American Crocodile

Crocodylus acutus

Federal Status:	**Endangered (Sept. 25, 1975)**
Critical Habitat:	**Designated (Dec. 1979)**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Florida distribution of the American crocodile; this species is only found in mangrove habitats within the shaded counties.

The American crocodile is one of two species of crocodilians endemic to the United States. The American crocodile inhabits coastal habitats of extreme South Florida, the Caribbean, Mexico, Central America and northern South America. At the northern limit of its range in Florida, American crocodiles coexist with American alligators. As with most other species of crocodilians, the American crocodile has been hunted for its hide and meat. Habitat loss and fragmentation due to increased urbanization and agricultural land uses are also threats to this species. In Florida, changes in the distribution, timing, and quantity of water flows also have affected the American crocodile, although the specifics of these effects are not clear. The crocodile population in Florida, although small, appears to be stable. The status throughout the remainder of its range is less certain. Future threats in Florida include stochastic natural disasters such as hurricanes and cold weather, road mortality, and continued habitat degradation. The American crocodile is a valuable indicator species of the health of South Florida's estuarine environments.

This account represents a revision of the existing recovery plan for the American crocodile (FWS 1984).

Description

The American crocodile is a large, greenish-gray crocodilian with black mottling. In Florida, adults reach lengths of about 3.8 m, although a specimen measuring 4.7 m was reported in the late 1800s (Moler 1992). In other portions of their range, individual crocodiles may reach 6.0 m (Ross and Magnusson 1989). Like all other crocodilians, males are larger than females. All adults have a hump above the eyes which may or may not be distinct, and irregular, asymmetrical dorsal armoring. Hatchlings measure approximately 27 cm and are normally yellowish tan to gray with dark crossmarkings on the body and tail. These markings fade as the animal grows. A lateral

indentation of the upper jaw leaves the fourth tooth of the lower jaw exposed when the mouth is closed. Compared to the alligator, the American crocodile may be distinguished by its longer, narrower, more tapered snout and the exposed fourth tooth of the lower jaw.

Taxonomy

The American crocodile is one of 22 species of crocodilians (*Crocodylidae*) found throughout the world, and one of 13 species of crocodiles (*Crocodylinae*). Four species of crocodilians are found in North America; only the American crocodile and American alligator (*Alligator mississippiensis*) occur in the United States. In addition to the present treatment as American crocodile (*Crocodylus acutus*, Cuvier), Florida populations have also been reported as *Crocodylus floridanus* (Hornaday) and *Crocodylus americanus* (Boulenger).

Distribution

The historic distribution of American crocodiles in southern Florida has been debated for many years. Kushlan and Mazzotti (1989) provided the most comprehensive review of information regarding crocodile distribution, and suggested that the overall range of American crocodiles has not changed substantially over the past 200 years. Historically, American crocodiles occurred at least as far north on the Florida east coast as Lake Worth, Palm Beach County (DeSola 1935, Hornaday 1914, FWS 1984), to Tampa Bay on the west coast (Kushlan and Mazzotti 1989), and as far south as Key West (Allen and Neill 1952, Neill 1971).

The current distribution of the American crocodile is limited to extreme South Florida, including coastal areas of Miami-Dade, Monroe, Collier, and Lee counties (Figure 1). In Biscayne Bay, crocodiles have been observed as far north as Crandon Park, Bill Baggs Cape Florida SRA, and Snapper Creek (J. Maguire, Miami-Dade County Park and Recreation Department, personal communication 1998). Occasional sightings are still reported farther north on the east coast, and there are also records from Broward County, along the entire length of Biscayne Bay (Barbour 1923, 1944, DeSola 1935, Dimock 1915, FWS 1984); a few isolated crocodiles still survive in remnant mangrove habitats there. Along Florida's southwest coast, several small groups and individual crocodiles have been documented from Sanibel Island, Lee County, south to Collier Seminole SP, Collier County. Very few reliable reports are available for the Ten Thousand Islands area. Crocodiles are regularly seen in Everglades NP along the mainland shoreline of Florida Bay from the Cape Sable peninsula east to U.S. Highway 1, in mangrove habitats on North Key Largo from Blackwater Sound north to Ocean Reef Club, and at Florida Power and Light's Turkey Point Nuclear Electrical Generating Facility. These areas include Federal or State owned/managed lands in Everglades NP and Biscayne NP; Crocodile Lake NWR and J. N. "Ding" Darling NWR; Collier Seminole SP; and Key Largo Hammocks State Botanical Preserve. Crocodiles possibly occur on Homestead AFB and John Pennekamp Coral Reef SP. There are also records further south in the Florida Keys to the Matecumbe Keys, Stock Island, and Bahia Honda (Carr 1940, FWS 1984, P. Moler, GFC,

American crocodile. *Original photograph by Paul Moler.*

personal communication 1998).

The distribution of crocodiles during the non-nesting season may vary considerably among years since adult crocodiles can disperse great distances (Kushlan and Mazzotti 1989). However, the majority of crocodiles are present in the vicinity of core nesting areas, located near Biscayne and Florida bays (Kushlan and Mazzotti 1989).

The American crocodile also occurs in Cuba, Hispaniola, Jamaica, Trinidad, Margarita; the Atlantic Coast of Mexico from the Bay of Campeche south through the offshore islands of Belize to Venezuela and Colombia. On the Pacific Coast it is found from Sinaloa, Mexico, and the Tres Marias Islands south to coastal Ecuador and the Rio Chira in Peru (King *et al*. 1982, Ross and Magnusson 1989). Throughout their range, American crocodiles are sympatric with other crocodilians, although they tend to inhabit more saline waters than most other species. In Cuba they overlap with the Cuban crocodile (*Crocodylus rhombifer*) and in Central America and southern Mexico with the common caiman (*Caiman crocodylus*) and Morelet's crocodile (*Crocodylus moreletti*). The American crocodile and alligator are sympatric in brackish-water portions of their range in South Florida, but, due to evolutionary divergence, no hybridization would be expected.

Habitat

The American crocodile is found primarily in mangrove swamps and along low-energy mangrove-lined bays, creeks, and inland swamps (Kushlan and Mazzotti 1989). In Florida, patterns of crocodile habitat use shift seasonally. During the breeding and nesting seasons, adults outside of Key Largo and Turkey Point use the exposed shoreline of Florida Bay. Males tend to stay more

inland than the females at this time (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998; P. Moler, GFC, personal communication 1998). During the non-nesting season, they are found primarily in the fresh and brackish-water inland swamps, creeks, and bays, retreating further into the back country in fall and winter (Kushlan and Mazzotti 1989). In a study by Kushlan and Mazzotti (1989) along northeastern Florida Bay, crocodiles were found in inland ponds and creeks (50 percent of observations), protected coves (25 percent of observations), exposed shorelines (6 percent of observations) and a small number were observed on mud flats. The high use of inland waters suggests crocodiles prefer less saline waters, using sheltered areas such as undercut banks and mangrove snags and roots that are protected from wind and wave action. Access to deep water (>1.0 m) is also an important component of preferred habitats (Mazzoti 1983).

Natural nesting habitat includes sites with sandy shorelines or raised marl creek banks adjacent to deep water. Crocodiles also nest on elevated man-made structures such as canal berms and other places where fill has been introduced. In natural nesting situations, creek bank nests are generally considered optimal since these sites provide a good incubation medium and are generally protected from wind and wave action. These nest sites also provide deep water refuge for adult females. Nests adjacent to open water provide little protection from wave action for the nest, hatchlings, or adults. Shore nests are typically not located near good nursery habitat, and mortality of hatchlings is generally higher than in inland nests (Kushlan and Mazzotti 1989). Both nesting sites are desirable as there are tradeoffs associated with each, and hatching success at each type of location will vary among years depending on climatic conditions (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998).

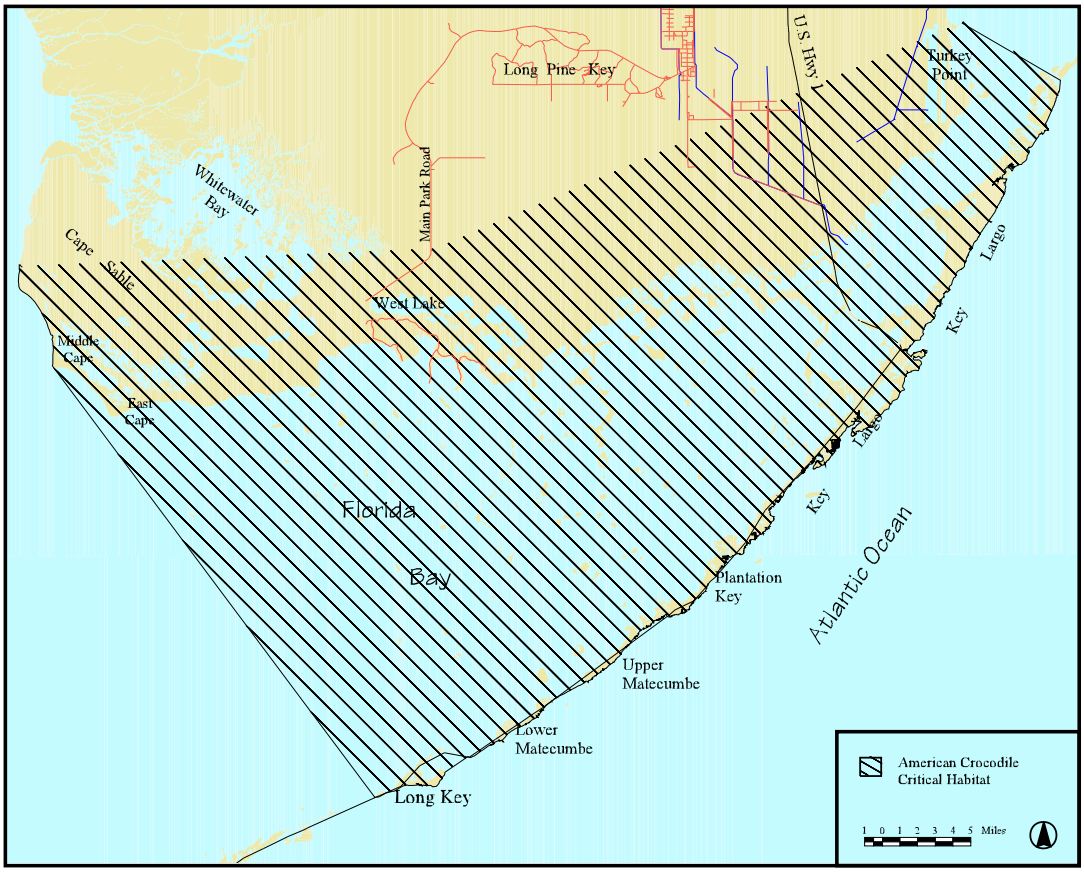
Critical Habitat

Critical habitat for the American crocodile (Figure 2) includes all land and water within an area encompassed by a line beginning at the easternmost tip of Turkey Point, Miami-Dade County, on the coast of Biscayne Bay; southeast along a straight line to Christmas Point at the southernmost tip of Elliott Key; southwest along a line following the shores of the Atlantic Ocean side of Old Rhodes Key, Palo Alto Key, Angelfish Key, Key Largo, Plantation Key, Lower Matecumbe Key, and Long Key, to the westernmost tip of Long Key; northwest along a straight line to the westernmost tip of Middle Cape; north along the shore of the Gulf of Mexico to the north side of the mouth of Little Sable Creek; east along a straight line to the northernmost point of Nine-Mile Pond; northeast along a straight line to the point of beginning (50 CFR 17.95).

Behavior

Reproduction

Females reach sexual maturity at about 2.25 m (Mazzotti 1983), a size reached at an age of about 10 to 13 years (LeBuff 1957). It is not known at what age and size females mature (Ogden 1978a). Similarly, the maximum



reproductive age for either sex is not known, although it is known that captively reared crocodilians eventually fail to reproduce.

As with most crocodilians, courtship and mating are stimulated by increasing ambient water and air temperatures. Reproductive behaviors peak when body temperatures reach levels necessary to sustain hormonal activity and gametogenesis. In South Florida, temperatures sufficient to allow initiation of courtship behavior are reached by late February through March. Like all other crocodilians, the mating system of the American crocodile is polygynous; each breeding male may mate with a number of females (Magnusson *et al.* 1989). Males typically establish and defend a breeding territory from late February through March (Moore 1953a, Garrick and Lang 1977). Vocalizations, body posturing, and outright aggression are used to maintain and defend territories and to secure mating privileges with females that roam freely between territories. Male and female American crocodiles go through a ritualistic mating sequence prior to copulation. Courtship in this species is considered to be one of the most structured of all crocodilians, with copulation predictably following precopulatory behaviors (Lang 1989, Thorbjarnarson 1991).

Following courtship and mating, females search for and eventually select a nest site in which they deposit an average of about 38 elongated oval eggs. Reported clutch size ranges from 8 to 56 eggs (Kushlan and Mazzotti 1989; P. Moler, GFC, personal communication 1998). Although American crocodile nesting is generally considered a non-social event, communal nesting is the norm

in parts of the Caribbean, southeast Cuba, and Haiti. In the U.S., several incidents of 2-clutch nests have been reported (Kushlan and Mazzotti 1989; P. Moler, GFC, personal communication 1998). Nest sites are typically selected where a sandy substrate exists above the normal high water level. Nesting sites include areas of well drained sands, marl, peat, and rocky spoil and may include areas such as sand/shell beaches, stream banks, and canal spoil banks that are adjacent to relatively deep water (Ogden 1978a, Kushlan and Mazzotti 1989). In some instances, where sand or river banks are not available for nesting sites, a hole will be dug in a pile of vegetation or marl the female has gathered. The use of mounds or holes for nesting is independent of the substrate type and may vary among years by the same female (Kushlan and Mazzotti 1989).

The success of American crocodile nesting in South Florida is dependent primarily on the maintenance of suitable egg cavity moisture throughout incubation. Predation and flooding also affect nest success. On Key Largo and other islands, failure of crocodile nests is typically attributed to desiccation due to low rainfall (Moler 1991a). On Key Largo, about 52 percent of nests were successful in hatching at least one young (Moler 1991a). Nest failures on the mainland may be associated with flooding, desiccation, or predation (Mazzotti *et al*. 1988, Mazzotti 1989). On the mainland, about 13 percent of nests monitored were affected by flooding or desiccation, whereas 13 percent of nests were partially or entirely depredated (Mazzotti *et al.* 1988, Mazzotti 1989). More recently, Mazzotti (1994) found that predation rates on the mainland increased to 27 percent, and only 9 percent of nests failed because of infertility or embryonic mortality. Most examined eggs have been fertile (90 percent, range 84 to 100 percent) (Kushlan and Mazzotti 1989, Mazzotti 1989).

Incubation of the clutch takes about 86 days (Lang 1975), during which time the female periodically visits the nest (Moore 1953a, Neill 1971, Ogden 1978a). Some females may also attend and defend their nest during incubation (Alvarez del Toro 1974, Ross and Magnusson 1989), but this behavior is highly variable among individuals and nest defense has not been observed in the U.S or Cuba (P. Moler, GFC, personal communication 1998). In Florida, American crocodiles are not known to regularly defend their nest against humans (Kushlan and Mazzotti 1989). However, all females must return to the nest to excavate hatchlings since the young are unable to liberate themselves from the nest cavity (Moore 1953b, Neill 1971, Ogden and Singletary 1973, FWS 1984). Parental care after hatching has not been reported for this species in Florida, even though this behavior has been documented in other American crocodile populations (Kushlan and Mazzotti 1989).

The young may remain together loosely for several days to several weeks following hatching, but they are rarely seen with adults (Lang 1975, Moler 1991b, Mazzotti 1983, Kushlan and Mazzotti 1989). Hatchling survival appears to be low in Everglades NP (< 5 percent) (Mazzotti 1983, Kushlan and Mazzotti 1989), higher at Turkey Point (8.5 percent) (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998), and even higher in the more sheltered habitats of North Key Largo (20.4 percent) (Moler 1991b). Higher survival on Key Largo has been attributed to the close proximity of nest sites to suitable nursery habitat. On the mainland, nest sites on exposed beaches are often far from nursery habitat, requiring recently hatched young to disperse

long distances in unsheltered water. Hatchlings seek shelter during the day in beach wrack or among mangrove roots when available (Mazzotti 1983). Predation during these dispersals is probably high, although little information is available to support this conclusion (Kushlan and Mazzotti 1989).

Foraging

The American crocodile is typically active from shortly before sunset to shortly after sunrise (Lang 1975, Mazzotti 1983). During these times, crocodiles forage opportunistically, eating whatever animals they can catch. Juveniles typically eat fish, crabs, snakes, and other small invertebrates, whereas adults are known to eat fish, crabs, snakes, turtles, birds, and small mammals (Ogden 1978b, Ross and Magnusson 1989). American crocodiles probably feed only rarely during periods of low ambient air temperatures, since metabolic and digestive systems are slowed at lower body temperatures.

Relationship to Other Species

As mentioned above, American crocodiles live sympatrically with American alligators where salinities are low. Most crocodilians tolerate others of the same species and of different ages provided food and other essential habitat requirements are not limiting. Where two or more species coexist, tolerance among species is also common and is usually ensured by species-specific differences in habitat utilization. In Florida, the American crocodile and alligator have probably coexisted for thousands of years and relied on changing salinity gradients of surface waters to dictate which species predominated in certain areas. Though these species probably intermingle frequently throughout the year, we are aware of only one location where both species may nest side-by-side. If substantiated, the nesting sites along a canal berm in the vicinity of Marco Island, Collier County, would indicate use of a common nesting area by these species. However, the species' breeding seasons may be sufficiently asynchronous in this area to allow crocodiles to breed and nest before alligators become reproductively active.

The depredation rate of American crocodile nests by raccoons (*Procyon lotor*) in South Florida is low compared to depredation rates other crocodilians suffer from terrestrial nest predators. Therefore, although the raccoon may locally be an important predator, their overall effect on the crocodile population is not considered limiting in areas where their populations are not unnaturally high. Once hatched, crocodilians may be eaten by several species of wading birds and gulls, blue crabs, sharks, and other crocodiles. Though limited, survival information from Key Largo suggests that predation does not limit recruitment of juveniles in that area.

Status and Trends

Crocodiles were listed as endangered throughout their range in 1975, (40 CFR 44151) and critical habitat was established for this species in 1979 (44 CFR 75076). The listing of the species and protection of habitat were required because of documented population declines most likely associated with habitat alterations and direct human disturbances to crocodiles and their nests (FWS 1984).

Historic estimates of the American crocodile population in South Florida are difficult to substantiate because many records are anecdotal and early observations may have been confused with sympatric alligators. In addition, estuarine habitats, preferred by crocodiles, were remote and inaccessible to early settlers, thereby precluding reliable and consistent observations. Ogden (1978a) estimated that between 1,000 to 2,000 American crocodiles existed in South Florida in the early 20th century, but he thought this probably underestimated the population because extensive settlement and associated hunting had already occurred by this time. During the late 19th century and the first half of the 20th century, many Florida crocodiles were collected for museums and live exhibits (Cory 1896, Hornaday 1914, Dimock 1915, DeSola 1935, Dickinson 1953, Behler 1978). The species was also legally hunted in Florida until about 1962. By the mid-1970s, crocodile numbers had been reduced to between 100 to 400 non-hatchling individuals (Ogden 1978a).

In addition to the taking of individual crocodiles, habitat modification and destruction has been occurring since the human settlement of South Florida. Formerly occupied habitats from Lake Worth, Palm Beach County, south to central Biscayne Bay, Miami-Dade County, have been largely destroyed by urbanization. In some of these areas, crocodiles have been essentially extirpated. (DeSola 1935, FWS 1984). Recent trends, however, indicate that they may be expanding back into central Biscayne Bay, and that they have successfully nested at Chapman Field Park (J. Maguire, Miami-Dade County Parks and Recreation Department, personal communication 1998). In the Middle and Lower Florida Keys urbanization has led to habitat degradation and loss. Though crocodiles were never abundant in these areas, further habitat loss limits opportunities for dispersing crocodiles to persist there. Crocodiles were also probably never common along Florida's west coast. Urbanization there has also substantially altered much of the habitat once occupied.

Human encroachment into estuarine habitats can disturb crocodiles to such an extent that normal behavior patterns are altered. As recreational demands increase on public lands, indirect disturbance by apparently innocuous human activities such as camping, fishing, and boating are expected to increasingly affect crocodiles. Observations suggest that repeated close human presence may cause female crocodiles to abandon nests or relocate nest sites (Kushlan and Mazzotti 1989). Recreational boating, including use of jet skis, has been limited in portions of the American crocodile's habitat within Everglades NP, but public demands for additional recreational opportunities will likely threaten these sanctuaries in the future.

Crocodiles are frequently killed on U.S. Highway 1 and Card Sound Road. On average, 3 to 4 crocodiles are killed annually while crossing these roads (Mazzotti 1983, Moler 1991b). Unfortunately, subadults and adults make up the majority of road mortalities. Efforts to preclude crocodile movement across portions of Card Sound Road by fencing sections of the road have been largely unsuccessful, due primarily to improper installation of the fence.

Natural, catastrophic, stochastic events such as hurricanes also are known to adversely affect American crocodiles and may be one of the most important factors limiting the number and distribution of this species in South Florida. Crocodiles are long-lived and suffer high juvenile mortality and must,

therefore, produce many young over their lifetime to ensure sufficient recruitment and population persistence. Natural events that add substantial adult mortality can result in long periods of little or no recruitment. Failure to successfully recruit age classes in consecutive years can, if repeated periodically, depress small populations.

Crocodiles undoubtedly perish during tropical storms and hurricanes that make landfall in extreme South Florida. The tidal surges, rough seas, and high winds probably result in direct mortality, but may also erode important nesting beaches, destroy nests, and alter other important habitat features. The adverse effects of tropical weather have not been quantified or reported extensively in the literature. Ogden (1978a) suggested that the occurrence of major hurricanes at regular intervals may be a factor that serves to hold the Florida crocodile population at some depressed level.

Even though extreme South Florida is considered sub-tropical, it is occasionally exposed to sub-freezing temperatures. The effect of freezing temperatures on American crocodile populations is not well known, principally because crocodiles which may be killed during freezes are rarely found (Dimock 1915, Barbour 1923, Mazzotti 1983). Critical minimum water temperatures are not known, but water temperatures of 13 to 14° C in sheltered canals did not result in crocodile mortality during an extremely hard freeze in southern Florida during 1989. Unconfirmed reports identified four dead crocodiles in exposed areas after this freeze; mortality was likely much higher since dead crocodiles were difficult to find (Moler 1991b). Moler (1991b) documented a substantial decline in nesting effort during the following spring, and suggested that adult mortality during the freeze may have been responsible for the observed decline in nesting.

Water salinity affects habitat use and may be locally important, especially during periods of low rainfall. Although American crocodiles have salt glands that excrete excess salt and physiological mechanisms to reduce water loss (Dunson 1970, 1980, 1982; Evans and Ellis 1977; Dunson and Mazzotti 1989; Mazzotti 1989), maintenance of an osmotic balance requires access to low salinity water for juveniles. Hatchling crocodiles are particularly susceptible to osmoregulatory stress and may need to have brackish to fresh water (4 ppt) available at least once per week to increase growth (Mazotti *et al.* 1986). Crocodiles larger than 200 g have sufficient mass to withstand osmoregulatory stress and are not typically believed to be affected by drought (Mazzotti and Dunson 1984). Freshwater needs of the crocodile are usually met with frequent rainfall, which results in a "lens" of fresh water on the surface that may persist for several days after rainfall (Mazzotti and Dunson 1984). Hatchling crocodiles are probably stressed and occasionally die during periods of low rainfall. Anthropogenic changes in the amount and timing of freshwater flow to South Florida may have resulted in shifts in the distribution of American crocodiles. Unfortunately, detailed data on crocodile distribution is only available since the early 1970s, and any changes that may have occurred due to hydrological perturbations over the past century cannot be identified with available information.

Combined, many of the natural and anthropogenic factors described above have resulted in adverse effects to the American crocodile. Compared to the

historical estimates of 1,000 to 2,000 animals (Ogden 1978a), populations have declined, and shifts in the nesting distribution have likely occurred. The lowest estimated population levels apparently occurred sometime during the 1960s or 70s, when Ogden (1978b) estimated the Florida population of the American crocodile to be between 100 and 400 non-hatchlings.

The American crocodile population in South Florida has increased substantially over the last 20 years. P. Moler (GFC, personal communication 1996) believes between 500 and 1,000 individuals (including hatchlings) persist there currently. The recent increase is best represented by changes in nesting effort. Survey data gathered with consistent effort indicate that nesting has increased from about 20 nests in the late 1970s to about 50 nests in 1997. Since female crocodiles produce only one clutch per year, it follows that the population of reproductively active females has more than doubled in the last 20 years. In addition, since at least a portion of the population's sex ratio approaches 1:1 (Moler 1991b), it is likely that the male portion of the population has also increased substantially.

Throughout the remainder of its range, the American crocodile has suffered from threats similar to those that have adversely affected the species in South Florida. Unfortunately, only Costa Rica and Venezuela have adequately protected the American crocodile and its habitat, although Cuba protects a number of areas with large crocodile populations (King 1989, P. Moler, GFC, personal communication 1998). Other countries have no or few laws to protect them or are unable to enforce conservation laws that do exist. Current threats to the continued survival of the American crocodile outside of the United States include changes in agricultural, ranching, and forestry practices that affect coastal habitats; developing tourism industries that seek to benefit from tropical, beachfront properties (Alcala and Dy-Lyiacco 1989); and legal and illegal hunting. As natural habitats are destroyed and replaced with landscapes that benefit humans, American crocodiles will become increasingly susceptible to the public's intolerance of human/crocodile conflicts.

Management

Protection of the American crocodile outside of the United States was enhanced when most countries throughout the range of the species became signatories to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES signatories agreed that, as an Appendix I species, the American crocodile would be afforded protection from international commerce. This protective measure has greatly reduced, and in some cases eliminated illegal harvests of the crocodile for its hide. Other protective measures include prohibitions against hunting all crocodilians in Mexico, and establishment of no-hunting areas in certain portions of Cuba (National Resolution No. 21-79).

In 1984 the FWS prepared a recovery plan for the American crocodile. Numerous conservation measures were identified in the recovery plan that were needed to ensure persistence and recovery of the crocodile in South Florida, including securing habitat for all life stages and establishment of self-sustaining populations at natural carrying capacity in appropriate habitats. In addition, the recovery plan for the American crocodile called for research to determine habitat needs, habitat distribution, ownership, and habitat availability to

crocodiles. Management options include controlling of human-related mortality, informing the public, reducing natural mortality, and protecting nest sites.

Recovery efforts for the American crocodile are underway and are likely responsible for increases in the number of crocodiles in South Florida. About 2,640 ha have been acquired for protection of crocodiles and other imperiled species at Crocodile Lake NWR. This area consists of 262 ha of wetlands and open water habitats that directly support crocodile conservation. Crocodile habitat is also protected in Everglades NP Biscayne NP, J. N. "Ding" Darling NWR, Ten Thousand Islands NWR, Collier Seminole SP, Key Largo Hammocks State Botanical Preserve, and several Miami-Dade County parks: Matheson, Snapper Creek, Black Point, Chapman Field and Crandon. The Biscayne Wetlands and Cutler Wetlands acquisition projects in Miami-Dade County seek to place over 810 additional ha of coastal habitat into public ownership; these areas border Biscayne National Park (J. Maguire, Miami-Dade County Park and Recreation Department, 1998). The only area extensively used by crocodiles that is not under public ownership is the habitat created by construction of Florida Power and Light's Turkey Point electrical generating facility.

Crocodile nesting continues to be monitored by the GFC and FWS on Key Largo, Florida Power and Light at Turkey Point, NPS on the mainland, and by Miami-Dade County at Chapman Field. In 1984, crocodile crossing signs were erected along U.S. Highway 1 to provide public awareness and reduce automobile/crocodile collisions. During future road widening of U.S. Highway 1, box culverts will replace existing small diameter culverts to allow crocodiles to pass under the highway. Fencing also may be erected along portions of U.S. Highway 1 to discourage crocodile movement over the road (P. Moler, GFC, personal communication 1996).

The timing and frequency of the freshwater hydroperiod substantially influences the health of the estuarine environment in South Florida and may be one of the most important large scale factors influencing crocodile populations on the mainland. It is well known that historic alterations to the natural flow have directly affected plant and animal communities. Although there is no direct causal relationship between freshwater flow alterations and American crocodile numbers, some of the population decline witnessed through the 1970s probably was attributable to changes in the amount and timing of surface water flow to South Florida. Future changes in hydrology that mimic natural flow conditions are likely to benefit crocodiles in the long-term, but care should be taken to ensure that changes in the delivery of water do not result in catastrophic, short-term, adverse effects. When added to all other natural and anthropogenic sources of mortality, such habitat changes could have substantial impacts on crocodile nesting and hatchling survival. As advances in water management are made in South Florida, research is expected to continue to assess the effects on the American crocodile of changes in the amount and timing of water delivery (Mazzotti 1996).

As discussed above, availability of fresh water is essential to hatchling crocodile survival. Instream freshwater flow and rainfall provide this water to hatchlings emerging from mainland nests, but hatchlings from islands (including Key Largo) depend solely on rainfall. During periods of low rainfall,

island hatchlings do not gain mass and are less likely to survive during winter months (Moler 1991b). To increase hatchling survival and recruitment, Moler (1991b) suggested that supplemental sources of fresh water be provided during the 3 to 4 month period following hatching. Supplemental sources of fresh water may be particularly important since recent efforts to restore functioning mangrove wetlands in Crocodile Lake NWR have increased salinities in an important crocodile nursery area. Restoration of suitable salinities in this area should be considered if future monitoring indicates low hatchling growth and survival.

The numerous hydrologic projects associated with the restoration of the South Florida Ecosystem are in various stages of planning and implementation. The FWS has determined that the Central and South Florida Restudy should provide a benefit to the American crocodile. These efforts propose to improve habitat conditions through decreased salinities in Florida Bay and Shark River Slough estuarine areas by increasing volume and improved timing of freshwater flows to those areas.

Encroachment of exotic vegetation has degraded thousands of hectares of wildlife habitat in South Florida. In coastal areas, and on Key Largo, Australian pine (*Casuarina equisetifolia*), cajeput (*Melaleuca quinquenervia*), and Brazilian pepper (*Schinus terebinthifolius*) aggressively invade levees and berms. Moler (1991a) found widespread invasion of *C. equisetifolia* and to a lesser extent *M. quinquenervia* and *S. terebinthifolius* at crocodile nesting sites on Key Largo. Many of the exotics were removed during habitat restoration efforts in 1994, but vigorous regrowth and reinvasion is inevitable, and periodic efforts to control exotic vegetation will likely be required to maintain suitability of crocodile nesting sites. F. Mazzotti (University of Florida, personal communication 1996) indicated that invasive exotics were also encroaching on crocodile nest sites at Turkey Point. However, he noted that if measures outlined in Florida Power and Light's crocodile management plan were followed, exotic vegetation would be controlled before it threatened crocodile nesting sites. Renewed efforts may be needed to control exotic plants at Turkey Point. Exotic plant control in Everglades NP should continue. Australian pine has been found, and destroyed by Park staff, on nesting beaches and keys (Brandt *et al.* 1995; L. Brandt and F. Mazzotti, University of Florida, personal communication 1998).

Management programs or land-use restrictions are used on some public lands to protect and conserve natural resources. In Everglades NP, closure of water bodies has reduced boat traffic and minimized human-crocodile encounters. Unfortunately, restrictions on land and water use are now being challenged, and increasing demands for recreational opportunities may threaten crocodiles in some areas. Although human exclusion may be the best management technique for protecting crocodiles and their habitat, it is clear that an increasing number of the general public do not support this management alternative.

Though management of the physical components of crocodile habitat is essential to the continued survival of this species, emphasis must be placed on mimimizing the potential for human-crocodile encounters. Human tolerance for and acceptance of increasing crocodile numbers is one of the primary reasons for the increase in population numbers over the last 20 years. However, as the crocodile population continues to increase, we anticipate an increasing number

of human-crocodile conflicts. Unfortunately, dredging of shallow waters and creation of exposed shorelines have resulted in artificial habitats that attract crocodiles to areas adjacent to human habitation. Although American crocodiles are generally considered to be non-aggressive, the public's perception of them is that of a large, dangerous, carnivore. If crocodile numbers continue to increase, we believe that more encounters will result in an increasing intolerance of crocodiles and more demands for action to reduce human-crocodile conflicts.

The GFC, through a cooperative agreement with the FWS, currently addresses human-crocodile conflicts on a case-by-case basis (GFC 1988). We believe that the GFC's guidelines for managing human-crocodile conflicts are a reasonable and flexible management alternative that can be used well into the future. These guidelines, however, are reactionary and do not attempt to address the factors leading to human-crocodile conflicts. As mentioned above, part of the reason for increasing conflicts is that humans have altered the landscape for residential, commercial, or recreational purposes without rendering this formerly potential crocodile habitat completely unsuitable. The expanding crocodile population will continue to move into these habitats and will occasionally come into conflict with humans. The guidelines should be updated to include guidance to land managers who are dealing with an increased presence of crocodilians near populated areas. The guidelines should then be incorporated into management plans.

It is unlikely that the expanding crocodile population can be prevented from using artificial habitats. These areas provide important components of crocodile habitat including basking, nesting, nursery, and deep water refugia. It is less likely that human use of already altered land can be substantially modified. For example, homeowners are not likely to abandon their houses because crocodiles bask or nest in their yards. Similarly, filling of deep water channels is improbable since these provide watercraft access to waterfront homesites. Seasonal restrictions for disruptive recreational uses such as powerboating, jet skis, camping, etc. may be appropriate near crocodile nesting locations. In other areas, new or increased recreational access may not be appropriate, since recreational use could result in greater human-crocodile conflict. Implementing recreational restrictions will be difficult, as demands for access continue to increase. Public education must provide the foundation for developing positive, proactive, attitudes about crocodile conservation. Aggressive public education

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is probably the most effective tool available to ensure the continued growth and recovery of South Florida's American crocodile population.

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Recovery for the American Crocodile

Crocodylus acutus

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The initial recovery plan for this species identified habitat alteration and human disturbances as the primary threats to this species and those that warranted its listing. Although efforts have been undertaken to ameliorate these threats, it is generally believed that these factors continue to act against the American crocodile to some extent. However, despite the ongoing influences of these threats, the crocodile has increased in numbers and is approaching population levels targeted by the initial recovery plan. It is apparent, therefore, that the effects of these threats are not as deleterious as previous assessments may have suggested, and that the reclassification of this species is possible.

Previous recovery efforts identified the need for a minimum of 60 breeding females within the population before reclassification could be considered. Since these criteria were developed, new information, based on consistent surveys, has indicated that the total number of nesting females has increased substantially over the last 20 years, from about 20 animals to about 50, and that nesting has remained stable at the major nesting areas. Based on the fact that the population appears stable, and that all of the threats as described in the original listing have been eliminated or reduced, reclassification of the crocodile will be possible, provided existing levels of protection continue to be afforded to crocodiles and their habitat, and that management efforts continue to maintain or enhance the amount and quality of available habitats necessary for all life stages

Species-level Recovery Actions

S1. **Conduct surveys to determine the current distribution and abundance of American crocodiles**. Survey all remaining suitable habitats in South Florida for American crocodiles. Most knowledge about the current distribution of crocodiles comes from surveys conducted within Everglades NP, the upper Florida Keys, and areas surrounding Turkey Point in Miami-Dade County. These areas correspond to locations with the highest known crocodile densities, but do not represent the entire range of the American crocodile. Surveys for crocodiles have not been conducted in large portions of South Florida; for example, American crocodiles have been observed in increasing numbers on the southwest coast of Florida, north to the J.N. Ding Darling NWR. These areas should be surveyed in order to determine the size and distribution of the American crocodile population and should include occurrence of individuals and nesting effort.

S1.1. **Evaluate coastal wetlands to determine their suitability for crocodiles**. Inventory potential habitat for American crocodiles with an emphasis on the southwest coast of Florida from Whitewater Bay north to Marco Island. Most known nesting and nursery sites are now publicly owned, but large areas of mangrove-lined coastline have not been surveyed for crocodiles. Before beginning time-consuming population surveys, coastal habitat in southwestern Florida should be assessed to identify areas that could support

American crocodiles. Continue to survey coastal wetlands of Biscayne Bay because of the increased potential for human/crocodile interactions.

S1.2. **Survey crocodile colonies in suitable habitats in South Florida**. In combination with **S1.1,** survey suitable habitats for all age classes of crocodile, especially in Biscayne Bay where nesting has been documented, and those areas of southwest Florida where information on the distribution and status of crocodiles is lacking. If substantial aggregations are located, they should be included in annual population monitoring programs.

S2. **Protect and enhance existing colonies of American crocodile**s. Although numbers of crocodiles are increasing in South Florida, habitat loss and degradation may limit the extent to which this expansion continues. In order to sustain the growth of the crocodile population, habitat that is suitable to meet the needs of all age classes must be protected. In some cases this habitat must be restored. Even though information is not available on the habitat requirements for each age class of American crocodile, the recovery team has basic information about the biotic and abiotic factors required for survival of this species. Although juvenile and adult crocodiles are less susceptible to fluctuations in their environment than hatchlings, the availability of refugia adjacent to deep water may be the single most important habitat characteristic that ensures the survival of these age classes.

S2.1. **Reduce or eliminate sources of American crocodile mortality**. All activities that affect crocodile habitat should be evaluated and appropriate steps taken to minimize or eliminate adverse affects to crocodiles and their habitat.

S2.1.1. **Control human-induced crocodile mortality and disturbance**. Reduce or eliminate anthropogenic sources of mortality. Human causes of mortality may be additive to an otherwise unknown level of natural mortality. However, many depressed populations can be pushed beyond their capability to recover when sources of additive mortality also affect population levels.

S2.1.2. **Alert motorists on roads where repeated collisions between automobiles and American crocodiles have occurred**. State Road 905, U.S. 1, and Card Sound Road have been posted with crocodile crossing warning signs for some time, but collisions with automobiles still occur periodically. An assessment of the effectiveness of signing should be conducted to determine if additional information would be useful in reducing American crocodile mortalities.

S2.1.3. **Reduce the incidence of American crocodile road mortalities by installing box culverts**. Construct culverts on portions of U.S. 1 to reduce automobile-crocodile collisions. Automobile-crocodile collisions have occurred periodically on portions of U.S. 1 and may be minimized through installation of pass-through culverts. Although there remains uncertainty about the effectiveness of installing culverts for the safe passage of crocodiles under highways, it is likely they will be used to some extent. When U.S. Highway 1 is widened, culverts should be installed at locations where crocodile mortalities have occurred.

S2.1.4. **Control terrestrial predators of crocodile eggs and hatchlings in areas where they may be artifically high**. Human visitation of some areas (such as Cape Sable in Everglades NP) create unnatural conditions

for predators such as raccoons. These animals could be adversely affecting survival and recruitment of the crocodile on public lands .

S2.2. **Continue long-term assessment of pesticide and heavy metal contamination levels in crocodile eggs**. Assessments of environmental contaminants in eggs should be conducted every 5 years.

S2.3. **Assure coordinated management actions by interagency agreements or other means**. Responsibility for the management of the American crocodile is currently divided between the State of Florida (GFC), the NPS, and the FWS. Currently the GFC, in consultation with the FWS, is managing human-crocodile conflicts outside of Everglades NP The NPS retains management authority for crocodiles within Everglades NP. The FWS protects the American crocodile throughout its range through its regulatory programs. Steps should be taken to insure that the actions of these agencies are coordinated and non-conflicting.

S3. **Conduct research on the biology and life history of crocodiles**. Although basic information on the biology of the American crocodile has been collected, more detailed information is needed to determine the status of the crocodile population in South Florida.

S3.1. **Determine the carrying capacity of remaining crocodile habitat in South Florida**. The expansion of the American crocodile population in South Florida will be limited by the amount of habitat suitable for one or more life-history stages (*e.g.*, nesting, feeding, dispersal, refuge, *etc.*). To estimate the potential for the American crocodile population to continue to grow, it will be necessary to identify limiting habitats. Historical information on the South Florida crocodile population and information on other American crocodile populations may be essential in determining the carrying capacity for South Florida.

S3.2. **Conduct research to determine basic biological needs of the American crocodile**. Conduct or continue mark-recapture efforts, population and nest surveys, and habitat monitoring in the vicinity of previous research and monitoring work done on Key Largo, Turkey Point, and Everglades NP Where other congregations of crocodiles are found in the future, conduct similar efforts. We know little about the species in southwest Florida or within the recently discovered breeding aggregation on Marco Island. Additional information is needed to determine the demographics of the American crocodile. Information on survival, recruitment, fecundity, and mortality are important in assessing the relative health of this population.

S3.3. **Evaluate the effects of human disturbances on crocodile behavior**. Conduct research to determine behavioral reactions to human disturbances.

S3.4. **Develop identification techniques for American crocodiles**. Distinguishing genetic differences between American crocodiles found in South Florida from American crocodiles throughout the remainder of their range will be essential in assessing the extent to which foreign crocodiles have contributed to the present genetic profile of crocodiles in South Florida.

S4. **Monitor the South Florida crocodile population**. Long-term monitoring is essential to the assessment of the status of the crocodile population.

S4.1. **Coordinate monitoring programs and protocols.** Data collected, marking system, and database management methods should be standardized among researchers.

S4.2. **Conduct surveys for American crocodiles**. Ongoing population surveys at Key Largo, Everglades NP, Turkey Point, and Biscayne Bay are important in the long-term assessment of the crocodile population in South Florida. Survey data should provide information on the number, distribution, and size class trends in these areas. As the population expands, survey efforts should be initiated in other areas where congregations of crocodiles occur.

S4.3. **Conduct a mark-recapture program for the American crocodile**. Mark-recapture data provide important information on growth, survival, and dispersal. These data will be essential in assessing the status of the crocodile in South Florida.

S5. **Inform the public about the recovery needs of crocodiles.** The public is generally unaware of the biology and status of the American crocodile, and misunderstandings still result in adverse sentiment towards this species. Public education is required to provide accurate biological information and to stimulate interest in the conservation of the American crocodile. Public information should include the general public, public officials, land managers, and policy makers.

S5.1. **Continue relocation of problem crocodiles**. GFC policy currently provides for the relocation of crocodiles that threaten human safety. Although this program results in the non-lethal removal of problem animals, it reduces the likelihood that habituated or bold crocodiles will be killed by members of the public. This program reduces mortality and provides opportunities for public education.

S5.2. **Assess the effectiveness of road signage for reducing the numbers of American crocodiles killed by automobiles**. U.S. 1 in the Florida Keys has been posted with crocodile crossing warning signs for some time, but collisions with automobiles still occur periodically. An assessment of the effectiveness of signing should be conducted to determine if different approaches to these signs should be used to reduce crocodile mortalities along these two roads. The signs that have been used for the West Indian manatee should be examined as alternative models.

S5.3. **Develop and distribute informational brochures regarding the biology and conservation of American crocodiles**. Distribution locations should include facilities that rent boats and personal watercraft, fishing charters, county and State parks, bait and tackle shops, restaurants along Florida Bay, and neighborhoods with resident crocodiles.

Habitat-level Recovery Actions

H1. **Protect nesting, basking, and nursery habitat of American crocodiles in South Florida**.

H1.1 **Acquire or otherwise protect habitat for crocodiles**. Large amounts of suitable habitat for American crocodiles have been protected inside Everglades NP, Biscayne NP, and Crocodile Lake NWR. However, extensive areas of suitable, occupied habitat and potentially restorable habitat for American crocodiles are not protected, particularly in southwestern Florida (Collier and Lee counties). Once lands that support suitable, occupied, or potentially restorable habitat for American crocodiles have been identified (see Task **S1**.), those lands should be protected either through additional land acquisition or cooperative management agreements with the land owner or land manager

H1.2. **Protect essential crocodile habitat on private lands**. If suitable habitat for American crocodiles is found on private lands, determine owner and appropriate conservation measures such as acquisition, easements, transfer of development rights, establishment of protective management plans, *etc*. Less than simple fee title acquisition may be required for crocodile habitat on private lands. Conservation agreements or easements or transfer of development rights may protect crocodile habitat on some private lands.

H2. Manage and restore suitable habitat of American crocodiles.

H2.1. **Continue to maintain nesting sites adequate to maintain viability of the American crocodile**. Crocodile Lake NWR on Key Largo, Everglades National Park, and Florida Power and Light's Turkey Point nuclear electrical generating facility currently provide the majority of nesting habitat for the American crocodile in South Florida. These areas must be adequately managed to sustain or increase the current level of nesting. Continue efforts to control exotic plants that have invaded portions of crocodile nesting habitat in these areas.

H2.2. **Restore areas to suitable habitat.** Much of the suitable habitat outside of Everglades and Biscayne national parks has been degraded or destroyed due to residential, commercial, or agricultural uses. Some of these areas may be suitable for restoration efforts. This will require: removal of exotic plants that degrade the quality of dispersal habitat for juvenile crocodiles, nesting sites, and basking areas; restoration of native vegetation in areas where the control of exotic vegetation or other human disturbances created large gaps in vegetated shoreline; and restoration of hydroperiods and hydropatterns in the Everglades and Big Cypress drainages so that hydrologic patterns mimic timing, flows, and depths that would have occurred under a rainfall-driven system. Natural hydroperiods will likely provide sufficient fresh water to periodically flush creek beds to maintain deepwater refugia for breeding adults. Restored hydroperiods also will decrease average salinities during late summer, when hatchlings require low-salinity water.

H2.1. **Complete the Project to Modify Water Deliveries to Everglades NP and the Canal 111 Project**. Both of these U.S. Army COE projects are designed to restore more natural patterns of water deliveries to eastern Florida Bay through Taylor Slough and Shark River Slough. Both projects should substantially improve habitat quality for American crocodiles in eastern Florida Bay. Although these projects have been authorized and construction on these projects initiated, they have not been completed. Both projects must be completed to increase the likelihood of the crocodiles' survival and recovery in the wild.

H2.2. **Continue to monitor the effects of the Program of Experimental Water Deliveries to Everglades NP on the American crocodile to determine optimal operational schedules**. As outlined in item **H2.1**. the COE is currently authorized to construct the Project to Modify Water Deliveries to Everglades National Park and the Canal 111 Project. Both of these projects are designed to restore more natural patterns of water deliveries to eastern Florida Bay through Taylor Slough and Shark River Slough and should substantially improve habitat quality for American crocodiles in eastern Florida Bay. However, the benefits of these projects to the American crocodile will depend on how the structures associated with the projects will be operated. The Program of Experimental Water Deliveries to Everglades NP iteratively assesses how the operations of water control structures affect the health of Everglades NP and associated

biota. American crocodiles are currently being monitored as part of the Experimental Program; this monitoring should continue with a specific emphasis on determining the response of American crocodiles and their habitat to different operational schedules.

H2.3. **Continue habitat and population modeling to determine operational schedules for structures associated with the Program to Modify Water Deliveries to Everglades NP, Canal 111, and the Central and Southern Florida Flood Control Project that provide optimal habitat for the American crocodile**. The operations of structures associated with these three projects will determine the actual benefits of these projects to the American crocodile. For example, these projects could be operated in ways that either restore or create nursery habitat for juvenile American crocodiles (see item **H2.4.**). Some of the information necessary to determine how to operate structures associated with these projects to optimize habitat for American crocodiles will be generated by the monitoring program associated with the Experimental Program of Water Deliveries to Everglades National Park, but additional evaluations will be necessary. Additional models that will help determine optimal operational schedules are being developed as part of the USGS's (BRD) Across Tropic Level System Simulation. This modeling effort should continue and new efforts should be initiated to determine optimal operational schedules for COE structures in South Florida.

H.2.4. **Create additional nesting habitat for crocodiles in South Florida.** Recovery of the American crocodile is dependent on the availability of adequate nesting sites, and an increase in the amount of suitable nesting habitat could increase recruitment into the population.

H2.5. **Restore or create nursery habitat for American crocodiles in South Florida.** This will generally require restoration of suitable, lower-salinity regimes to nursery areas for juvenile American crocodiles. Restoration of mangrove wetlands within Crocodile Lake NWR has resulted in increased salinity in one important nursery area, rendering the area less suitable for hatchlings. On Florida's southeastern coast, three COE projects (Project to Modify Water Deliveries to Everglades NP, Canal 111 Project, and the Central and Southern Florida Flood Control Project) will have significant effects on salinity regimes in nursery habitat for American crocodiles. On Florida's southwestern coast, efforts to restore Rookery Bay, the Big Cypress drainage, and the Ten Thousand Islands Region could have similar benefits to the American crocodile. As these projects undergo further development, benefits to nursery habitat for American crocodiles should be included as performance criteria to determine project benefits.

H2.6. **Continue to enforce land-use restrictions in essential crocodile habitat**. The NPS and FWS preclude human use in important crocodile habitat in the areas these two agencies manage in Florida Bay and on Key Largo. These restrictions, as well as others that may be required if new crocodile congregations are located, will help protect crocodiles during their recovery. Periodic assessments should be conducted to determine the need for land-use restrictions.

H3. **Conduct research on the habitat relationships of the American crocodile**. Much of the habitat-based research needed for the recovery of the American crocodile is currently addressed in one or more research projects dealing with the maintenance and recovery of the Florida Bay ecosystem. However, specific research information on the relationship of

American crocodiles to salinity regimes, exotic species, and adjacent land uses will be critical to the design of future management actions for the American crocodile.

H4. Continue to monitor crocodile habitat.

H4.1. Continue to monitor crocodile nesting habitat to determine environmental factors that affect nesting success.

H4.2. Continue long-term assessments of pesticide and heavy metal contamination levels in South Florida ecosystems. Numerous contaminant assessment projects are ongoing in South Florida. Support of these projects and use of the periodic data they provide will be important in assessing the quality of crocodile habitat.

H5. Increase public awareness of the habitat needs of crocodiles. Tidally influenced areas provide important habitat for crocodiles, but these areas are also attractive to humans for recreational and residential uses. Efforts to protect crocodile habitat will probably not be well received because of the public's general misperceptions about crocodiles. Effective protection and restoration of habitat can only be achieved if these efforts demonstrate that such protection will also benefit other commercially and recreationally important species. Habitat protection should be approached from an ecosystem perspective, emphasizing conservation benefits to Florida Bay. The efforts that have been used to increase public awareness of the habitat needs of the West Indian manatee should serve as the model for these efforts.