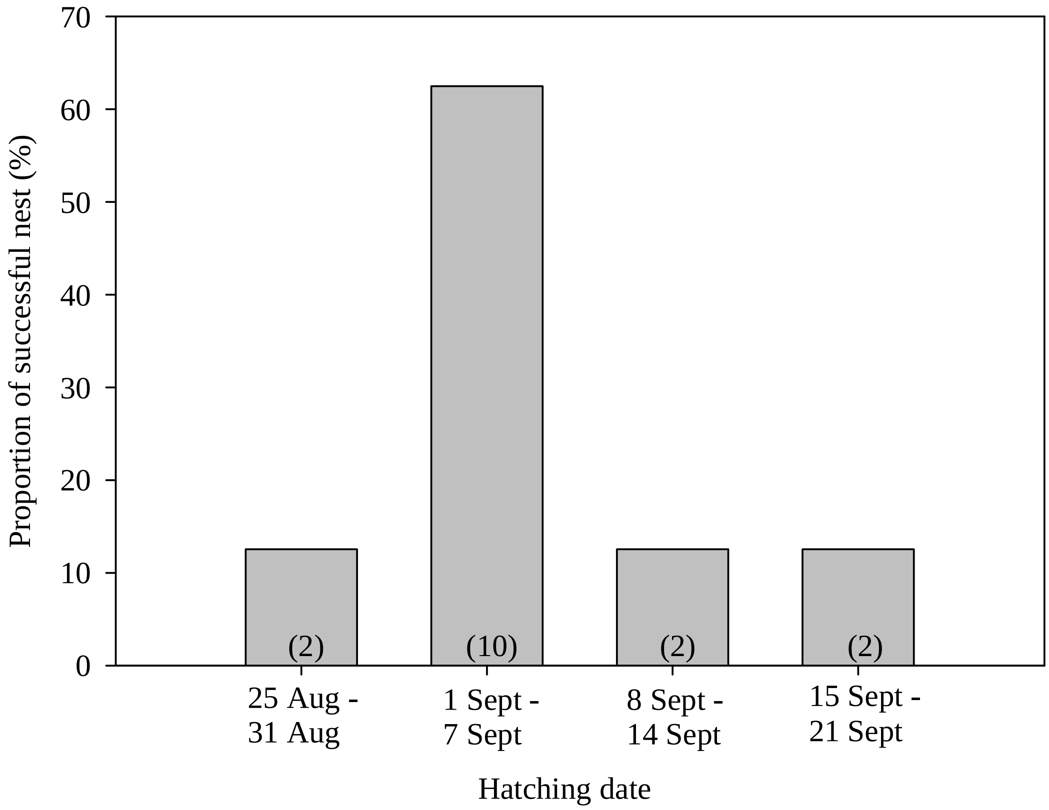

Figure 2.3. Percentage of successful American alligator (*Alligator mississippiensis*) nests located within east Texas wetlands, 2006 – 2008. Numbers in parentheses correspond to number of successful alligator nests within each time period.

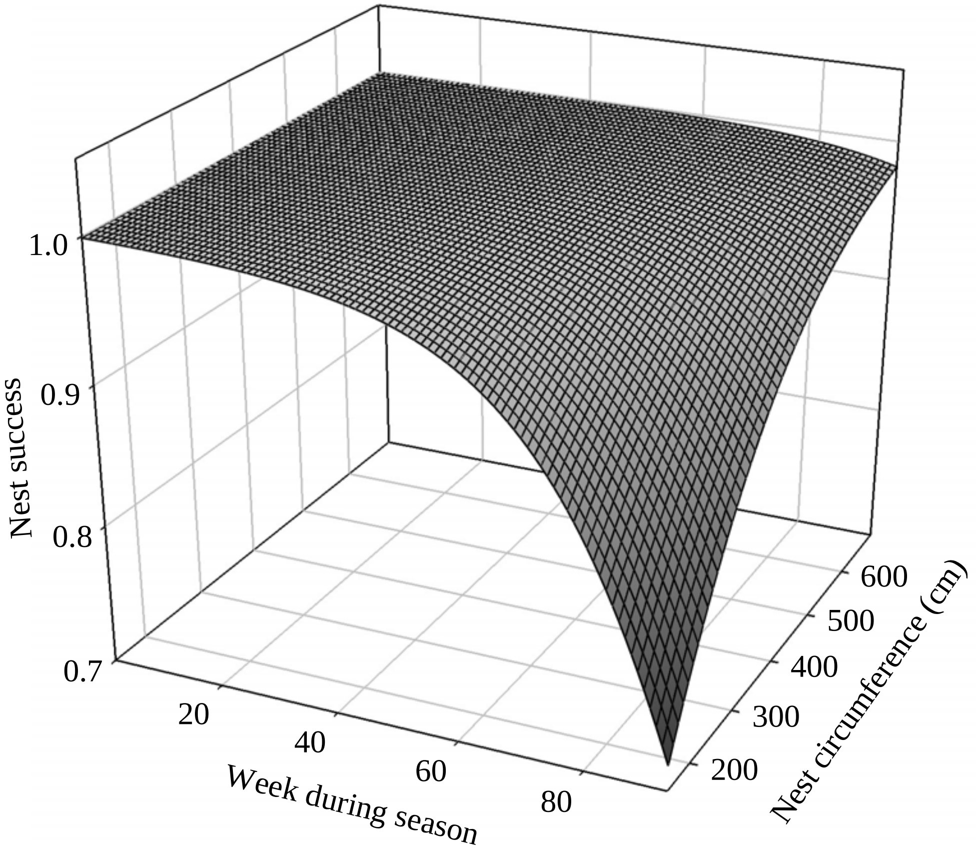

Figure 2.4. Nest success of American alligators (*Alligator mississippiensis*) as predicted from model = S (linear time trend + nest circumference) in wetlands of east Texas, 2006 – 2007.

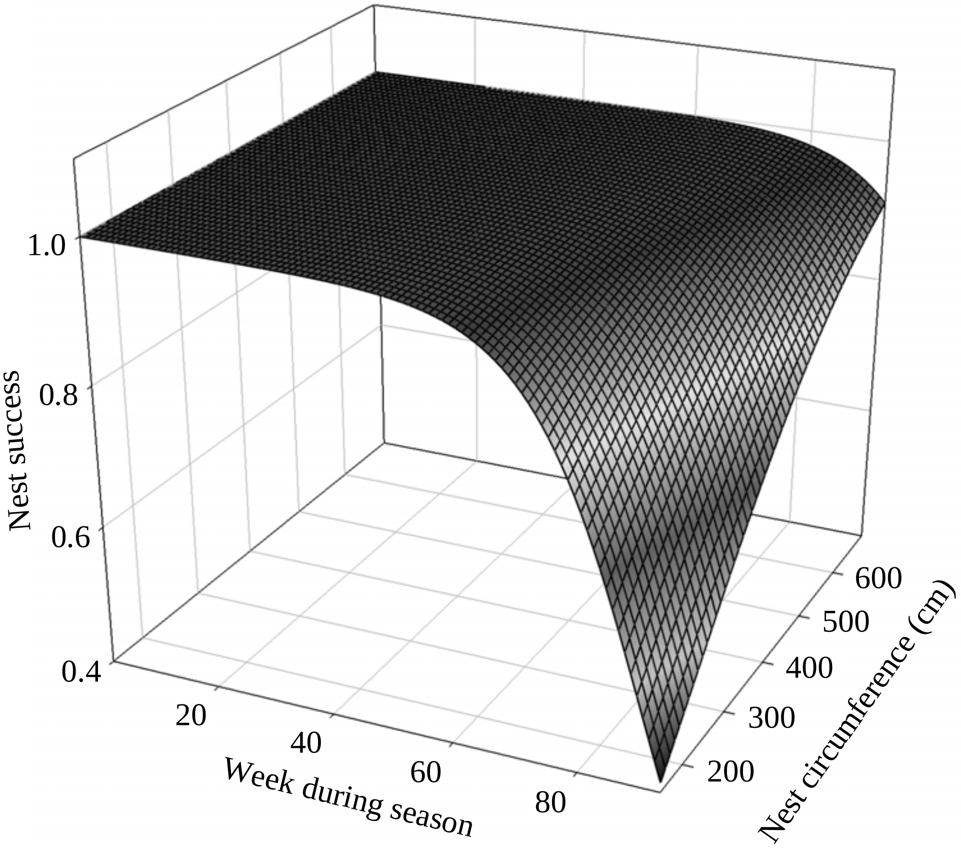

Figure 2.5. Nest success of American alligators (*Alligator mississippiensis*) as predicted from model = S (linear time trend + nest circumference + year) in wetlands of east Texas, 2006.

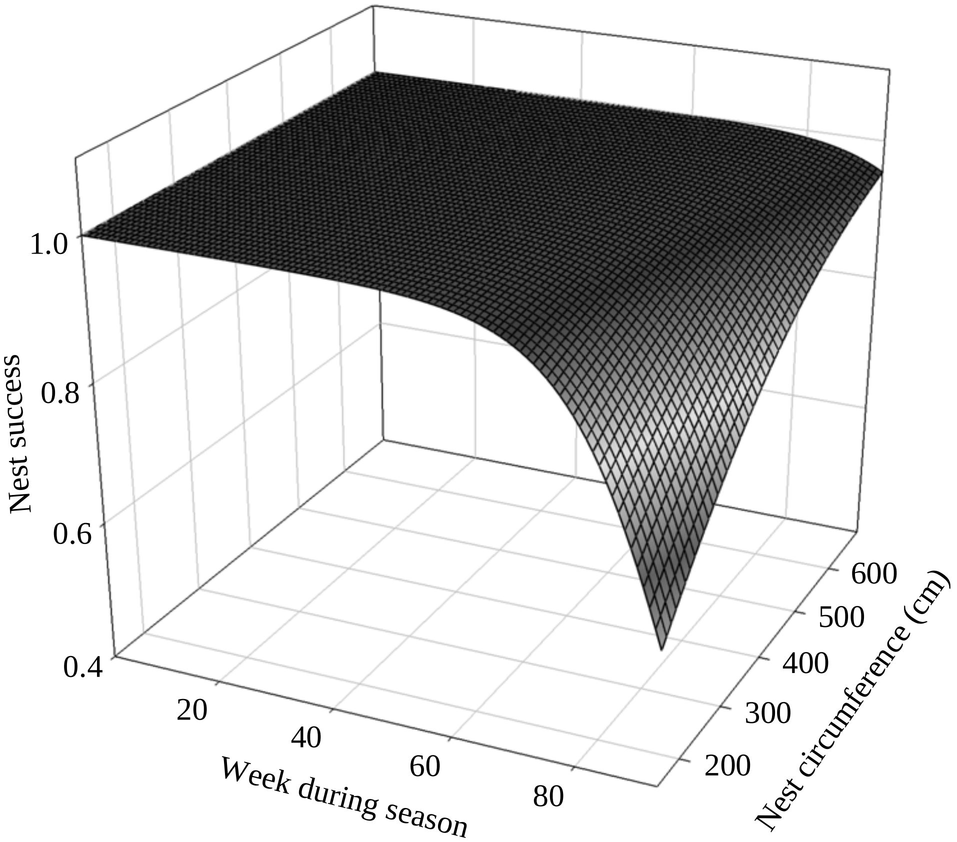

Figure 2.6. Nest success of American alligators (*Alligator mississippiensis*) as predicted from model = S (linear time trend + nest circumference + year) in wetlands of east Texas, 2007.

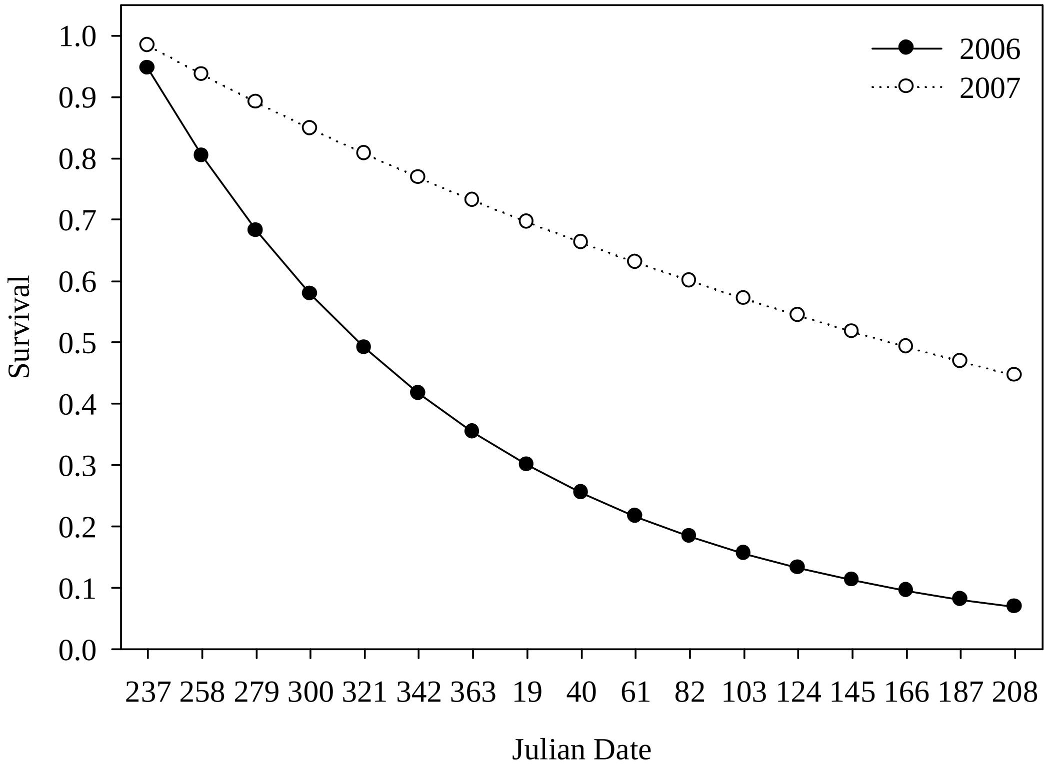

Figure 2.7. Weekly estimates of survival rates for hatchling American alligators (*Alligator mississippiensis*) born in 2006 and 2007 at Little Sandy National Wildlife Refuge, Texas.

Table 2.1. Means ($\bar{x}$) and standard errors (SE) of variables potentially influencing success of American alligator (*Alligator mississippiensis*) nests within east Texas wetlands, 2006 – 2008.

	Successful (n = 16)		Unsuccessful (n = 14)	
	$\bar{x}$	SE	$\bar{x}$	SE
Nest circumference (cm)	381.1	34.1	317.6	38.3
Nest height (cm)	75.9	6.4	75.7	6.0
Elevation (m)	91.8	0.9	93.4	2.1
Basal area (m^2/ha)	2.2	0.6	3.1	0.9
Canopy cover (%)	32.2	8.8	45.7	10.3
Distance to water (cm)[a]	29.3	11.8	41.1	94.5
Distance to nearest tree (cm)	218.0	72.8	81.3	26.5
Distance to shore (m)	134.0	45.5	93.3	23.1

[a] Distance between nest and water's edge when nest was located.

Table 2.2. Model results from nest success analysis of daily survival rates of American alligator (*Alligator mississippiensis*) nests within east Texas wetlands, 2006 – 2008.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
S (linear time trend + nest circumference)[c]	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 [d])	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

Table 2.2. Continued.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
S (year)	2	11.91	0.00
S (year x nest circumference)[e]	4	12.55	0.00
S (year x 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 (.)[f]	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

Table 2.2. Continued.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
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 and the lowest AIC_c value.

[b] AIC_c relative weight attributed to model.

[c] Model of additive effects of linear time trend, and nest circumference.

[d] Distance between nest and water's edge when nest was located.

[e] Model of additive effects of year and nest circumference and the interaction.

[f] Model of no effects on nest survival.

Table 2.3. Means ($\bar{x}$) and standard errors (SE) of habitat variables potentially influencing nest site selection of American alligators (*Alligator mississippiensis*) within east Texas wetlands, 2006 – 2008.

	Nest		Random	
Variable	$\bar{x}$	SE	$\bar{x}$	SE
Microhabitat (n = 30)[a]				
Elevation (m)	92.5	1.1	91.9	0.7
Basal area (m^2/ha)	2.6	0.6	1.6	0.5
Canopy cover (%)	38.5	6.7	29.5	6.8
Herbaceous (%)[b]	50.7	6.1	64.4	5.4
Woody (%)	29.0	4.2	17.6	4.4
Water (%)	7.0	2.9	6.7	1.9
Bare ground (%)	13.3	3.2	11.3	2.5
Distance to water (cm)[c]	34.8	7.6	32.6	11.0
Distance to nearest tree (cm)	349.7	101.4	832.0	114.0
Distance to shore (m)	134.0	45.5	93.3	23.1
Distance to shallow marsh (m)	18.0	2.7	26.9	10.6
Distance to open water (m)	152.5	35.6	70.0	17.7
Distance to island (m)	38.6	18.7	50.2	15.9
Distance to deep marsh (m)	65.8	10.3	68.3	16.0

Table 2.3. Continued.

	Nest		Random	
Variable	$\bar{x}$	SE	$\bar{x}$	SE
Macrohabitat (n = 48)[d]				
Deep marsh (%)	11.0	3.0	9.4	2.4
Island (%)	13.5	3.8	19.1	3.6
Open water (%)	10.8	3.1	17.0	3.6
Shallow marsh (%)	47.6	5.5	26.3	4.0
Shoreline (%)	17.0	5.0	28.2	5.4

[a] Microhabitat data collected within a 1/100 ha plot centered on each nest and random point.

[b] Habitat percent composition within 1/100 ha plot centered on each nest and random point.

[c] Distance between nest and water's edge when nest was located.

[d] Macrohabitat data estimated in ArcGIS 9.2 (ESRI, Redlands, CA) within a 100 m diameter plot centered on each nest and random point.

Table 2.4. Logistic regression models for variables predicting nest site selection of American alligator (*Alligator mississippiensis*) nests within east Texas wetlands, 2006 – 2008.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
% shallow water + distance to nearest tree + distance to open water[c]	4	0.00	0.87
Distance to open water + distance to nearest tree	3	5.01	0.07
% shallow water + distance to open water	3	8.28	0.01
% shallow water	2	8.35	0.01
Distance to nearest tree	2	8.46	0.01
% shallow water + distance to nearest tree	3	9.03	0.01
Distance to open water	2	13.19	0.00
Intercept[d]	2	13.56	0.00
% woody vegetation	2	14.17	0.00
% herbaceous vegetation	2	14.78	0.00

Table 2.4. Continued.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
% shoreline	2	15.37	0.00
Basal area	2	15.73	0.00
% open water	2	15.90	0.00
% island	2	16.55	0.00
% canopy cover	2	16.79	0.00
Distance to shallow marsh	2	16.97	0.00
Distance to shore	2	17.03	0.00
Elevation	2	17.45	0.00
% bare ground	2	17.45	0.00
Distance to island	2	17.46	0.00
% deep marsh	2	17.49	0.00

Table 2.4. Continued.

Model	No. parameters	ΔAIC_c[a]	AIC_w[b]
Distance to water[e]	2	17.67	0.00
Distance to deep marsh	2	17.68	0.00
% water	2	17.68	0.00

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

[b] AIC_c relative weight attributed to model.

[c] Model of additive effects % shallow water, distance to nearest tree, and distance to open water.

[d] Model of no effects on nest site selection.

[e] Distance between nest and water's edge when nest was located.

Table 2.5. Cormack-Jolly-Seber models for 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		
Year	φ	p	No. parameters	$\Delta \mathrm{AIC}_c$[b]	AIC_w[c]
2006	*c*	*t*	16	0.00	0.96
	c	*c*	2	6.12	0.04
	t	*c*	16	26.74	0.00
	t	*t*	29	46.02	0.00
2007	*c*	*t*	16	0.00	1.00
	t	*t*	29	12.47	0.00
	c	*c*	2	48.58	0.00

Table 2.5. Continued.

	Model structure[a]		Model statistics		
Year	φ	p	No. parameters	ΔAIC_c[b]	AIC_w[c]
	t	c	16	55.61	0.00

[a] Model factors included: $c = \varphi$ or p remain constant among sampling intervals and $t = \varphi$ and p vary among sampling intervals.

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

[c] AIC_c relative weight attributed to model.

Table 2.6. Cormack-Jolly-Seber parameter estimates, standard errors (SE), and 95% confidence intervals (CI) for apparent survival (φ) and probability of recapture (p) by sampling interval (i.e., an estimate for each period between sampling events) from the top model of hatchling American alligators (*Alligator mississippiensis*) captured at Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
2006	φ	1 – 15 [a]	0.947	0.009	0.925 – 0.963
	p	1	0.000[b]	0.000	0.000 – 0.000
	p	2	0.000	0.000	0.000 – 0.000
	p	3	0.000	0.000	0.000 – 0.000
	p	4	0.000	0.000	0.000 – 0.000
	p	5	0.366	0.135	0.156 – 0.643
	p	6	0.137	0.090	0.034 – 0.416
	p	7	0.352	0.129	0.152 – 0.623
	p	8	0.194	0.102	0.063 – 0.462
	p	9	0.319	0.120	0.136 – 0.581
	p	10	0.200	0.105	0.065 – 0.474
	p	11	0.283	0.124	0.106 – 0.566
	p	12	0.151	0.100	0.037 – 0.451

Table 2.6. Continued.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
	p	13	0.080	0.078	0.011 – 0.409
	p	14	0.085	0.083	0.012 – 0.4280
	p	15	0.630	0.189	0.257 – 0.8932
2007	φ	1 – 15 [a]	0.984	0.003	0.975 – 0.989
	p	1	0.000	0.000	0.000 – 1.000
	p	2	0.054	0.031	0.018 – 0.156
	p	3	0.000	0.000	0.000 – 0.000
	p	4	0.167	0.048	0.092 – 0.283
	p	5	0.218	0.044	0.143 – 0.317
	p	6	0.137	0.034	0.083 – 0.218
	p	7	0.032	0.016	0.012 – 0.083
	p	8	0.119	0.030	0.072 – 0.191
	p	9	0.031	0.016	0.012 – 0.081
	p	10	0.133	0.031	0.083 – 0.207
	p	11	0.119	0.029	0.073 – 0.188
	p	12	0.023	0.013	0.007 – 0.068

Table 2.6. Continued.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
	p	13	0.090	0.026	0.051 – 0.155
	p	14	0.045	0.018	0.020 – 0.097
	p	15	0.152	0.033	0.097 – 0.229

[a] Apparent survival remained constant among sampling intervals.

[b] Parameter estimates = 0.000 indicate a parameter that was unable to be estimated or the parameter estimate approached 0.

Table 2.7. Modified Jolly-Seber models for survival (*φ*), probability of recapture (*p*), and probability of entrance (*b*) of hatchling American alligators (*Alligator mississippiensis*) captured at Little Sandy National Wildlife Refuge in east Texas, 2006 – 2008.

	Model structure[a]			Model statistics		
Year	*φ*	*p*	*b*	No. parameters	ΔAIC_c[b]	AIC_w[c]
2006	*c*	*t*	*t*	32	0.00	0.77
	c	*c*	*t*	18	2.44	0.23
	t	*c*	*t*	32	28.93	0.00
	t	*t*	*t*	45	68.54	0.00
2007	*c*	*t*	*t*	32	0.00	1.00
	t	*t*	*t*	45	12.44	0.00
	t	*c*	*t*	32	56.10	0.00

Table 2.7. Continued.

	Model structure[a]			Model statistics		
Year	φ	*p*	*b*	No. parameters	ΔAIC_c[b]	AIC_w[c]
	c	*c*	*t*	18	64.03	0.00

[a] Model factors included: $c = \varphi$ or p remain constant among sampling intervals and $t = \varphi$ and p vary among sampling intervals.

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

[c] AIC_c relative weight attributed to model.

Table 2.8. Modified Jolly-Seber parameter estimates, standard errors (SE), and 95% confidence intervals (CI) for apparent survival (φ), probability of recapture (p), and probability of entrance (b) by sampling interval (i.e., an estimate for each period between sampling events) for the top models of hatchling American alligator (*Alligator mississippiensis*) abundances at Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
2006	φ	1 – 15[a]	0.933	0.010	0.909 – 0.950
	p	1	0.040	0.019	0.016 – 0.098
	p	2	0.000[b]	0.000	0.000 – 0.000
	p	3	0.114	0.044	0.052 – 0.233
	p	4	0.359	0.109	0.181 – 0.587
	p	5	0.352	0.112	0.172 – 0.587
	p	6	0.110	0.074	0.027 – 0.351
	p	7	0.400	0.121	0.199 – 0.641
	p	8	0.242	0.170	0.092 – 0.500
	p	9	0.320	0.121	0.136 – 0.584
	p	10	0.203	0.106	0. 066 – 0.480
	p	11	0.291	0.127	0.109 – 0.578

Table 2.8. Continued.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
	p	12	0.158	0.105	0.038 – 0.467
	p	13	0.086	0.083	0.012 – 0.429
	p	14	0.092	0.090	0.012 – 0.454
	p	15	0.694	0.208	0.250 – 0.939
	b	1	0.953	0.021	0.889 – 0.981
	b	2 – 15[c]	0.000	0.000	0.000 – 0.000
2007	φ	1 – 15[a]	0.979	0.004	0.971 – 0.985
	p	1	0.089	0.017	0.061 – 0.128
	p	2	0.088	0.017	0.060 – 0.127
	p	3	0.062	0.014	0.040 – 0.095
	p	4	0.229	0.033	0.171 – 0.300
	p	5	0.203	0.032	0.147 – 0.272
	p	6	0.178	0.031	0.126 – 0.247
	p	7	0.046	0.016	0.023 – 0.090
	p	8	0.111	0.025	0.070 – 0.171
	p	9	0.042	0.016	0.020 – 0.086

Table 2.8. Continued.

Year	Parameter	Sampling interval	Estimate	SE	95% CI
	p	10	0.159	0.031	0.107 – 0.230
	p	11	0.100	0.025	0.061 – 0.161
	p	12	0.038	0.016	0.017 – 0.084
	p	13	0.098	0.026	0.058 – 0.161
	p	14	0.040	0.016	0.018 – 0.088
	p	15	0.143	0.032	0.091 – 0.218
	b	1	0.950	0.012	0.920 – 0.969
	b	2 – 15[c]	0.000	0.000	0.000 – 0.000

[a] Apparent survival remained constant among sampling intervals.

[b] Parameter estimates = 0.000 indicate a parameter that was unable to be estimated or the parameter estimate approached 0.

[c] Sampling intervals 2 – 15 are not able to be estimated or the parameter estimate approached 0.

CHAPTER III

GROWTH AND CONDITION OF AMERICAN ALLIGATORS IN INLAND WETLANDS OF EAST TEXAS

INTRODUCTION

Somatic growth is a fundamental biological process necessary for survival, enabling an organism to increase in body size from an embryo to a reproductive adult (Arnott et al. 2006). The rate at which somatic growth occurs varies among endothermic and ectothermic organisms, but also among and within a species, and throughout an individual's life, all of which are attributable to many external (e.g., temperature, food abundance, and competition) and internal (e.g., age, hormones, and genetics; Abrams et al. 1996, Arnott et al. 2006) factors. Among ectotherms, temperature and energetics may be important factors controlling growth (Hawkins 1986, Sweeney and Vannote 1986). Growth rates of ectotherms tend to increase with increasing temperatures to some physiological limit (Avery 1994). However, higher temperatures entail greater metabolic costs, especially for animals of relatively large mass (Avery 1994). Rapid growth is generally perceived as beneficial, where attaining larger body size more quickly than conspecifics may increase fitness, improve predator avoidance, and increase competitive ability, reproductive success, and/or survival (Roff 1992, Arnott et al. 2006). The optimal life history strategy for a species is one that maximizes lifetime reproduction, which is determined by maximizing age-specific survival and fecundity (Roff 1992). For many organisms it is size, rather than age, that determines both survival probability and fecundity; such species' optimal life history strategy would favor faster growth rates to increase lifetime fitness.

American alligators (*Alligator mississippiensis*) are long-lived (i.e., up to 80 years), reach sexual maturity at a minimum size rather than age (i.e., > 1.8 m in total length), and exhibit a size related social hierarchy, where larger individuals can prevent smaller ones from entering the breeding population (Joanen and McNease 1975, Hunt 1990, Hall 1991). Although both sexes are capable of reproduction at 1.8 m, most breeding is achieved by individuals > 2.1 m (Joanen and McNease 1975, Wilkinson 1983), although minimum length at sexual maturity is likely variable among populations and geographic regions. Rapid growth is beneficial for alligators, as fast growth rates are beneficial to juvenile survival (Jacobsen and Kushlan 1989, Brandt 1991, Rootes et al. 1991) and allow individuals to reach breeding size at a younger age (i.e., shorter time to sexual maturity; Jacobsen and Kushlan 1989, Rootes et al. 1991).

Growth rates and time to sexual maturity vary among populations and geographic regions (Hines et al. 1968, Deitz 1979, Jacobsen and Kushlan 1989, Brandt 1991, Dalrymple 1996, Wilkinson and Rhodes 1997), and have been described for populations in South Carolina (Brandt 1991, Wilkinson and Rhodes 1997), Louisiana (Chabreck and Joanen 1979, Elsey et al. 1992), Florida (Hines et al. 1968, Deitz 1979, Jacobsen and Kushlan 1989, Dalrymple 1996, Temsiripong 1999), and east Texas (Webb 2005, Saalfeld et al. 2008). In general, alligator growth rates are known to be influenced singularly or concomitantly by growing season length (Coulson et al. 1973, Bara 1977, Murphy 1977, Deitz 1979, Jacobsen and Kushlan 1989, Brandt 1991, Temsiripong 1999), habitat (Deitz 1979, Andrews 1982, Jacobsen and Kushlan 1989, Brandt 1991, Rootes et al. 1991), population densities (Saalfeld et al. 2008), food availability (Coulson et al. 1973, Deitz 1979, Jacobsen and Kushlan 1989, Dalrymple 1996), thermoregulation (Jacobsen and Kushlan 1989, Avery 1994), and incubation conditions (Joanen et al. 1987, Deeming and Ferguson 1989, Schulte and Chabreck 1990). Growth rates typically increase with growing season length (Hines et al. 1968, Chabreck and Joanen 1979), but growth can slow or stop altogether during a prolonged growing season with high ambient temperatures, which elevate metabolic costs (Jacobsen and Kushlan 1989, Dalrymple 1996). Overall, greater food availability (Deitz 1979, Rootes et al. 1991, Dalrymple 1996), better habitat quality (Deitz 1979), favorable incubation temperatures (i.e., 30.6 C or 31.7 C; Joanen *et al.* 1987), and lower population densities (Saalfeld et al. 2008) typically increase growth rates.

Although alligators reach sexual maturity at a minimum length, if they are not in good condition (i.e., index derived from the relationship between length and mass) upon reaching sexual maturity, they may not be able to compete for mates or other limiting resources (i.e., territories, food, basking spots, and/or den sites). Relative condition factors or indices of condition are measures of relative fatness of individuals within a population (Hutton 1987), and can indicate how well individuals and/or a population is existing within a particular environment (Taylor 1979). Although condition has not been widely quantified nor commonly reported in alligator research (Brandt 1989, Elsey et al.

1992, Dalrymple 1996, Delany et al. 1999, Rice 2004), within east Texas, alligators have been documented growing faster but in poorer condition than previous studies (Saalfeld et al. 2008). Despite this shorter time to sexual maturity (due to faster growth rates) in east Texas, if alligators are in poor condition upon reaching sexual maturity, they may be unable to reproduce and compete for limited resources (e.g., optimum nesting sites and prey). This could have important management implications for long term viability of alligator populations, particularly those exposed to regulated hunting pressure.

Growth rate and condition estimates are key elements for development of any alligator conservation and management strategy, although local and regional estimates are needed due to extreme variability in both parameters throughout its geographic range. Unfortunately, few long-term data sets exist for alligator populations range-wide (Nichols 1987), further complicating current alligator management strategies. For example, management of harvested alligator populations may be more complicated than other species, where the impacts of alligator harvest may be strongly driven by the lack of (or inability to incorporate) age, size, and/or sex related harvest restrictions. Additionally, inland Texas alligator harvest management strategies are based upon assumptions that inland and coastal alligators exist at similar densities and exhibit similar growth rates (Webb 2005). As resource availability, alligator densities, and growing season length generally vary between coastal and inland wetlands (Saalfeld et al. 2008, Webb et al. 2009), growth rates and condition also likely vary regionally. Therefore, determining growth rates and body condition on a larger scale remains important for implementing alligator harvest management strategies throughout all of east Texas. Thus, the objectives of this study were to quantify growth rates and body condition of inland alligators within 3 wetlands in east Texas and determine any potential differences between sexes or among wetlands and size classes.

METHODS

Study Area

This research was conducted at three wetlands in east Texas (Angelina-Neches/Dam B Wildlife Management Area [Dam B WMA], Kurth Lake, and Little Sandy National Wildlife Refuge [NWR]; Figure 1.1). Dam B WMA is 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 (Figure 1.2). Dam B WMA is characterized by riverine, open lake, and shallow marsh habitats (Webb 2005, Webb et al. 2009). Dominant aquatic plants include water hyacinth (*Eichhornia crassipes*), common salvinia (*Salvinia minima*), giant salvinia (*S. molesta*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticellata*), smartweeds (*Polygonum* spp.), and yellow pond lily (*Nuphar luteum*). Dominant woody species along wetland margins are baldcypress (*Taxodium distichum*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), Chinese tallow (*Triadica sebifera*), water oak (*Quercus nigra*), overcup oak (*Q. lyrata*), water tupelo (*Nyssa aquatica*), and pine (*Pinus* spp.; Godfrey and Wooten 1981).

Kurth Lake is 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; Saalfeld et al., unpublished data) and a few shallow bays with isolated pockets of emergent marsh (Figure 1.3). Dominant aquatic species are American lotus (*Nelumbo lutea*), hydrilla, coontail (*Ceratophyllum demersum*), and yellow pond lily. Dominant woody species along wetland margins are buttonbush, black willow, Chinese tallow, water oak, overcup oak, and pine (Godfrey and Wooten 1981).

Little Sandy NWR consists of 1,539 ha, of which ≈ 1100 ha are bottomland hardwood forest, located on the northern bank of the Sabine River in southern Wood County. Little Sandy NWR contains four main lentic bodies: Overton Lake, Brumley Lake, Bradford Lake, and Beaver Lake. Of these, only Overton Lake (an impoundment of Jim Ned Creek) and Brumley Lake (an impoundment of Little Sandy Creek) were used as study sites. Overton Lake is approximately 175 ha and Brumley Lake is approximately 200 ha. Both lakes are connected by several creeks and canals, essentially making these two lakes one large wetland. Hereafter, these two lakes will be referred to as Little Sandy NWR. Little Sandy NWR is characterized primarily by shallow marsh with little open water or creek channels (Figure 1.4). Dominant aquatic species are American frog-bit (*Limnobium spongia*), American lotus, Carolina fanwort (*Cabomba caroliniana*), coontail, cutgrass (*Zizaniopsis miliacea*), and yellow pond lily. Woody species include Chinese tallow, buttonbush, black willow, and southern wax myrtle (*Morella cerifera*; Godfrey and Wooten 1981).

Capture and Handling

From 1 April – 31 October, 2003 – 2008, American alligators were captured, uniquely marked, and released at Dam B WMA, Kurth Lake, and Little Sandy NWR using several capture techniques (i.e., snake tongs, pole snares, hands, and swim in live traps; see Webb 2005 for complete capture descriptions). During capture sessions, efforts were made to capture all individuals sighted resulting in equal capture effort for successive captures (Deitz 1979). At night, spotlights affixed with red filters were used to locate alligators with a 4.9 m Go-Devil® boat outfitted with a 20 hp Go-Devil® mud motor. Alligators < 125 cm were captured using snares, tongs, or hands, while swim-in live traps (Ryberg and Cathey 2004) were used to capture larger alligators (> 1.6 m). Traps, baited with chicken or fish, were deployed in areas where alligators had been observed, set during afternoon or evening, and left open for at least a 24-hour period. Each trap was checked at 0000 h and by 1000 h the following morning.

Upon capture, alligators were restrained with duct tape, and each individual > 50 cm in total length was sexed 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, due to small genitalia size and low light conditions it was not possible to consistently and accurately obtain these measurements; so alligators < 50 cm were not sexed. For all captured individuals (regardless of size), the following morphological features were measured: total length (cm; ventral tip of snout to tip of tail), snout-vent length (cm; ventral tip of snout to proximal tip of vent), eye to nare length (cm), total head length (cm; dorsal tip of snout to distal part of head scute), tail girth (cm, circumference of tail directly behind rear legs), right hind leg length (cm), chest girth (cm; circumference of chest directly behind front legs), and mass (g; only obtained for individuals < 50 kg). All length measurements were obtained using a flexible tape measure and mass was obtained using a Pesola® hanging scale (Baar, Switzerland) for individuals > 50 cm or an Ohaus Scout® Pro digital scale (Pine Brook, NJ) for those < 50 cm. All alligators were uniquely marked by at least two of the following: dorsal tail-scute removal, numbered Monel tags (#681 Monel tags for alligators > 152 cm; #1 Monel tags for alligators < 152 cm), or passive integrated transponder (PIT) tags. All aforementioned morphological features were also measured for all recaptured alligators. In addition, a GPS location was obtained using a Garmin eTrex Legend Cx (Olathe, KS) for each capture/recapture. Water temperatures were also obtained each time an alligator was captured using an YSI data logger (model number: 556 MPS) with a water temperature probe (Yellow Springs, OH)

DATA ANALYSIS

Growth Rates and Body Condition Estimation

Growth rates were estimated using total length (TL), as measured from tip of snout to tip of tail; snout to vent length was not used as no tail loss was documented (Chabreck and Joanen 1979, Wilkinson and Rhodes 1997, Saalfeld et al. 2008). As alligator growth rates are not constant (Chabreck and Joanen 1979, Rootes et al. 1991), annual growth rates were adjusted according to growing season duration as indicated by air and water temperatures. Alligator growing season length was estimated using average daily air temperature (data obtained from the National Climate Data Center; http://cdo.ncdc.noaa.gov/) and water temperatures (data obtained from YSI data logger). Average daily air temperatures were regressed against water temperatures in order to fill in gaps when water temperatures were not obtained. Assuming that alligators within east Texas wetlands grew after water temperatures exceeded 20 – 23°C (Brisbin et al. 1982, Coulson and Hernandez 1983), growing season length was calculated for each year by summing the number of days water temperatures were > 20°C. Growing season was estimated to be 214 days (i.e., 1 April – 31 October) based upon water and ambient air temperatures (i.e., water temperature consistently > 20.0°C), with number of growing season days between recapture events ranging from 1 – 1360 days ($\bar{x}$ = 87.7 days).

Because growing season length was consistent across years (i.e., 2003 – 2008), mean growing season length for all years was used.

Daily growth (cm/day) for each recaptured individual was calculated by dividing change in TL by the number of growing days between captures. Individuals recaptured within 12 days of initial capture were excluded from subsequent analyses to eliminate any possible measurement error resulting in negative growth (Saalfeld et al. 2008). If an individual was recaptured in a different year (e.g., an alligator was marked in 2006, but not recaptured until 2008), change in TL was still divided by number of growth days between captures. Annual growth rates (cm/yr) were calculated by multiplying daily growth rates by growing season length. Intrinsic growth rate variable (k), maximum attainable length (L_∞), and age at maturity (assumed to be 1.83 m, McIlhenny 1934, Giles and Childs 1949, Joanen and McNease 1975, Klause 1984) were estimated through the construction of von Bertalanffy, logistic, and Gompertz growth curves (Chabreck and Joanen 1979, Jacobsen and Kushlan 1989, Elsey et al. 1992). Each growth curve was fitted similar to Fabens' (1965) modification of a von Bertalanffy growth curve for mark/recapture data without known ages. Values for k and L_∞ were estimated by iterated least squares methods using nonlinear regression (PROC NLIN; SAS Institute 1999). Akaike's Information Criterion (AIC) was used to select the best, most parsimonious growth curve to fit the data (Akaike 1973).

Body condition (K; Le Cren 1951), an index of the relative fatness of an animal and also an indicator of its well being/health (Taylor 1979), was estimated from the relationship between length and mass using the equation: $K = M * L^{-b}$, where M = mass (g), L = total length (cm) and b = slope of the regression of ln (TL) and ln (M). If growth is isometric, b would be approximately equal to 3 (Le Cren 1951, Brandt 1991).

Statistical Analysis

A repeated measures full-factorial analysis of variance (ANOVA; PROC MIXED; SAS Institute 1999) repeated among capture events with a compound symmetric covariance structure was used to examine differences in growth rates among size classes (size class 1 < 50 cm [young of year; Chabreck and Joanen, 1979; Saalfeld et al., 2008], size class 2 = 50 – 125 cm [subadult or juveniles; Dalrymple, 1996; Saalfeld et al. 2008], size class 3 = 125.1 – 160 cm [non-breeding, often dispersing size class, and no longer considered a prey item except for larger alligators] and size class 4 > 160 cm [approximate minimum breeding size; Dalrymple, 1996]) wetlands, and between sexes, where sufficient sample sizes of recaptured individuals were available. An alpha level of 0.05 was maintained for these analyses and least squared means separation was used to examine differences ($P < 0.05$).

Additionally, a repeated measures full-factorial analysis of variance (ANOVA; PROC MIXED; SAS Institute 1999), repeated among capture events with a compound symmetric covariance structure was used to examine differences in condition among size classes (size class 1 < 50.0 cm, size class 2 = 50.1 – 125.0 cm, size class 3 = 125.1 –

160.0 cm, and size class 4 > 160.1 cm), wetlands, seasons (seasons were classified as spring [April – June], summer [July – September], and fall [October – December]) and between sexes, where sufficient sample sizes were available. An alpha level of 0.05 was maintained for these analyses and least squared means separation was used to examine differences ($P < 0.05$).

RESULTS

A total of 1064 American alligators ranging in size from 20.9 cm to 363.5 cm (TL) were captured, measured, marked, and released at Dam B WMA from 12 May 2003 – 31 October 2008 (excluding 2005), Little Sandy NWR from 1 July 2006 – 31 October 2008, and Kurth Lake from 19 June 2006 – 31 October 2008 (Table 3.1; Figure 3.1). Alligators were captured using tongs ($n = 182$), hand grabbing ($n = 658$), walk-in cage traps ($n = 74$), pole snare ($n = 127$), and other methods (i.e., dowel sets, ropes, and nets; $n = 23$). During this time, 472 individuals were recaptured, of which 313 were unique (Table 3.1), ranging in size from 25.4 cm to 292.1 cm (TL; Figure 3.2).

Mean growth rate for recaptured alligators was 32.5 cm/yr (SE = 1.0), irrespective of size class, wetland, and sex. There were no wetland * size class * sex ($F_{3, 18} = 0.72$; $P = 0.550$), wetland * size class ($F_{4, 18} = 0.52$; $P = 0.724$), or size class * sex ($F_{3, 18} = 0.19$; $P = 0.904$) interactions for alligator growth rates. With wetlands combined, male and female alligators grew at similar rates ($F_{1, 182} = 3.32$; $P = 0.070$), irrespective of size class. Growth rates varied among wetlands ($F_{2, 268} = 12.76$; $P < 0.001$), with alligators growing faster at Little Sandy NWR than Kurth Lake and Dam B WMA, where alligators grew at similar rates. Growth rates declined as alligator size ($y = -1.65x + 37.77$, $r^2 = 0.665$; Figure 3.3) and size class increased ($F_{3, 28} = 12.06$; $P < 0.001$; Table 3.2), irrespective of wetland and sex.

The best growth curve model for all data combined was the modified von Bertalanffy (Table 3.3). The modified von Bertalanffy growth curve (Figure 3.4) fitted to the combined mark/recapture data provided an estimate of 388.1 cm for L_∞ and 0.0003 for k, where the estimated time to maturity was 9 years. Growth model estimates of L_∞ and k varied among wetlands, where alligators at Dam B WMA ($L_\infty = 316.5$ cm) had a greater estimated maximum attainable length than alligators at Kurth Lake ($L_\infty = 247.3$ cm) or Little Sandy NWR ($L_\infty = 243.2$ cm; Figure 3.5 – 3.7). With wetlands combined, male alligators ($L_\infty = 317.3$ cm; k = 0.0004) had a greater asymptotic length (i.e., maximum attainable length) than females ($L_\infty = 255.8$ cm; k = 0.0.00563; Figure 3.8 – 3.9). However, estimated time to maturity (9 years) was similar between sexes. At Little Sandy NWR, similar length at age estimates were obtained from growth curve models and known age alligators (for ages 1 – 3), thereby validating growth models for these age classes within this wetland (Figure 3.10).

Condition for all size classes, sexes, and wetlands combined was 2.2 (SE = 0.1). There were no wetland * size class ($F_{6, 45} = 1.27$; $P = 0.289$), sex * size class ($F_{4, 45} = 1.01$; $P = 0.411$), wetland * sex ($F_{4, 135} = 0.67$; $P = 0.611$), or wetland * sex * size class ($F_{4, 45} = 1.27$; $P = 0.298$) interactions for alligator condition (Table 3.4). Condition varied among wetlands ($F_{2, 857} = 59.77$; $P < 0.001$), where alligators at Little Sandy NWR and Dam B WMA were in better condition than alligators at Kurth Lake. However, alligators at Dam B WMA and Little Sandy NWR were in similar condition. With all wetlands combined, condition increased as size increased ($y = 4.27x + 1.81$, $r^2 = 0.724$;

Figure 3.11). Condition varied among size classes ($F_{3, 59} = 11.26$; $P < 0.001$), where size class 4 alligators were in better condition than size classes 1 – 3. Male and female alligators were in similar ($F_{1, 546} = 0.01$; $P = 0.914$) condition irrespective of wetland, size class, year, or season. Alligators were in poor condition at the beginning of the growing season (i.e., April), but condition increased ($y = 0.05x + 1.83$; $r^2 = 0.859$; Figure 3.12) as the growing season progressed. Condition varied among seasons ($F_{2, 139} = 43.76$; $P < 0.001$), where alligators were in better condition in fall, than spring and summer, which were similar.

DISCUSSION

Growth rates of American alligators vary throughout their geographic range (Hines et al. 1968, Deitz 1979, Brandt 1991, Dalrymple 1996, Wilkinson and Rhodes 1997, Saalfeld et al. 2008). Food availability (Deitz 1979, Jacobsen and Kushlan 1989, Brandt 1991, Rootes et al. 1991, Dalrymple 1996), habitat (Brandt 1991, Rootes et al. 1991, Wilkinson and Rhodes 1997), growing season length (Coulson et al. 1973, Bara 1977, Murphy 1977, Deitz 1979, Jacobsen and Kushlan 1989, Brandt 1991, Temsiripong 1999), and population density (Brandt 1991, Saalfeld et al. 2008) will also independently or collectively influence growth rates, over short or long geographic distances. However, no studies have compared growth rates among wetlands in close proximity to each other (i.e., ≈ 80 – 240 km apart) to verify this assumption. In this study, alligators at Kurth Lake had lower growth rates and were in poorer condition than alligators at Little Sandy NWR and Dam B WMA, potentially due to inferior habitat (i.e. food) conditions at Kurth Lake (see Chapter IV). Furthermore, alligator densities at Kurth Lake (1.1 ha/alligator, ~262 alligators within wetland) are also lower than at Little Sandy NWR (0.4 ha/alligator, ~893 alligators within wetland), indicating that Kurth Lake may be unable to support as many alligators as other similar sized wetlands.

Alligators within east Texas use habitats with a mosaic of open water, floating vegetation, and emergent vegetation (Webb et al. 2009), where regionally suitable alligator habitat has been described as 20 – 40% open water, < 20% open water > 1.2 m deep, high interspersion, and ponded water < 15 cm deep (Newsom et al. 1987, Webb et al. 2009). Kurth Lake is primarily deep open water habitat (> 80 % open water; > 3 m deep) with very little shallow marsh habitat (i.e., areas < 1.2 m deep dominated by emergent and/or aquatic vegetation). Lack of shallow vegetated habitats tend to concentrate alligators, decrease ability to ambush prey, decrease capture efficiency, and therefore impede growth rates and negatively influence body condition (Delany and Abercrombie 1986). Alligators were caught from only 4 small coves (only areas with any shallow vegetated habitat) within Kurth Lake, which comprised < 5% of the total area of the lake. In contrast, alligators were not concentrated within Dam B WMA and Little Sandy NWR, where these wetlands were comprised of > 45% shallow marsh habitat. Because alligators are concentrated within these areas at Kurth Lake (i.e., estimated density within occupied areas was > 0.05 ha/alligator), growth rates and condition may be lower than other wetlands due to greater competition for food and other resources (i.e., territories, mates, basking spots, and/or den sites).

Previously, subadult alligators (< 125.0 cm in TL) at Dam B WMA (2003 – 2004) were documented growing more rapidly than most previous studies (29.4 cm/year; Saalfeld et al. 2008). This current study corroborated past results, as alligators grew 32.5 cm/year, faster than previous studies north of Shark Slough, Florida (31.0 cm/yr; Hines et al. 1968), Shark Valley region of Florida (13.3 cm/yr; Jacobsen and Kushlan 1989, 13.6 cm/yr; Dalrymple 1996), north Florida (11.9 – 21.1 cm/yr; Deitz 1979, and 24.0 cm/yr;

Temsiripong 1999), South Carolina (14.6 cm/yr; Bara 1977, 23.5 cm/yr; Brandt 1991, 18.0 – 20.2 cm/yr; Wilkinson and Rhodes 1997), and Louisiana (22.0 cm/yr; Chabreck and Joanen 1979). Although growth rates were lower for subadult alligators at Kurth Lake (20.6 cm/yr) than Little Sandy NWR and Dam B WMA, growth rates were still greater than or similar to most studies. Abundant shallow marsh habitat (at Dam B WMA and Little Sandy NWR) and a longer growing season (i.e., 214 day) without a thermally stressful period (e.g., Florida Everglades have a longer growing season but alligators experience thermally stressful periods that reduce growth rates) could result in faster growth rates as compared to other regions (Coulson et al. 1973, Bara 1977, Murphy 1977, Deitz 1979, Jacobsen and Kushlan 1989, Brandt 1991, Temsiripong 1999). Therefore, because water temperatures remain warmer for a longer period of time in fall and there are fewer thermally stressful time periods as compared to most other regions, alligators are able to feed for a prolonged period, resulting in faster growth rates.

Along with habitat and growing season, population density could also affect growth rates. Although no studies have specifically tested the influence of population densities on growth rates in alligators, some have speculated that growth rates are density dependent (Brandt 1991, Webb 2005). For example, if alligators exist at relatively high densities and food resources are limiting, competition for food may result in decreased growth rates. However, it is not known at what densities growth rates begin to slow. Therefore, although population densities at Little Sandy NWR (0.4 ha/alligator) may be higher than previous studies (Saalfeld et al. unpublished), it is unlikely (due to high reproductive success and survival of hatchlings; see Chapter II) that population size has reached a point where growth rates are negatively affected. Once populations reach that point, competition among conspecifics would increase, resulting in population parameters and life history characteristics such as reproductive success, survival of hatchlings, and growth rates to decline. However, because reproductive success and survival of hatchlings was similar to previous studies, it is unlikely that alligator densities have reached a level to negatively influence population and life history parameters.

Although alligators apparently achieve faster growth rates, alligators were in poorer condition ($\bar{x}$ = 2.2) as compared to previous studies (2.5; Temsiripong 1999, 2.7; Rice 2004). At Little Sandy NWR, high population densities may force potential trade-offs between growth and condition. Additionally, at Dam B WMA, where population densities are lower, alligators may have added stress due to fluctuating water levels, potentially affecting prey and habitat availability. Water levels within this reservoir are managed by the United States Army Corps of Engineers, where often conflicting management goals (e.g., flood control, drinking water downstream, electricity, and recreation) result in water levels fluctuating with no consideration for alligators. Fluctuating water levels can shift prey distributions and limit available habitat (i.e., limiting access or reducing shallow water habitat), making it difficult for alligators to find and access food. Additionally, fluctuating water levels often force alligators to feed in open water habitats, decreasing feeding efficiency. By having an inconsistently accessible prey source, alligators at Dam B WMA may also have to trade-off between growth rates and condition.

Estimates of asymptotic size (i.e., mean size at which growth stops; Wilkinson and Rhodes 1997) for male (3.2 m) and female (2.6 m) alligators within east Texas inland wetlands were lower than estimates for alligators in South Carolina (male = 3.8 m, female = 2.8 m; Wilkinson and Rhodes 1997), and coastal Louisiana (male = 4.2 m, female = 2.7 m; Chabreck and Joanen 1979, male = 3.7 m, female = 2.4 m; Rootes et al. 1991), suggesting that the size structure within this study was skewed to smaller individuals. As larger alligators can restrict smaller alligators from entering breeding population (Joanen and McNease 1975, Hunt 1990, Hall 1991), faster growth rates may be driven by smaller size class individuals attempting to reach breeding size quickly as they are no longer inhibited by larger adult alligators. However, when smaller non-dominant alligators breed, these populations can exhibit reduced clutch sizes, increased hatchling mortality, decreased nest success, and reduced growth rates (Ferguson 1985). Time to sexual maturity (9 years for both males and females) was shorter than the estimated 13 – 17 years for South Carolina (Murphy and Fuller 1982) and 13 – 18 years for the Everglades (Jacobsen and Kushlan 1989, Dalrymple 1996), but similar to the estimated 8 – 10 years for Louisiana (Joanen and McNease 1975;1987).

Discrepancies between growth rates and condition may also be influenced by harvest management strategies, where at both Dam B WMA and Little Sandy NWR, alligator harvests have removed many large individuals (> 2.8 m in TL) from the population. For example, 74 alligators > 2.8 m have been harvested from Dam D WMA since 1997. Since 1997, average size of harvested alligators has decreased from 3.0 m to < 2.3 m, possibly indicating the number of large, potentially dominant, individuals could be decreasing within this population (Saalfeld et al. unpublished data). When larger alligators are removed from a population, vacant breeding territories are created. As alligators reach sexual maturity at a minimum length rather than age, it may be beneficial for smaller alligators to grow fast, but remain in poor condition so they can reach breeding size in a shorter period of time. Upon reaching breeding length, alligators may slow linear growth, but increase condition (i.e., adding mass) to compete for or defend breeding territories and exploit new/larger food resources (Brandt 1991). If alligators are in poor condition when they reach maturity they may be less able to reproduce and compete for limited resources (e.g., optimum nesting sites and prey). However, as condition improves as length increases, alligators may still be in adequate condition for breeding upon reaching sexual maturity. For example, condition improved from 2.2 for non-breeding size individuals (< 1.6 m) to 2.5 for breeding sized individuals (> 1.6 m), where breeding size alligators were in similar condition to alligators in Florida (2.5; Temsiripong 1999, 2.7; Rice 2004). Therefore, alligators appear to be able to trade-off poor condition for increased growth rates in order to reach breeding size more quickly. After achieving breeding length, energy can they be put towards improving condition to aid in competing for mates, nest sites, and territories.

MANAGEMENT IMPLICATIONS

There are important geographic differences in age at maturity, condition, size structure, and growth rates among alligator populations, where such, regional differences could have dramatic effects on alligator population parameters such as recruitment, survival, and overall population size and age characteristics. Thus, it may be necessary to modify current management strategies as such variability in basic life history parameters likely requires regionally specific management guidelines. Population models need to be established that account for variability in size distributions, hatchling survival, nest success, population densities, and sex ratios. Without a better understanding of how these population parameters are affected by harvest, it is impossible to predict the sustainability of current harvest strategies.

Because growth rates and condition are intimately tied to food availability and quality, management should also focus upon maintaining a diversity of prey items. As such, conservation of diverse wetland habitats, removal of exotic invasive species, and maintaining consistent water levels should occur. Species such as water hyacinth, alligatorweed, and salvinia form large mono-specific stands, resulting in large areas of the wetland becoming inaccessible to alligators. These large mats within a wetland, limit food availability and reduce amount of shallow water habitat (where alligators more efficiently feed) accessible to alligators. Two common techniques for the removal of aquatic vegetation is spraying with herbicides and mechanically harvesting. Both of which, if not properly timed or at the right intensity could negatively influence alligator populations (see Chapter II and IV). Therefore, herbicide treatments should be applied during cooler month to avoid negative impacts to fish populations or applied to smaller areas during warmer months. Additionally, mechanical harvest of aquatic vegetation should take place during warmer months and away from nesting locations to minimize mortality of adult and hatchling alligators. In addition to removal of exotic invasive species, more consistent water levels could increase food availability. Fluctuating water levels can shift prey distributions and limit available habitat, making it difficult for alligator to find and access food. Additionally, fluctuating water levels often force alligators to feed in open water habitats, decreasing feeding efficiency. By keeping water levels from fluctuating dramatically throughout the growing season (i.e., April 1 – October 31), alligators would have a more consistent prey base that are in more predictable locations.

Faster growth rates and poor condition observed in this study could be the result of current harvest management strategies. Currently, non-selective harvest techniques (e.g., hook and line techniques used on Dam B WMA and Little Sandy) have dominated throughout east Texas. Due to non-selectivity of current harvest strategies, size structure of harvested alligators should reflect the natural size distribution. However, hunters typically place baits high above the water that only larger alligators are targeted. Therefore, at the three study sites, harvest has resulted in many of the large, most likely dominant, individuals being removed from the population (Texas Parks and Wildlife Department unpublished, Saalfeld et al. unpublished). By removing large, presumably dominant, individuals from the population, smaller alligators are no longer inhibited from breeding, potentially leading to decreased growth rates as well as decreased clutch size, hatchling survival, and nest success. Because of this, harvest strategies within these wetlands needs to be more selective (e.g., bow and arrow), where intermediate size classes (e.g., 1.2 – 1.8 m) are targeted to reduce populations that are at higher density and to lessen hunting pressure on dominant individuals.

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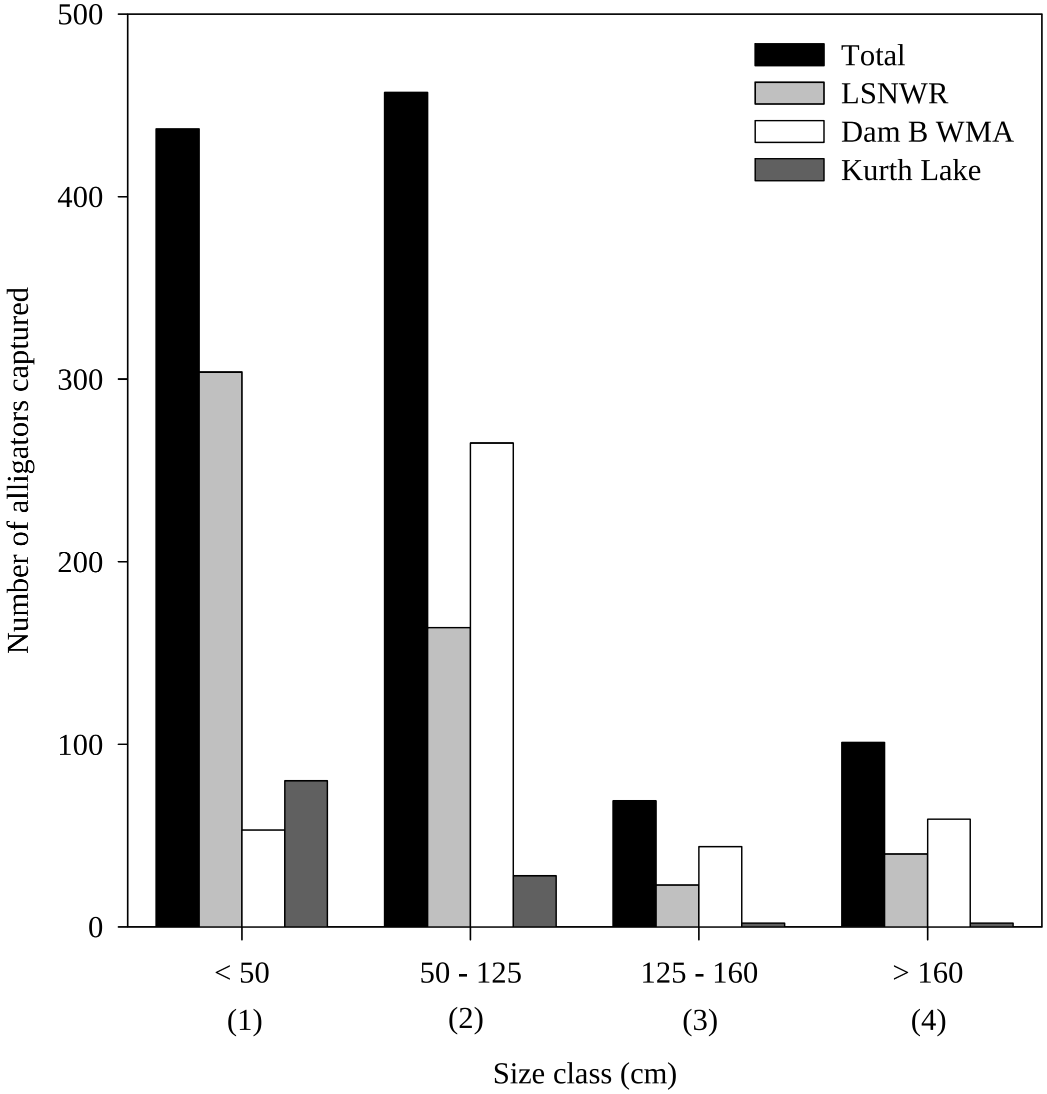

Figure 3.1. Number of American alligators (*Alligator mississippiensis*) captured by size class at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2003 – 2008.

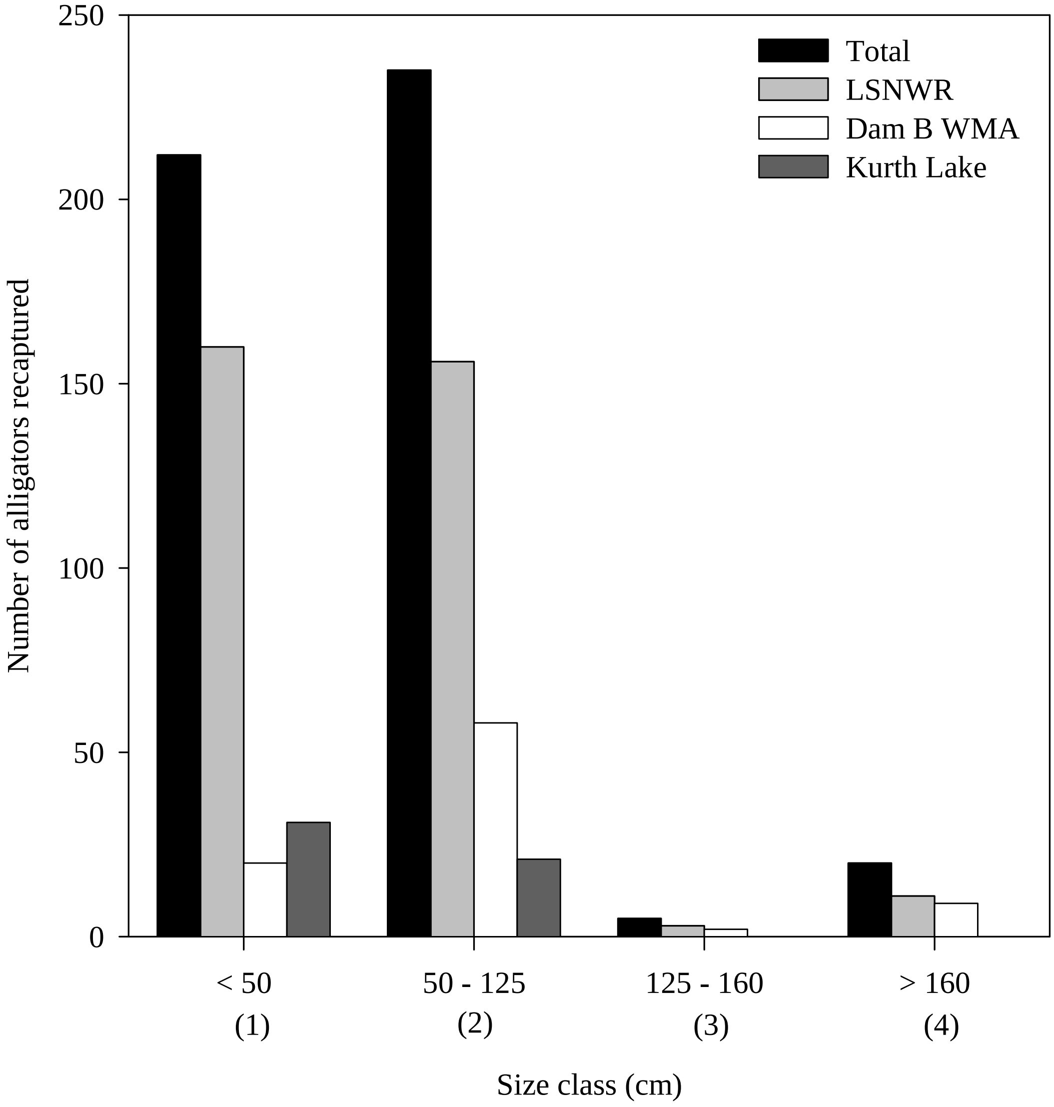

Figure 3.2. Number of American alligators (*Alligator mississippiensis*) recaptured by size class at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2003 – 2008.

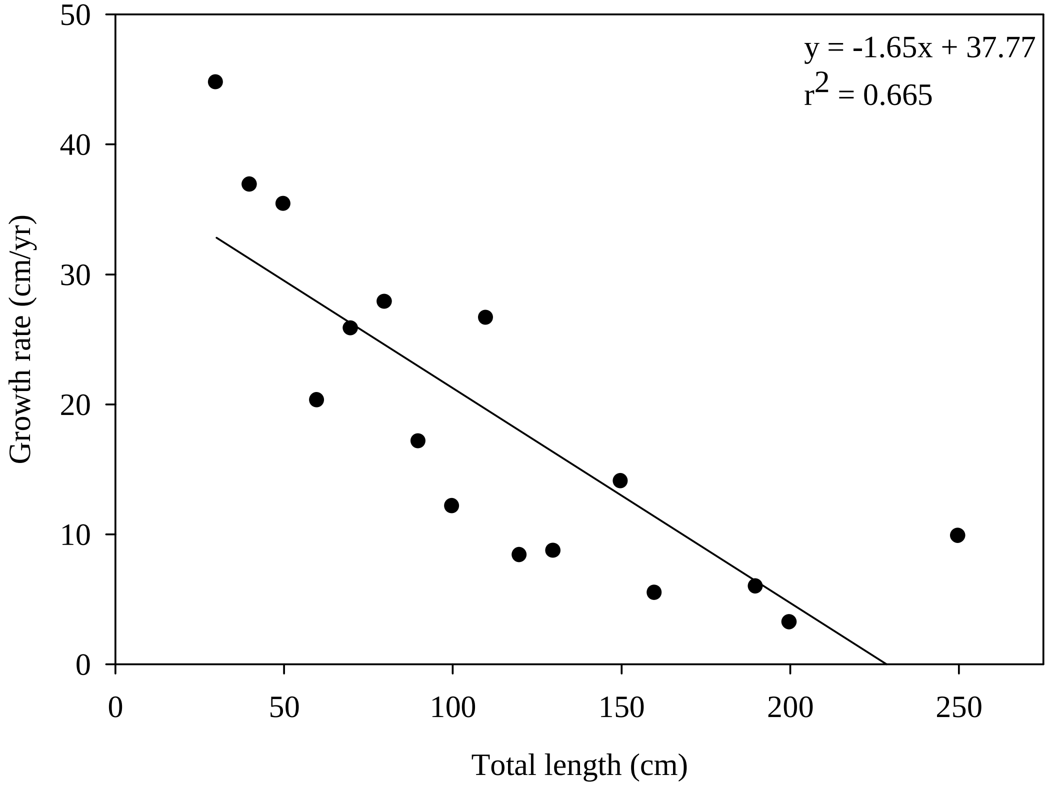

Figure 3.3. Mean growth rates (cm/yr) of recaptured American alligators (*Alligator mississippiensis*) by total length (10-cm size classes) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

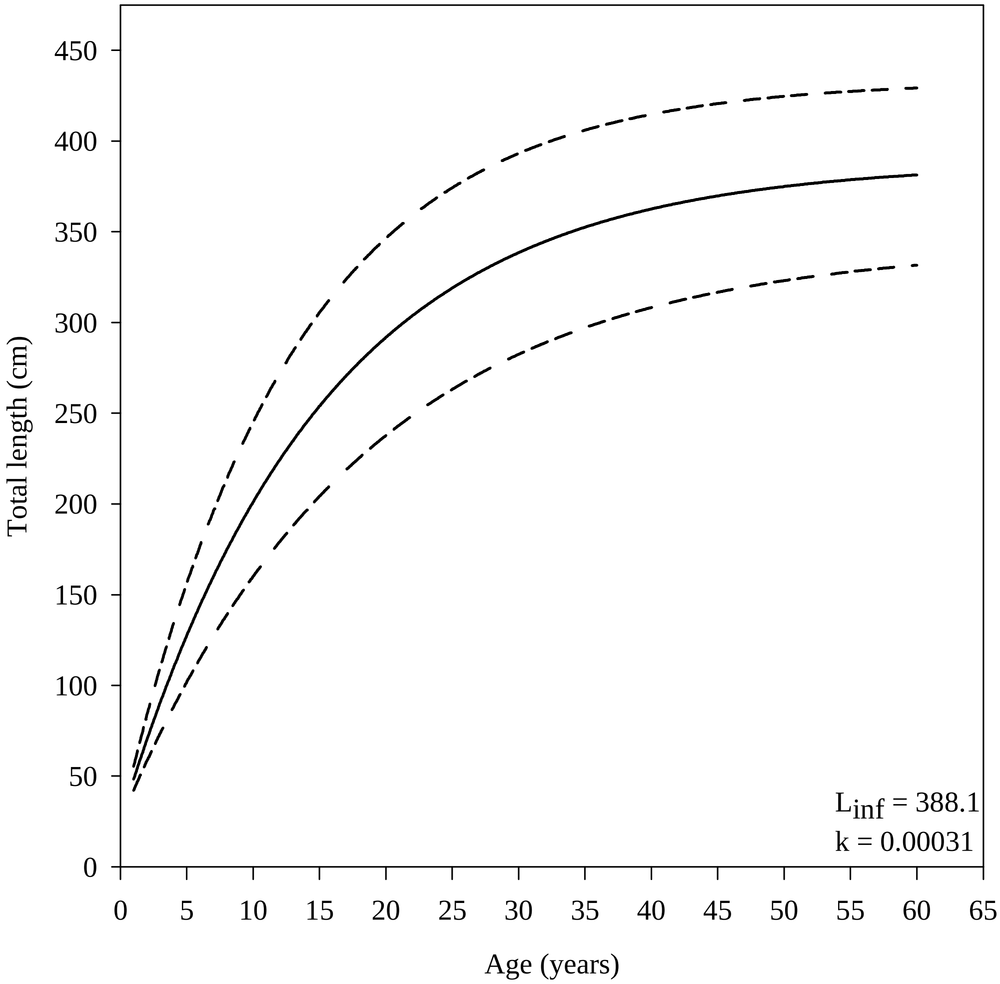

Figure 3.4. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

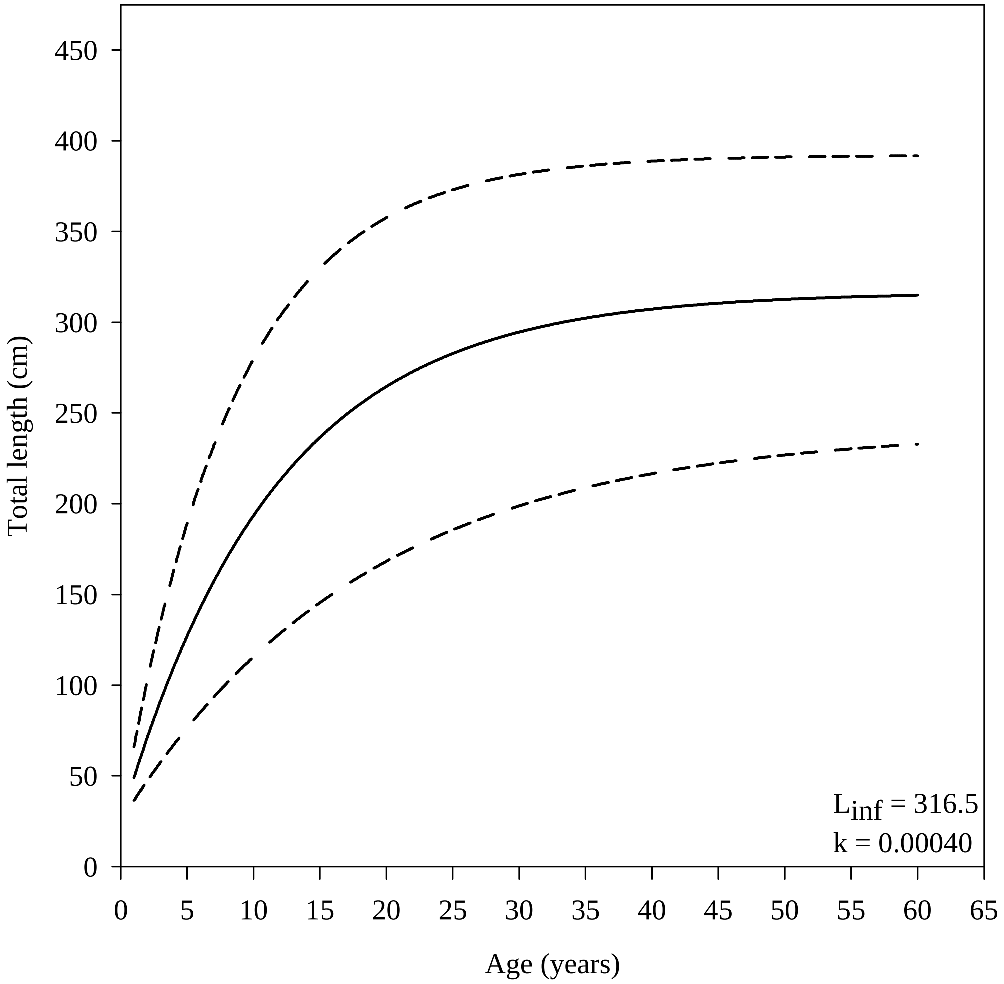

Figure 3.5. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Texas, 2003 – 2008.

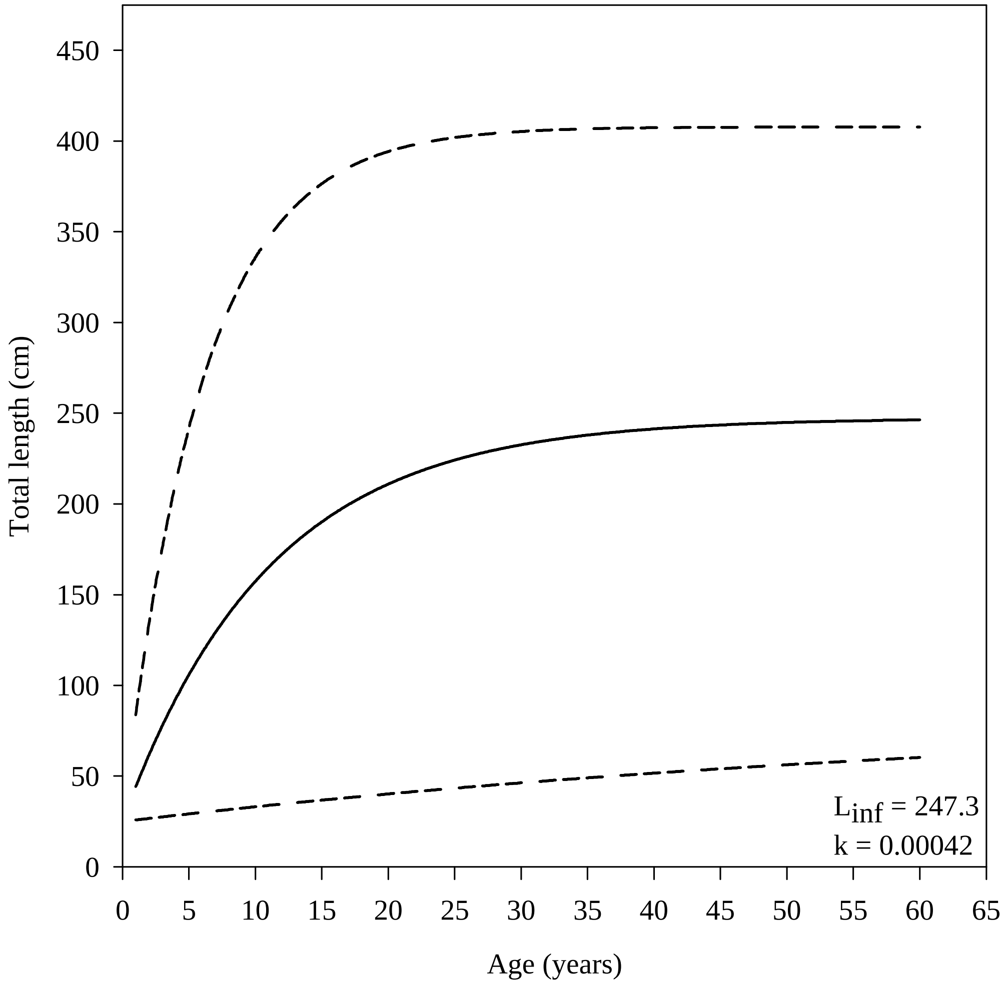

Figure 3.6. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of American alligators (*Alligator mississippiensis*) at Kurth Lake, Texas, 2006 – 2008.

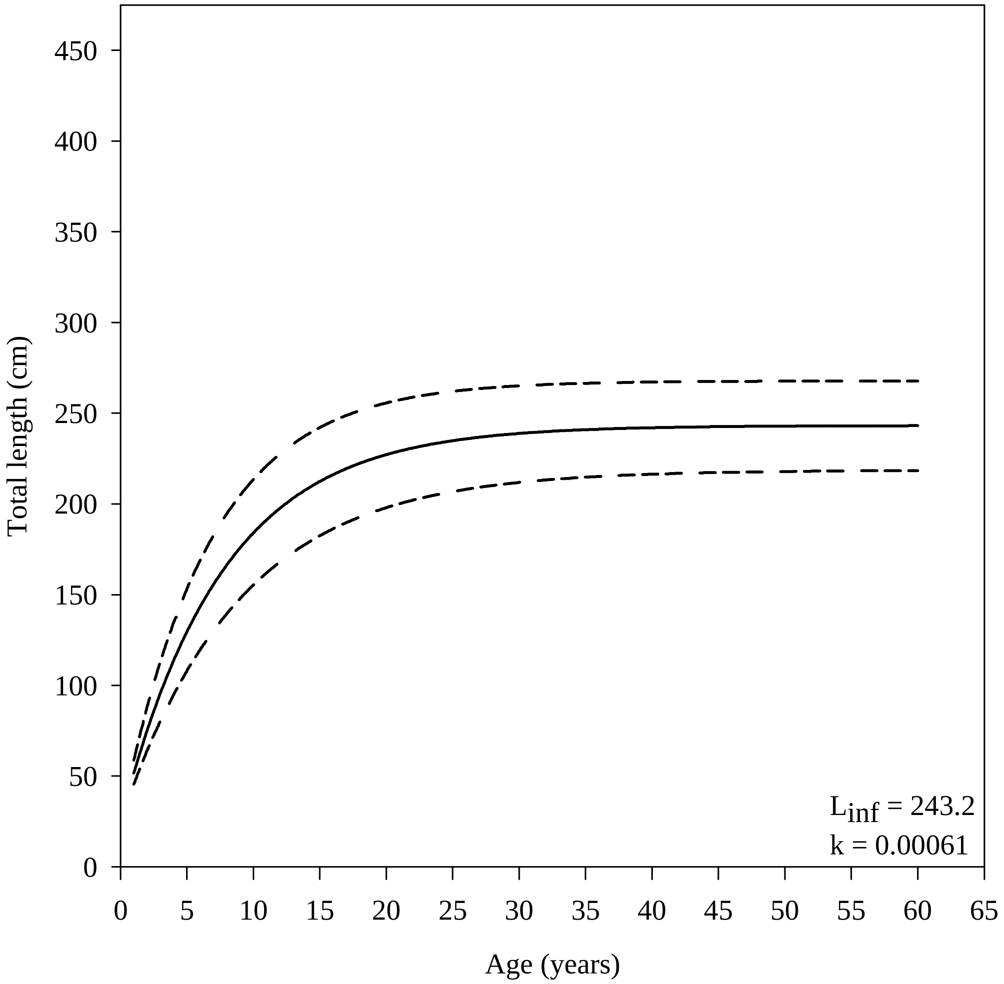

Figure 3.7. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

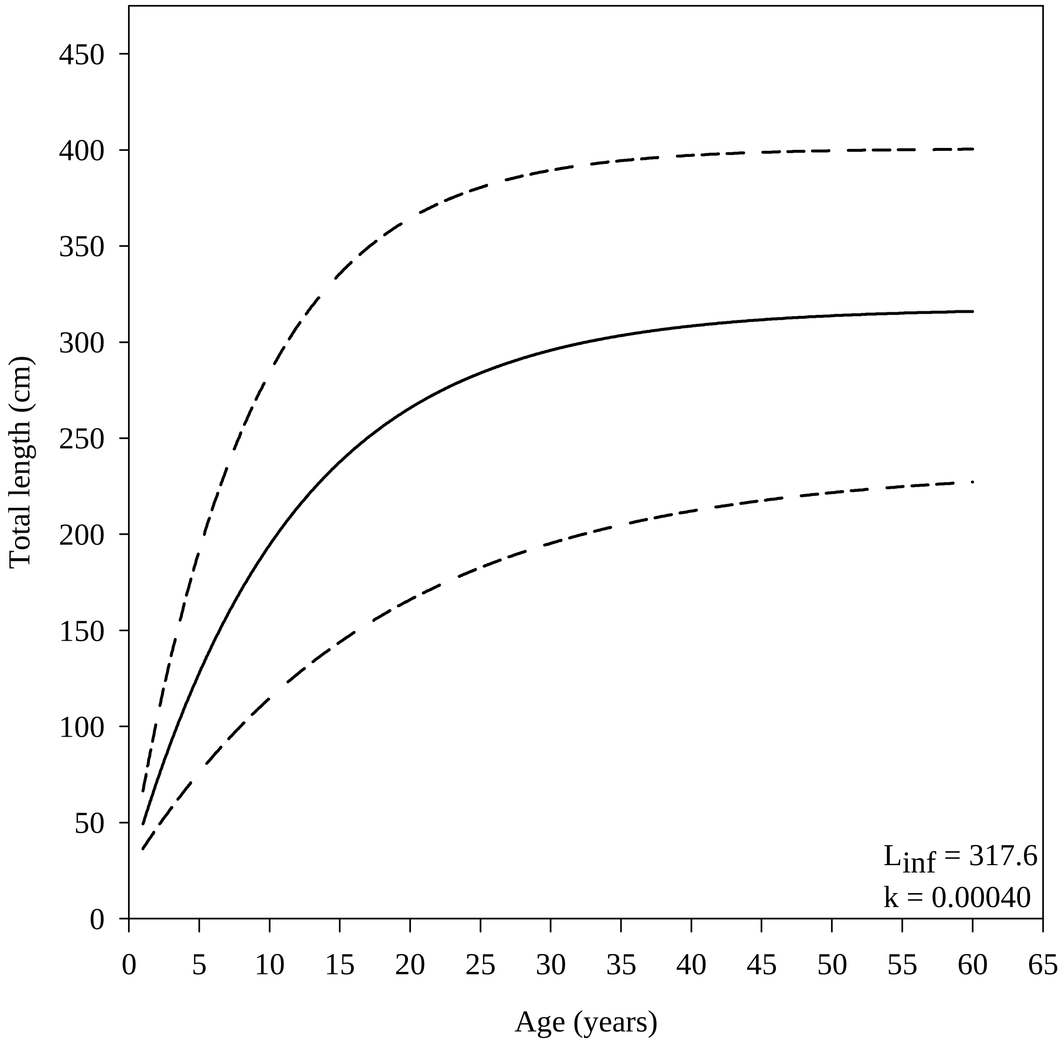

Figure 3.8. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of male American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

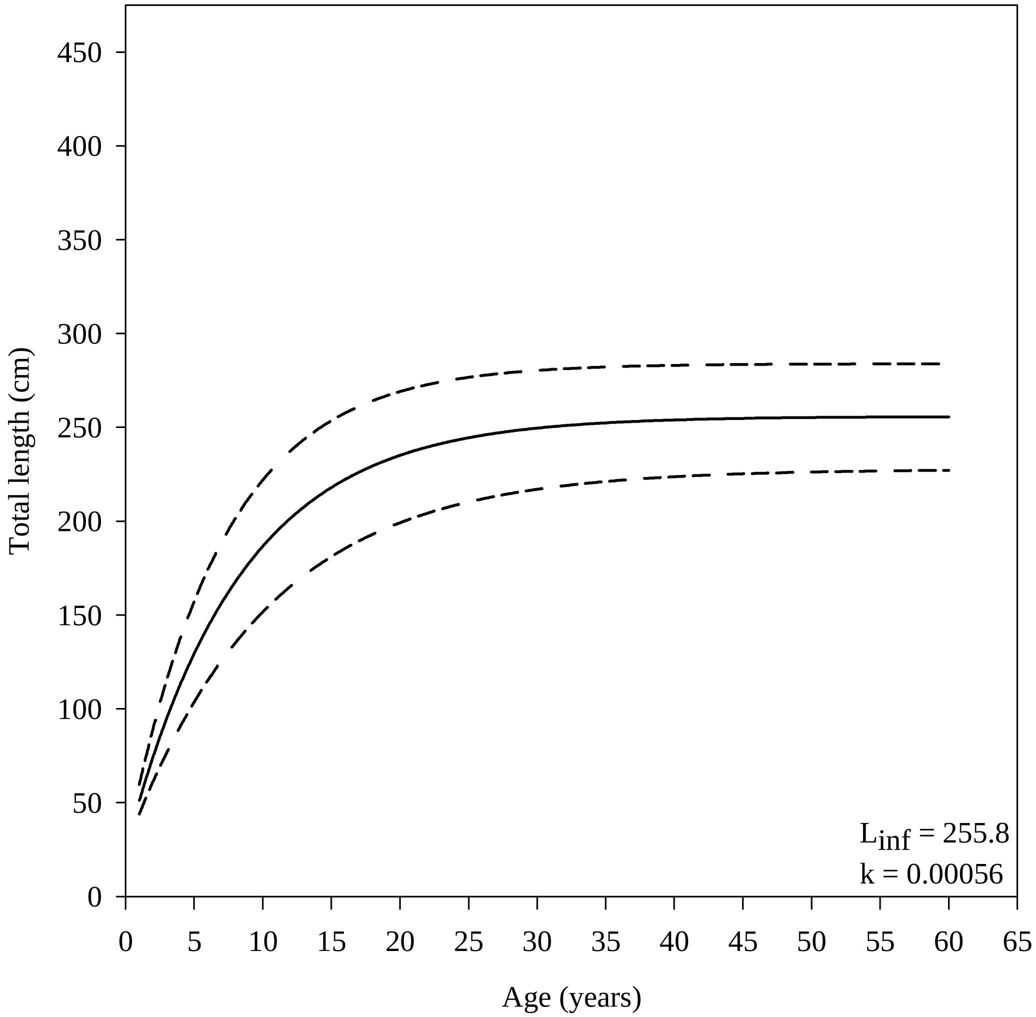

Figure 3.9. Length at age regression and 95% confidence intervals derived from fitting a modified von Bertalanffy growth curve to mark/recapture data of female American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

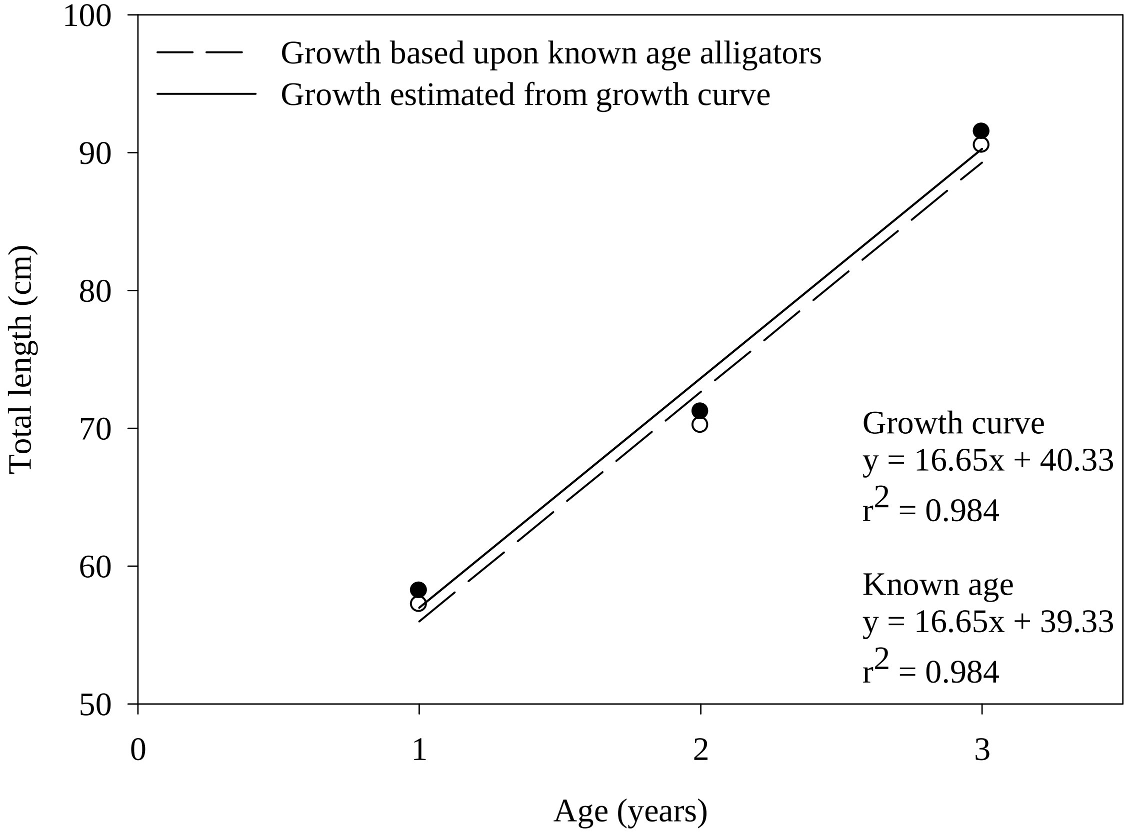

Figure 3.10. Length at age regression derived from fitting a modified von Bertalanffy growth curve and from known age American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

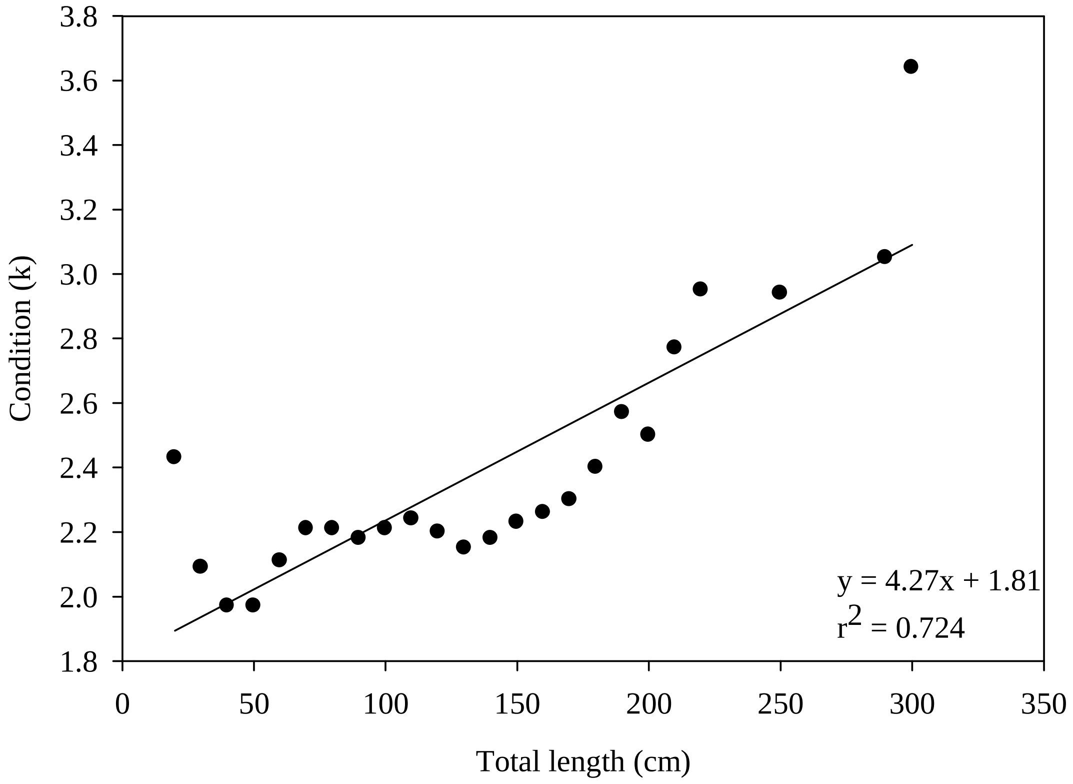

Figure 3.11. Condition (K) of American alligators (*Alligator mississippiensis*) by total length (10-cm size classes) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

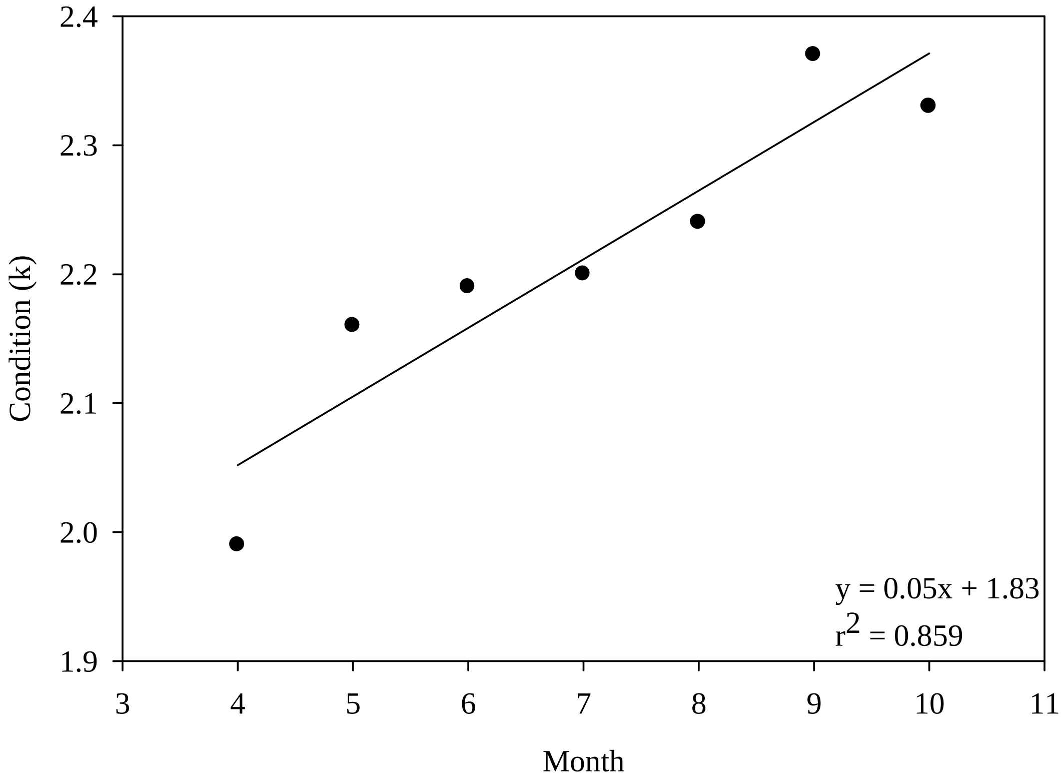

Figure 3.12. Condition (K) of American alligators (*Alligator mississippiensis*) by month at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2003 – 2008.

Table 3.1. Number of captures, recaptures, and unique recaptures (i.e., number of different alligators recaptured) of American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2003 – 2008.

Study Area	Sex	Unique captures	Recaptures	Unique recaptures
Dam B WMA	M	211	52	37
	F	171	26	20
	UD[a]	39	11	10
	Totals	421	89	67
Kurth Lake	M	26	22	13
	F	18	8	6
	UD	68	23	20
	Totals	112	53	39
LSNWR	M	164	122	74
	F	118	104	55
	UD	249	104	78
	Totals	531	330	207
Combined	M	401	196	124
	F	307	138	81

Table 3.1. Continued.

Study Area	Sex	Unique captures	Recaptures	Unique Recaptures
	UD	356	138	108
	Totals	1064	472	313

[a] UD (undetermined) refers to alligators < 50 cm in total length that were not sexed.

Table 3.2. Means ($\bar{x}$) and Standard Errors (SE) for growth rates (cm/year) of American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (NWR), Texas, 2003 – 2008.

Wetland	Sex	Size class[a]	*n*[b]	$\bar{x}$ (cm/year)[c]	SE
Dam B WMA	Combined[d]	Combined	64	26.8 b	2.08
Kurth Lake	Combined	Combined	37	20.6 b	1.45
Little Sandy NWR	Combined	Combined	259	35.6 a	1.28
Combined	Female	Combined	107	33.9 *a*	2.08
Combined	Male	Combined	148	28.2 *a*	1.47
Combined	Combined	1	159	38.0 a	1.48
Combined	Combined	2	183	29.6 b	1.46
Combined	Combined	3	4	12.4 bc	3.09
Combined	Combined	4	14	12.8 c	2.01
Dam B WMA	Female	Combined	20	21.1[e]	1.93
Kurth Lake	Female	Combined	3	18.3[e]	3.39

Table 3.2. Continued.

Wetland	Sex	Size class[a]	*n*[b]	$\bar{x}$ (cm/year)[c]	SE
Little Sandy NWR	Female	Combined	84	37.5[e]	2.47
Dam B WMA	Male	Combined	39	29.9[e]	3.10
Kurth Lake	Male	Combined	16	18.2[e]	1.24
Little Sandy NWR	Male	Combined	93	29.2[e]	1.88
Dam B WMA	Combined	1	12	31.9 *A*	3.71
Dam B WMA	Combined	2	42	27.9 *A*	2.83
Dam B WMA	Combined	3	2	16.2 *A*	4.38
Dam B WMA	Combined	4	8	15.8 *A*	2.32
Kurth Lake	Combined	1	21	22.7 *A*	2.29
Kurth Lake	Combined	2	16	17.8 *A*	1.22
Little Sandy NWR	Combined	1	126	41.7 *A*	1.68
Little Sandy NWR	Combined	2	125	31.7 *A*	1.87
Little Sandy NWR	Combined	3	2	8.7 *A*	3.16
Little Sandy NWR	Combined	4	6	8.9 *A*	3.01
Combined	Female	1	30	40.4 A	2.23

Table 3.2. Continued.

Wetland	Sex	Size class[a]	*n*[b]	$\bar{x}$ (cm/year)[c]	SE
Combined	Female	2	67	34.5 A	2.73
Combined	Female	3	3	12.6 A	7.56
Combined	Female	4	7	9.1 A	3.55
Combined	Male	1	24	38.9 A	3.37
Combined	Male	2	116	26.9 A	1.64
Combined	Male	3	1	11.8 A	2.64
Combined	Male	4	7	16.6 A	3.31
Dam B WMA	Female	1	1	33.5 *A*	.
Dam B WMA	Female	2	15	22.1 *A*	8.41
Dam B WMA	Female	3	1	20.6 *A*	.
Dam B WMA	Female	4	3	12.1 *A*	2.32
Kurth Lake	Female	1	1	25.1 *A*	.
Kurth Lake	Female	2	2	15.0 *A*	1.05
Little Sandy NWR	Female	1	28	41.2 *A*	18.07
Little Sandy NWR	Female	2	50	38.9 *A*	23.81
Little Sandy NWR	Female	3	2	8.7 *A*	4.48

Table 3.2. Continued.

Wetland	Sex	Size class[a]	n[b]	$\bar{x}$ (cm/year)[c]	SE
Little Sandy NWR	Female	4	4	6.8 $\underline{A}$	2.29
Dam B WMA	Male	1	6	37.5 $\underline{A}$	11.31
Dam B WMA	Male	2	27	31.1 $\underline{A}$	21.46
Dam B WMA	Male	3	1	11.8 $\underline{A}$	.
Dam B WMA	Male	4	5	18.0 $\underline{A}$	7.54
Kurth Lake	Male	1	2	18.4 $\underline{A}$	6.06
Kurth Lake	Male	2	14	18.2 $\underline{A}$	5.09
Little Sandy NWR	Male	1	16	42.0 $\underline{A}$	17.49
Little Sandy NWR	Male	2	75	26.9 $\underline{A}$	17.23

Table 3.2. Continued.

Wetland	Sex	Size class[a]	n[b]	$\bar{x}$ (cm/year)[c]	SE
Little Sandy NWR	Male	4	2	13.2 *A*	14.15

[a] Size class corresponds to 1 (< 50 cm), 2 (50 – 125 cm), 3 (125 – 160 cm), and 4 (> 160 cm).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

Table 3.3. Akaike's Information Criterion (AIC), intrinsic growth rate variable (k), and maximum attainable length (L_∞) for each growth curve fitted to American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge Texas, 2003 – 2008.

Model	AIC	L_∞	k
von Bertalanffy	11826	388.1	0.0003
Logistic	28630	237.8	0.0019
Gompertz	84599	78.5	-0.0037

Table 3.4. Means ($\bar{x}$) and Standard Errors (SE) for condition (K) of American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Size class [a]	Season [b]	n[c]	$\bar{x}$ [d]	SE
Dam B WMA	Combined[e]	Combined	Combined	268	2.23 a	0.02
Kurth Lake	Combined	Combined	Combined	160	1.84 b	0.02
Little Sandy NWR	Combined	Combined	Combined	785	2.20 ab	0.01
Combined	Female	Combined	Combined	325	2.14 *a*	0.02
Combined	Male	Combined	Combined	462	2.15 *a*	0.02
Combined	Combined	1	Combined	551	2.15 b	0.02
Combined	Combined	2	Combined	571	2.14 b	0.02
Combined	Combined	3	Combined	57	2.19 b	0.04
Combined	Combined	4	Combined	34	2.53 a	0.07
Combined	Combined	Combined	Spring	209	2.14 *b*	0.02
Combined	Combined	Combined	Summer	735	2.10 *b*	0.01

Table 3.4. Continued.

Wetland	Sex	Size class[a]	Season[b]	*n*[c]	$\bar{x}$[d]	SE
Combined	Combined	Combined	Fall	269	2.35 *a*	0.02
Dam B WMA	Female	Combined	Combined	117	2.21 A	0.03
Kurth Lake	Female	Combined	Combined	25	1.77 A	0.05
Little Sandy NWR	Female	Combined	Combined	183	2.14 A	0.03
Dam B WMA	Male	Combined	Combined	142	2.25 A	0.03
Kurth Lake	Male	Combined	Combined	46	1.75 A	0.05
Little Sandy NWR	Male	Combined	Combined	274	2.16 A	0.02
Dam B WMA	Combined	1	Combined	11	2.06 *A*	0.05
Dam B WMA	Combined	2	Combined	212	2.21 *A*	0.02
Dam B WMA	Combined	3	Combined	30	2.22 *A*	0.06
Dam B WMA	Combined	4	Combined	15	2.65 *A*	0.12
Kurth Lake	Combined	1	Combined	109	1.86 *A*	0.03
Kurth Lake	Combined	2	Combined	48	1.79 *A*	0.05
Kurth Lake	Combined	3	Combined	2	2.01 *A*	0.04
Kurth Lake	Combined	4	Combined	1	2.39 *A*	.

Table 3.4. Continued.

Wetland	Sex	Size class[a]	Season[b]	*n*[c]	$\bar{x}$[d]	SE
Little Sandy NWR	Combined	1	Combined	431	2.23 *A*	0.02
Little Sandy NWR	Combined	2	Combined	311	2.15 *A*	0.02
Little Sandy NWR	Combined	3	Combined	25	2.17 *A*	0.07
Little Sandy NWR	Combined	4	Combined	18	2.45 *A*	0.08
Combined	Female	1	Combined	60	2.02 A	0.04
Combined	Female	2	Combined	213	2.15 A	0.02
Combined	Female	3	Combined	30	2.10 A	0.06
Combined	Female	4	Combined	15	2.65 A	0.12
Combined	Male	1	Combined	66	2.04 A	0.05
Combined	Male	2	Combined	357	2.14 A	0.02
Combined	Male	3	Combined	27	2.30 A	0.06
Combined	Male	4	Combined	12	2.70 A	0.14
Dam B WMA	Female	2	Combined	93	2.21 *A*	0.04
Dam B WMA	Female	3	Combined	15	2.14 *A*	0.06
Dam B WMA	Female	4	Combined	9	2.44 *A*	0.13

Table 3.4. Continued.

Wetland	Sex	Size class [a]	Season [b]	n [c]	$\bar{x}$ [d]	SE
Kurth Lake	Female	1	Combined	5	1.59 A	0.03
Kurth Lake	Female	2	Combined	18	1.78 A	0.05
Kurth Lake	Female	3	Combined	1	1.97 A	.
Kurth Lake	Female	4	Combined	1	2.39 A	.
Little Sandy NWR	Female	1	Combined	55	2.06 A	0.04
Little Sandy NWR	Female	2	Combined	102	2.16 A	0.03
Little Sandy NWR	Female	3	Combined	14	2.07 A	0.10
Little Sandy NWR	Female	4	Combined	12	2.45 A	0.09
Dam B WMA	Male	1	Combined	2	2.14 A	0.30
Dam B WMA	Male	2	Combined	119	2.20 A	0.03
Dam B WMA	Male	3	Combined	15	2.31 A	0.10
Dam B WMA	Male	4	Combined	6	2.97 A	0.17
Kurth Lake	Male	1	Combined	16	1.65 A	0.05
Kurth Lake	Male	2	Combined	29	1.80 A	0.08
Kurth Lake	Male	3	Combined	1	2.05 A	.
Little Sandy NWR	Male	1	Combined	48	2.17 A	0.05
Little Sandy NWR	Male	2	Combined	209	2.14 A	0.03

Table 3.4. Continued.

Wetland	Sex	Size class [a]	Season [b]	n[c]	$\bar{x}$ [d]	SE
Little Sandy NWR	Male	3	Combined	11	2.30 $\underline{A}$	0.06
Little Sandy NWR	Male	4	Combined	6	2.44 $\underline{A}$	0.02

[a] Size class corresponds to 1 (< 50 cm), 2 (50 – 125 cm), 3 (125 – 160 cm), and 4 (> 160 cm).

[b] Season corresponds to spring (April – June), summer (July – September), and fall (October – December).

[c] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[d] Means followed by the same letter in the same case and font style are not different ($P >$ 0.05; least squares cross validation).

[e] “Combined” corresponds to instances when all data within a column heading (i.e., variable) are pooled.

CHAPTER IV

FOOD HABITS OF AMERICAN ALLIGATORS IN INLAND WETLANDS OF EAST TEXAS

INTRODUCTION

Throughout the southeastern United States, American alligators (*Alligator mississippiensis*) exist as top carnivores in aquatic and wetland systems and perform an important role in structuring coexisting animal populations within their environment (Barr 1994, Barr 1997). Opportunistic predators, alligators exhibit a varied diet, depending upon size, and are adept at exploiting local prey resources that encompass a wide diversity of sizes and taxa, ranging from small insects and crustaceans to large vertebrates (Chabreck 1971, Valentine et al. 1972, Taylor 1979, Webb et al. 1982, Delany and Abercrombie 1986, Rice 2004). Alligator diets vary geographically, by specific location and habitat, prey encountered, and prey vulnerability and size, as well as alligator size (Dodson 1975, McNease and Joanen 1977, Delany and Abercrombie 1986, Wolfe et al. 1987, Barr 1994, Barr 1997). For example, smaller (juvenile) alligators largely consume invertebrates (i.e., crayfish, giant water bugs, crabs, shrimp, gastropods, etc.) and small fish (Giles and Childs 1949, Fogarty and Albury 1967, Chabreck 1971, Valentine et al. 1972, Dodson 1975, Delany 1990, Barr 1994), whereas larger adults consume mainly vertebrates (reptiles, fish, birds, and mammals; Giles and Childs 1949, McNease and Joanen 1977, Delany and Abercrombie 1986).

Alligator diet studies have been concentrated in Louisiana (Valentine et al. 1972, Taylor 1986, Wolfe et al. 1987), north central and central Florida (Delany and

Abercrombie 1986, Delany 1990, Delany *et al.* 1999, Rice 2004), and southern Florida (Fogarty and Albury 1967, Barr 1994, Barr 1997). Such basic, descriptive studies of alligator diet and food habits allow for speculation about ontogenic, geographic, and temporal variation in resource utilization and food habits for alligators throughout their geographic range (Barr 1994). Diet analyses and food habits are essential elements for understanding functional roles of key predators in any ecosystem, but also reveal basic predator-prey relationships and allow comparisons among individuals of different sizes and among habitats (Barr 1994, Rice 2004). Moreover, diet and food habits can directly affect growth rates and body condition (Chabreck 1971, McNease and Joanen 1981). As such, food habit data are key for identifying and isolating possible causes for geographic variation in growth rates and body condition among alligator populations.

However, no dietary studies have been performed in the western portion of its geographic range. Previous work in east Texas inland wetlands has shown that alligators exhibited faster growth rates and poorer body condition than most other populations (Webb 2005, Saalfeld et al. 2008). Therefore, quantifying diets regionally could elucidate potential causes for these regional discrepancies in growth rates and body condition. Thus, the objectives of this study were to quantify food habits of inland alligators within 3 wetlands in east Texas and determine any potential differences between or among sexes, sizes, and wetlands.

METHODS

Study Area

This research was conducted at three wetlands in east Texas (Angelina-Neches/Dam B Wildlife Management Area [Dam B WMA], Kurth Lake, and Little Sandy National Wildlife Refuge [NWR]; Figure 1.1). Dam B WMA is 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 (Figure 1.2). Dam B WMA is characterized by riverine, open lake, and shallow marsh habitats (Webb 2005, Webb et al. 2009). Dominant aquatic plants include water hyacinth (*Eichhornia crassipes*), common salvinia (*Salvinia minima*), giant salvinia (*S. molesta*), alligatorweed (*Alternanthera philoxeroides*), hydrilla (*Hydrilla verticellata*), smartweeds (*Polygonum* spp.), and yellow pond lily (*Nuphar luteum*). Dominant woody species along wetland margins are baldcypress (*Taxodium distichum*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), Chinese tallow (*Triadica sebifera*), water oak (*Quercus nigra*), overcup oak (*Q. lyrata*), water tupelo (*Nyssa aquatica*), and pine (*Pinus* spp.; Godfrey and Wooten 1981).

Kurth Lake is 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; Saalfeld et al., unpublished data) and a few shallow bays with isolated pockets of emergent marsh (Figure 1.3). Dominant aquatic species are American lotus (*Nelumbo lutea*), hydrilla, coontail (*Ceratophyllum demersum*), and yellow pond lily. Dominant woody species along wetland margins are buttonbush, black willow, Chinese tallow, water oak, overcup oak, and pine (Godfrey and Wooten 1981).

Little Sandy NWR consists of 1,539 ha, of which ≈ 1100 ha are bottomland hardwood forest, located on the northern bank of the Sabine River in southern Wood County. Little Sandy NWR contains four main lentic bodies: Overton Lake, Brumley Lake, Bradford Lake, and Beaver Lake. Of these, only Overton Lake (an impoundment of Jim Ned Creek) and Brumley Lake (an impoundment of Little Sandy Creek) were used as study sites. Overton Lake is approximately 175 ha and Brumley Lake is approximately 200 ha. Both lakes are connected by several creeks and canals, essentially making these two lakes one large wetland. Hereafter, these two lakes will be referred to as Little Sandy NWR. Little Sandy NWR is characterized primarily by shallow marsh with little open water or creek channels (Figure 1.4). Dominant aquatic species are American frog-bit (*Limnobium spongia*), American lotus, Carolina fanwort (*Cabomba caroliniana*), coontail, cutgrass (*Zizaniopsis miliacea*), and yellow pond lily. Woody species include Chinese tallow, buttonbush, black willow, and southern wax myrtle (*Morella cerifera*; Godfrey and Wooten 1981).

Capture and Handling

From May – October 2006, 2007, and 2008, American alligators were captured, uniquely marked, and released at Dam B WMA, Kurth Lake, and Little Sandy NWR using several capture techniques (i.e., snake tongs, pole snares, hands, and swim in live traps; see Webb 2005 for complete capture descriptions). During capture sessions, efforts were made to capture all individuals sighted resulting in equal capture effort for successive captures (Deitz 1979). At night, spotlights affixed with red filters were used to locate alligators with a 4.9 m Go-Devil® boat outfitted with a 20 hp Go-Devil® mud motor. Alligators < 125 cm were captured using snares, tongs, or hands, while swim-in live traps (Ryberg and Cathey 2004) were used to capture larger alligators (> 1.6 m). Traps, baited with chicken or fish, were deployed in areas where alligators had been observed, set during afternoon or evening, and left open for at least a 24-hour period. Each trap was checked at 0000 h and by 1000 h the following morning.

Upon capture, alligators were restrained with duct tape, and each individual > 50.0 cm in total length was sexed 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, due to small genitalia size and low light conditions it was not possible to consistently and accurately obtain these measurements; so alligators < 50 cm were not sexed. For all captured individuals (regardless of size), the following morphological features were measured: total length (cm; ventral tip of snout to tip of tail), snout-vent length (cm; ventral tip of snout to proximal tip of vent), eye to nare length (cm), total head length (cm; dorsal tip of snout to distal part of head scute), tail girth (cm, circumference of tail directly behind rear legs), right hind leg length (cm), chest girth (cm; circumference of chest directly behind front legs), and mass (g; only obtained for individuals < 50 kg). All length measurements were obtained using a flexible tape measure and mass was obtained using a Pesola® hanging scale (Baar, Switzerland) for individuals > 50 cm or an Ohaus Scout® Pro digital scale (Pine Brook, NJ) for those < 50 cm. All alligators were uniquely marked by at least two of the following: dorsal tail-scute removal, numbered Monel tags (#681 Monel tags for alligators > 152 cm; #1 Monel tags for alligators < 152 cm), or passive integrated transponder (PIT) tags. In addition, a GPS location was obtained using a Garmin eTrex Legend Cx (Olathe, KS) for each capture/recapture.

Food Habits

Alligators between 106 cm and 244 cm in total length (i.e., alligators < 106 cm in total length were too small and alligators > 244 cm in total length were too large to effectively use this technique) were fastened to a plywood board and placed at an incline with jaws secured open with a piece of PVC pipe and duct tape. The hose-Heimlich method (Fitzgerald 1989, Barr 1994, Rice et al. 2005) was used to remove all stomach contents. The hose-Heimlich method was performed by carefully inserting a Teflon hose down the esophagus and into the alligator's stomach. An external mark for the distance the Teflon hose was inserted into the esophagus/stomach corresponded to the fourth whirl of scutes anterior to the hind legs (Rice 2004, Rice et al. 2005). A bilge pump connected to a garden hose was then connected to the Teflon hose in the alligator's stomach and water was pumped (≈ 50 L/min) into the stomach until full. With the hose still in place, a mixture of stomach contents and water was then expelled into a collection basin by a person standing beside the alligator similar to the Heimlich maneuver. This procedure continued until the water flushing the stomach was clear and free of any particulate matter. All stomach contents were then poured through a 0.5 mm mesh sieve, placed into a labeled plastic bag, and frozen. Diet samples (from whole stomachs) of alligators > 244 cm in total length were obtained from harvested individuals during Texas Parks and Wildlife's annual alligator harvest at Dam B WMA. Similar to those obtained from the hose-Heimlich method, all stomach contents were poured through a 0.5 mm mesh sieve, placed into a labeled plastic bag, and frozen. Because the hose-Heimlich method is nearly 100% effective in removing all food contents from an alligator's stomach (Fitzgerald 1989, Barr 1994, Rice et al. 2005), diet samples from whole stomachs were directly compared with diet samples from the hose-Heimlich in all analyses.

Samples were thawed, washed through a 0.5 mm mesh sieve, and weighed to obtain total wet mass (g) of all stomach contents. Samples were sorted into identifiable prey items (e.g., fish, reptiles, mammals, birds, amphibians, gastropods, insects, crustaceans, or bivalves) and non-prey items (e.g., rocks, plant material, artificial objects, etc.) and identified to lowest possible taxa. Minimum number of individuals (i.e., fewest number) was determined based upon the occurrence of specific items (e.g., fish otolith, water bug thoraxes, etc.). Along with occurrence, wet masses were obtained for each taxon within a given stomach sample.

DATA ANALYSIS

Chi-square (PROC FREQ; SAS Institute 1999) was used to examine variation in prey presence/absence (i.e., of fish, herptiles, mammals, birds, and invertebrates) among wetlands, between sexes, and sizes (breeding size [> 1.8 m in total length] and non-breeding size [< 1.8 m in total length]). Because most large alligators were captured from Dam B WMA, no large size comparisons were made among wetlands. Additionally, Analysis of Variance (ANOVA; PROC GLM; SAS Institute 1999) was used to examine differences in percent composition of prey items by wet mass (i.e., proportion [%] a prey taxon mass comprised of the total mass of a sample) and percent occurrence (i.e., proportion [%] a single prey item comprised of the total number of prey items within a diet sample) between or among sizes, sexes, and wetlands. Interactions among these variables (i.e., sex, size class, and wetland) could not be run due to sample size limitations. An alpha level of 0.05 was maintained for these analyses and least squared means separation was used to examine differences.

RESULTS

From 1 April 2006 – 31 October 2008, a total of 62 American alligator diet samples (24 from Dam B WMA, 35 from Little Sandy NWR, and 3 from Kurth Lake) were obtained. Samples were obtained from alligators ranging in size (i.e., total length) from 94.7 cm to 386.0 cm. A majority of the diet samples were obtained non-lethally using the Hose-Heimlich technique (49 alligator diet samples); however, 13 diet samples were obtained from harvested alligators collected during hunts conducted at Dam B WMA in 2007 ($n = 9$) and 2008 ($n = 4$).

Although many prey items were damaged (i.e., due to digestion, jaw pressure, and/or prey capture), a total of 33 different prey taxons and 1 parasite were identified (Table 4.1), comprising 670 individual prey items (excluding parasites). Irrespective of size class, sex, and wetland, > 47% of individual prey items identified were giant water bugs (Belostomatidae), with a least 1 giant water bug documented in 66% of diet samples (Table 4.2). Nearly all (> 97%) samples contained organic by-catch (e.g., woody debris, aquatic plants, seeds, etc.). Alligator samples also contained rocks/stones (52% of samples) and foreign matter (e.g., plastic bottle caps, fishing tackle, tent spike, shotgun shell, etc.; 19% of samples). Additionally, 53% of all samples had ≥ 1 tapeworm/parasite.

Invertebrates, fish, birds, mammals, and herptiles occurred equally ($P > 0.05$) between males and females (Table 4.3). Invertebrates, fish, birds, and herptiles ($P > 0.05$) occurred at similar frequencies among wetlands, however, mammals ($\chi^2 = 6.53$; $P = 0.038$) occurred more often in alligator diets at Dam B WMA than other wetlands (Table 4.4). Irrespective of wetland, invertebrates occurred more often ($\chi^2 = 8.34$; $P = 0.004$) in non-breeding size (< 1.8 m in total length) alligators than breeding size alligators (> 1.8 m in total length). Conversely, mammals ($\chi^2 = 11.34$; $P < 0.001$) and herptiles ($\chi^2 = 5.67$; $P = 0.017$) occurred more often in breeding size alligator diets, whereas birds and fish occurred in both size classes equally ($P > 0.05$; Table 4.5).

Irrespective of size, wetland, and sex, percent composition (by mass) was 48.2% food and 51.8% non-food (e.g., stones/rocks, plastic, woody debris, etc.). Overall, percent composition by mass of invertebrates, fish, birds, mammals, and herptiles ($P > 0.05$; Table 4.6) was similar between male and female alligators. Additionally, percent composition by mass of invertebrates, fish, herptiles, birds, and mammals ($P > 0.05$; Table 4.7) was similar among wetlands. However, similar to frequency of food items, percent composition by mass for breeding size alligators contained a greater percentage of vertebrates ($\bar{x}$ = 42.7%) as compared to non-breeding size alligators ($\bar{x}$ = 25.7%). Additionally, breeding size alligators consumed more mammals by mass ($F_{1, 60} = 8.29$; $P = 0.006$; Table 4.8) than smaller alligators. Both size classes had similar percent composition by mass of fish, herptiles, and birds ($P > 0.05$; Table 4.8). However, diets of smaller alligators had greater percent composition by mass of invertebrates ($F_{1,\,60} = 7.80$; $P = 0.007$; Table 4.8) than breeding size alligators.

Males and females had similar percent occurrence of invertebrates, fish, herptiles, birds, and mammals ($P > 0.05$; Table 4.9). Among wetlands, alligators also had similar percent occurrence of invertebrates, fish, herptiles, birds, and mammals ($P > 0.05$; Table 4.10). Similar to previous analyses, a greater percentage of invertebrate prey items were detected within non-breeding size alligator diets ($F_{1,\,60} = 18.72$; $P < 0.001$; Table 4.11) when compared to breeding size alligators. However, breeding size alligators had a greater percentage of herptiles ($F_{1,\,60} = 5.41$; $P = 0.024$) and mammals ($F_{1,\,60} = 7.34$; $P = 0.009$) in their diet samples than non-breeding size alligators (Table 4.11). Both size classes had similar percentages of birds and fish within their diet samples ($P > 0.05$; Table 4.11).

DISCUSSION

American alligators exhibit an extremely varied diet, as evidenced by their opportunistic strategy of exploiting locally available and/or abundant prey. Many studies have documented alligator prey, which encompass a wide diversity of sizes and taxa, ranging from small insects and crustaceans to large vertebrates (Chabreck 1971, Valentine et al. 1972, Taylor 1979, Webb et al. 1982, Delany and Abercrombie 1986, Wolfe et al. 1987, Rice 2004). Alligator food habits in this study mirrored previous work in that alligators appear to forage opportunistically, and in the feeding process, pick up relatively large quantities of non-food items. Although most food habit studies documented similar vertebrate prey items (i.e., herptiles, mammals, and fish; McNease and Joanen 1977, Delany and Abercrombie 1986, Barr 1994, Barr 1997), food availability estimates are difficult to quantify due to the diversity of prey items consumed and the apparently very generalized-opportunistic foraging strategy employed by alligators, regardless of region. Such constraints make it difficult to estimate specific food selectivity or preferences, where any geographic differences in food habits are most likely influenced by food availability rather than selection (McNease and Joanen 1977, Delany and Abercrombie 1986, Barr 1994, Barr 1997).

Alligators did consume a variety of both vertebrates and invertebrates, including wading birds, turtles, snakes, fish, mammals, and invertebrates (see Tables 4.1).

Although previous alligator diet studies reported fish to be the top prey item for all size classes (Fogarty and Albury 1967, Chabreck 1971, Valentine et al. 1972, McNease and Joanen 1977, Delany and Abercrombie 1986, Delany 1990, Platt et al. 1990, Hayes 1992), fish are thought to be under-represented, due to their rapid decomposition rates (Barr 1997, Rice 2004). Such discrepancies likely underestimate the importance of fish prey (of various size and species) to alligators, regardless of size, sex, or social dominance. For example, Barr (1997) found that alligators completely digested golden shiners (*Notemigonus crysoleucas*) within 24 hours and concluded that fish species with similar body sizes and scales (e.g., minnows [Cyprinidae], shad [Clupeidae], top minnows [Fundulidae], mosquito fish [Poeciliidae], and sunfish [Centrarchidae]) would have similar residence times.

In this study, fish were the most prevalent vertebrate in alligator diet samples; however, most fish were found in diet samples from alligators at Little Sandy NWR, where > 70% of diet samples in which fish were present were collected from this study site. Although fish have short residence times, they still occurred in diet samples more frequently than other vertebrates (that have longer residence time), indicating that fish may be the most important or most available vertebrate prey item for all size classes at Little Sandy NWR. Conversely, at Dam B WMA (25% of diet samples with fish) and Kurth Lake (< 5% of diet samples with fish) fish were not as important. However, at Dam B WMA, fewer fish were likely available due to a long drawdown event occurring during 2006 and 2007 for repairs to the Town Bluff Dam. This drawdown lasted for over a year and substantially reduced the abundance of both fish and other aquatic vertebrates (e.g., turtles; personal observations, and Texas Parks and Wildlife Department, personal communication). After repairs were completed and water levels returned to normal pool level, many exotic invasive plant species such as alligatorweed, giant salvinia, and water hyacinth became re-established, and expanded their extent and densities throughout the study site. These exotic invasive plants formed thick mats, and appear to both reduce alligator movements and limit their access to shallow water habitat where alligators tend to feed more efficiently. Subsequent control efforts (e.g., herbicides) used at Dam B WMA resulted in rapid decomposition rates, which lowered dissolved oxygen levels throughout the wetland, resulting in relatively high rates of fish mortality in both 2007 and 2008 (Texas Parks and Wildlife Department unpublished data). Decreased fish abundances after the drawdown likely forced alligators to focus on alternative prey items, such as mammals and other alligators. As cannibalism was only documented at Dam B WMA after the drawdown, it is likely the resulting low water levels, concentration of alligators of all sizes, and the subsequent expansion and spread of exotic invasive species, allowed for unknown rates of cannibalism due to ease in finding and capturing conspecifics.

In contrast to Dam B WMA and Little Sandy NWR, Kurth Lake had a poor diversity of food items, possibly related to different (e.g., less suitable) habitat conditions. Kurth Lake is comprised primarily of deep open water (> 80 % open water; average depth > 3 m) with very little shallow marsh habitat (i.e., areas < 1.2 m deep dominated by aquatic vegetation). Such a lack of shallow vegetated habitats can decrease ambush ability, resulting ultimately in lower capture efficiency. Additionally, without shallow marsh habitats, mammals, herptiles, and wading birds (and other vertebrate and invertebrate prey) are not as common or abundant. Such a limited available prey base within this wetland and ostensibly poor capture efficiency also likely resulted in slower growth rates and poor condition of alligators at Kurth Lake as compared to other wetlands (see Chapter III).

Overall, alligators within this study had faster growth rates but were in poorer condition as compared to other geographic regions (see Chapter III). Although constraints in determining food availability make it difficult to assess the role of food availability on alligator growth and condition within these wetlands, food availability is likely an important factor influencing geographic variation in growth rates and condition. For example, the drawdown and introduction of exotic invasive species at Dam B WMA could have reduced prey abundances and/or availability causing alligators to be in poor condition. Additionally, the abundance of open water at Kurth Lake could have limited prey diversity and availability resulting in both slower growth rates and poorer condition. Little Sandy NWR contained abundant sources of fish and wading birds (numerous vegetated islands for rookeries), however, many of these prey items were not always available. For example, only young wading birds (which most likely fell out of nests) were found in alligator diet samples. Wading birds synchronize nesting and migration, resulting in only a short time span when these prey items are available to alligators.

Additionally, other large vertebrate prey items (e.g., mammals) may not occur in high densities within this wetland due to its small size (375 ha) and control measures taken to reduce their populations (e.g., trapping and shooting of North American beavers [*Castor canadensis*], nutria [*Myocastor coypus*], and feral hogs [*Sus scrofa*]). Therefore, relying only upon fish and seasonally available wading birds may result in alligators within this population being in poor condition.

Despite generally being opportunistic, alligators appear to shift diets from invertebrates to vertebrates as they increase in size, a phenomenon documented in many studies (McIlhenny 1935, Giles and Childs 1949, Chabreck 1971, Valentine et al. 1972, McNease and Joanen 1977, Delany and Abercrombie 1986, Taylor 1986, Wolfe et al. 1987, Barr 1997, Delany et al. 1999). Specifically, within this study, mammals (i.e., pig, nutria, and/or other small semi-aquatic mammals) and herptiles (i.e., snakes [Serpentes] and turtles [Testudines]) occurred most often in diets of larger alligators (>1.83 m). Conversely, insects (i.e., Belostomatids and various beetles), crayfish (*Procambarus* sp.), and small fish (*Gambusia* spp. or Centrarchid) occurred most often in diets of smaller alligators (i.e., < 1.83 m). However, beetles and giant water bugs may be over represented in diet samples due to longer residence times of exoskeletons (Barr 1994, Barr 1997). Additionally, after the drawdown at Dam B WMA these species are likely the first to re-colonize, leading to their greater frequencies in diet samples. Because they occurred at similar frequencies among wetlands, these are all important food items for alligators in east Texas, especially for smaller size classes. As alligators increase in size, they become more capable (i.e., due to changes in ontogenetic skull structure) of exploiting larger food resources (Dodson 1975, Delany 1990, Delany et al. 1999), but also have greater energy requirements and metabolic costs (Dodson 1975, Thorbjarnarson 1993). Therefore, shifting to larger prey items meets increased energy demands (Delany et al. 1999) and maximizes their feeding efficiency (Wolfe et al. 1987) for adults (or larger alligators).

MANAGEMENT IMPLICATIONS

Because of the diverse food habits of American alligators in inland wetlands of east Texas, in order to properly manage these populations, conservation of diverse wetland habitats should occur; thereby providing diversity in prey items. To provide a diversity of habitats, removal of invasive aquatic plants is necessary. Species such as water hyacinth, alligatorweed, and salvinia form large mono-specific stands, resulting in large areas being inaccessible to alligators. Although salvinia and water hyacinth typically form floating mats, their abundances within wetlands can become high enough that alligators can walk on top of the vegetation (as seen at Dam B WMA). These large mats within the wetland, limit food availability, reduce amount of shallow water habitat (where alligators more efficiently feed) accessible to alligators, and limit access to islands where wading bird rookeries are located. However, removal of exotic invasive plants needs to be done in ways that do not exacerbate the problems.

Two common techniques for the removal aquatic vegetation is spraying with herbicides and mechanically harvesting, both of which if not properly timed or at the right intensity can negatively impact alligator populations. For example, at Dam B WMA, removal of exotic invasive plants is done exclusively by spraying herbicides. However, large mats of decomposing plant material can lead to sharp decreases in dissolved oxygen levels, especially in shallow water, leading to fish kills and decreased prey abundances. Therefore, control of aquatic invasive species should be done early in the season (e.g., spring) when temperatures are lower and the impact on dissolved oxygen levels would be less severe. However, if spraying is to occur in warmer, summer months, spraying smaller patches to create channels in shallow water habitat may be more effective. By spraying small patches, dissolved oxygen levels may not decline as severely and patches may be opened for alligators to access foraging areas. Additionally, removal of exotic invasive plants can be accomplished with the aid of a mechanical harvester. However, use of this technique should only be applied during the warmer months when alligators have enough energy to avoid mortality inflicted from the harvester (see Chapter II). Additionally, mechanical harvesters should be used only in deeper water, away from shoreline and islands, so additional disturbance or mortality is not inflicted to nesting females and hatchlings.

In addition to removal of exotic invasive species, more consistent water levels could increase food availability. Fluctuating water levels can shift prey distributions and limit available habitat, making it difficult for alligator to find and access food. Additionally, fluctuating water levels often force alligators to feed in open water habitats, decreasing feeding efficiency. By keeping water levels from fluctuating dramatically throughout the growing season (i.e., April 1 – October 31), alligators would have a more consistent prey base that are in more predictable locations.

To better manage alligator populations, future work should assess abundances and nutritive quality of dominant prey items (e.g., mammals, herptiles, fish, wading birds, and invertebrates). As diets tend to mirror prey abundances (McNease and Joanen 1977, Delany and Abercrombie 1986, Barr 1994, Barr 1997), changes in prey populations (e.g., fish kills following drawdown), may result in lower quality prey (e.g., invertebrates and small fish) being consumed. Therefore, understanding food availability and quality could provide insights into selection patterns, influencing growth rates and condition.

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Table 4.1. Occurrence of food items in American alligator (*Alligator mississippiensis*) diet samples (identified to lowest possible taxon) at Angelina-Neches/Dam B Wildlife Management Area (DMB), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2006 – 2008.

Taxon	DMB	LSNWR	Kurth Lake
MOLLUSCA			
Bivalvia			
Unionida			
Unionidae (Freshwater mussel)	X	X	X
PLATYHELMINTHES			
Cestoda (Tapeworm)	X	X	
ANNELIDA			
Clitellata (Leech)	X	X	
ARTHROPODA			

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Malacostraca			
Decapoda			
Palaemonidae (Freshwater shrimp)		X	
Cambaridae (Crayfish)	X	X	X
Insecta			
Odonata			
Lestidae (Spreadwing damselfly)	X	X	
Aeshnidae (Dragonfly)	X	X	
Orthoptera (Grasshopper)	X	X	
Hemiptera			
Nepidae (Water scorpion)	X	X	

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Belostomatidae (Giant water bug)	X	X	
Coleoptera (Beetle)	X	X	X
Gyrinidae (Whirligig beetle)		X	
Psephenidae (Water penny)		X	
Diptera			
Tipulidae (Cranefly larva)	X	X	
Arachnida			
Araneae			
Pisauridae (Fishing spider)	X	X	
CHORDATA			
Actinopterygii			

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Lepisosteiformes			
Lepisosteidae			
Lepisosteus oculatus (Spotted gar)		X	X
Cypriniformes			
Cyprinidae			
Cyprinella lutrensis (Red shiner)		X	
Cyprinodontiformes			
Fundulidae			
Fundulus spp. (Top minnow)		X	
Poeciliidae			
Gambusia affinis (Western mosquitofish)	X	X	

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Perciformes			
Centrarchidae			
Lepomis gulosus (Warmouth)		X	
Lepomis macrochirus (Bluegill)	X	X	
Lepomis miniatus (Redspotted sunfish)		X	
Micropterus salmoides (Largemouth bass)		X	
Amphibia			
Anura			
Hylidae			
Hyla cinerea (Green tree frog)			X
Reptilia			

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Testudines			
Kinosternidae			
Kinosternon flavescens (Yellow mud turtle)	X		
Emydidae			
Trachemys scripta (Red-eared slider)	X	X	
Squamata			
Colubridae			
Nerodia spp. (Unidentified water snake)	X	X	
Viperidae			
Agkistrodon piscivorus (Water moccasin)	X	X	
Crocodilia			

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Alligatoridae			
Alligator mississippiensis (Alligator)	X		
Aves			
Pelecaniformes			
Anhingidae			
Anhinga anhinga (Anhinga)		X	
Ciconiiformes			
Ardeidae			
Bubulcus ibis (Cattle egret)		X	
Gruiformes			
Rallidae			

Table 4.1. Continued.

Taxon	DMB	LSNWR	Kurth Lake
Gallinula chloropus (Common moorhen)		X	
Mammalia			
Rodentia			
Myocastor			
Myocastor coypus (Nutria)	X		
Artiodactyla			
Suidae			
Sus scrofa (Feral hog)	X		

Table 4.2. Total number of individuals of each prey item, percentage each prey item comprises, number of diet samples that contained each prey item, and percentage of diet samples that contained that prey item for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake and, Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Number of individuals (*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Invertebrates				
Freshwater mussel	4	0.60	4	6.45
Freshwater shrimp	4	0.60	4	6.45
Crayfish	47	7.01	26	41.94
Spreadwing damselfly	12	1.79	8	12.90
Dragonfly	7	1.04	6	9.68
Grasshopper	6	0.90	5	8.06
Water scorpion	5	0.75	5	8.06

Table 4.2. Continued.

	Number of individuals(*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Giant water bug	319	47.61	41	66.13
Unidentified beetles	143	21.34	27	43.55
Whirligig beetle	4	0.60	3	4.84
Water penny	1	0.15	1	1.61
Cranefly larva	2	0.30	2	3.23
Unidentified insect	8	1.19	7	11.29
Fishing spider	6	0.90	6	9.68
Total invertebrates	**568**	**84.78**	**52**	**83.87**
Fish				
Spotted gar	3	0.45	3	4.83

Table 4.2. Continued.

	Number of individuals (*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Red shiner	1	0.15	1	1.61
Topminnow	10	1.49	4	6.45
Western mosquitofish	3	0.45	2	3.23
Warmouth	1	0.15	1	1.61
Bluegill	4	0.60	3	4.84
Redspotted sunfish	1	0.15	1	1.61
Largemouth bass	2	0.30	2	3.23
Unidentified fish	30	4.48	25	40.32
Total fish	**55**	**8.21**	**32**	**51.61**

Table 4.2. Continued.

	Number of individuals(*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Herptiles				
Green tree frog	1	0.15	1	1.61
Yellow mud turtle	1	0.15	1	1.61
Red-eared slider	5	0.75	5	8.06
Unidentified turtles	4	0.60	4	6.45
Unidentified snake	5	0.75	5	8.06
Water moccasin	2	0.30	2	3.23
Alligator	1	0.15	1	1.61
Total herptiles	**19**	**2.84**	**18**	**29.03**

Table 4.2. Continued.

	Number of individuals (*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Birds				
Anhinga	1	0.15	1	1.61
Cattle egret	6	0.90	3	4.84
Common moorhen	1	0.15	1	1.61
Unidentified bird	9	1.34	7	11.29
Total birds	**17**	**2.54**	**11**	**17.74**
Mammals				
Nutria	1	0.15	1	1.61
Feral hog	2	0.30	2	3.23

Table 4.2. Continued.

	Number of individuals (*n*)	Proportion of total individuals (%)	Number of diet samples (*n*)	Proportion of diet samples (%)
Unidentified mammal	8	1.19	8	12.90
Total mammals	**11**	**1.64**	**11**	**17.74**

Table 4.3. Presence/absence (*n*), Chi-square (χ^2), and *P*-value resulting from Chi-square analysis of invertebrate, fish, herptile, bird, and mammal prey item frequency between male and female American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Male		Female			
Variable	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	χ^2	*P*
Invertebrates	32	6	20	4	0.01	0.927
Fish	20	18	12	12	0.04	0.840
Herptiles	13	25	5	19	1.28	0.258
Birds	6	32	5	19	0.26	0.613
Mammals	8	30	3	21	0.74	0.391

Table 4.4. Presence/absence (*n*), Chi-square (χ^2), and *P*-values resulting from Chi-square analysis of invertebrate, fish, herptile, bird, and mammal prey item frequency among wetlands for sub-adult (< 1.83 m in total length) American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2006 – 2008.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	χ^2	*P*
Invertebrates	10	1	3	0	30	3	0.30	0.862
Fish	5	6	2	1	17	16	0.43	0.805
Herptiles	3	8	1	2	6	27	0.69	0.710
Birds	1	10	0	3	9	24	2.49	0.287

Table 4.4. Continued.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	χ^2	*P*
Mammals	3	8	0	3	1	32	6.53	0.038

Table 4.5. Presence/absence (*n*), Chi-square (χ^2), and *P*-values resulting from Chi-square analysis of invertebrate, fish, herptile, bird, and mammal prey item frequency between size classes (breeding: > 1.83 m in total length and non-breeding: < 1.83 m in total length) for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas in 2006 – 2008.

	Non-breeding		Breeding			
Variable	Present (*n*)	Absent (*n*)	Present (*n*)	Absent (*n*)	χ^2	*P*
Invertebrates	43	4	9	6	8.34	0.004
Fish	24	23	8	7	0.02	0.878
Herptiles	10	37	8	7	5.67	0.017
Birds	10	37	1	14	1.66	0.197
Mammals	4	43	7	8	11.34	0.001

Table 4.6. Means ($\bar{x}$), standard errors (SE), and ***F*** and ***P***-values resulting from analysis of variance of percent (%) composition by mass of invertebrate, fish, herptile, bird, and mammal prey items for male and female American alligators (***Alligator mississippiensis***) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Male		Female			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	***P***
Invertebrates	14.27	3.02	21.81	5.77	1.61	0.210
Fish	6.11	2.13	11.13	4.81	1.16	0.285
Herptiles	9.69	3.46	8.70	4.75	0.03	0.865
Birds	8.43	4.17	3.16	1.93	0.92	0.340
Mammals	8.95	3.87	0.08	0.08	3.29	0.075

Table 4.7. Means ($\bar{x}$), standard errors (SE), and F and P-values resulting from analysis of variance of percent (%) composition by mass of invertebrate, fish, herptile, bird, and mammal prey items among wetland for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2006 – 2008.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	F	P
Invertebrates	15.67	5.32	34.62	18.61	16.73	3.35	0.93	0.402
Fish	5.85	4.18	0.78	0.78	10.20	2.81	0.68	0.513
Herptiles	11.88	5.12	26.02	26.02	0.33	0.14	1.43	0.248
Birds	0.03	0.03	0.00	0.00	11.29	4.58	2.28	0.111

Table 4.7. Continued.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	*P*
Mammals	11.42	5.44	0.00	0.00	1.95	1.95	1.94	0.153

Table 4.8. Means ($\bar{x}$), standard errors (SE), and ***F*** and ***P***-values resulting from analysis of variance of percent (%) composition by mass of invertebrate, fish, herptile, bird, and mammal prey items between size classes (breeding: > 1.83 m in total length and non-breeding: < 1.83 m in total length) for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Non-breeding		Breeding			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	***F***	***P***
Invertebrates	21.54	3.58	3.54	1.82	7.80	0.007
Fish	8.00	2.17	8.22	6.65	0.00	0.967
Herptiles	7.61	2.99	14.64	6.69	1.17	0.283
Birds	8.43	3.48	0.00	0.00	1.85	0.178
Mammals	1.79	1.48	17.20	8.40	8.29	0.006

Table 4.9. Means ($\bar{x}$), standard errors (SE), and ***F*** and ***P***-values resulting from analysis of variance of percent (%) occurrence of invertebrate, fish, herptile, bird, and mammal prey items for male and female American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Male		Female			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	*P*
Invertebrates	60.64	5.60	64.72	7.17	0.20	0.654
Fish	15.33	3.58	15.95	4.92	0.01	0.917
Herptiles	10.18	3.37	10.07	4.84	0.00	0.985
Birds	5.74	3.04	3.35	1.49	0.35	0.554
Mammals	8.11	3.76	5.90	4.27	0.14	0.706

Table 4.10. Means ($\bar{x}$), standard errors (SE), and *F* and *P*-values resulting from analysis of variance of percent (%) composition by mass of invertebrate, fish, herptile, bird, and mammal prey items among wetlands for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA), Kurth Lake, and Little Sandy National Wildlife Refuge (LSNWR), Texas, 2006 – 2008.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	*P*
Invertebrates	52.04	8.43	70.00	6.94	68.53	4.95	1.75	0.183
Fish	16.56	5.71	18.89	11.60	14.61	3.24	0.08	0.920
Herptiles	14.74	5.27	11.11	11.11	6.89	3.16	0.93	0.401
Birds	2.08	1.44	0.00	0.00	7.10	3.28	0.92	0.406

Table 4.10. Continued.

	Dam B WMA		Kurth Lake		LSNWR			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	*P*
Mammals	14.58	5.74	0.00	0.00	2.86	2.86	2.25	0.115

Table 4.11. Means ($\bar{x}$), standard errors (SE), and *F* and *P*-values resulting from analysis of variance of percent (%) occurrence of invertebrate, fish, herptile, bird, and mammal prey items between size classes (breeding > 1.83 m total length; non-breeding < 1.83 m total length) for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Kurth Lake, and Little Sandy National Wildlife Refuge, Texas, 2006 – 2008.

	Non-breeding		Breeding			
Variable	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	*F*	*P*
Invertebrates	71.65	4.28	32.67	1.82	18.72	<0.001
Fish	12.74	2.60	24.44	6.65	3.13	0.082
Herptiles	6.63	2.71	21.11	6.69	5.41	0.024
Birds	5.82	2.50	1.67	0.00	0.83	0.365
Mammals	3.16	2.20	20.11	8.40	7.34	0.009

CHAPTER V

SUMMARY OF MANAGEMENT IMPLICATIONS

MANAGEMENT IMPLICATIONS

Geographic and regional differences in American alligator home ranges, movements, nest densities, nest success, hatchling survival, age at maturity, condition, size structure, growth rates, and food availability make it challenging to establish broad-scale or even regional conservation, management, or harvest recommendations. Therefore, obtaining site specific data are key for proper management. For example, geographic differences in the above metrics could have dramatic impacts on alligator population parameters such as recruitment, survival, and overall population size and age characteristics. Thus, it may be necessary to modify current management strategies as such variability in basic life history parameters likely requires regionally specific management guidelines. Population models need to be established/modified to account for variability in size distributions, hatchling survival, nest success, population densities, and sex ratios. Without a better understanding of how these population parameters are affected by harvest, it is impossible to predict the sustainability of current harvest strategies.

Additionally, such population parameters may be affected by habitat conditions. For example, one potentially important alteration in wetland habitats in east Texas is the introduction or continued expansion of exotic invasive plant species. For example, at Dam B WMA, salvinia, alligatorweed, and water hyacinth have formed large mats, reducing the amount of habitat for alligators. Additionally, most of the vegetated islands at Little Sandy NWR and Dam B WMA are dominated by dense stands of Chinese tallow, effectively limiting physical space for nesting alligators. Moreover, most nesting islands at Dam B WMA are surrounded by exotic invasive aquatic plants such as salvinia, alligatorweed, and water hyacinth, all of which combine to reduce available nesting habitat and limit shallow water habitats critical for hatchling survival. Species such as water hyacinth, alligatorweed, and salvinia form large mono-specific stands, resulting in large areas of the wetland becoming inaccessible to alligators. These large mats within a wetland, limit food availability and reduce amount of shallow water habitat (where alligators more efficiently feed) accessible to alligators.

Two common techniques for the removal aquatic vegetation are spraying with herbicides and mechanically harvesting, both of which if not properly timed or at the right intensity can negatively impact alligator populations. For example, at Dam B WMA, removal of exotic invasive plants is done exclusively by spraying herbicides. However, large mats of decomposing plant material can lead to sharp decreases in dissolved oxygen levels, especially in shallow water, leading to fish kills and decreased prey abundances. Therefore, control of aquatic invasive species should be done early in the season (e.g., spring) when temperatures are lower and the impact on dissolved oxygen levels would be less severe. However, if spraying is to occur in warmer, summer months, spraying smaller patches to create channels in shallow water habitat may be more effective. By spraying small patches, dissolved oxygen levels may not decline as severely and patches may be opened for alligators to access foraging areas. Additionally, removal of exotic invasive plants can be accomplished with the aid of a mechanical harvester. However, use of this technique should only be applied during the warmer months when alligators have enough energy to avoid mortality inflicted from the harvester. Additionally, mechanical harvesters should be used only in deeper water, away from shoreline and islands, so additional disturbance or mortality is not inflicted to nesting females and hatchlings.

Water level fluctuations can also dramatically impact extent of available habitat, either naturally (based upon precipitation patterns) or anthropogenically (through water manipulation on reservoirs), food availability, hatchling survival and nest success. Alligators cannot *a priori* account for unseasonable floods during the nesting season, which often result in nest failures. In reservoirs like Dam B WMA, water levels can fluctuate based upon management goals in addition to precipitation. Such fluctuations can negatively impact both alligator nests and hatchlings. If water levels drop, shallow marsh habitat may become reduced, thereby, exposing nests and/or hatchling alligators to increased risks of predation and/or cannibalism. Conversely, if water levels stay high for extended periods of time, nests could be flooded. Additionally, fluctuating water levels can shift prey distributions and limit available habitat, making it difficult for alligators to find and access food. Fluctuating water levels often force alligators to feed in open water habitats, decreasing feeding efficiency. To promote better nest success, hatchling survival, and food availability, water levels within reservoirs should remain consistent during the growing season (i.e., April – October). By keeping water at constant levels, female alligators can safely select nest sites above high water marks and shallow marsh habitat for hatchlings will remain available. Although water levels can be maintained by varying rates of discharge, this may not be possible in every year or at every wetland containing alligators. Therefore, it remains important to understand the relationship between water levels, nest success, hatchling survival, and food availability to incorporate water levels into population and harvest models for American alligators.

Alligator harvest is predicted to continue to increase in east Texas; however, it is unknown how the potentially additive effects of harvest and geographic variability in home range size, movements, growth rates, and body condition may impact these populations. Alligators at the three study sites have been subjected to harvest for at least the past 15 years, resulting in many of the large (most likely dominant) individuals being removed from the population (Texas Parks and Wildlife Department unpublished, Saalfeld et al. unpublished). Current non-selective harvest (e.g., hook and line techniques used on Dam B WMA and Little Sandy) combined with geographic variability in life history characteristics may result in unsustainable harvest. By removing large, presumably dominant, individuals from the population, smaller alligators are no longer inhibited from breeding, potentially leading to decreased clutch size, hatchling survival, growth rates, and nest success. Although, current harvest strategies are non-selective and size structure of harvested alligators should reflect the natural size distribution, hunters place baits high enough such that only larger alligators are targeted. Harvest within these wetlands needs to be more selective, where intermediate size classes (e.g., 1.2 – 1.8 m) are targeted to reduce higher density portions of the population and to lessen pressure on dominant individuals (e.g., instituting a slot limit). Therefore, harvest of intermediate size classes could potentially lessen the additive impact of small home range sizes and removal of dominant individuals and potentially promote sustainable harvest.

Alligator harvest regulations also need to accommodate variability in nest success by including site specific yearly estimates of nest success into harvest models. Not accounting for spatial and temporal variation in nest success could result in unsustainable and/or over-harvest. 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 D WMA since 1997 (~ 17 alligators/year), however, < 15 alligators (~ 1 alligator/year) were harvested at Little Sandy NWR during the same time frame. Therefore, the cumulative 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 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. For example, in years when few pods are located and/or water levels rise dramatically during the nesting season, a more conservative quota can be set.

APPENDIX A

MEANS ($\bar{x}$) AND STANDARD ERRORS (SE) OF 50% FIXED KERNEL HOME RANGES (HA) FOR TRANSMITTERED AMERICAN ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*) AT ANGELINA-NECHES/DAM B WILDLIFE MANAGEMENT AREA (DAM B WMA) AND LITTLE SANDY NATIONAL WILDLIFE REFUGE (NWR), TEXAS, 2006 – 2008

Appendix A. Means ($\bar{x}$) and standard errors (SE) of 50% fixed kernel home ranges (ha) for transmittered American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA) and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	8	9.4 a	2.4
LSNWR	Combined	Combined	Combined	90	11.5 a	1.1
Combined	Female	Combined	Combined	78	11.1 ***a***	1.2
Combined	Male	Combined	Combined	20	12.2 ***a***	2.2
Combined	Combined	2006	Combined	5	5.4 ab	3.3
Combined	Combined	2007	Combined	28	15.5 a	2.5
Combined	Combined	2008	Combined	65	10.0 b	1.0
Combined	Combined	Combined	Spring	33	13.9 ***a***	2.1
Combined	Combined	Combined	Summer	51	10.3 ***a***	1.3
Combined	Combined	Combined	Winter	14	8.8 ***a***	1.9

Appendix A. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Female	2006	Combined	5	5.4 A	3.3
Combined	Female	2007	Combined	24	15.8 A	3.3
Combined	Female	2008	Combined	49	9.3 A	1.1
Combined	Male	2007	Combined	4	13.6 A	4.6
Combined	Male	2008	Combined	16	11.9 A	2.6
Combined	Female	Combined	Spring	28	13.8 *A*	2.3
Combined	Female	Combined	Summer	42	10.1 *A*	1.5
Combined	Female	Combined	Winter	8	6.9 *A*	1.4
Combined	Male	Combined	Spring	5	14.7 *A*	6.1
Combined	Male	Combined	Summer	9	11.4 *A*	2.9
Combined	Male	Combined	Winter	6	11.5 *A*	4.0
Combined	Combined	2006	Summer	5	5.4 A	3.3
Combined	Combined	2007	Spring	10	14.2 A	5.0
Combined	Combined	2007	Summer	18	16.2 A	2.9
Combined	Combined	2008	Spring	23	13.8 A	2.2

Appendix A. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Combined	2008	Summer	28	7.4 A	1.0
Combined	Combined	2008	Winter	14	8.8 A	1.9
Combined	Female	2006	Summer	5	5.4 *A*	3.3
Combined	Female	2007	Spring	9	15.1 *A*	5.5
Combined	Female	2007	Summer	15	16.2 *A*	5.3
Combined	Female	2008	Spring	19	13.2 *A*	2.2
Combined	Female	2008	Summer	22	7.0 *A*	1.0
Combined	Female	2008	Winter	8	6.9 *A*	1.4
Combined	Male	2007	Spring	2	5.9 *A*	2.4
Combined	Male	2007	Summer	3	16.2 *A*	3.4
Combined	Male	2008	Spring	4	16.9 *A*	7.4
Combined	Male	2008	Summer	6	9.0 *A*	2.2

Appendix A. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Combined	Male	2008	Winter	6	11.5 $\underline{A}$	4.0

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

APPENDIX B

MEANS ($\bar{x}$) AND STANDARD ERRORS (SE) OF 100% MINIMUM CONVEX POLYGON HOME RANGES (HA) FOR TRANSMITTERED AMERICAN ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*) AT ANGELINA-NECHES/DAM B WILDLIFE MANAGEMENT AREA (DAM B WMA) AND LITTLE SANDY NATIONAL WILDLIFE REFUGE (NWR), TEXAS, 2006 – 2008

Appendix B. Means ($\bar{x}$) and standard errors (SE) of 100% minimum convex polygon home ranges (ha) for transmittered American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA) and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	6	10.0 a	3.5
LSNWR	Combined	Combined	Combined	88	19.3 a	2.0
Combined	Female	Combined	Combined	76	18.6 ***a***	2.0
Combined	Male	Combined	Combined	18	19.1 ***a***	5.3
Combined	Combined	2006	Combined	4	5.9 ab	2.8
Combined	Combined	2007	Combined	28	27.8 a	4.3
Combined	Combined	2008	Combined	62	15.4 b	1.9
Combined	Combined	Combined	Spring	33	22.9 *a*	3.2
Combined	Combined	Combined	Summer	50	18.4 *a*	2.7
Combined	Combined	Combined	Winter	11	7.8 *a*	2.2

Appendix B. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Female	2006	Combined	4	5.9 A	2.8
Combined	Female	2007	Combined	24	27.1 A	4.3
Combined	Female	2008	Combined	48	15.5 A	2.0
Combined	Male	2007	Combined	4	32.1 A	17.5
Combined	Male	2008	Combined	14	15.3 A	4.7
Combined	Female	Combined	Spring	28	22.8 *A*	3.3
Combined	Female	Combined	Summer	42	17.9 *A*	2.7
Combined	Female	Combined	Winter	6	4.0 *A*	1.0
Combined	Male	Combined	Spring	5	23.5 *A*	12.1
Combined	Male	Combined	Summer	8	20.8 *A*	9.4
Combined	Male	Combined	Winter	5	12.1 *A*	4.1
Combined	Combined	2006	Summer	4	5.9 C	2.8
Combined	Combined	2007	Spring	10	18.7 BC	5.8
Combined	Combined	2007	Summer	18	32.8 A	5.6
Combined	Combined	2008	Spring	23	24.7 AC	3.9

Appendix B. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Combined	Combined	2008	Summer	28	10.9 C	1.0
Combined	Combined	2008	Winter	11	7.8 C	1.9
Combined	Female	2006	Summer	4	5.9 *A*	2.8
Combined	Female	2007	Spring	9	20.1 *A*	6.3
Combined	Female	2007	Summer	15	31.2 *A*	5.6
Combined	Female	2008	Spring	19	23.9 *A*	3.9
Combined	Female	2008	Summer	23	11.4 *A*	1.9
Combined	Female	2008	Winter	6	4.2 *A*	1.0
Combined	Male	2007	Spring	2	5.4 *A*	2.1
Combined	Male	2007	Summer	3	41.0 *A*	21.2
Combined	Male	2008	Spring	3	28.0 *A*	14.5
Combined	Male	2008	Summer	5	8.5 *A*	3.3

Appendix B. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Combined	Male	2008	Winter	6	12.1 $\underline{A}$	4.2

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] "Combined" corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

APPENDIX C

MEANS ($\bar{x}$) AND STANDARD ERRORS (SE) OF 95% MINIMUM CONVEX POLYGON HOME RANGES (HA) FOR TRANSMITTERED AMERICAN ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*) AT ANGELINA-NECHES/DAM B WILDLIFE MANAGEMENT AREA (DAM B WMA) AND LITTLE SANDY NATIONAL WILDLIFE REFUGE (NWR), TEXAS, 2006 – 2008

Appendix C. Means ($\bar{x}$) and standard errors (SE) of 95% minimum convex polygon home ranges (ha) for transmittered American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area (Dam B WMA) and Little Sandy National Wildlife Refuge (NWR), Texas, 2006 – 2008.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Dam B WMA	Combined[d]	Combined	Combined	6	3.4 a	1.5
LSNWR	Combined	Combined	Combined	88	13.7 a	1.6
Combined	Female	Combined	Combined	76	13.7 ***a***	1.7
Combined	Male	Combined	Combined	18	10.1 ***a***	3.5
Combined	Combined	2006	Combined	4	3.8 a	1.7
Combined	Combined	2007	Combined	28	21.2 a	3.9
Combined	Combined	2008	Combined	62	9.9 a	1.3
Combined	Combined	Combined	Spring	33	15.1 ***a***	2.1
Combined	Combined	Combined	Summer	50	13.9 ***a***	2.5
Combined	Combined	Combined	Winter	11	2.9 ***a***	0.6

Appendix C. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Female	2006	Combined	4	3.8 A	1.7
Combined	Female	2007	Combined	24	20.8 A	4.0
Combined	Female	2008	Combined	48	11.0 A	1.6
Combined	Male	2007	Combined	4	23.7 A	14.1
Combined	Male	2008	Combined	14	6.5 A	1.9
Combined	Female	Combined	Spring	28	15.9 *A*	2.4
Combined	Female	Combined	Summer	42	14.0 *A*	2.6
Combined	Female	Combined	Winter	6	1.8 *A*	0.4
Combined	Male	Combined	Spring	5	10.4 *A*	5.6
Combined	Male	Combined	Summer	8	13.3 *A*	6.7
Combined	Male	Combined	Winter	5	4.2 *A*	0.9
Combined	Combined	2006	Summer	4	3.8 BC	1.7
Combined	Combined	2007	Spring	10	10.7 BC	3.3
Combined	Combined	2007	Summer	18	27.0 A	5.4
Combined	Combined	2008	Spring	23	17.0 B	2.7

Appendix C. Continued.

Wetland	Sex	Year	Season[a]	*n*[b]	$\bar{x}$ (ha)[c]	SE
Combined	Combined	2008	Summer	28	6.8 C	1.1
Combined	Combined	2008	Winter	11	2.9 C	0.6
Combined	Female	2006	Summer	4	3.8 *A*	1.7
Combined	Female	2007	Spring	9	11.7 *A*	3.5
Combined	Female	2007	Summer	15	26.2 *A*	5.5
Combined	Female	2008	Spring	19	17.9 *A*	3.0
Combined	Female	2008	Summer	23	7.5 *A*	1.3
Combined	Female	2008	Winter	6	1.8 *A*	0.4
Combined	Male	2007	Spring	2	1.7 *A*	0.6
Combined	Male	2007	Summer	3	31.1 *A*	17.1
Combined	Male	2008	Spring	3	12.5 *A*	6.7
Combined	Male	2008	Summer	5	4.4 *A*	1.1

Appendix C. Continued.

Wetland	Sex	Year	Season[a]	n[b]	$\bar{x}$ (ha)[c]	SE
Combined	Male	2008	Winter	6	4.2 $\underline{A}$	0.9

[a] Season corresponds to spring (April – June), summer (July – September), and winter (January – March).

[b] Total number of observations used for repeated measures analysis, potentially including multiple observations made on the same individual.

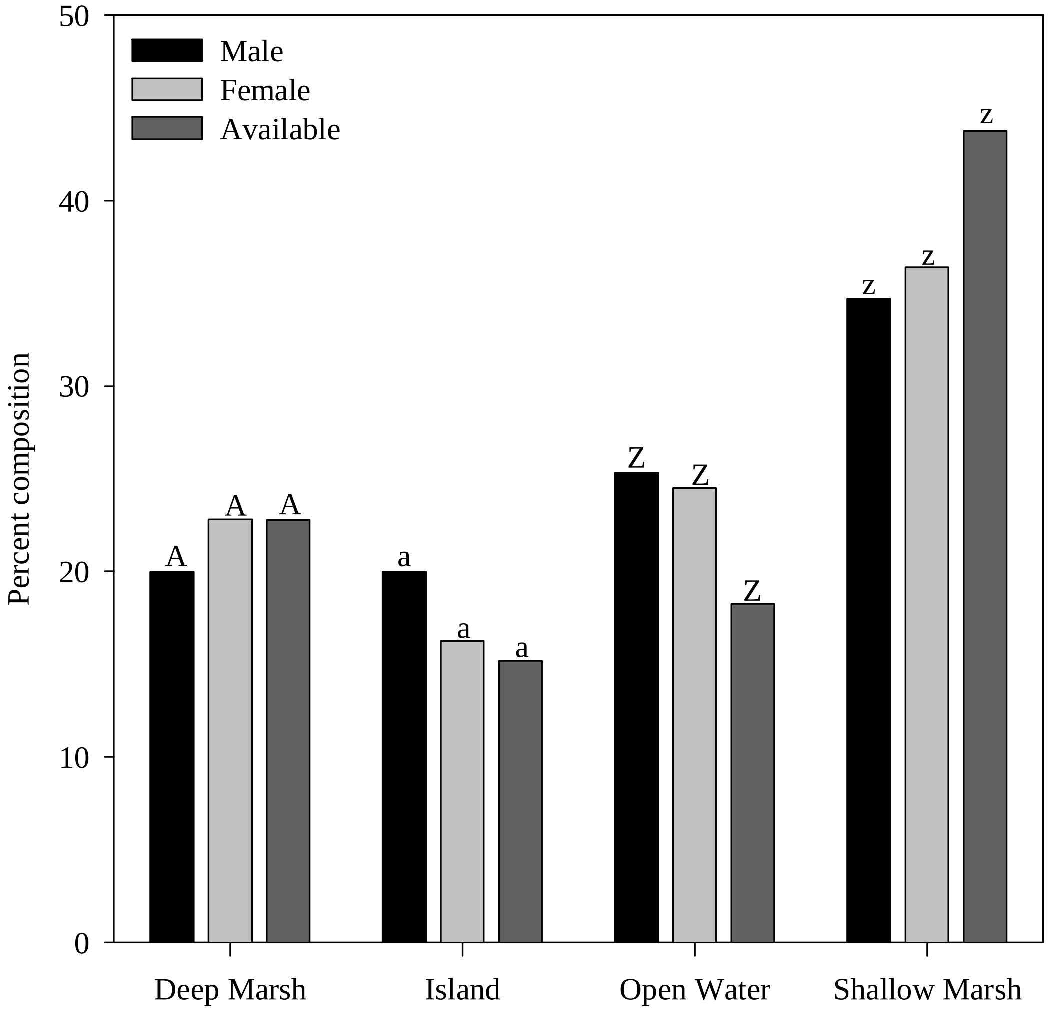
[c] Means followed by the same letter in the same case and font style are not different ($P > 0.05$; least squares cross validation).

[d] “Combined” corresponds to instances when all data within a column heading (i.e., variable) are pooled.

[e] Least squares cross validation was not able to be estimated.

APPENDIX D

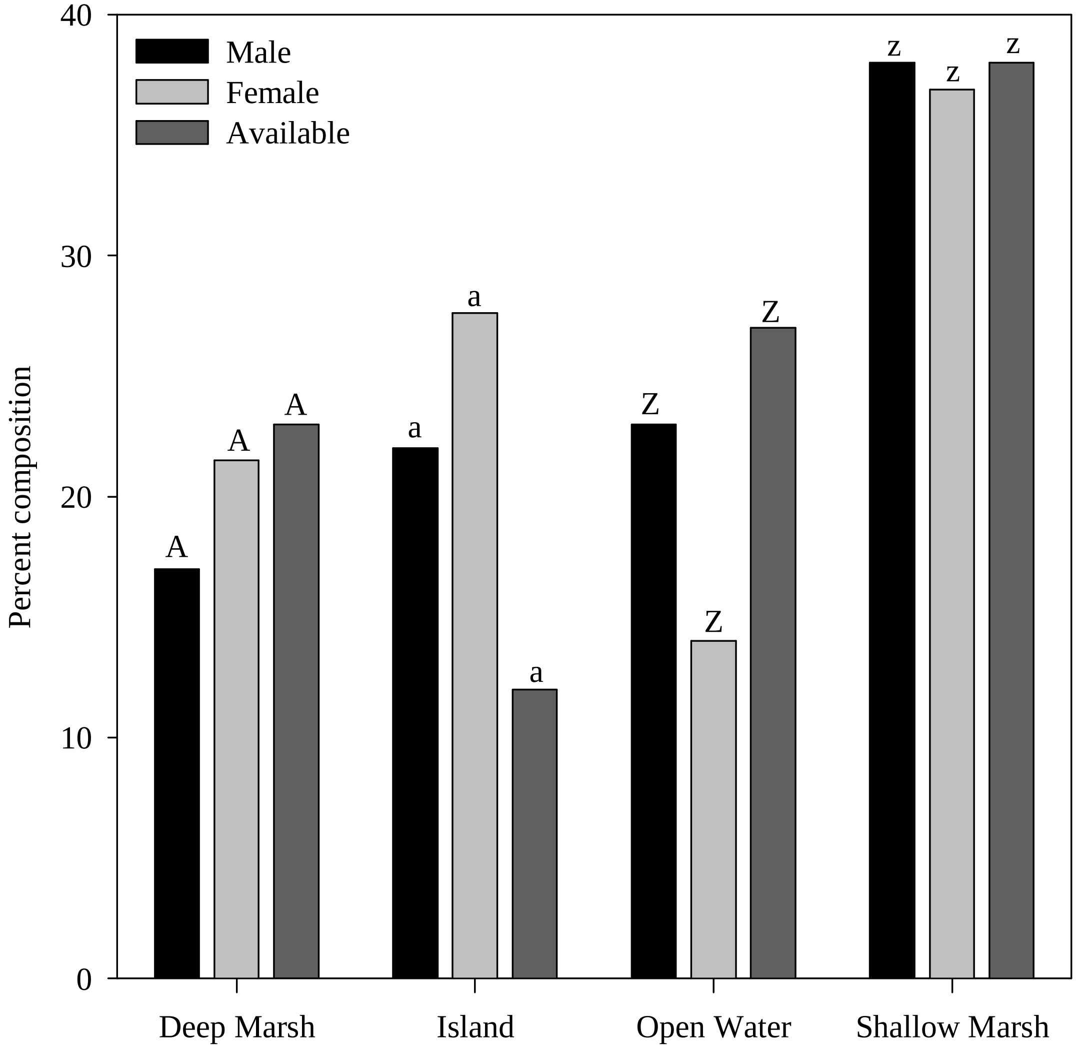
PERCENT COMPOSITION OF HABITAT USE (BASED ON 95% FIXED KERNEL HOME RANGES) FOR AMERICAN ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*) AT LITTLE SANDY NATIONAL WILDLIFE REFUGE, TEXAS, 2006 – 2008. MEANS WITH THE SAME LETTERS WITHIN A HABITAT TYPE ARE NOT DIFFERENT (CHI-SQUARE ANALYSIS; ***P*** > 0.05)



Appendix D. Percent composition of habitat use (based on 95% fixed kernel home ranges) for American alligators (*Alligator mississippiensis*) at Little Sandy National Wildlife Refuge, Texas, 2006 – 2008. Means with the same letters within a habitat type are not different (Chi-square analysis; *P* > 0.05).

APPENDIX E

PERCENT COMPOSITION OF HABITAT USE (BASED ON 95% FIXED KERNEL HOME RANGES) FOR AMERICAN ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*) AT ANGELINA-NECHES/DAM B WILDLIFE MANAGEMENT AREA, TEXAS, 2006 – 2008. MEANS WITH THE SAME LETTERS WITHIN A HABITAT TYPE ARE NOT DIFFERENT (CHI-SQUARE ANALYSIS; *P* > 0.05)



Appendix E. Percent composition of habitat use (based on 95% fixed kernel home ranges) for American alligators (*Alligator mississippiensis*) at Angelina-Neches/Dam B Wildlife Management Area, Texas, 2006 – 2008. Means with the same letters within a habitat type are not different (Chi-square analysis; *P* > 0.05).

VITA

David Thomas Saalfeld was born in Cincinnati, Ohio on January 13, 1980. He grew up in Northern Kentucky and graduated from Newport Central Catholic High School in Newport, Kentucky in 1998. Following this, he attended Thomas More College where he worked for three years at Thomas More College's Center for Ohio River Research and Education. David graduated from Thomas More College cum laude with a Bachelor of Arts in Biology in 2002. He then began his graduate education as a research assistant in Fisheries and Allied Aquacultures at Auburn University and as an intern at Alabama Power. David finished his degree requirements for a Masters of Science in Fisheries and Allied Aquacultures in May 2006. He continued his graduate education as a research assistant in Forestry at Stephen F. Austin State University. David finished his degree requirements for a Doctor of Philosophy in Forestry in August 2010.

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