Preliminary Analysis of Survival of Farm-released Alligators in Southwest Louisiana

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Abstract: The Louisiana Department of Wildlife and Fisheries regulates an experimental alligator (*Alligator mississippiensis*) egg collection program which requires the return of a portion of juvenile alligators to ensure recruitment and maintain populations. An extensive tag and release program of farm-released juvenile alligators was evaluated by analysis of later harvest of recaptured sub-adult and adult alligators. Results suggest fairly high survival rates of farm-released alligators. The minimum known alive method estimated survival to be 85.3% to 4 years post-release.

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An extensive research program on the ecology, reproductive biology, and captive propagation of alligators was initiated in 1964 by the Louisiana Department of Wildlife and Fisheries (LDWF). The technology of egg incubation, post-hatchling culture, and juvenile and adult alligator culture has been researched thoroughly and refined (Joanen and McNease 1987), leading to development of numerous successful alligator farms in Louisiana. Although alligators have been shown to breed in captivity (Joanen and McNease 1987), success has been limited and emphasis has shifted to "ranching" programs.

In 1986 the LDWF instituted a program in which 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. As part of this experimental program, the alligator rancher is obligated to return to the wild healthy alligators between 0.92 m and 1.52 m representing a calculated percentage of his annual hatch rate based on estimated mortality/survivorship curves (Taylor and Neal 1984). Because mortality rates of alligator eggs and young alligators are high, egg ranching allows for prudent utilization of a segment of the population which would otherwise be lost to natural mortality. The high mortality of immature size classes (pre- and post-hatching) makes management of alligator populations through egg collection programs viable and may lead to greater population increases than if no such program is in place (Nichols et al. 1976, Staton 1989). This program in Louisiana has been successful and provides a strong economic incentive for landowners to conserve and manage their wetlands. Sustained utilization of alligators and their eggs is well recognized as an effective management practice and a conservation tool to preserve wetlands (Joanen et al. 1997).

Louisiana's alligator egg ranching program increased dramatically between 1986 and 1990. Before 1986, the farm inventory was relatively low due to limitations with stock procurement, and the initial few farmers were supplied hatchlings from eggs collected by department personnel from state-owned lands. Increasing interest in alligator farming/ranching during the late 1980's led to a rapid expansion of the program, and the demand for hatchlings for the growing industry could not be met from agency resources. The LDWF in 1986 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 during the warm months of the year to the original egg collection site for restocking to ensure the viability of the wild population.

The LDWF initially required a quantity of juvenile alligators equal to 17% of the eggs hatched by the rancher to be returned within 2 years of hatching. In the first 3 years of the release program (1988–1990) returns were limited to a total of <15,000 alligators, and sizes at release were generally small, averaging 91–97 cm. In 1991, a sliding scale return rate was established based on the estimated 17% survival rate from hatching to 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 91.4 cm to 152.4 cm. For example, more alligators must be returned if the average is smaller (example 18% at 119.4 cm average) and fewer animals are required if the average is larger (example 14% at a 134.6 cm average). Alligators must be ≥ 91.4 cm and are usually <152.4 cm at release and must be free of disease or deformities to be acceptable for release.

Limited data exist on survival 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). Blake and Loveridge (1975) expressed concern that captive raised and released crocodilians might not thrive, possibly as a result of having to learn to hunt for food and adapt to a new environment. The purpose of this study was to evaluate survival of alligators raised in captivity and released to the wild. These data may be used to further refine management recommendations and more precisely determine appropriate return rates of ranched alligators to the wild needed to maintain populations.

We acknowledge the assistance of numerous LDWF employees in collection of data in the field. We appreciate the cooperation of the administrative and land management staff on the study areas, including Earl Abshire, Judge Edwards, and Roger Vincent, Jr.

Methods

Releases are made from 15 March to 30 September once the weather is believed to be warm enough to enhance survivorship. LDWF personnel supervise each release, and the "put-back" alligators are marked individually with serially numbered monel web tags, and 1 or more tail scutes are removed. Length to the nearest 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 trappers are requested to collect specific information and to notify department personnel if a tagged alligator is taken during the annual wild alligator harvest. Data on length, sex, web tag, and tail notch are collected at the time of recapture so that interval growth rates may be determined. As this program developed, it became apparent that having LWDF staff members present in centralized processing sheds would greatly increase tag recovery rates during the wild harvest. This would also improve data collection (i.e., correct tag numbers being recorded, accurate lengths obtained, etc.). Many tag recoveries are undoubtedly missed, as the numerous processing sheds often operate 24 hours daily during the first several days of the alligator season, and logistically cannot all be covered by the limited staff available.

Although Louisiana's alligator ranching program is statewide, we chose 3 land companies as study areas for this preliminary analysis, selected due to several years of participation in egg ranching/returns, proximity to a field office, and a history of having the majority of their alligators which were harvested processed at an accessible skinning facility. Vermilion Corporation comprises >45,700 ha, with nearly equal mixtures of fresh, intermediate, and brackish marshes. Miami Corporation encompasses some 91,000 ha of predominately fresh and intermediate marshes. Amoco (White Lake) has just over 28,300 ha of fresh marsh. The 3 study sites collectively total approximately 165,000 ha in southwestern Louisiana.

Due to the small sample size of alligators released in 1988 and 1989, we began the analysis with the 1990 releases; 42,319 alligators were released to these wetlands from 1990 through 1997. The released alligators are juveniles, and grow approximately 18–20 cm/year (Elsey et al. 1992*a*, R. M. Elsey, unpubl. data). Thus, they do not approach the normal harvestable size class (182 cm) until several years after release.

As the alligators grow, often the web tags are displaced from between the toes and lost. This precludes identification of those individual alligators for growth data, but year-specific tail notches were used starting in 1994 (and occasionally before). Thus in many cases a retrapped alligator might be assigned to a cohort release year even if the foot web tag was missing. In some cases a "conservative" release year was assigned to a recaptured alligator. For example "C" notches were used on some Vermilion Corporation alligators in 1989 and 1991. If a "C' notched alligator from that area was recaptured (with web tag missing), we assigned the later year possible (1991) as the release year, although it may have been released 2 years earlier, and thus survived 2 years longer. Therefore, survival rates reported herein are minimum rates, as many may have survived longer than assumed by the conservative cohort year assigned.

Several survival models were fit to the tag recovery data from the alligator harvests. The band recovery models with year-specific survival and catchability (Brownie et al. 1985) along with age-specific (time since release) survival modifications, were fit using the program SURVIV (White 1983) for the cohort years of 1990 through 1997. Various submodels with survival constrained to be constant with time or age, or catchability constrained to be constant with time were also fit (see Brownie et al. 1985). Several of these models have parameter identifiability problems, but are included because they indicate the potential goodness-of-fit of these approaches.

A minimum known alive approach was also used to estimate the probability of surviving to a specified harvest season following release and then being caught. Recoveries through time were used to establish the minimum known number of individuals that had to have been alive to be able to observe the known recoveries. The recoveries were treated as coming from a binomial distribution and the probabilities were pooled over cohorts. To estimate the survival probabilities, the survival-catchability estimate was divided by a catchability of 4%, based upon harvest quotas and population survey data. This approach is analagous to a life-table approach and assumes that the cohorts are sufficiently sampled through time that few if any remain to be harvested, otherwise survival will be underestimated. It also assumes that catchability is known and constant with time.

All of the models assume that tag loss and reporting errors are negligible, and that all tagged gators within a cohort are homogeneous with respect to catchability and survival. In several models (e.g., year-specific or age-specific models and the life-table method), it is also assumed that survival and catchability are homogeneous among cohorts according to time or age.

Results and Discussion

Alligator trappers target their catch effort for larger alligators (which are more valuable) by scouting trapping sites and adjusting the height of the baited line. Unlike most survival analyses, our results tend to reveal increasing numbers of recaptures in successive years, as the alligators grow and reach the targeted harvestable size (Table 1). Most survival models on waterfowl and other species show decreasing band recoveries with successive years as the cohort gradually succumbs to nat-

Table 1. The number of juvenile alligators released by year and recovered in subsequent annual September harvests.

Year released	*N* Released	Harvest year 1990	1991	1992	1993	1994	1995	1996	1997	Total Cohort
1990	186	2	5	2	7	4	4	1	2	27
1991	9,392	x[a]	1	12	41	89	183	117	148	591
1992	4,354	x	x	0	1	10	22	22	28	83
1993	5,256	x	x	x	9	27	114	62	132	344
1994	4,295	x	x	x	x	0	34	26	69	129
1995	3,280	x	x	x	x	x	14	14	18	46
1996	7,756	x	x	x	x	x	x	30	27	57
1997	7,800	x	x	x	x	x	x	x	17	17
Total Retraps		2	6	14	58	130	371	272	441	1,294

a. An "x" indicates a retrap was not yet possible (i.e., alligators released in 1992 could not be harvested in 1990 or 1991).

ural and hunter mortality. This unusual pattern seen in alligators is of great interest and is being evaluated separately as part of a long-term study (E. B. Moser, unpubl. data).

Louisiana's annual September harvest has a quota of 4% of the population. The minimum known alive model provided a fit that was consistent with the Taylor and Neal (1984) model of survival though considerable variability exists among years of release resulting in large chi-square measures of fit (4 years post release model: $\chi^2 = 139$, $P \leq 0.001$). The age-specific band recovery models tested fit poorly ($\chi^2 = 316$, df $= 9$, $P \leq 0.001$). This may be in part attributed to the fact that the smaller alligators (early years following release) are not fully recruited into the harvest and there is not a sufficiently long history of the cohorts through this harvest period. It is also very likely that both survival and catchability are both age- and year-specific in alligators because their size would certainly affect catchability (and desirability) along with its survival. The results from our model suggest fairly high survival rates, although the model "goodness of fit" is not optimum. We anticipate that fits will improve with time as more data are accumulated.

The minimum known alive method estimated survival to 4 years post release to be 0.85 (range 0.79–0.92) and 0.55 to 5 years post release (range 0.49–0.61, Table 2). Lower survival rates 5–6 years after release are likely due in part to the large number of "retraps" that have been captured 6 or 7 years after release and which had lost their foot web tags, and could not be identified as one from the study area.

Several factors limited our ability to document all known retraps, and thus survival of the farm-released alligators is likely greater than we estimate in this study. Tag-reporting rates by trappers are probably low, as is the case with band-reporting rates in waterfowl (Reinecke et al. 1992). The monel tags used tend to darken with time and thereby were easily overlooked. Incomplete data are often reported by trappers (i.e., 4 or 5 digits of a 6-digit tag number reported), making the data of limited use. One study on marine turtles documented a probability of monel tags being lost approaching 100% after a tag age of about 10 years (Limpus 1992).

Table 2. Survival estimates (95% confidence interval) based upon the binomial model as estimated by logistic regression analysis of the minimum known alive since release.[a]

Years since release	Survival estimate	Range
0 (within 6 months)	0.764	(0.72–0.80)
1	0.886	(0.83–0.93)
2	1.033	(0.97–1.09)
3	0.959	(0.89–1.02)
4	0.853	(0.79–0.92)
5	0.554	(0.49–0.61)
6	0.414	(0.35–0.48)
7	0.311	(0.07–1.20)

a. Catchability is assumed to be the 4% harvest quota.

The wild harvest is scheduled in September because breeding females will be in the remote marsh interior at nest sites during this period (Joanen and McNease 1989) and thus less vulnerable to trapping. Trappers generally access large open water canals by outboards or mudboats and select larger adult males which typically comprise 70%–75% of the harvest (Elsey et al. 1994). Because alligators have temperature dependent sex determination (Ferguson and Joanen 1982), alligator farmers can program the sex and resultant post-hatching growth rate of the hatchlings resulting from eggs incubated at optimum temperatures (Joanen et al. 1987). Until recently, alligator releases have been slightly female biased. Through the 1994 release season, statewide releases were 57.6% female, 37.4% male, and 5.0% unknown or unreported. Because 57.6% of the farm releases are female, the September season harvest (which strategically selects for surplus adult males, to protect breeding females) will select against farm releases being caught. Survival of farm releases is likely higher than catch rates (which favor males) would indicate. Releasing a large percentage of females should enhance population recruitment, as one male is able to breed with several females in a breeding season and therefore generate more nesting by additional females. A similar strategy has been suggested for conservation programs that artificially incubate turtle eggs (Vogt 1994).

Another factor that can limit the catch rate of farm-released alligators is that all alligators (unlike waterfowl for example) are not equally desirable or catchable. In general, larger alligators are more valuable to the trapper, who is paid depending on the total length of the alligator. Trappers set their lines at a high level to ensure catching large alligators. Thereby, farm-released juvenile alligators are not targeted for harvest until several years after release, when they grow into the adult size class.

Many farm-released juvenile alligators undoubtedly succumb to the same natural mortality factors (cannibalism, adverse weather events, road kills, propeller strikes, etc.) that affect native wild alligators prior to reaching the adult harvestable size class. Taylor and Neal (1984) calculated that from a cohort of eggs and hatchlings that survived to become juveniles, of 103 left alive at 121.9 cm total length only 45 would live to be 182.9 cm, and only 25 would live to be 213.4 cm, which are generally considered to be the adult size classes for harvest. Thus, we assume 56% of the juvenile farm-releases succumb to natural mortality before reaching harvestable adult size classes, as predicted for their native wild counterparts of the same size structure (Taylor and Neal 1984). Some of this expected mortality may be averted due to the superior body condition and accelerated growth rates reported in farm-releases (Elsey et al. 1992*a*).

Another factor that may influence recovery rates of farm releases (which in the early phases of this study were somewhat smaller at harvest recovery than the statewide 213 cm average) is the current market price of alligator hides. For example, in a strong market the high prices make it profitable for a trapper to spend more time scouting and be more selective in his trapping effort in order to catch larger alligators. If prices are poor, the extra time required to be more selective may be cost prohibitive, so the trapper will be less selective, complete his harvest quickly, and fill his quota with smaller alligators, a higher percentage of which may be farm-releases in the early stages after release. For example, a strong market in 1996 encouraged trappers to be very selective, and fewer recaptures of released animals were caught than in 1995 and 1997, when low prices deterred selective trapping for large alligators, and more retraps were encountered (Table 1). Adverse climatic events (such as the severe drought in 1996) led to a lowered harvest quota that year, resulting in fewer tag recoveries. Cannibalism would be expected to be high in drought years as alligators are concentrated in remaining water (Woodward et al. 1987).

During September harvests, trappers were issued a form on which to report harvest of a marked (tail notched) alligator and to record the date harvested, length at harvest, web tag number (if present), etc. Few were obtained in the early years of the program; so in 1994 we showed trappers (at the time of tag issuance) color photos of a tail notch and web tag in the alligator's foot and further encouraged reporting "retrapped" alligators. Also, having Department staff available in processing sheds clearly affects tag recovery rate, as was evident in recent years.

As farm alligators grow through time, more reached harvestable size around 1994. For example, the first significant releases (statewide) were made in 1991 at a 114 cm average, and in 1992 at a 109 cm average. At an estimated growth of 18 cm per year these alligators would not reach the 183 cm size class until 1994 and 1995. Thus, although the farm-releases began in 1988, the September season harvest recoveries were limited until recent years. Of approximately 4,450 farm releases harvested statewide, over 1,500 (nearly 34%) were recovered in the most recent 1997 season. Survival analysis done prior to this would certainly have underestimated survival rate of farm-released alligators.

Studies of survival in native wild alligators have provided widely varying results. Often the studies are short term and focused on a local population, and often involve hatchling and small juvenile alligators, which have high mortality rates. The methods used to evaluate survival can affect data interpretation. Woodward et al. (1987) estimated survival to 1 year of hatchling alligators in a Florida lake to be 41%, and survival to 2 years to be 8%, using Jolly-Seber analysis of recapture data. Using minimum-known-alive (MKA) estimates, their results were much lower (46% of the

Jolly-Seber estimate for 1-year survival), leading them to conclude MKA methods underestimate survival. In South Carolina, Brandt (1989) found 63% survival from 4 clutches, with another clutch having only 17% first year survival. Of the 5 clutches combined, Brandt (1989) reported a 2-year survival rate of 37%, and 16% survival to 3 years. This small study was on a sparsely populated 1,120-ha area thought to have a total population of approximately 200 alligators, of which 62 were members of 4 clutches hatched in 1985. Deitz (1979) reported survivorship through the first year post-hatching to be 30% in a lake habitat, and 17% in a shallow marsh (3 pods only). Two-year survival in a small sample of lake habitat was 14% (2 pods). Carbonneau (1987) estimated 83.6% of hatchlings were lost before reaching 1 year of age.

We are not aware of any large scale, long-term studies on survival rates of larger juvenile alligators (91–122 cm) prior to our present study, which is an experimental part of a statewide management program of millions of hectares of alligator habitat. An unedited and unreviewed report (Chabreck et al. 1997) on a small intensive study site (4,203 ha) in southeastern Louisiana suggested survival rates were much lower than in the present study. This may be due to the different habitat affecting growth rates or density dependent survival on their study area. Also, selection of release sites in non-juvenile habitat probably adversely affected survival in that study (R. Moertle, pers. commun.). A telemetry study done concurrently on the same study area (Addison 1993) showed good survival of farm-releases (67% annual survival estimated), and found no difference between native-wild or farm-releases in either seasonal or annual survival rates. Both groups survived slightly better than might have been estimated by Taylor and Neal's methods (1984).

Most young crocodilians have high mortality rates (Thorbjarnarson 1988, Webb and Manolis 1989) and therefore egg ranching of many crocodilian species has evolved as a conservation tool (Hutton and Webb 1992). Many international programs have incorporated release of "head-start" captive raised crocodilians to enhance recruitment of natural populations or restock depleted habitats.

Early studies on *Crocodylus niloticus* in Rhodesia (now Zimbabwe) showed good survival of station-reared crocodiles, which were longer and much heavier than wild crocodiles of the same age, and therefore well able to survive in the wild (Blake and Loveridge 1975). Child (1987) reported released crocodiles prospered, judging from both subjective observations and from the results of a mark-recapture program. In contrast, a recent study has shown high mortality of released Nile crocodiles (R. Fergusson, pers. commun.). This may be due to limited habitat available (i.e., a river and its fringes) with no separation of adult and juvenile habitat leading to high intraspecific competition. Vast wetlands with separate juvenile and adult habitat in coastal Louisiana may promote survival of released juveniles due to extensive available habitat for dispersal. Graham (1968) noted that in *C. niloticus*, where habitat (bare shoreline) is unsuitable for juveniles, mortality may be nearly 100%.

Tropical habitats with distinct wet and dry seasons (and no separation of juvenile and adult habitat) may not be suitable for release of crocodilians. Density dependent mortality and intraspecific competition will be accentuated when the available habitat shrinks during the prolonged dry season.

Crocodilains have also been released in India for many years, and in some sanctuaries gharial (*Gavialis gangeticus*) population increases are thought to be mainly due to the releasing program (Rao 1990). Whitaker (1982,1987) stated that most of the gharial, muggers, and saltwater crocodiles (*G. gangeticus, Crocodylus palustris,* and *C. porosus*) released into Indian waters in the last few years have survived, and the Forest Department authorities believe most releases have been successful.

In Australia, Smith and Webb (1985) found that captive-raised, released *C. johnstoni* survive as well as wild freshwater crocodiles of equivalent sizes. Preliminary reports in Venezuela are that released Orinoco crocodiles have adapted well (Thorbjarnarson 1993), and Arteaga (1997) estimated survival of wild *C. acutus* in a Venezuelan reservoir to be 10%, considerably less than introduced animals (25%) in his study. Another critically endangered species (*C. rhombifer*) appears to be dispersing and thriving after release in Cuba (Soberson et al. 1996).

Our preliminary results suggest that farm-released alligators grow at least as well as and often superior to native wild counterparts matched for size and sex (Elsey et al. 1992*a*, R. M. Elsey, unpupl. data). They also are able to forage for food successfully after release, despite having been raised entirely in captivity prior to release (Elsey et al. 1992*b*). Chabreck (1971) noted "pen-reared alligators responded similarly to wild alligators when transferred to new locations and released." We also have documented attainment of sexual maturity in female farm-released alligators with evidence of ovulation and production of eggs (Elsey et al. 1998).

These preliminary results suggest the "release to the wild" program appears successful thus far, but close monitoring will continue for many years. Nesting surveys through 1997 (McNease et al. 1994, LDWF unpupl. data) show a significant increase in nesting/population in coastal Louisiana, despite the harvest of over 2.3 million eggs since 1986 and some 27,000 adults annually. 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 alligator ranching programs, with emphasis on recommendations for techniques in selecting relocation sites, release season, optimum size at which to release alligators, and precise quotas needed for restocking to maintain healthy wild alligator populations.

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