GROWTH RATES AND BODY CONDITION FACTORS OF ALLIGATOR MISSISSIPPIENSIS IN COASTAL LOUISIANA WETLANDS: A COMPARISON OF WILD AND FARM-RELEASED JUVENILES

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Abstract—1. Growth rates and body condition factors for native wild and captive-raised juvenile alligators (Alligator mississippiensis) that had been released to the wild were studied using tag-recapture methods for 274 alligators over a 4-year period. Alligators were grouped by sex, size class, source (farm-release vs native wild) and as to whether they had overwintered or not.

2. In most groups, the farm-released alligators grew significantly better than wild alligators matched for sex and size; in the remaining groups the post-release alligators grew as well as their counterparts, though not better.

3. Overwintering tended to slow growth rates in both groups, but farm-released alligators still demonstrated superior growth over native wild alligators even after overwintering.

4. Males tended to grow faster than females, though this trend was not always significantly greater. In no matched group did females grow faster than males.

5. Growth rates diminished with increasing size in native wild alligators (smaller alligators grew faster), but growth rates of farm-released alligators remained accelerated even at the larger size classes.

6. Growth curves were constructed using known recapture data with three growth models (von Bertalanffy, Gompertz and logistic); the calculated maximum attainable length and growth parameters were significantly larger (P < 0.01) for farm-released alligators than wild using all three models.

7. Body condition factors were not different in captive-raised post-released alligators than native wild alligators.

INTRODUCTION

The feasibility and practicality of raising crocodilians in captivity for commercial and conservation purposes is well documented (Joanen and McNease, 1990, 1991; Webb et al., 1987; Hutton and Webb, 1992). An extensive research program on the ecology, reproductive biology and captive propagation of Alligator mississippiensis was initiated in 1964 by the Louisiana Department of Wildlife and Fisheries (LDWF). The technology of egg incubation, post-hatching culture, and juvenile and adult alligator culture was researched thoroughly and refined (Joanen and McNease, 1971, 1975, 1976, 1977, 1979, 1987), and led to successful development of numerous alligator farms in Louisiana.

Although alligators have been shown to breed in captivity (Joanen and McNease, 1971, 1975, 1979, 1987), success has been limited and emphasis shifted to ranching programs. Alligator farmers/ranchers may contract to collect eggs from privately owned wetlands, after nesting populations and habitat suitability are reviewed by LDWF personnel and conservative egg harvest quotas are set. The alligator "rancher", as part of his contract, is obligated to return to the wild healthy alligators between 36 and 60 in. (0.92–1.52 m) representing a calculated percentage of his annual hatch rate based on mortality/survivorship curves. The LDWF requires that alligators be "put-back" during the warm months of the year into the same wetlands from which the eggs were collected.

Growth rates in wild alligator populations in several habitats have been documented, including Louisiana (McIlhenny, 1934; Nichols et al., 1976; Chabreck and Joanen, 1979; Rootes, 1989), Florida (Hines et al., 1968; Dietz, 1979; Jacobsen and Kushlan, 1989), Georgia (Hunt, 1990), Texas (Smith and Adams, unpublished data), North Carolina (Fuller, 1981) and South Carolina (Bara, 1972; Murphy, 1977; Brandt, 1989).

Limited data exists, however, on growth rates of restocked crocodilians returned to the wild from captivity, or on the success rate of relocation, repatriation and translocation efforts in crocodilians (Dodd and Siegel, 1991). Also, early concern was expressed that captive released crocodilians might not thrive, possibly as a result of having to learn to hunt for food and adapt to a new environment (Blake and Loveridge, 1975). Thus, the purpose of this study was to evaluate growth rates and body conditions of alligators raised in captivity and released back to the wild. This data may be used further to refine management recommendations and more precisely determine appropriate return rates of rached alligators to the wild to maintain healthy populations.
MATERIALS AND METHODS

Description of Louisiana Department of Wildlife and Fisheries alligator farming/ranching program

The LDWF supervises an alligator farming/ranching program which increased 10-fold between 1986 and 1990. Until 1986 the farming program was small due to limitations with stock procurement, and the initial few farmers were supplied hatchlings which came from eggs collected by department personnel from state-owned lands. Recent interest in alligator farming/ranching led to a rapid expansion of the program, and the demand for hatchlings for this growing industry could not be met from resources of the agency. The LDWF then developed guidelines and strict quotas whereby potential farmers/ranchers might obtain eggs from suitable private wetlands, which historically have been shown to support significant populations of alligators. The alligator farmer/rancher is required to return a certain quota of healthy captive-raised juvenile alligators to the original egg collection site for restocking, to ensure the viability of the wild population.

The LDWF initially required that 17% of the fertile eggs hatched by farmers be returned at 48 in. (121.9 cm). In 1991, a sliding scale return rate was established based on 17% survival at 48 in. (121.9 cm) and utilizing the relationship of survival between size classes as specified in Taylor and Neal (1984) to extrapolate to survival rates for alligators from 36 in. (91.4 cm) to 60 in. (152.4 cm). For example, more alligators must be returned if the average is smaller [example 18% at 47 in. (119.4 cm) average] and fewer animals are required if the average is larger [example 14% at a 53 in. (134.6 cm) average]. Alligators must be at least 36 in. (91.4 cm) and preferably less than 60 in. (152.4 cm) and free of disease or deformities to be acceptable for release. Releases are made from 15 March to 30 September if the weather is warm enough to enhance survivorship.

Department personnel supervise each release, and the “put-back” alligators are marked individually with serially numbered monel web tags, and a tail scute is removed. Length to the nearest half inch (1.27 cm) is recorded, and sex determined by visual examination after exposing the penis/clitoris by opening the cloaca with a nasal speculum.

Various alligator program participants are encouraged by department personnel to provide tag return data to the agency. Alligator farmers, land managers and hunters are requested to collect specific information and to notify department personnel if a tagged alligator is taken during the annual wild alligator harvest. Similar data on length and sex is taken at the time of recapture such that interval growth rates may be determined.

Tagging and recapture methods

In order to compare growth rates of released alligators to wild populations, LDWF personnel intensified a pre-existing tag/recapture program to tag numerous wild alligators in the 3–4 ft (91.4–121.9 cm) size class to facilitate comparison to the farm/ranch released size structure. Alligators were captured on privately owned wetlands (in which alligator harvests occur in the annual September season) and on state-owned wetlands which have experimental annual harvests, and from which egg collections and juvenile alligator releases are made as part of the LDWF alligator ranching program.

Wild alligators were caught for tagging at night from airboats after locating eyeshines with a “Q-Beam” spotlight. Alligators were caught by hand, or by a self-locking cable snare (“Cooncatchers”), Southeastern Outdoor Supplies, Inc., Bassett, Virginia. Wild alligators were marked, tagged, sexed and measured as described for farm “put-backs” then released at the capture site, and growth data obtained when recaptured later by LDWF personnel or when harvested. Areas selected for capture/retrap attempts were sites where farm reared alligators had been previously released such that...

Fig. 1. Growth rates for recaptured juvenile alligators that did not overwinter between the time of initial release or capture and subsequent recapture. The sample size for each group (N) is in parentheses at the base of each bar. Error bars represent the SEM. Size class at initial release or capture are Class I = 76–102 cm, Class II = 103–127 cm and Class III = 128–152 cm.

Fig. 2. Growth rates for recaptured juvenile alligators that had sustained at least one overwintering period between the time of initial release or capture and subsequent recapture. The sample size for each group (N) is in parentheses at the base of each bar. Error bars represent the SEM. Size class at initial release or capture are Class I = 76–102 cm, Class II = 103–127 cm and Class III = 128–152 cm.
data might be obtained on native wild alligators as well as possibly recatching the ranched “post-release” alligators.

Recapture data was available on a total of 274 alligators. One hundred and seventy-three (173) males were recaptured (102 post-release from an alligator farm and 71 wild), and 101 females (66 farm-released, 35 wild).

Data analysis—growth rates

Growth rates were expressed in centimeters growth per growing month. Alligators were considered to have 6 growing months per year (April–September) as previously described (Chabreck and Joanne, 1979).

Alligators were divided into different groups by sex, source (farm-released or native wild) and as to whether or not they had overwintered. Alligators were also classified into size groups based on length at the time of release or initial capture/ tagging as follows: Class I being 30–40 in. (76–102 cm), Class II being 41–50 in. (103–127 cm) and Class III having initial lengths of 51–60 in. (128–152 cm). No females were recaptured in Class III that had overwintered. The number of alligators in each group are as shown in Figs 1 and 2. Time intervals between initial tagging and subsequent capture ranged from 0.5 to 47 months with the average time for alligators that did not overwinter being 3.3 months, and for those that did overwinter being 18.0 months. Data between paired groups were compared using Student’s t-test.

Growth curves

Data from the 274 recaptured alligators used to construct growth curves based on three models using Von Bertalanffy, Gompertz and logistic growth curve models, to test for difference in growth rates between farm-released and wild alligators with known time intervals between two measurements. “LINF” or “length infinity” is the calculated maximum length attainable. The k factor (yearly rate) is a calculated growth parameter related to the growth rate, with higher values indicative of better growth rates (Fabens, 1965). Likelihood ratio tests were used to determine jointly whether LINF and/or the k factor differed significantly between wild and farm-released alligators. This model is independent of the age of animals used, can be used with data only on sizes and known time differences, with no knowledge of absolute age, and adjusts for exponential decreases in growth with time/increasing age (Fabens, 1965).

Condition factors/robusticity indices

Condition factors (Le Cren, 1951) are an index of the robustness of an animal and can be an indicator of well-being (Taylor, 1979). The relationship between length and weight in alligators was assumed to fit the equation

\[ W = aL^b, \]

where \( W \) = weight in kg, \( L \) = total length in m, and \( a \) is the condition factor (ponderal index). The factor \( b \) is a constant, and is equal to 3 when growth is isometric. The equation is solved by use of least square regression on the linear form of the model

\[ \log(W) = \log(a) + b \log(L) + E \]

where \( \log \) represents the natural logarithm, \( \log(a) \) represents the log of the condition index, \( b \) represents the slope of the regression and \( E \) represents an error term. Two separate linear regressions were evaluated on our data, and analysis of covariance was used to compare the condition of wild and farm-released alligators. Lengths and weights were available for the 89 farm-released alligators that were taken in wild harvest; we also obtained lengths and weights from 180 similar sized native wild alligators taken in the same harvest area for comparison and condition factor analysis.

**RESULTS**

**Farm-released vs wild alligators.** Growth rates for 274 recaptured alligators (168 farm-released, 106 wild) are shown in Figs 1 and 2, with alligators that were recaptured before having had to overwinter being shown in Fig. 1, and alligators that had overwintered shown in Fig. 2. In most groups, the farm-released alligators clearly showed significantly better growth rates than the wild alligators matched for sex and size. This was evident in all size classes of the males that overwintered: being highly significant \((P < 0.05)\) in Class I and in Class II \((P < 0.01)\), though small sample sizes limited statistical evaluation in Class III; but the trend was that farm-released exceeded wild. Growth in Class II farm-released females that overwintered also exceeded the wild counterparts \((P < 0.05)\), as did Class III of the males \((P < 0.01)\) and females \((N = 2\) precluded statistical analysis) that did not overwinter. The farm released Class I males that did not overwinter tended to grow faster than the wild of this group, but not significantly so. In the remaining groups (Class I females that overwintered, Class II males that did not overwinter, and Class II females that did not overwinter), the farm-released alligators grew as well as the wild counterparts, though not better. In no group did the wild alligators grow better than post-released farm alligators (except in Class I females that did not overwinter; however, only one wild alligator was caught in this group, thus comparisons are not reliable here). It should be noted that the farm-released alligators are much younger than the wild counterparts, and reach a size suitable for release approximately 12–18 months after hatching, whereas a wild alligator takes 4–5 years to reach that size class (Coulson et al., 1973; Joanne and McNeece, 1975, 1987).

**Overwinter vs no overwinter.** In general, animals that had not overwintered \((N = 159)\) grew faster than those that had sustained an overwintering period \((N = 115, P < 0.01\) for Class I farm-released males, Class I and II native wild males, and \(P < 0.05\) for Class II native wild females). Similar trends for overwintering to slow growth were seen in the Class III farm-released and native wild males, and the Class I farm-released and native wild females, but small sample sizes precluded statistical analysis. In the farm-released Class II males and the farm-released Class II females, no differences were noted in growth between alligators that had overwintered vs those that had not.

**Males vs females.** Males tended to grow faster than females, although these differences were generally trends (Figs 1 and 2), and only statistically significant in the Class I farm-released alligators that had overwintered \((P < 0.01)\). In several groups, there was a trend towards males growing faster than females, but not significantly so (Class II, farm, no overwinter, Class II, farm, did overwinter, Class I and II wild alligators that did overwinter, Class I, farm released, no overwinter, and Class III, wild, no overwinter). The remaining three groups showed no differences in growth rates between sexes.

**Size class differences.** Growth rates as shown in Figs 1 and 2 clearly illustrate trends that native
wild alligators had a reduction in growth rate as the animals reach larger size classes, i.e. smaller size classes grew faster. This is seen in the wild males that overwintered (Class I > Class II > Class III), in the wild females that overwintered (P < 0.05, Class I > Class II, no Class III available), in the wild males that did not overwinter (Class I > Class II > Class III; P < 0.05 I vs III) and in the wild females that did not overwinter (Class II > Class III; N = 1 for Class I precluding analysis). However, in the farm-released alligators, growth rates continued to be accelerated, even at the larger size classes, and the declining growth rates at larger size classes was not seen. In some cases, the Class III farm-released animals actually grew faster than the Class II animals as seen for both males and females that did not overwinter (Fig. 1).

Growth curves

Tag/recapture data on the 274 alligators were evaluated using three different growth curve models as shown in Table 1. These models did not indicate any growth differences between male and female juvenile alligators in this study. The mean square error for the three models was smallest for the logistic model, indicating that this model gave the “best fit” for the known data points, but all were very close. In all cases the LINF was greater for farm-released alligators than the wild alligators, and the growth parameter k was higher for farm-released alligators than wild in two of the three models tested, including the model with the lowest MSE, or “best fit”. The likelihood ratio (chi squared) of the joint tests to compare the maximum attainable length and growth parameter of farm-released vs native wild alligators was highly significant (P < 0.01) indicating that farm-released alligators had significantly higher growth rates and might eventually reach longer maximum lengths than native wild alligators.

Condition factors

Captive-reared alligators have been shown to be 10% heavier (Coulson et al., 1973) and grow faster than wild alligators (Joanne and McNeese, 1979, 1987). However, in captivity the alligators are fed ad lib and maintained at constant high temperatures to stimulate feeding and growth. In the present study, however, farm-released alligators had become less robust several months after release to the wild, to a body habitus similar to native wild alligators.

Body condition factors and linear regression slopes derived from length and weights of 89 farm-released alligators and 180 similar sized native wild alligators obtained in annual harvests were not significantly different using analysis of covariance (P > 0.05). The y-intercept for wild alligators was −5.72 ± 0.35, and farm-released was −6.17 ± 0.94; with slopes of the lines being 2.97 ± 0.07 for wild and 3.05 ± 0.19 for farm-released.

DISCUSSION

Conservation strategies involving relocation, repatriation and translocation have become extremely controversial, particularly in reptiles, with some authors suggesting these conservation methods may be successful management options (Burke, 1991; Reinert, 1991) while others (Dodd and Seigel, 1991) do not advocate relocation, repatriation and translocation practices for reptiles. Thus, this study was initiated to follow the growth of “put-back” alligators used as a conservation method to enhance the sustained utilization management practices and supplement natural recruitment in Louisiana’s alligator program.

Our data indicate that juvenile alligators hatched and raised entirely in captivity, then released to the wild at approximately a 4-ft size (122 cm) grow as well as, and usually have superior growth rates than wild alligators of similar size.

Although numerous studies have documented growth rates in wild alligators as previously mentioned, it can be difficult to compare growth rates of alligators from different habitats with different ambient temperatures and therefore variability in the number of “growing months” per year in that habitat. Also, many prior studies have been conducted on immature alligators where sex could not reliably be determined, and as larger/older alligators appear to have differential growth rates between sexes this can limit comparisons between studies.

Our data on growth rates in native wild alligators appear consistent with previously reported data for alligators in Louisiana (McIlhenny, 1934; Chabreck and Joanne, 1979) but our data on farm-released alligators indicate their growth rates after release, and before overwintering, far exceed those seen in other studies. For example, our Class I farm-released males had growth rates of >7.5 cm per growing month (approximately 45 cm/year), Class III farm-released males and females grew 6.2 cm per growing month (approximately 37 cm/year); as compared to previous studies reporting alligator growth rates of 2.95 cm/month (Hines et al., 1968, for immature alligators in South Florida), 15–16 cm/year for immature alligators in South Carolina (Bala, 1972), 21.6 cm/year for 1–3 year old alligators in South Carolina (Brandt, 1989), approximately 20 cm/year for juvenile alligators in North Florida (Dietz, 1979), 19–25 cm/year in South Carolina (Murphy, 1977) for hatchlings 3 years old; and 12.4 cm/year in North Carolina (Fuller, 1981).

We were concerned prior to releasing large numbers of farm-reared alligators into the wild that the animals
might not thrive when the weather turned cooler, as farm alligators raised in heated buildings and released in spring/summer had not previously been exposed to cold weather. Growth rates did slow after farm-reared alligators had overwintered, however, the farm-reared alligators still showed superior growth as compared to their wild counterparts and appeared to have adapted well to the changing environmental temperature.

In our study, male alligators tended to grow somewhat faster than females, though in some groups, growth rates were similar between sexes. Chabreck and Joanen (1979) also noted higher growth rates in male alligators although not in the small size classes (< 100 cm). Similarly, Nichols et al. (1976) noted no difference in growth rates between male and female alligators until a snout-vent length of 60 cm was reached. Likewise, Rootes (1989) noted that male and female wild alligators grew at comparable rates up to 1.0 m total length on Lacassine National Wildlife Refuge and Rockefeller Wildlife Refuge. Webb et al. (1978) found that in another crocodileid (Crocodylus porosus), males grew faster than females. Dietz (1979) saw no difference in growth rates in male and female alligators in Florida but the largest animals in his study were classified as “larger juveniles, snout vent length 31 cm” and were likely too small to have yet reached sizes for differential growth rates between sexes. Also, Brandt (1989) found no differences in growth rates between sexes of juvenile alligators up to 3 years old in South Carolina. However, these data were from alligators with total lengths of only approximately 70–80 cm (SVL 35–40 cm).

Several previous studies have documented that younger/smaller alligators have faster growth rates than larger animals in several habitats (Chabreck and Joanen, 1979; Dietz, 1979; Brandt, 1989; Smith and Adams, unpublished), and the same phenomena is seen in Crocodylus porosus (Webb et al., 1978). Our present study also showed decreasing growth rates as size class increased in wild alligators (Fig. 1), but farm-released alligators still maintained higher growth rates even at the largest size group; although small sample sizes limit interpretation of this data in our study. Whether these growth rates will diminish when these juvenile/sub-adult alligators reach adulthood remains to be seen. It has been shown that post-hatching growth rates in alligators are dependent upon egg incubation temperature (Joanen et al., 1987), and thus incubation at “optimal” temperatures could improve performance of farm-raised alligators. This incubation-temperature effect combined with the “head-start” afforded captive-raised alligators may contribute to the accelerated growth rates seen in post-released alligators in this study.

Our data using growth curve models (von Bertalanffy, Gompertz and logistic) also all reflected the superior growth rates in the farm-released alligators in our study. Body condition factors several months post-release were similar to the wild alligators. The maximum attainable lengths are conservative projections based on initial data from juvenile alligators, and are slightly smaller than the known maximum lengths attained by some very old male alligators. However, the data used both male and female alligators, and females do not grow as large as male alligators, also decreasing the LINF measurement somewhat but they are consistent with previously reported data of females growing to approximately 8–9 ft (approximately 250–275 cm) and males to 13–14 ft (400–424 cm).

Preliminary data in this study clearly indicates that it is feasible to release captive-reared alligators back into the wild to supplement natural population recruitment, and that released alligators will grow as well or better than wild alligators, which presumably would enhance survivorship. Long term mark-recapture studies are currently underway and should provide adequate data to evaluate survivorship of farm-released alligators. Similar release programs with other crocodilians have demonstrated good survival based on mark-recapture programs of released captive reared Crocodylus niloticus (Blake and Loveridge, 1975), though growth was not as fast as in wild Nile crocodiles. A more recent study on C. johnstoni also showed that captive raised crocodiles survive as well as wild ones of equivalent size (Smith and Webb, 1985). It has been shown that captive reared crocodiles of 1 m size are very much heavier than wild crocodiles of the same size, and well able to survive in the wild (Blake and Loveridge, 1975). Other crocodilians including C. palustris, C. porosus and Gavialis gangeticus also have fared well in release programs. Long term studies have demonstrated recovery of populations and rising nesting incidence after release of young crocodiles (Rao, 1990; Rath et al., 1990) and breeding by restocked C. palustris has been recorded (Choudhury, 1981).

In summary, this preliminary study showed that growth in farm raised, post-release alligators is as good as or better than wild alligators of similar size. This can be advantageous, as growth in young alligators can greatly affect survivorship (Rootes, 1989) and survivorship in sub-adult alligators has been shown to be a function of size, with survivorship increasing as size increases (Nichols et al., 1976). Jacobsen and Kushlan (1989) suggest that if an alligator grows slower, it will take longer to reach sexual maturity, and increases its susceptibility to predation, disease and cannibalism. Supplementing natural wild recruitment of alligator populations with release of a percentage of juvenile alligators after utilization of alligator egg resources appears to be a valuable management tool for this species, particularly since their accelerated growth may enhance survival to sexual maturity. Continuation of this on-going study over the next several years should provide data to further refine management practices in crocodilian ranching programs, with emphasis on recommendations for techniques in selecting relocation sites, optimum size at which to release crocodilians, and precise quotas needed for restocking to maintain healthy wild crocodilian populations.

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