THE STATUS OF CROCODILIANS IN SOUTH FLORIDA

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Two species of crocodilians occur naturally in South Florida, the American Crocodile (Crocodylus acutus) and the American alligator (Alligator mississippiensis). The American crocodile is considered by the United States Government to be endangered, and the American alligator is presently considered to be threatened in Florida. Recent and ongoing studies have provided an increasingly precise understanding of the status of and threats to these species. In this report I discuss some of the preliminary findings.

AMERICAN CROCODILE

The American crocodile has an extensive neotropical range, which includes the west and north coasts of South America, both coasts of Mexico, the Greater Antilles, and South Florida. Only in Jamaica, Hispaniola, Cuba, and Florida do potentially viable populations persist, and each of these is in some jeopardy. Crocodiles in Florida are at the northern limit of their range, grasping tenuously to the barely tropical tip of the Florida peninsula. This fact is of considerable importance in understanding the species' status in South Florida, as it is probably near the limit of certain of its ecological or physiological tolerances. Under such circumstances, it would be unlikely to maintain a large population covering extensive areas.

The status of this population has long been a matter of concern, however. Moore (1953) documented its occurrence and distribution; Ogden (1978) monitored nesting success from 1968 to 1974 and drew some conclusions about its status. Preliminary results from that study supported the species' placement on the Federal list of endangered species. A recovery plan outlining steps for conservation has been approved (Klukas et al. 1979). Coordinated research efforts by several groups over the last few years have led to a substantial increase in our understanding of potential threats to this population. My colleagues and I began our work on the core of the extant population in Everglades National Park in 1977.

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Ogden (1978) estimated that the population consisted of 100-400 non-juvenile animals. This estimate was based on the percentage of productive females in other crocodilian populations. Although it is probably a reasonable range, it is not rigorously derived. Our mark-recapture studies have proved ineffective in generating a population estimate. However, we expect to do so from population and survey data, at least in a gross way. Whatever the result of that effort, what we do understand well from our studies is the distribution of the population, the minimum number of nest sites, and, with increasing precision, the impact of some potentially limiting factors.

Crocodiles occur along both Florida coasts (Fig. 1). P. Moler (pers. comm.) has verified northern occurrences at Fort Lauderdale, where adults occupy power plant cooling canals, and at Naples. An animal recently took up residence on Sanibel Island. Farther south, we know of reliable records on the edge of southern Biscayne Bay and south of Everglades City. On the lower Florida Keys, recent searches have not been able to verify the natural, current occurrences of crocodiles there (Jacobsen in prep.).

Most remaining crocodiles occur along the mainland of extreme southern Florida. They occupy canals at a nuclear power plant at Turkey Point, and canals, pools, and mangroves on northern Key Largo. The bulk of the population occurs in northern Florida Bay and associated coastal swamps in Everglades National Park, the site of our studies.

The known range of nesting animals is even more restricted. Gaby (pers. comm.) has found a maximum of two nest sites at Turkey Point. Moler (pers. comm.) has found a maximum of seven nest sites on North Key Largo. Most of the latter nests are located in the area that has been authorized to be purchased by the Federal government as the Crocodile Lake Wildlife Refuge. Currently, no purchase activity is underway. Over half of the known nest sites are in Everglades National Park, with at least 14 clutch sites known to be used by this subpopulation in some years. Two sites are used sporadically near Flamingo on the southwest coast. As many as 12 nest sites are known from a small area of northeast Florida Bay.

I have attempted to develop a system of monitoring the population on aerial surveys using fixed-wing aircraft and helicopters, each of which we flew monthly for a year, by boat surveys, and by capture-recapture studies. While substantial biological information has been obtained, it is probable that none of these methods will prove adequate as a population monitoring technique. Although probably not all nest sites are now known, many are and it is possible to search carefully the core nesting area each year. Monitoring these nest sites will probably be the best system available for tracking population status.

We can examine the number of active nests found in recent years from this perspective. Ogden (1978) found a maximum of eight clutches in 1971-74 in the primary area of crocodile occurrence near Little Madeira Bay and nearby Florida Bay. Since then, we have increased the number to 12. In certain sites two clutches of eggs occur together, probably from

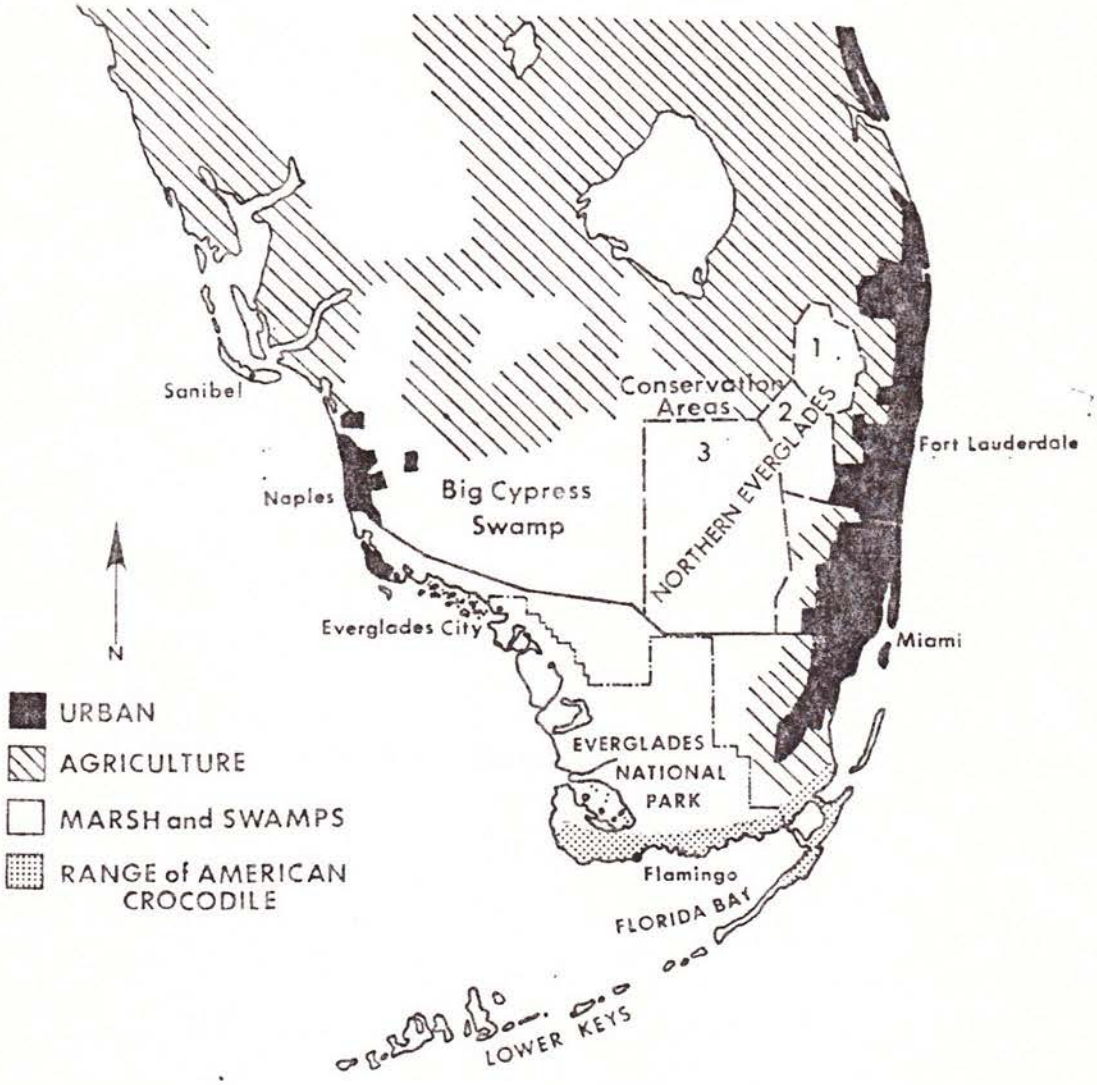

Figure 1. Natural and altered wetland habitat in South Florida and the distribution of the American Crocodile.

different animals. Some of the increase in the number of known clutches is due to our increasing skill at finding nests, but some nests are at entirely new sites. One nest contained few small eggs and was attended by a small animal. It seems such clutches may be from animals new to the breeding population.

We have been particularly concerned with nesting success (Patty, Kushlan, and Robertson in prep.). Ogden (1978) considered "embryonic mortality" to be an important limiting factor. Whether lack of hatching is due to infertility or early death has not been clear. We studied this phenomenon, especially thermal characteristics, diffusion, gas concentrations, and flooding of nest cavities. Preliminary results show that high CO_2 and low O_2 levels occur late in incubation, and in some years temperatures can approach expected lethal levels (38°C) (Lutz and Dunbar-Cooper in prep.). High nest temperatures may affect sex of the developing embryos. Short-term flooding takes place in some years (Mazzotti, Kushlan, and Dunbar-Cooper in prep.). Nonviable eggs have occurred in up to 25% of the nests in some years. However, we have found a mean egg loss of 14% (Patty, Kushlan, and Robertson in prep.), which is not overwhelming, and lack of hatching does not appear to be a major limiting recruitment. Predation on nests also has been considered to be an important cause of nest failure. However, we have found predation to average about 20% over 12 years, a figure that is not excessive for crocodilian populations. Thus, we believe that hatching success is fairly high, with 64% of all nests producing young (Patty, Kushlan, and Robertson in prep). In some years a conservative minimum of over 200 eggs are hatched.

Limited survival of hatchlings is another possible limiting factor. We have studied the survival of these hatchlings through radio telemetry and by tagging over 200 hatchlings in two years (Mazzotti and Kushlan in prep.). Although hatching occurs during the season of maximum freshwater runoff, salinities near nests are typically 50-100% sea water. Evans and Ellis (1977) showed that in the laboratory hatchlings submerged in salinities as low as 25% of sea water lose weight rapidly. As a result, a major concern has been adverse effect of ambient salinity on survival. We found, through telemetry, that hatchlings lose weight initially but begin to gain weight at two weeks of age (Mazzotti and Kushlan in prep.). Grigg and Taplin (in press) demonstrated the existence of salt secreting glands in Crocodylus porosus, and Grigg, Taplin, Dunson, and Ellis (pers. comm.) have extended this finding to C. acutus. Dunson (1970, in press) studied wild animals in Florida Bay, and found that their survival may be due to drinking fresh water and eating water-bearing prey. The functioning of glands in wild animals, the effect of high salinity on gland function, and the energy costs of osmoregulation remain to be determined; it appears that some osmoregulatory compensation exists, either physiological, behavioral, or both (Dunson in press). Data suggest that survival of hatchlings is possible in some locations, and that growth of young can be relatively rapid.

I have also examined whether adult interaction or lack of interaction could be limiting to the population. Through aerial surveys and radio telemetry, we have found seasonal shifts of adult females from inland swamps into Florida Bay during the summer (Kushlan and Mazzotti in prep.). We have also determined that adults have rather large activity areas. Many potential nest sites exist and, as noted previously, more than one female uses a single nest site. it does not appear that adult habitat requirements adversely affect the population.

Pesticide accumulation is often a matter of concern for an endangered carnivore. However, Hall et al. (1979) have shown that levels of pesticide residues in crocodile eggs are unlikely to affect reproductive success in the South Florida population. Heavy metal residue analyses are in progress.

An answer to the basic question of "does recruitment occur?" seems to be yes. The size distribution data shows the occurrence of juveniles (< 1 m in length), subadults (1-3 m), and adults (> 3 m) in the population. Considering the rapid growth rates, and perhaps the secretive nature of the subadults, it is encouraging that the existence of this potential breeding pool has been documented. We now need to know more about the distribution and growth rates of subadults.

Thus our preliminary analyses show crocodiles have a restricted distribution and a relatively small breeding population, but one which may be stable or perhaps increasing. Our ecological work and that of our colleagues suggest cause for optimism. There is also cause for optimism on the political front. Most nest sites are in Everglades National Park where environmental conditions remain relatively natural. The National Park Service has recently established a crocodile sanctuary in the center of the known distribution, prohibiting access by the public. This ecosystem approach to management of crocodiles in the park is supplemented by the planned, although currently inactive, purchase of the Crocodile Lake Wildlife Refuge on Key Largo. There most of the additional nest sites will be protected and, if necessary, the habitat can be enhanced for the benefit of crocodiles. This combined approach of ecosystem protection and restoration in one area and single-species management in another, bodes well for the future survival of the American crocodile in South Florida.

AMERICAN ALLIGATOR

Under historic conditions nearly all of South Florida was wetland, although Schortemeyer (1972) estimated that about 30% of this historic alligator habitat has been lost to development. Much of the inland area of southern Florida remains freshwater wetlands, including the Everglades, the Big Cypress Swamp, and coastal mangrove swamps, most of which is managed or protected by agencies of the State or Federal governments.

Alligator numbers were reduced throughout South Florida during the 1950's and 1960's, but the population responded to legislative protection and popular support. The recent population recovery of alligators in Florida is fairly well documented (Hines 1980). A statewide management program removes nuisance alligators from contact with Florida residents and sells hides and meat under state control (Hines and Woodward 1978).

Hunting and killing alligators is illegal throughout the undeveloped Everglades and Big Cypress Swamp, but illegal killing of alligators appears to have increased in recent years. Such killings do not yet seem to be numerous enough to impact population levels, but they are cause for concern, especially along the boundaries of reserves such as Everglades National Park.

The status of the American alligator differs somewhat in the various remaining natural areas in southern Florida, the Big Cypress Swamp, the northern Everglades included in Water Conservation Areas 1, 2, and 3, and the southern Everglades of Everglades National Park (Fig. 1).

The Big Cypress Swamp is a complex mosaic of cypress (Taxodium distichum) swamp, marsh prairies, and ponds. Much of the swamp is now owned by the Federal government as part of the Big Cypress National Preserve. Although some data exist on the ecological role of alligators, particularly the ecological effects of previous population losses (Kushlan 1974), little information is available on the current status of alligators in the swamp. The population appears to have increased in recent years, especially among juvenile age classes, but old alligator ponds remain overgrown in many areas, suggesting full recovery in numbers of large animals has not occurred.

The Everglades is an extensive sedge marsh, characteristically vegetated by sawgrass (Cladium jamaicense). The northern Everglades is now encompassed by the levees of three Water Conservation Areas, the northernmost (Area 1) being the Loxahatchee National Wildlife Refuge (Fig. 1). This area continues to support high alligator populations. Animals along perimeter canals especially appear to be of large size classes. Nesting sites on high islands are in good supply and overall the population appears healthy. In contrast, in Conservation Area 2, water levels have been held unnaturally high for several years. There J. Schortemeyer (pers. comm.) has been able to locate very few nests, most of which flood before hatching.

The status of the alligator population is better understood in Conservation Area 3, where alligators have been studied over a number of years by personnel of the Florida Game and Fresh Water Fish Commission under the direction of M. Fogarty and J. Schortemeyer. Since the conservation area generally slopes from north to south, water drains from the north and impounds behind southern levees. As a result, the northern part is drier than it would be under natural conditions and the southern part is wetter. Alligators in the north endure a long dry season, often accompanied by fires. In the southern end, high water floods nests. We

have conducted surveys by helicopter and observed no nests in the southern, deep water end of Conservation Area 3-A. This confirms the findings of J. Schortemeyer (pers. comm.), who has been unable to find nests farther south than midway down the area. We have also conducted 3 years of nighttime line surveys along canals in this area and have found fewer animals (avg 5/mi, max 6.5/mi) than just to the south in Everglades National Park. Thus, alligators occur throughout Conservation Area 3 but are stressed in the north and south by drying and flooding, respectively.

These observations on alligator status in the Conservation Areas suggest a primary factor limiting alligator populations in South Florida is the effect of water management, provided harassment, illegal killing, and habitat destruction are minimized. The primary objective of my studies in Everglades National Park was to examine the relation of water level fluctuations to alligator population ecology. The management goal of the park is to recreate, as closely as possible, natural ecological conditions, and the alligator is an essential component of this ecosystem.

Because of the levees surrounding the Water Conservation Areas, natural surface water sheet flow into Everglades National Park has been blocked. Water enters the park from the north by four gated structures, through which flow is controlled by several government agencies. A certain amount of water is guaranteed to the park each month by Federal legislation. Should water levels become higher than desired in the Conservation Area, excess water is vented into the park, the amount and timing depending on hydrologic and engineering considerations upstream. The status of alligators in Everglades National Park is affected by such water management actions. So far we have been able to dissect some of these effects and are approaching an understanding of the Everglades alligator population.

As noted above, alligator populations in the southern Everglades are higher than those of the southern parts of the Conservation Areas. Line surveys were run monthly for two years along a transect of the Everglades from the northern boundary of the park into the coastal mangrove swamps, nearly to the Gulf of Mexico. Our longest span of data is from L-67 canal on the eastern boundary of the park. There alligator numbers vary inversely with water level and can achieve densities of over 50 animals per linear mile of survey.

Much of our research was conducted primarily in five 10 km^2 study areas along the northeast-southwest axis of the southern Everglades. Dry season counts of alligators in ponds in each of these areas were conducted for three years. The number of alligators at any time appears to depend on water level at the time of the survey. However, within a single year, alligator densities per pond varied from area to area, for example from 0.7 to over 2 animals per pond. Thus, even within a relatively homogeneous habitat such as the Everglades, alligator densities can vary substantially.

The intensity of alligator nesting has varied from 3 to 18 nests in the 10 km^2 main study area. Our preliminary analysis suggests that the number of nests may be directly related to water levels occurring in spring

(Kushlan and Kushlan 1981). Thus, nesting effort is highest in years of high water conditions.

Very few nests are lost to predation, and as a result, water level plays the most critical role in egg mortality in the Everglades. Once eggs are deposited, their position with respect to ground level is set for the 2-month incubation period. Attending alligators may later add vegetation to the top of their nest but it does not affect egg placement. Thus, eggs are subject to inundation should water levels rise too high. It appears that the height of the lowest egg above ground level is correlated with the water level on the date of laying. The higher the water level, the higher the eggs are located.

Some eggs are lost to flooding in most years. The loss of eggs in the main study area varied from none in 1976, to 35% in 1978, and probably 100% in 1981. The latter was due to a tropical storm. The 1978 loss was very useful in analyzing the effect of water management on alligators (Kushlan and Kushlan 1981). In 1978 water levels in Conservation Area 3 exceeded regulation level in July. In order to bring water stages down to regulation level, a relatively large amount of water was discharged into the park beginning in mid-July. This water reached the study area on 30 July. Alligator eggs began flooding at the beginning of August, and flooding increased through 12 August. Overall, 35% of the eggs flooded during a 2-week period. Since flooding can result from either on-site rainfall or from discharge into the park from higher marshes to the north, we subtracted the effect of rainfall and determined that a 32% egg loss was due to discharge of water into the park.

Although a 30% loss of potential productivity in one year probably would not adversely affect an otherwise healthy alligator population, it does indicate the potentially severe impact of water management actions. Combined with the low alligator nesting success in deep water parts of the Conservation Areas, data from Everglades National Park suggest that water management can in itself be a primary determinant of alligator populations in South Florida. Thus, even with protection, the alligator populations continue to be subject to man-made threats in the remaining wetlands of South Florida.

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LITERATURE CITED

Dunson, W.A. 1970. Some aspects of electrolyte and water balance in three estuarine reptiles, the diamondback terrapin, American and "salt water" crocodiles. Comp. Biochem. Physiol. 32: 161-174.

_____. In press. Salinity as a limiting factor for crocodiles in Florida Bay.

Evans, D.H., and T.M. Ellis. 1977. Sodium balance in the hatchling American crocodile, Crocodylus acutus. Comp. Biochem. Physiol. 58A: 159-162.

Grigg, G.C., and L.E. Taplin. In press. Physiological strategies by which Crocodylus porosus live in sea water. Symposium on the reproductive biology of crocodilians. Milwaukee, Wisc.

Hall, R.J., T.E. Kaiser, W.B. Robertson, Jr., and P.C. Patty. 1979. Organochlorine residues in eggs of the endangered American crocodile (Crocodylus acutus). Bull. Environ. Contam. Toxicol. 23: 87-90.

Hines, T.C. 1980. The past and present status of the alligator (Alligator mississippiensis) in Florida. Proc. S.E. Assoc. Fish Wildl. Agencies 33.

_____, and A.R. Woodward. 1978. A nuisance alligator control study in Florida. Florida Game and Fresh Water Fish Comm. Mimeo. 12 p.

Klukas, R., J.C. Ogden, T.C. Hines, W.B. Robertson, Jr., J.A. Kushlan, and H.W. Campbell. 1979. American crocodile recovery plan. U.S. Fish Wildl. Serv. 24 p.

Kushlan, J.A. 1974. Observations on the role of the American alligator (Alligator mississippiensis) in the southern Florida wetlands. Copeia 1974: 993-996.

_____, and M.S. Kushlan. 1981. Water levels and alligator nesting in the Everglades. Proc. 2nd Conf. Res. in National Parks, Washington, D.C.

Moore, J.C. 1953. The crocodile in the Everglades National Park. Copeia 1953: 54-59.

Ogden, J.C. 1978. Status and nesting biology of the American crocodile, Crocodylus acutus (Reptilia, Crocodilidae) in Florida. J. Herp. 12: 183-196.

Schortemeyer, J.L. 1972. Destruction of alligator habitat in Florida. American Alligator Council Symposium.