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Terri Jacobsen

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CROCODILIANS AND ISLANDS: STATUS OF THE AMERICAN ALLIGATOR AND THE AMERICAN CROCODILE IN THE LOWER FLORIDA KEYS

TERRI JACOBSEN

16940 SW 272 St., Homestead, Florida 33031

Crocodilian populations located in geographically or ecologically marginal habitats are of special interest from a biogeographic perspective and also with respect to their conservation. Worldwide, crocodilian species are threatened with extinction, and in the United States hunting had decimated most populations by the 1940's (Allen and Neill 1949). With protection, many populations of the American alligator *(Alligator mississippiensis)* have recovered rapidly, and recent research in some states has been directed toward developing a program of sustained harvest (Nichols et al. 1976). The status of the apparently less resilient American crocodile *(Crocodylus acutus)* is more difficult to determine, and efforts for protection in the United States have focused primarily on ecosystem management (Kushlan 1982).

In the lower Florida Keys, crocodilians face an island environment removed from the nearest portion of their mainland ranges by an extensive open body of seawater. Three National Wildlife Refuges provide the opportunity for their conservation and management. In this study I examine the distribution and status of a small, apparently isolated population of alligators in the lower Florida Keys, Monroe County, Florida, and evaluate reports of crocodiles in the area.

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Methods

Field work was conducted from May, 1979, to November, 1981. During this period I searched for alligators and nests, charted fresh water areas, and monitored seasonal changes in salinity and water level on Big Pine Key. Selected habitats of all salinities representative of those available to alligators were surveyed quarterly from Fall 1979 to Summer 1980. I searched other areas of Big Pine Key and parts of Little Pine and Howe Keys less frequently.

I used salinity measurements, taken at each alligator sighting, to document the association of alligators with the range of salinities available in the lower keys. To document seasonal fluctuations in salinity, I also took measurements at least quarterly in five habitats: ditched areas (including some natural areas with ditches nearby); natural areas (including hammocks and buttonwood sloughs); man-made areas (including canals and borrow pits); mangrove flats; and marine areas (including open water and tidal canals). In compiling data on habitat use and salinity associations, alligators identified as individuals were tallied only once in the total count and for each salinity and each habitat type in which they were found.

An aerial survey in May 1979 covered Little Pine Key west to Sugarloaf Key including parts of Big Pine, Mayo, Annette, Howe, Water, Raccoon, and Cudjoe Keys. I searched for alligator nests in the summers of 1979 and 1980. Due to logistic and financial constraints, I did not undertake the extensive surveys of marine areas necessary to completely document crocodile occurrence. For this and for historic information I rely on previous surveys, published literature, unpublished references, and interviews with local citizens and crocodilian experts. Unfortunately, the history of crocodilian presence in the lower keys is poorly documented and is especially complicated because the two species are sometimes difficult for inexperienced observers to tell apart. Observations based on information from single witnesses are subject to uncertainty and should be interpreted with caution.

Study Area

The Florida Keys comprise a chain of islands stretching for over 240 km off the southern tip of Florida from Soldier Key southwest to Key West, bordered by the Atlantic Ocean, Florida Bay, and the Gulf of Mexico (Hoffmeister 1974). The upper and lower keys, distinguished by their geologic history and present vegetation (Duellman and Schwartz 1958), are separated by an 11-km span of open water, which provides a partial barrier to dispersal and interchange for many terrestrial vertebrates. A seawater gap of about 48 km separates the lower keys from mainland Florida (Dunson and Lazell 1982).

The lower keys are more varied in their vegetation than the upper keys, supporting at one time large areas of pineland and extensive hammocks (Small 1913). Most of the islands are surrounded by a thick growth of red mangroves *(Rhizophora mangle)*, which entirely covers many of the smaller, low-lying keys (Dickson 1955). Sandy beaches are rare and limited in extent (Hoffmeister 1974). Shallow intertidal flats surround most of the islands.

I studied the distribution of alligators primarily on Big Pine Key, the largest of the lower keys (2 400 ha) (Fig. 1). This island is 3.2 km wide and 12.9 km long and probably provides the greatest amont of fresh water habitat of any of the lower keys (Jacobson 1974, Hanson 1980). Although most of the land in the southern end of the island is privately owned, a large part of the island, particularly its northern end, is in the National Key Deer Wildlife Refuge.

Like the southern part of the mainland, all rocks of the keys are made of limestone. The lower keys are composed of oolite of the Miami limestone formation (Hoffmeister 1974), a porous rock which accounts for an important feature of the lower keys—the availability of fresh water. Hanson (1980) conducted a detailed study of the nature and extent of fresh water resources underlying Big Pine Key. Miami oolite extends from land surface to depths of about 4.0-7.0 meters at various parts of the island. Porosity of this formation is high, but the permeability is low due to the small interconnections between the voids. Fresh water storage occurs in both the oolite and the underlying Key Large limestone as a lens overlying denser seawater.

The areal and depth configurations of the lenses are influenced by five factors: fresh water recharge; fresh water discharge; tidal fluctuations; proximity to saltwater bodies; and permeability of subsurface materials. Rainfall is the only source of recharge, as the lower keys platform is not continuous with the Biscayne aquifer, which underlies mainland southern Florida. Average rainfall is 100 cm, of which 75-85 percent falls from May to October.

The seasonal variation in the availability of surface fresh water is marked, as suggested by the highly seasonal rainfall pattern. Endemic vertebrates such as the key deer *(Odocoileus virginianus clavium)* depend on this resource and show behavioral or physiological adaptations to the spatially and temporally limited nature of its availability (Dickson 1955, Dunson 1981, Dunson and Lazell 1982). During extended droughts the fresh water lenses may totally dissipate, and the stressful lack of surface fresh water seasonally occurs as a natural phenomenon. However, the increased stress induced by pumping from residential and commercial wells is expected to show detrimental effects in the future, particularly in areas of Big Pine Key zoned for commercial development. This would result in an even further decrease in fresh water availability owing to salt water intrusion and would create an unnaturally stressful situation for wildlife in the lower keys.

Results

Historic Distribution of Alligators

Accounts of early explorers and naturalists in the Keys are notable for their lack of any reference to crocodilians (Fontenada 1575, Gifford 1934, Henshall 1884, Holder 1971, Munroe and Gilpin 1930, Romans 1775, Simpson 1920, Williams 1837). In the earliest written reference to alligators in the lower keys, Fowler (1906) reported that alligators occurred on Little Pine Key, although he did

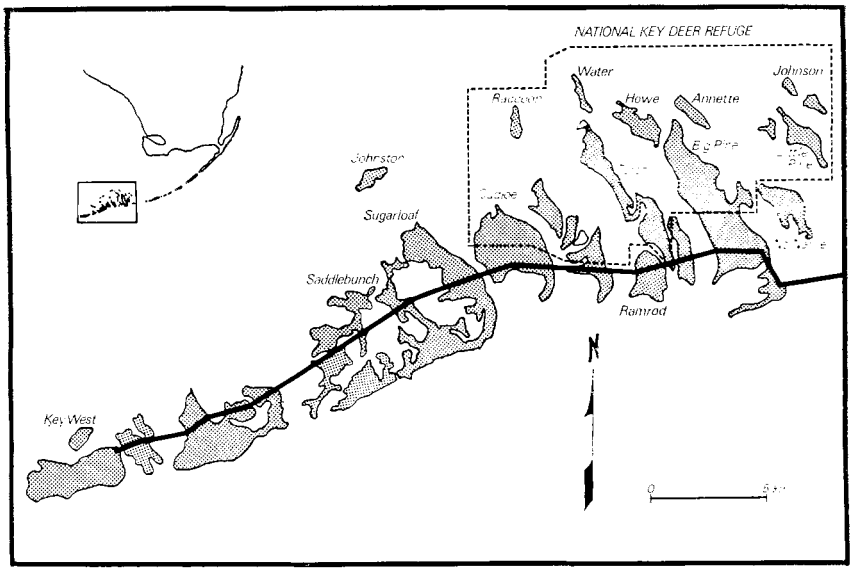

Fig. 1. Lower Florida Keys, showing boundaries of the National Key Deer Wildlife Refuge.

not personally observe them there. Two alligator skulls from Key West collected "prior to 1913" are in the National Museum of Natural History (Roy McDairmid pers. comm.). Small (1923) reported that in 1921 "some of the limesinks [in the hammocks on Big Pine Key] . . . were formerly frequented by alligators and crocodiles, but these animals have mostly disappeared. . . ." Two newspaper stories reported alligators on Big Pine Key "about 1920" (Parks 1975) and on No Name Key "sometime after 1919" (Parks 1969). In 1937, three alligators were collected "on Key West proper . . . in salt water" (Allen and Slatten 1945), and this account was later taken by Neill (1971) to indicate the presence of a permanent population.

Present Distribution of Alligators

Habitat Availability and Use.—Habitats available to alligators in the lower keys are spatially and temporally discontinuous. Spatially, the isolation of fresh water habitats by dry ground, roads, and development may be a partial barrier to movement. In May, 1979 however, a male alligator 3 meters long crossed 0.8 km of dry pineland (straight line distance) from one pond to another, indicating that such movement does occur. Temporally, the prolonged

dry season in the lower keys creates a rigorous environment for organisms dependent on restricted and fluctuating areas of fresh water (Dickson 1955, Dunson 1981, Lauren and Lance 1981).

I found most alligators in the lower keys in fresh and low-salinity brackish water (Fig. 2), although these data may be biased by less survey effort in open water areas. The scarcity and patchiness of natural fresh water habitats may contribute to a greater use of marine areas by alligators than would otherwise be expected. No evidence for seasonal movements is available, although the alligator's need for an aquatic environment on an island with restricted fresh water availability makes it reasonable to predict that alligators would leave the island for marine areas or other keys when inland water sources become dry or otherwise limiting.

Survey data and sightings from other sources show that alligators use all suitable habitat available (Fig. 3). Alligators occur in marine areas; in fact a majority of nuisance alligator complaints occur in man-made tidal canals in housing subdivisions (T. J. Reuther pers. comm.). Data on sightings in marine areas include 16 nuisance alligators relocated from such areas by the State Game and Fresh Water Fish Commission during 1977-1979. At least 34 relocations were reported; many of these alligators returned in a short time to the original capture site to become nuisances again. Other sightings in marine areas included four alligators observed in open water during a 1978 boat survey (Paul Moler pers. comm.). Night surveys in this study showed that mangrove flats bordering the island are used occasionally, although some of these areas dry seasonally, and salinities can reach 80 ppt.

The most frequently used natural areas are depressions near the edges of higher ground (hammocks and pinelands). These depressions are deeper than the prevailing water table and are generally associated with buttonwood trees *(Conocarpus erectus)* (Dunson 1981). The distribution and salinity of these holes during the dry season can be limiting to alligators when the extent of surface water depends entirely on rainfall. Alligators are known to maintain the size of ponds by their activities in swamp areas of the Everglades where the peat substrate is easily moved (Kushlan 1974). Such activity is rare in the lower keys, and I have seen evidence of the maintenance of ponds only twice, in the buttonwood sloughs of Big Pine and Little Pine Keys where the limestone is overlain by soft peaty deposits (Dickson 1955).

The alteration of natural areas has greatly increased the availability of fresh and brackish water habitat in the lower Florida

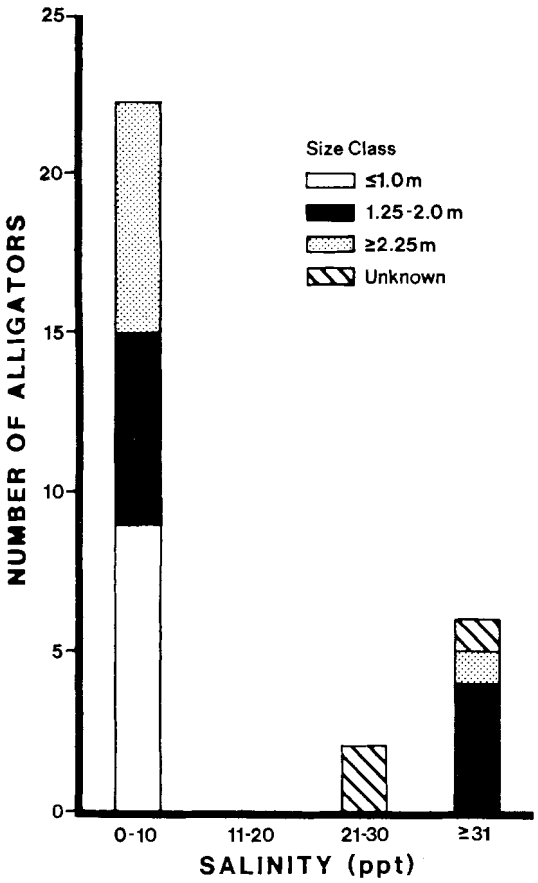

Fig. 2. Number and size classes of alligators observed in various salinities in the lower Florida Keys. Data used are those where salinities were measured at the time of observation.

Keys. On Big Pine Key, man-made inland canals, vestiges of abandoned development, and borrow pits used for fill for construction provided year-round deep-water habitats of low salinities. The severity of seasonal conditions is partially alleviated by a system of ditches, constructed in 1965 as part of the Anti-mosquito Control Program (Parks 1975). On Big Pine Key, over 160 unmapped kilometers of mosquito ditches, 40 cm wide and 120 cm deep (Silvy 1975), link natural depressions in 1 990 of the island's 2 440 hectares (Hardin 1974), creating a locally continuous aquatic system. These inland fresh water mosquito ditches are used frequently by small alligators, although I observed alligators of various sizes (.25-3.0 m total length) in ditched areas (Fig. 3).

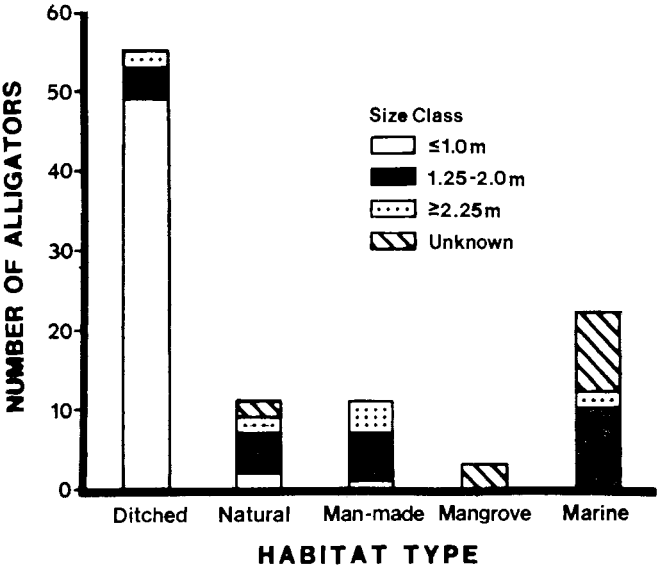

Fig. 3. Number and sizes of alligators observed in various habitats, in the lower Florida Keys.

The contrast in the seasonal availability of fresh water between natural and ditched areas is potentially important to alligator survival in the lower keys. Several natural ponds and most mosquito ditches retained water during the study period and apparently harbored alligators throughout the dry season. Most fresh water habitats on the island probably dry completely in more severe dry seasons. Under late dry season conditions, natural ponds appeared during this study to be extremely stressful because of their small size and high temperatures. Salinities never exceeded 10 ppt (Fig. 4) and so were probably not stressful. In natural areas, food availability was low to nonexistent, and it appears that prey levels are never high, because of the extreme seasonality of environmental conditions. Some mosquito ditches, however, retained water at cool temperatures and maintained a rich concentration of fish, invertebrates, and other aquatic vertebrates, which could restock areas flooded when water levels rise in the early summer. A sampling of prey items found in the ditches included prawns *(Palaemonetes paludosus)*, sailfin mollies *(Poecillia latipinna)*, mosquitofish *(Gambusia affinis)*, marsh killifish *(Fundulus confluentus)*, crayfish (*Procambarus alleni*), leopard frogs (*Rana sphenocephala*), and numerous unidentified aquatic insects. In other fresh and brackish

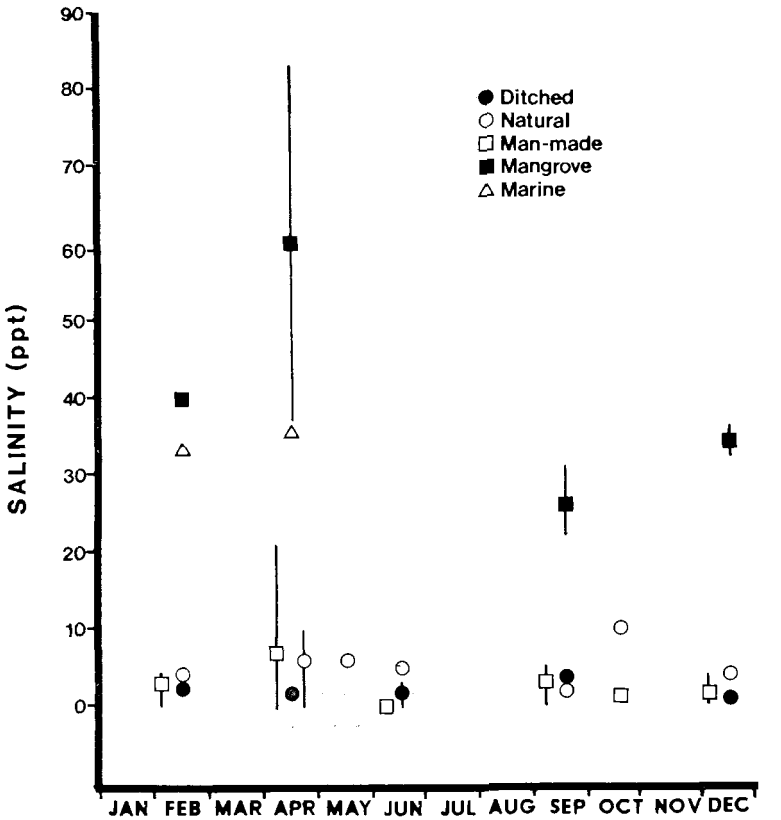

Fig. 4. Salinity measurements taken in various habitats, in the lower Florida Keys. Symbols show the mean reading and vertical lines show the ranges of measurements taken in each habitat for each month.

water habitats I found additional species, including bluegills *(Lepomis macrochirus)*, redear sunfish *(Lepomis microlophus)*, spotted sunfish *(Lepomis punctatus)*, sheepshead minnows *(Cyprinodon variegatus)*, goldspotted killifish *(Florichythys carpio)*, rainwater killifish *(Lucania parva)*, and the exotic Texas cichlid *(Cichlasoma cyanoguttatum)*, which appears to be replacing native species in the Blue Hole borrow pit lake on Big Pine Key. Observations during my study suggest that the high food availability, generally consistent temperature regimes, low salinities, and more permanent water provided by some mosquito ditches create an environment suitable for growth and survival of young alligators (Chabrek 1971).

Several other keys near Big Pine Key reportedly have small patches of standing fresh water (Dickson 1955), although only

Little Pine Key appears to support alligators in any numbers. Buttonwood sloughs occur on Little Pine Key on both sides of the small pineland ridge extending north and south on the key. At least one large, and probably permanent, pond was found at the southern end of the eastern slough, along with numerous fresh water ponds scattered along each slough. One pond showed signs of being actively maintained by alligators, but in all areas the availability of aquatic prey appeared extremely low. I observed three adult alligators in three separate ponds on Little Pine Key in November, 1981. Two small alligators (0.5 m total length) were subsequently observed in one of these ponds in February, 1982 (Steve Klett pers. comm.). On Howe Key, during the 1981 wet season, all holes were either dry, saline or extremely small, and no alligators were observed. Dunson (pers. comm.) reported no alligators in the numerous ponds on Johnston Key. Other holes on Johnson, Water and Annette Keys are monitored bi-monthly by Steve Klett, wildlife biologist at the Key Deer Refuge, who reported (pers. comm.) no alligator or crocodile sightings in these areas. W. D. Klimstra (pers. comm.) reported the sighting of a 1.5-2 m alligator on Johnson Key in 1965.

NUMBERS AND SIZES.—During the study period 133 alligator sightings throughout the lower keys were compiled from survey data, personal observations, and reports which I judged to be reliable. Alligators of a wide range of sizes occur in the lower keys population (Fig. 5). Young alligators were sighted on Little Pine Key, which suggests that natural areas can support a reproducing population, although the scarcity of small size classes there suggests that survivorship to the second year in natural areas is quite low. The observation of 46 young, healthy alligators in ditched areas of Big Pine Key suggests that the overall survivorship in the lower keys may be enhanced by the mosquito ditches.

REPRODUCTIVE SUCCESS.—I received three specific reports of nesting activity occurring prior to this study, in hammocks at the northern end of Big Pine Key (Nova Silvy pers. comm.), near the site of the old Big Pine Inn (William Robertson, Jr. pers. comm.), and near a canal south of Watson Hammock on Big Pine Key (T. J. Reuther pers. comm.). No nesting occurred in these areas in 1979 or 1980. I found two nests in 1979, and one of these sites had another nest in 1980. Both nest sites were on private property, and none of the three nests hatched successfully. However, the occurrence of

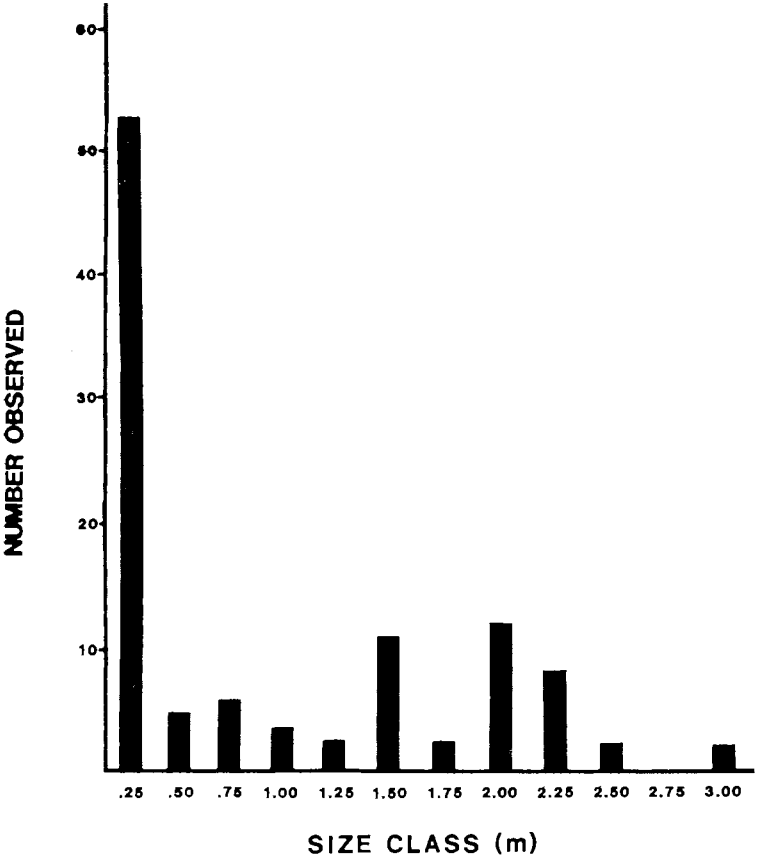

Fig. 5. Number of alligators observed throughout the lower Florida Keys in .25-meter size classes.

hatchlings (Fig. 5) demonstrated the existence of successful nesting in other locations.

Historic Distribution of Crocodiles

The earliest evidence of crocodiles in the lower keys is Neill's 1935 photograph of a crocodile on a beach in Key West (Neill 1971: 332). Previously, though, Allen and Neill (1949) reported the crocodile's range to include Key West "before 1925". Crocodile specimens collected in the late 1800's are available from the upper keys only, and crocodile eggs were taken in 1875 from the "Florida Keys" (exact location unknown) (Roy McDiarmid pers. comm.). At least

two early accounts include the Keys in the range of the crocodile, stating that they are "occasionally seen off Key West" (Carr 1940) and that they range as far south as Big Pine Key, where a specimen was reportedly collected in 1953 (Duellman and Schwartz 1958). Moore (1953), in an exhaustive review of the crocodile's status for Everglades National Park, does not report information from the lower keys, although he cited records from Florida Bay as far south as Plantation Key.

Ogden (1978) reported information from Jack Watson, former National Key Deer Refuge manager, that "small numbers of crocodiles were regularly reported during the late 60's and early 70's in the lower keys· . . ." Rather than representing members of a resident population, some of these individuals may have been displaced by hurricanes (Ogden 1978). Theatre of the Sea, an attraction in Islamorada, reported the loss of several crocodiles during the 1948 hurricane (Robert P. Allen, 1948, letter to Everglades National Park Superintendent, located at South Florida Research Center library, Homestead, Florida).

In the late 1960's (Parks 1970) or early 1970's (Ogden 1978), a crocodile nest was reported on Little Pine Key. It is possible that two crocodile nests occurred. Jack Watson (pers. comm.) saw hatchling crocodiles in a natural setting and also collected eggs from a nest opened by raccoons. These eggs were artificially hatched at the Key Deer Refuge headquarters (Jack Watson pers. comm., Parks 1970).

Present Status of Crocodiles

The abundance and reproductive status of crocodiles in the lower keys have always been unresolved issues. Hines et al. (1980) cited no evidence for the continued presence of crocodiles in the lower keys, although not refuting the possibility that a disjunct population may occur or may have occurred at some time. Four aerial and boat surveys conducted by Howard Campbell in 1978 and 1979 did not result in any crocodile sightings (1980, unpublished report on a summary of surveys conducted in the lower keys, located at the National Key Deer Refuge Headquarters, Big Pine Key, Florida).

The capture of a crocodile in a canal on Big Pine Key in May, 1979, after its release three weeks earlier in Barnes Sound on the upper Keys, indicates the feasibility of long distance travel by transient crocodiles. Other reports of crocodiles, although infrequent and unconfirmed, continue to occur. These may include alligators

misidentified as crocodiles. Including the capture and removal just mentioned, at least six crocodile sightings have been recorded in the last five years. Reported locations include Coupon Bight on Big Pine Key in 1976 or 1977 (T. J. Reuther pers. comm.), No Name Bridge in 1978 (T. J. Reuther pers. comm.), Missouri Key in 1979 (Barbara Bohnsack pers. comm.), and in a Big Pine Key canal in 1981 (Paul Moler pers. comm.). A crocodile was reportedly relocated in 1978 from the upper to the lower keys by the State Game and Fresh Water Fish Commission officer (T. J. Reuther pers. comm.), and it was later returned to the upper keys. I am unaware of any other reports of crocodiles being intentionally moved to the lower keys.

For a crocodile population to be self-sustaining, it must have suitable nesting habitat. A patch of such habitat can be found on Little Pine Key on the western side of the southern tip. This beach was monitored in 1978 and 1979 without showing any signs of crocodile nesting activity (Howard Campbell pers. comm.). During these periods, the area had been infiltrated with land crab burrows *(Cardisoma guanhumi)* and has since (1981) become overgrown with grass. Based on a ground search of the northwest shore, examination of aerial photographs and explorations by Refuge personnel, it appears that no other suitable habitat occurs on Little Pine Key. Other sandy beaches occur on the Content and Sawyer Keys and along some shorelines behind the mangrove fringe as on Sugarloaf and Ramrod Keys. These beaches are not extensive but include potential crocodile nesting habitat that is available in the lower keys.

Discussion

The Florida Keys lie within the range defined by three areas of crocodile concentration, the Greater Antilles, Central America, and northeast Florida Bay (Powell 1971, 1973, Schwartz and Thomas 1975, Wilson and Hahn 1973, Kushlan 1982). Furthermore, the proximity of crocodile and alligator populations to the north in Florida Bay suggests that crocodilians might disperse to the lower keys with little difficulty. Alternatively, the existence of a land bridge during the last part of the Pleistocene may have allowed the colonization of the lower keys, and, with the subsequent submergence of the Florida Bay area, populations on the lower keys that were once contiguous with the mainland may have become isolated (Auffenberg 1958, Duellman and Schwartz 1958, Neill 1957, Barbour and Humphrey 1982).

Recruitment in the alligator population of the lower keys appears to be occurring despite the apparently marginal nature of the island habitat. The fragile fresh water habitat of the lower keys is critical. Continued survival of alligators in an island environment surrounded by seawater is made possible in large part by the increase in fresh water habitat afforded by mosquito ditches, although the existence of areas removed from human activity may be important for nesting success. Dry season conditions can be severe, and low levels of prey availability might contribute to cannibalism or other forms of predation on young alligators, accounting for the paucity of these size classes in natural areas.

Considering the secretive nature of the crocodile and its probable low density in the lower keys (if it occurs there at all), the negative results of ground and aerial surveys for crocodiles are not unexpected. Crocodile sightings in the lower keys appear not to consist of residents but of transients or of individuals displaced by hurricanes. My observations in these areas suggest that some suitable crocodile nesting habitat is available in the lower keys, although it is limited in extent. The heavy public use of many open sandy beaches reduces the likelihood of crocodile nesting in the lower keys given the shy and easily disturbed nature of the species.

The historical evidence for the crocodile's occurrence and nesting in the lower keys is based on published and anecdotal testimony of a few individuals. No evidence exists that a population of crocodiles other than a few transient individuals existed in the lower keys at any time during at least the last two centuries.

Crocodilians have probably never been abundant in the lower keys because of seasonally stressful conditions, and the limited availability and patchiness of nesting areas and of habitat conducive to hatchling growth. The small alligator population in the lower keys has been preserved in part by the inclusion of fresh water habitat in the National Wildlife Refuge system. These conditions may be modified by management recommendations for the key deer that call for filling the ditches to reduce fawn mortality (Klimstra et al. 1980). A further threat is posed by the increasing commercial and residential demand on the already moderate fresh water supply underlying the lower keys. Evidence obtained during this study shows that mosquito ditches support alligators and that the preservation of mosquito ditches may be important to the future survival of the alligator population in the face of increasing loss, fragmentation, and deterioration of essential habitat.

Other management recommendations are suggested. Translocations of crocodilians from other areas to the lower keys should not be made, as such actions will disrupt the resident population. Exotic crocodilians should be removed from the lower keys to protect the native population and should be relocated to suitable zoos or attractions.

The lower keys provide a unique and fragile island habitat, which is being developed and otherwise modified at a rapid rate. From this viewpoint, the alligator population in the lower keys remains a threatened population according to the definitions of the Endangered Species Act of 1973, which calls for the threatened classification if a species "is likely to become endangered in the foreseeable future." Results of this study suggest that the lower Florida Keys should be considered a separate geographical unit in considering the statewide status of the alligator in Florida.

SUMMARY

There is a small, isolated, reproducing population of alligators in the lower Florida Keys. The cover, food, and low salinity environment provided by fresh water mosquito ditches contribute to their continued survival. No self-sustaining population of crocodiles seems to exist in this area although occasional transient individuals occur. Data are not available to evaluate adequately historical trends in population status. The seasonally stressful environment and the limited availability of suitable nesting habitat suggest that alligators and crocodiles have not at any time occurred in substantially greater numbers than presently exist in the lower Florida Keys.

ACKNOWLEDGMENTS

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