

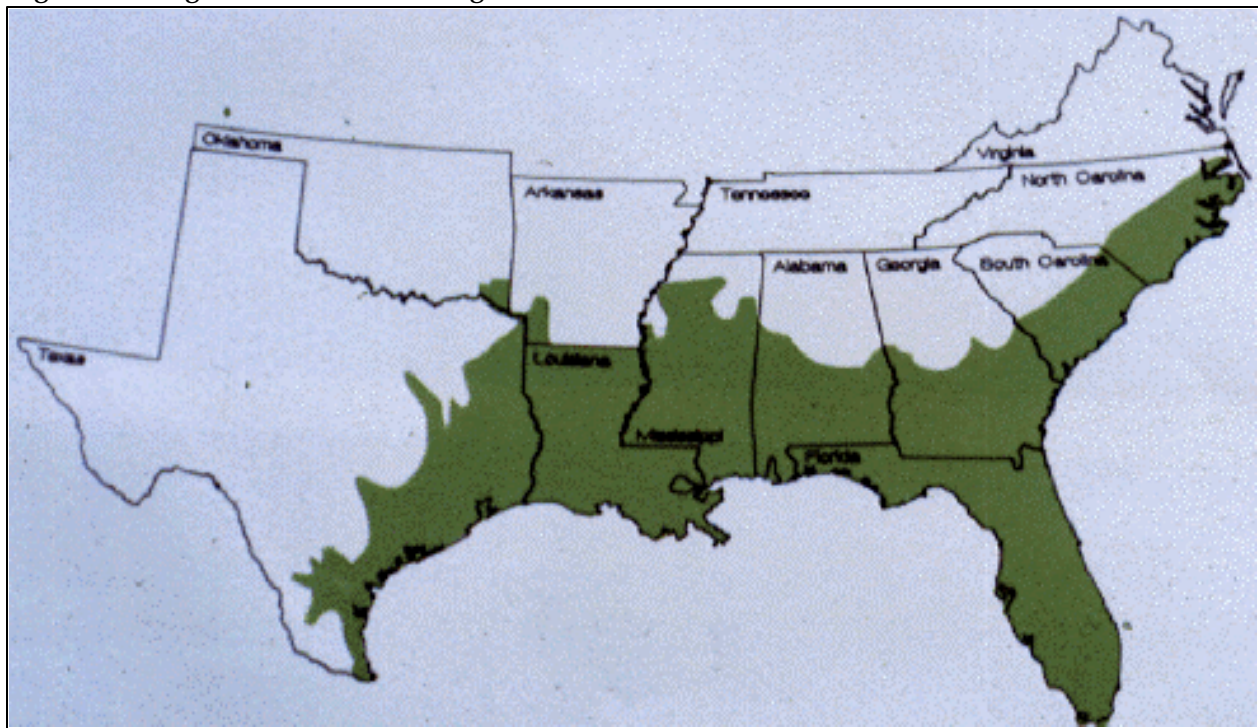


## Introduction

### History

The natural range of the American alligator extends across the southeastern U. S. from the Carolinas to Texas and north into Oklahoma and Arkansas (Figure 1). The alligator once again is an abundant species throughout its range after heavy hunting reduced its numbers. The classic work on alligators by McIlhenny (1934), *The Alligator's Life History*, describes the abundance of alligators in Louisiana and the noticeable decline in numbers due to heavy hunting.

Figure 1. Range of the American Alligator.



Source: Florida Game and Fresh Water Fish Commission web site.

The large decline in the alligator's population eventually raised concerns enough that progressively tighter restrictions were placed on the hunting of alligators. In Florida, a four-foot minimum size limit was imposed in 1943, and increased to six feet in 1954. These measures did not stop the decline in alligator numbers, so in 1962 the legal harvesting of alligators was closed.

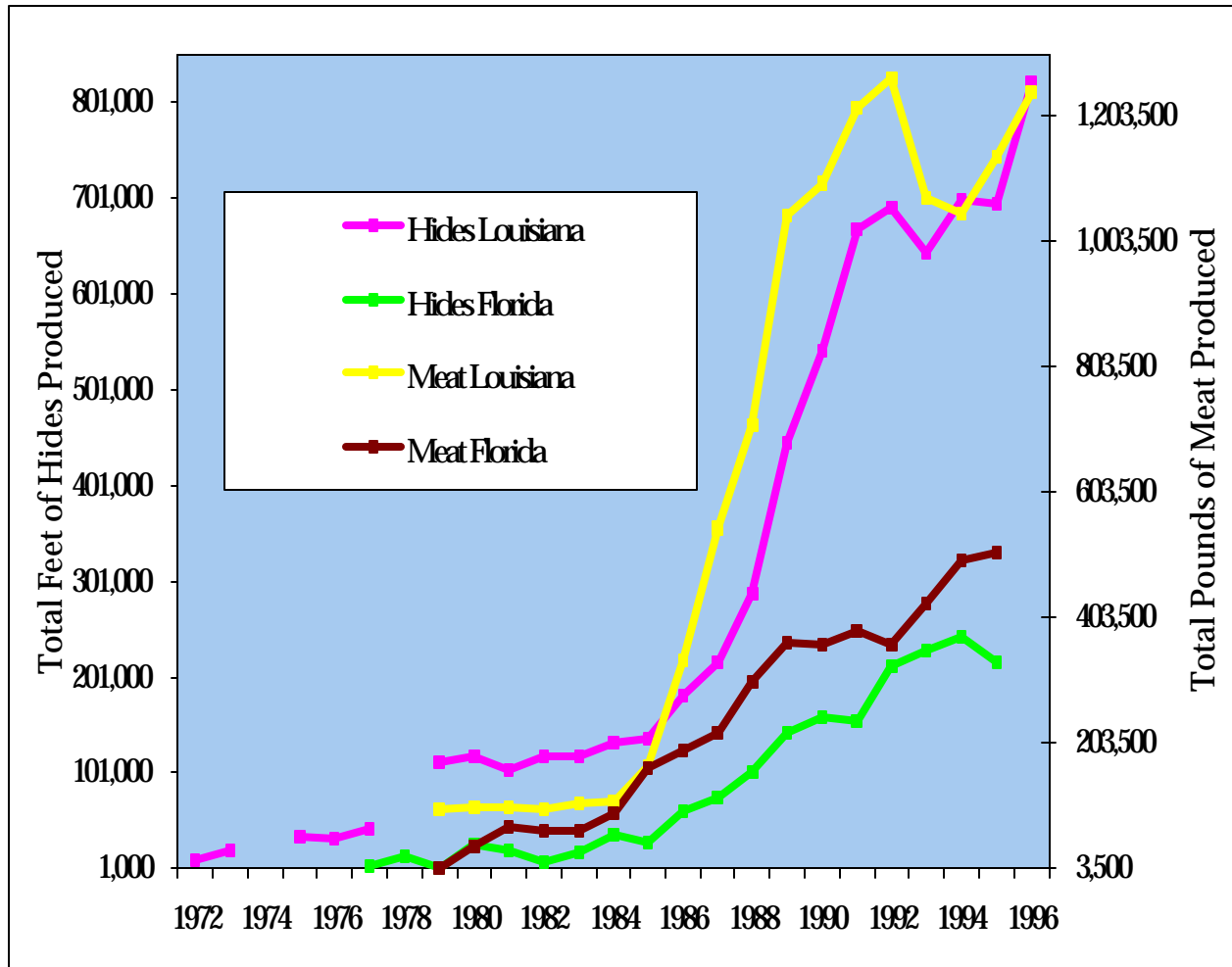
However, because of a loophole in state laws, interstate shipment of hides could not be stopped and alligator populations continued to diminish during the 1960s. In 1967, the alligator was placed on the first Endangered Species List, but poaching continued until 1970 when an amendment to the federal Lacey Act made the interstate shipment of illegally taken alligators a federal violation.

Alligators have made a remarkable comeback and have been returned to abundance. In 1977, the alligator was reclassified in Florida from endangered to threatened and in 1987, the Fish and Wildlife Service pronounced the American alligator fully recovered and removed it from the list of endangered species. Currently, it still is listed as threatened due to its similarity in appearance with the Black caiman, which is an endangered species (FL Dept. of Ag. and Cons. Svcs.). Because the American alligator still is listed as threatened, commercial harvesting and trade is regulated strictly. This discourages the illegal trade of hides from endangered, similar species, such as the Black caiman and the American crocodile, under the guise of alligator skins.

### Current Management

Reclassifying the alligator to threatened allowed the alligator to be available again for commercial use. Louisiana again began harvesting in 1972 and Florida followed in 1977 (Figure 2). This time, however, harvesting was regulated carefully with the goal of sustainable use (SU). In developing an alligator hunting program, four primary factors were considered in Florida (Anon 1986, Woodward et al. 1992): 1) Biological capacity of populations to sustain harvest; 2) Ecological and aesthetic effects of alligator hunting; 3) Sociological aspects of alligator hunting, such as tradition, user groups, and economic impact and; 4) Wildlife conservation implications.

Figure2: Total Harvest of Alligator Hides and Meat in Florida and Louisiana.



Source: Florida Game and Fresh Water Fish Commission.  
Louisiana Wildlife and Fisheries Service.

Notes: No alligator hunting was allowed in 1974 as a result of passage of the Federal Endangered Species Act.  
In Louisiana there was no hunting in 1978 due to limited markets for hides within the U.S. and a ban on overseas shipment of hides.

### Farms and Ranches <sup>1</sup>

The first commercial alligator farm in Florida was started in 1891 and currently there are over 150 farms across the U. S. The commercial production of alligators can be divided into three

<sup>1</sup> Farms maintain breeding stock and produce their own hatchlings while ranches have no breeding stock and collect eggs and/or hatchlings from wild populations or purchase them from other producers.

phases: 1.) Management of adult alligators (breeders), 2.) Egg collection, incubation, and hatching, 3.) Grow-out of juvenile alligators to market size.

Maintaining a successful and consistent breeding program is difficult, because exact environmental, social, and dietary needs of adult alligators are understood poorly. Stress, disease, age, and genetics also impact nesting success of captive alligators (Cardeilhac 1988). Although alligators do breed in captivity, success has been limited and emphasis has shifted to ranching programs (Elsley et al. 1992).

Egg collection from wild populations is regulated by state agencies that set site-specific quotas for the number of nests that may be harvested. Ranchers have to meet certain requirements to be eligible and must buy permits.

Captive-raised alligators have higher survival rates, due to greatly reduced mortality from predators and cannibalism, and faster growth rates due to warm, indoor pens and abundant food supplies.

Management programs for alligators, then, involve both the wild and domestic populations. The wild population is a source of young stock for domestic populations and in Louisiana, where a portion of hatchlings are returned to the wild, the domestic population is a source of juveniles for the wild population.

### Statement of the Research Problem and Objectives

Crocodylians in general and the American alligator specifically have been researched widely and in detail. Despite the plethora of research on alligators, very little has been done in the area of economics. Currently, wild alligators are managed with cursory regard for economics. State regulations are set up based on biological considerations with a goal of maximum SU. There is some thought that since economics caused the decimation of crocodylians, it must not be given too much

influence in current population management. The fear is that economic optimum will not lead to SU.

We investigate that thought with a formal study of the economics of the U.S.' alligator industry. Specifically, we set up an economic model of the industry. The model will determine optimal values for producers' decision variables, which are:

- 1.) Number of clutches to harvest from wild populations.
- 2.) Number of alligators at various sizes to return to the wild.
- 3.) Number of alligators to slaughter at different sizes.

## Conceptual Framework

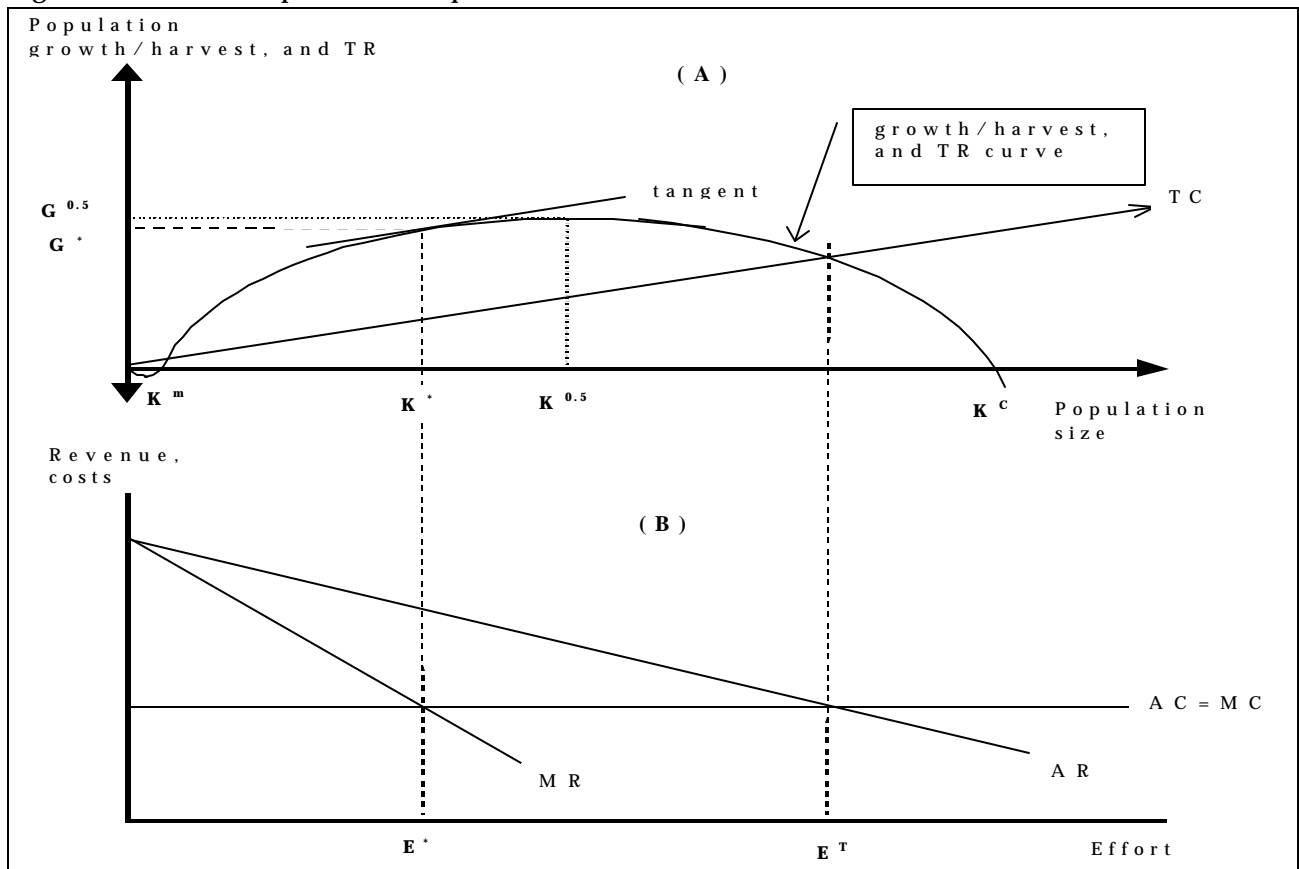
### Biology of Harvesting

A sustainable harvest of alligators means that the number of alligators harvested must be equal to or less than the number of new alligators added to the population. The growth of a population depends on several factors, which can be divided into two categories: Density-dependent (DD) and density-independent (DI). Density-dependent factors are those that change with population density such as the availability of food, adequate shelter from predators and weather elements. Density-independent factors are those that are not affected by population density such as weather occurrences (hurricanes, droughts). Since DI factors occur independent of population density, DD factors limit population under normal conditions. Density-dependent factors assume there is a maximum number of alligators that can be sustained in a given environmental area.

Figure 3A shows these relationships. (The following discussion is based on Kahn 1998, and Tietenberg 1988.) The size of the population is represented on the horizontal axis and the growth of the population on the vertical axis.  $K^c$  is the carrying capacity and is known as the *natural equilibrium*.  $K^s$  is the maximum population size that can be sustained by a given area and is the

population size that would persist in the absence of outside influences. Reductions in the stock due to mortality or emigration are offset exactly by increases in the stock due to births or immigration. This natural equilibrium persists because it is stable. A stable equilibrium is one in which movements away from this population level set forces in motion to restore it. If, for example, the stock temporarily exceeded  $K^c$ , it would be exceeding the carrying capacity. As a result, mortality rates or emigration would increase until the stock once again was within the confines of the carrying capacity. This tendency for the population size to return to  $K^c$  works in the other direction as well. If the population is reduced below  $K^c$ , growth is positive and will increase the size of the stock. Over time, the population will move along the curve to the right until  $K^c$  is reached again.

Figure 3 : Relationship Between Population Size and Growth, and Sustained Yield.



The point  $K^m$ , is known as the minimum viable population and represents the level of population below which growth in the population is negative. In contrast to  $K^c$ , this equilibrium is unstable. Population sizes to the right of  $K^m$  lead to positive growth and a movement along the curve to  $K^c$ . When the population moves to the left of  $K^m$ , the population declines until eventually it becomes extinct. In this region, there are no forces acting to return the population to a viable level.

Mathematically, these concepts can be described as follows. Assuming a population structure (i.e. sex ratio, age structure, reproductive parameters, etc.), a population will grow at a certain rate,  $r$ , which is the number of new individuals per current individuals. Therefore, the growth,  $G$ , of a population size  $K$ , is  $G=rK$ . Assuming a positive growth rate, it is clear population growth increases each period. However, in a finite environment a population cannot grow infinitely. Assuming a carrying capacity at population size  $K^c$ , population growth is affected by DD factors. As the population size gets closer to  $K^c$ , growth decreases until  $G=0$  at  $K=K^c$ . Thus, a population's growth is  $G=rK(1-K/K^c)$ . This equation is the logistic growth function. At a very low population size ( $K$  approaches 0) or a very high population size ( $K$  approaches  $K^c$ ), growth is very low. From this equation, it can be seen that  $G$  is greatest when  $K=0.5K^c$ . This point is shown in Figure 3A as  $K^{0.5}$ .

$K^{0.5}$  represents a population size of one half the carrying capacity. It is the population size at which growth is maximum (Shown as  $G^{0.5}$  on the vertical axis.).  $K^{0.5}$  is known as the maximum sustainable yield population and it represents the population size at which the largest harvest ( $G^{0.5}$ ) can be sustained perpetually.

### Economics of Harvesting

Adding costs and prices generates total cost (TC) and total revenue (TR) curves (Figure 3B). A constant price for alligators is assumed here, as shown by a linear average revenue (AR) curve, thus generating a total revenue curve with the same shape as the growth curve. Maximum profit occurs



where marginal revenue equals marginal cost (MR=MC). This is the point where the TC curve is tangent to the TR curve and the difference is greatest between TR and TC. The tangency point corresponds to a harvest rate of  $G^*$  and a population size  $K^*$ .

Thus, an efficient population size and an efficient harvest rate can be determined for a given location based on carrying capacity, population growth, and costs and prices.

### Modeling Alligator Populations

#### Wild Alligators

An equation that describes the alligator population for each size group is:

$$(1) \quad f_t^w(A) = f_{t-1}^w(A-1)[1 - d^w(A-1)]$$

$f_t^w(A)$  - number of wild alligators at size (length)  $A$  during time  $t$

$d^w(A-1)$  - mortality rate of wild alligators at size  $A - 1$

Equation 1 describes the number of alligators in a specific size group, as the number of alligators surviving from the previous size group. Alligator mortality occurs through natural mortality as well as hunting mortality. These two mortality factors act in a complementary manner to arrive at a “net” mortality. That is, hunting mortality eliminates some animals that otherwise would have died due to natural mortality. The compensatory nature of hunting mortality and natural mortality can be described as (Wagner et al. 1965):

$$a = m + n - mn$$

$a$  - crude annual mortality rate

$m$  - mortality rate from hunting or fishing

$n$  - natural mortality rate

Louisiana and Florida both allow hunting of wild alligators, while only Louisiana requires ranches to return to the wild a portion of the wild eggs harvested. Adding in these factors thus changes equation 1 to:

$$(2A) \quad f_t^W(A) = f_{t-1}^W(A-1)[1 - (m(A-1) + n(A-1) - mn(A-1))]$$

$$(2) \quad f_t^W(A) = f_{t-1}^W(A-1)[1 - (m(A-1) + n(A-1) - mn(A-1))] + R_t(A)$$

Equation 2A describes the (Florida) alligator population where no alligators are returned to the wild and equation 2 describes the (Louisiana) population where alligators are returned.  $R_t(A)$  thus accounts for the number of alligators at size  $A$ , returned by ranchers during time  $t$ .

A separate equation is necessary to account for hatchlings since they are the start of the population and are not the outgrowth of a previous size group. The number of hatchlings is determined by the number of eggs hatched, which is determined by the number of adult females that nest and the hatch rate. The average number of eggs per clutch is 30-50 while not all eggs hatch as some clutches are raided by predators or eggs fail to hatch for various other reasons. Additionally, some clutches are harvested by alligator ranchers. Accounting for all these factors:

$$(3) \quad f_t^W(1) = [(f_{t-1}^W(A^b)gc) - H_t]e h^W$$

$f_t^W(1)$  - number of wild hatchlings

$f_{t-1}^W(A^b)$  - number of alligators in breeding-age population

$g$  - percent breeding population that is female

$c$  - percent of breeding-age females that nest

$H_t$  - number of clutches harvested by ranches

$e$  - eggs per clutch

$h^W$  - hatch rate of wild eggs

## Domestic Alligators

Domestic alligators are similar biologically to wild alligators. However, domestic alligators are maintained under (near) ideal conditions for maximum growth and minimum mortality and are grouped according to size, which eliminates cannibalism. Domestic alligators are raised for slaughter and a percentage of hatchlings from wild eggs is returned to the wild in Louisiana. Adding these factors to equation 1 and changing superscripts to signify farm (versus wild) alligators:

$$(4) \quad f_t^F(A) = f_{t-1}^F(A-1)[1 - d^F(A-1)] - S_t(A) - R_t(A)$$

$S_t(A)$  - alligators slaughtered at size  $A$

The alligator industry obtains hatchlings from either domestic breeding stock, by hatching eggs harvested from the wild population, or through both methods. Again, note the similarity with the wild population as shown in equation 3. In equation 5,  $H_t$  has the same value as in equation 3 with only the sign changed.

$$(5) \quad f_t^F(1) = [f_{t-1}^F(A^b)gc + H_t]eh^F$$

Equation 5 can be used by alligator farmers as well simply by setting  $H_t$  equal to zero.

## Alligator Economics

The previous section described population dynamics. In this section economic factors are added to introduce a profit function for alligator producers. Alligator producers derive revenue from the sale of hides, meat, and some heads, teeth, and feet. On the cost side, alligator producers have variable expenses (feed, labor, medication, etc.) that vary by size of the alligator (larger alligators eat more, while smaller alligators are more labor intensive) and are incurred while raising alligators. Additionally, producers incur costs at slaughter. Assuming an average maximum length of 14 feet (Woodward et al. 1995) and discounting for the time value of money will allow a producer's profit

function to be considered for all sizes of alligators over several years. The net present value (NPV) of profits can be shown as:

$$(6) \text{NR}_{\text{NPV}} = \sum_{t=0}^{\infty} \mathbf{b}_t \sum_{A=1}^{14} [ S_t(A) [ k(A) P(A)_t^k + m(A) P_t^m + I_t^{\text{htf}}(A) - P_t^s(A) ] - f_t^F(A) V(A) ]$$

$\mathbf{b}_t$  - discount factor

$S_t(A)$  - number of alligators slaughtered at size  $A$

$k(A)$  - amount of hide produced per alligator size  $A$

$P(A)_t^k$  - price (per foot) of skin size  $A$  at time  $t$

$m(A)$  - amount of meat produced per alligator size  $A$

$P_t^m$  - price of meat (per pound)

$I_t^{\text{htf}}(A)$  - income from head, teeth, and feet per alligator

$P_t^s(A)$  - slaughter cost per alligator

$V(A)$  - variable costs per alligator

Equation 6, then, is the profit function for alligator producers. Equation 6 considers the revenue from hide, meat, and head, teeth, and feet produced by alligators at different sizes, minus slaughter costs, to derive a net revenue from harvesting alligators. The second part of equation 6 accounts for the remaining alligators that have not been slaughtered. Thus, equation 6 sums the profit of raising and slaughtering alligators from 1 ft to 14 ft in length and discounts that sum to current dollars over all time periods.

## Conclusion

Equations 2-6 can be used to model alligator production and include wild and domestic segments of the overall population. Equations 2 and 3 model the wild population and equations 4

and 5 the domestic population. The objective function in equation 6 will choose  $H_t$ ,  $R_t(A)$ , and  $S_t(A)$  to maximize the net present value of profits.

Wildlife agencies will be able to determine optimal clutch removal rates,  $H_t$ , and hatchling return rates,  $R_t(A)$ , in managing alligator populations for sustainable use. Alligator producers can determine optimal slaughter sizes,  $S_t(A)$ , and optimal return sizes,  $R_t(A)$ , for alligators.

An interesting idiosyncrasy of the alligator industry is the interaction between the wild population and the domestic population. Each is responsible for the survival of the other. Domestic alligator production was instrumental in the recovery of the wild population and the wild population is an essential source of young stock for domestic producers.

Lessons learned from managing the American alligator can be applied to other wildlife/agricultural livestock. An example is cattle ranchers managing for white-tail deer while also managing for agricultural production profits. An additional factor in management of the American alligator is its listing as a threatened species. Therefore, lessons learned from the harvesting management of the alligator can be applied to other, endangered species.

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