Estuaries and Coasts (2011) 34:529–535
DOI 10.1007/s12237-011-9378-6

NOTE

The American Crocodile in Biscayne Bay, Florida

Michael S. Cherkiss · Stephanie S. Romañach · Frank J. Mazzotti

Received: 10 October 2009 / Revised: 28 December 2010 / Accepted: 11 January 2011 / Published online: 25 February 2011

Abstract Intensive crocodile monitoring programs conducted during the late 1970s and early 1980s in southern Florida resulted in an optimistic outlook for recovery of the protected species population. However, some areas with suitable crocodile habitat were not investigated, such as Biscayne Bay and the mainland shorelines of Barnes and Card Sounds. The objective of our study was to determine status and habitat use of crocodiles in the aforementioned areas. Spotlight and nesting surveys were conducted from September 1996 to December 2005. The results revealed annual increases in the number of crocodiles. Crocodiles preferred protected habitats such as canals and ponds. Fewer crocodiles were observed in higher salinity water. The distribution and abundance of crocodilians in estuaries is directly dependent on timing, amount, and location of freshwater delivery, providing an opportunity to integrate habitat enhancement with ongoing ecosystem restoration and management activities.

Keywords *Crocodylus acutus* · Ecosystem restoration · Management · Biscayne Bay · Salinity · Threatened species

M. S. Cherkiss (✉) · F. J. Mazzotti
Fort Lauderdale Research and Education Center,
University of Florida,
3205 College Ave.,
Davie, FL 33314, USA
e-mail: mcherkis@ufl.edu

S. S. Romañach
U.S. Geological Survey,
3205 College Ave.,
Davie, FL 33314, USA

Introduction

The American crocodile, *Crocodylus acutus*, is a primarily coastal crocodilian which occurs in parts of Mexico, Central and South America, the Caribbean, and South Florida (Thorbjarnarson 1989). Research on *C. acutus* has shown that restricted distributions, small population sizes, hunting, and habitat loss have endangered populations throughout the species' range (Lang 1975; King et al. 1982; Mazzotti 1983; Thorbjarnarson 1988; Platt and Thorbjarnarson 2000). In 1975, the U.S. Fish and Wildlife Service (FWS) declared the Florida population endangered (Federal Register 40: 44151 1975). Following an increase in crocodile numbers over the next three decades (Mazzotti et al. 2007a), the Florida population was reclassified as threatened in 2007 (Federal Register 72: 13027 2007).

The American crocodile was first discovered in Florida in a tributary of Biscayne Bay in 1869 with the collection of a specimen from Arch Creek in present-day North Miami (Wyman 1870). Although Hornaday (1875) collected abundant evidence of crocodiles in various tributaries of Biscayne Bay, he considered them rare. The American crocodile has been observed as far south as Key West and as far north as Lake Worth on the east coast of Florida, and as far south as Cape Sable and as far north as Charlotte Harbor on the west coast (Fig. 1; Hornaday 1875, 1904; LeBuff 1957; Neill 1971; Kushlan and Mazzotti 1989a). By the 1980s, most sightings were concentrated around North Key Largo, northeastern Florida Bay, and the southern extent of Biscayne Bay at Turkey Point Power Plant (TP; Kushlan and Mazzotti 1989a; Mazzotti 1999).

The American crocodile is typically found in freshwater or brackish coastal habitats, including rivers, coastal

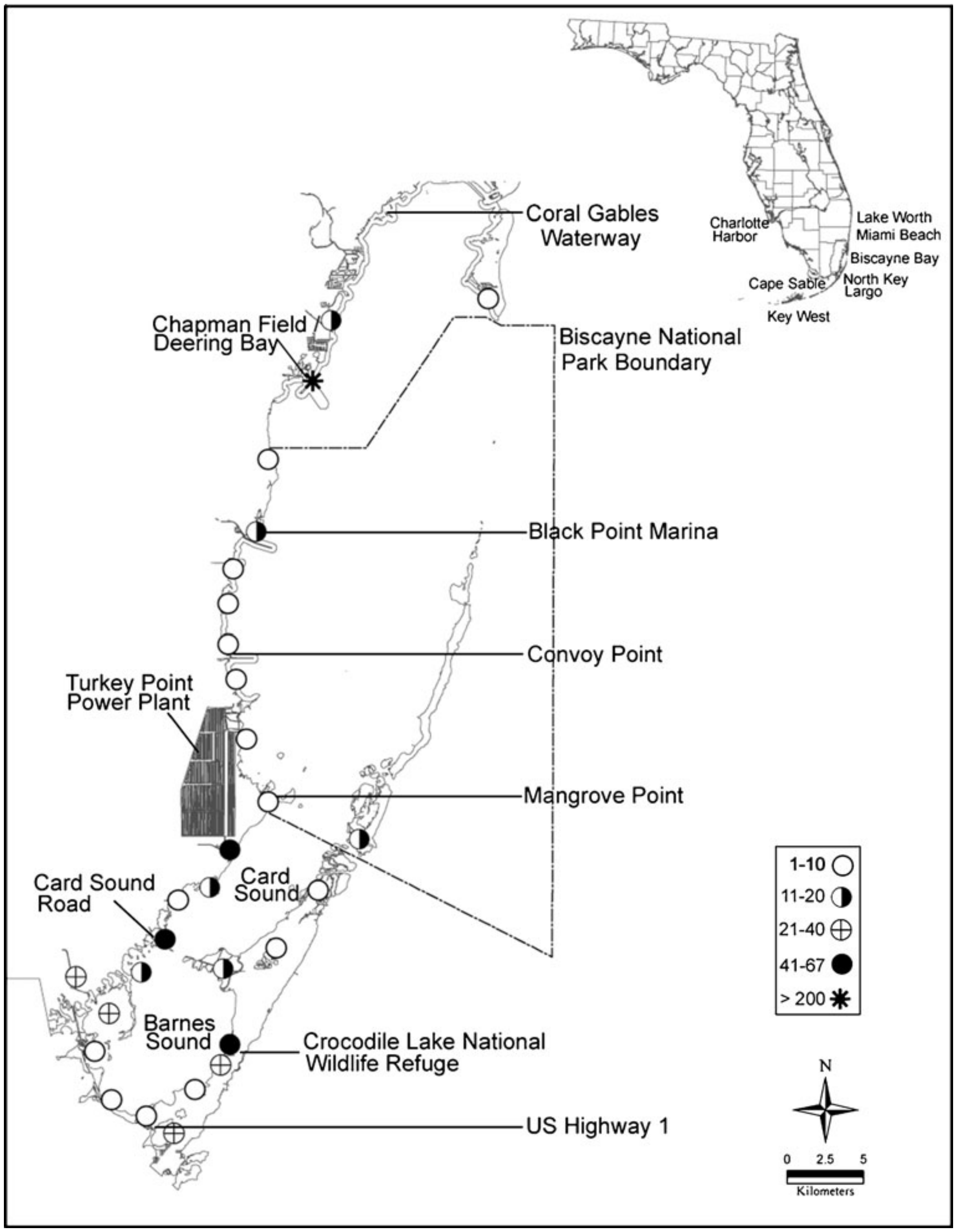

Fig. 1 Location of the BBE study area and distribution and numbers of crocodile observations

lagoons, and mangrove swamps (Thorbjarnarson 1989). The presence of nesting habitat is one of the principal environmental factors determining crocodile habitat use (Thorbjarnarson 1989). Mazzotti (1989) defined optimal nesting habitat as the presence of elevated, well-drained nesting substrate that is sheltered from effects of wind and wave action and free from human disturbance.

Historically, crocodile nesting occurred on the shorelines of Lake Worth, Miami Beach, tributaries to Biscayne Bay, Florida Bay (Fig. 1), and associated islands (termed keys; Smith 1896; Moore 1953; Kushlan and Mazzotti 1989a; Mazzotti 1999). Smith (1896) reported the last known nesting effort along Biscayne Bay prior to the discovery of crocodile nests at Turkey Point in 1978 (Brandt et al. 1995). In addition to TP, nesting occurs along Florida Bay in Everglades National Park (ENP) and on Barnes Sound in Crocodile Lake National Wildlife Refuge (CLNWR; Mazzotti et al. 2007a).

The population of *C. acutus* in southern Florida has been monitored over the past three decades (Ogden 1978; Kushlan 1982; Mazzotti 1983, 1989, 1999; Gaby et al. 1985; Kushlan and Mazzotti 1989a, b; Moler 1992a, b; Brandt et al. 1995; Mazzotti et al. 2007a, b). These studies show that although crocodiles are not abundant in South Florida, there are more crocodiles today than 30 years ago (Mazzotti et al. 2007a). However, surveys have not previously been conducted in the canals, shorelines, and ponds associated with Biscayne Bay and the mainland shorelines of Barnes and Card Sounds, all of which comprise suitable habitat for crocodiles.

Further recovery of the crocodile population in southern Florida will be dependent on decisions made during ongoing ecosystem restoration efforts in the region (see www.evergladesplan.org for details on the Comprehensive Everglades Restoration Plan). Improved freshwater delivery into Biscayne Bay and Barnes and Card Sounds will improve growth of individuals and probability of survival to maturity. Decreased survival of hatchlings has been shown to correlate with increasing distance traveled to nursery habitats, which are areas protected from wind and waves having low to moderately saline water (<20 ppt), sufficient food availability, and places to hide from predators (Moler 1992a; Mazzotti 1999; Mazzotti et al. 2007a).

The objective of this study was to determine the distribution, abundance, movement, nesting activity, population structure, habitat use, and environmental relations of the American crocodile in Biscayne Bay and Barnes and Card Sounds, Florida.

Methods

The study was conducted in southern Florida along the shorelines of southern Biscayne Bay, Card Sound, and Barnes Sound. We refer to this study area as the Biscayne Bay Estuary (BBE), which is bounded by the Coral Gables Waterway at the north and US 1 at the southern end of Barnes Sound (Fig. 1). The BBE is a shallow, subtropical estuary. Although the BBE watershed has been disturbed by human activities, its coastline has remained largely undeveloped (Alleman et al. 1995) as most has been designated as protected. Red mangroves (*Rhizophora mangle*), black mangroves (*Avicennia germinans*), white mangroves (*Laguncularia racemosa*), and buttonwoods (*Conocarpus erectus*) dominate the exposed shoreline along the mainland through most of Biscayne Bay, Card Sound, and Barnes Sound (Fish and Stewart 1991; Alleman et al. 1995). Mangroves, as well as two exotic species Australian pine (*Casuarina* spp.) and Brazilian pepper (*Schinus terebinthifolius*), dominate the protected shorelines of canals and ponds.

Quarterly nocturnal spotlight surveys were conducted by boat along canals, shorelines, ponds, and creeks within the BBE between September 1996 and December 2005. Surveys were conducted only during the absence of environmental conditions such as full moon and high winds (>15 knots), which negatively affect detectability (Woodward and Marion 1978), and low tide, which makes the shoreline unnavigable by boat. Crocodiles were located by the reflective layer in their eyes (*tapetum lucidum*), which when illuminated produces a red, orange, or yellow “eyeshine.” All crocodilians were approached as closely as possible for identification as *C. acutus*, *Alligator mississippiensis*, or *Caiman crocodylus*. After identification, an attempt was made to capture each crocodile for measurements and marking. Animals that could not be caught were categorized by size class (described below) when possible. Where crocodiles were sighted, we recorded the date, location (measured by global positioning system, GPS), water salinity (measured with an optical refractometer on a scale of 0–100 ppt), air and water temperatures, and habitat description (canal, shoreline, pond, or creek, and presence or absence of vegetation). The following data were also recorded for animals that were captured: previous markings (if none, then the animal was marked according to the system described in Mazzotti 1983), total length (TL; measured from tip of snout to tip of tail) and snout-vent length (measured from tip of snout to posterior end of vent) in centimeters, mass (g), and sex. Upon completion of measurements and marking, crocodiles were released into the water at the site of capture.

Crocodiles were categorized into four size classes: hatchling (<0.65 m TL), juvenile (0.65 to <1.5 m TL), subadult (1.5 to <2.25 m TL), and adult (≥2.25 m TL; Cherkiss 1999). Additionally, to be classified as hatchlings, animals must have been caught during the hatching season from July to September.

Nesting surveys were performed on foot during daylight hours throughout the March–April period of nest preparation (Mazzotti 1989). During the July–August hatching period, hatchlings were located and captured when possible, and the data recorded were the same as for other crocodile captures. Additional crocodile observations and nesting activity data were collected through interviews and personal observations and from public records (files and reports) of the Florida Fish and Wildlife Conservation Commission (FWC).

To estimate relative abundance throughout the study site, we used encounter rate calculated as the number of crocodiles observed per kilometer of survey route in crocodile habitat (Bayliss 1987). Distance traveled during each survey was determined with a hand-held GPS, and the amount of each habitat type (measured in kilometers) along the survey route was calculated in ArcGIS 9.1 by overlaying the route on a land cover layer obtained from the South Florida Water Management District. Differences in abundance were determined by analysis of variance. A general linear mixed-model approach was used for the analysis of abundance in relation to air and water temperatures and salinity (SAS Institute 1988). This approach treated survey routes as subjects to account for repeated measurements taken over time. Trends in habitat (canal, shoreline, pond, and creek) use were analyzed using loglinear regression models. Chi-square analyses were used to compare distributions within each habitat.

Results

Distribution, Abundance, and Movement

Six hundred eighty-six observations of crocodiles (294 captures and 392 sightings) were distributed throughout the study area (Fig. 1). Barnes and Card Sounds (Fig. 1) had the most crocodile observations (377), whereas the area surveyed near Deering Bay had the highest abundance during a single survey (3.24 crocodiles/km). One hundred ninety-seven non-hatchlings were captured during the study period.

Overall, relative abundance of crocodiles increased annually throughout this study (1996 through 2005). Numbers of hatchlings and juveniles encountered did not significantly increase, whereas an annual increase was observed for both subadult and adult crocodiles by 13% (P=0.0466, R^2=0.4539) and 24% (P=0.0067, R^2=0.6731).

Throughout the study, we recaptured 24 males and 10 females. The males moved an average of 18.5 km (range 1.8–36.1) and the females an average of 13.9 km (1.6–42.6). Among these 34 crocodiles that moved between captures, 11 dispersed into two concentrated areas in Card Sound (represented in Fig. 1 by the two half-moon circles north and south of Card Sound Road). All four crocodiles that moved to the location north of Card Sound Road were males originally marked at TP. Of the seven crocodiles that dispersed to the location south of Card Sound Road, two (males) came from TP to the north and five (three males, two females) came from CLNWR to the south.

Population Structure

Out of our 686 observations (captures and sightings), we were able to assign a size class to 603 individuals in the field. The size class breakdown was: 37% hatchlings, 22% juveniles, 28% subadults, and 13% adults.

The ratio of females to males in the BBE was 0.62:1 for all animals captured and 0.64:1 for adults. A chi-square test with a Yates correction (for small samples size) showed that the ratio differed significantly from 1:1 when considering all captures, but was not significant for adults (χ^2, critical value 3.841).

Habitat Use

Crocodiles were observed only in areas with vegetation. They were found in canals, shorelines, ponds, creeks, and a freshwater marsh. Excluding hatchlings and the single individual captured within a marsh, there was a significant difference in the numbers of crocodiles observed in canals (169), shorelines (109), ponds (87), and creeks (17; Table 1). Abundance of non-hatchlings were significantly higher in ponds (2.10/km) compared to other habitat types: 0.25/km in canals, 0.03/km along shorelines, and 0.36/km in creeks (F=23.50, P<0.0001).

Environmental Relations

Crocodiles were observed in habitats characterized by intermediate salinities, averaging 18.79 ppt (SE=0.56, range 0–45 ppt, n=623). Forty percent of all non-hatchling crocodiles were in water with salinity between 0 and 20 ppt, 56% between 20 and 40 ppt, and 4% in >40 ppt. Greater numbers of hatchlings (124 individuals, 63%) were found in the lowest salinity category (0–20 ppt) compared to 70 (35%) in 20–40 ppt and only 4 (2%) in >40 ppt (F=12.18, P<0.0001). No relationship was observed between abundance and air temperature (P=0.2659, R^2=0.0165) or water temperature (P=0.0897, R^2=0.0379).

Nesting

In August 1997, the first documented nest along Biscayne Bay outside of TP since 1896 was reported at Chapman Field County Park (George Dalrymple, personal communication). When this nesting site was discovered in 1997, evidence of nesting the previous year was observed. This nest was active for seven nesting seasons between 1996 and 2005. There was one other successful nest (North Key Largo) and one failed nest (Deering Bay) in 2004, and one failed nest (on a canal near Black Point Marina) in 2005. These were the only nests observed in our study area over the course of this study. The Florida Power and Light Company at TP and the FWC along with the FWS at CLNWR also monitored nesting during this period (Mazzotti et al. 2007b).

Discussion

Distribution, Abundance, and Movement

American crocodiles now occur throughout the BBE, with the greatest number of observations occurring between Card Sound Road and US 1 (Fig 1). Additional crocodile movements from the BBE into adjacent populated areas are evidenced by an increasing trend in both human-caused mortality and requested translocations in southern Florida (Mazzotti et al. 2007a).

Abundance estimates for *C. acutus* vary across its range from 0.02 to 8 crocodiles per kilometer (Seijas 1988;

Table 1 Habitat use by crocodile age class and sex

	No. of observations	Canals (19%)	Shoreline (73%)	Ponds (4%)	Creeks (4%)	*P*
Adult	79	52	27	11	10	<0.0001
Subadult	170	38	33	27	2	<0.0001
Juvenile	134	48	24	24	4	<0.0001
Male	72	42	39	11	8	<0.0002
Female	49	59	25	14	2	<0.0001

The percentage of habitat available within the survey area is noted under each habitat type. Preference was analyzed using a chi-square test

Thorbjarnarson 1988; Lazcano-Barrero 1989; King et al. 1990; Platt and Thorbjarnarson 2000). The BBE population falls into the lower range of estimates, ranging from 0 to 3.24 crocodiles per kilometer. The relatively low abundances could be due to the relatively short time over which crocodiles have began to naturally recolonize the area, or to the overall low population numbers throughout the state, or to both of these factors.

Thirty-four recaptured crocodiles moved between capture sites, with one female traveling over 46 km. The two areas in Card Sound where crocodiles congregated after dispersing do not have any obvious features making them particularly attractive to crocodiles; however, in Florida and other regions, *C. acutus* of intermediate size classes (1–2 m) are frequently found in suboptimal habitats (Thorbjarnarson 1989; Brandt et al. 1995).

Population Structure

The size class distribution found during this study (few adults) is consistent with that of a population in a state of recovery. Populations with few adults were also observed with *Crocodylus porosus* in Queensland (Read et al. 2004) and the Northern Territory (Webb et al. 2000) of Australia and with *Crocodylus niloticus* in Uganda and Zimbabwe (Cott 1961). The smallest size classes are present at the highest frequencies with decreasing numbers of individuals in each of the larger size classes. Mazzotti (1983), Thorbjarnarson (1988), and Lazcano-Barrero (1989) found this same pattern in Florida, Haiti, and Mexico, respectively. The 14% annual increase in crocodile observations, along with the greater annual increase in larger size classes in the BBE, underscores the small population size at the onset of this study.

Habitat Use

C. acutus uses a variety of habitats throughout its range. Crocodiles have adapted to disturbed and human-made habitats in Panama (Dugan et al. 1981; Rodda 1984), Venezuela (Seijas 1988; Thorbjarnarson 1989), Belize (F.J. Mazzotti, personal observation), and Jamaica (M.S. Cherkiss, personal observation). This is also the case in southern Florida where abundances are higher in human-made ponds (2.10/km), canals (0.25/km), and creeks (0.36/km) compared to exposed mangrove shorelines (0.03/km).

While all sizes of crocodiles preferred sheltered habitats such as canals and ponds, habitat use varied with size class (Table 1). This relationship has also been documented in ENP (Mazzotti 1983) and at TP (Gaby et al. 1985) where different size classes were found to use available habitats differently. This difference in habitat use is partially due to requirements at different life stages, but is also related to a dominance hierarchy in which larger animals inhabit optimal areas (Cott 1961; Mazzotti 1983; Thorbjarnarson 1988, 1989; Hutton 1989; Abadia 1996). However, when crocodilian population density is low (as it currently is in southern Biscayne Bay), there is little competition for the most suitable habitats, and competition is further reduced for the smaller size classes by the congregation of adult crocodiles near nesting sites at TP.

Many young crocodiles were sighted in optimal habitat, including canals and inland ponds (Table 1) where protective cover was present and salinity was relatively low. The pattern of habitat use observed during this study was characterized by a preference for calm, sheltered bodies of water with low salinity and shorelines with vegetation; this is typical for most populations of crocodilians (Cott 1961; Woodward and Marion 1978; Mazzotti 1983; Gaby et al. 1985; Thorbjarnarson 1988; Kushlan and Mazzotti 1989b), including *C. acutus*. We found increases in annual abundance in canals, shorelines, and creeks, but not in ponds, which may indicate that ponds are the preferred habitat, and when they are saturated, animals move into less preferred habitat types.

Environmental Relations

We kept environmental factors (tidal period, moon phase, wind speed, wave height) as consistent as possible among surveys to reduce variability in factors known to affect crocodile observability (Woodward and Marion 1978). Although crocodiles are generally more easily observed at low tide, low tide waters were not navigable by boat; therefore, surveys could not be performed under optimal conditions. Consequently, abundance of crocodiles on shorelines may be higher than recorded.

While we found no correlation between abundance and air and water temperatures, we did find a strong negative relationship with salinity. Survival of crocodiles has been linked to regional hydrologic conditions (Mazzotti 1983, 1999; Moler 1992a, b), and restoration plans to improve water delivery into southern Florida estuaries may change salinities in the receiving water bodies (Mazzotti and Cherkiss 2003), thereby affecting crocodile survival.

Nesting

For the first time since 1896, a crocodile nest was recorded in 1997 in Biscayne Bay north of TP; this nest was observed at Chapman Field County Park. This nest was active during seven subsequent seasons through 2005. In 2004, additional nesting attempts were made along the Biscayne Bay coastline at two private golf course communities (one successful, one failed) and along a canal. These new locations and those at TP (Brandt et al. 1995) and at North Key Largo (Moler 1992a) are located in human-altered habitats. Kushlan and Mazzotti (1989a) found that human creation of nest sites where none were previously available has, to some extent, compensated for the loss of nesting sites elsewhere in south Florida. When nest sites are limited, human creation of new sites could be used as an important management tool for aiding in recovery of crocodilian populations (Mazzotti et al. 2007b).

Summary and Recommendations

Our systematic surveys provide the first comprehensive data on distribution, abundance, and habitat use of American crocodiles in the Biscayne Bay Estuary. The presence of crocodiles throughout the Biscayne Bay, Card Sound, and Barnes Sound study area is good news for this once endangered species; however, it presents challenges for land and water managers.

Effective ecosystem management requires detailed information about how and when crocodiles utilize various habitats to better inform decisions regarding restoration and maintenance of habitats for crocodile recovery. Crocodiles will benefit from restoration of freshwater flows into their estuarine habitat (Mazzotti et al. 2007a). Location, timing, and amount of flow are crucial. Where possible, freshwater flows would achieve better results if directed through the fringing mangrove swamps rather than simply discharged through canals to give a more even distribution of freshwater into Biscayne Bay and adjacent sounds. Ideal conditions for crocodile recovery and ecosystem restoration would be for flow to peak in the rainy season and continue discharging into the dry season, in most years through December and January.

Crocodiles require vegetated shorelines for cover, with scattered open, elevated areas for nesting and basking; therefore, maintaining vegetated areas should improve chances for continued crocodile recovery. In some areas, non-native vegetation is being removed, but to maintain vegetated areas for crocodiles, native vegetation can be planted in its place.

As crocodiles continue to increase in number and range throughout Biscayne Bay, encounters with humans will increase. Many people are unaware of the mild temperament of *C. acutus* and its threatened status and so feel threatened by the presence of crocodiles in their neighborhoods; this is evidenced by the increasing number of calls to FWC requesting removal of nuisance crocodiles (Cherkiss et al. 2008). Mazzotti et al. (2007a) reported an increasing trend in mortality and translocations of crocodiles in southern Florida after complaints to FWC. Brien et al. (2008) reported on known crocodile mortalities from 1967 to November 2007 and showed that 79% (113 individuals) died from human-related causes (e.g., roadkills). Geographical expansion of populations is a sign of recovery, so removing crocodiles from newly recolonized areas can be counterproductive to recovery. One solution is to develop proactive educational programs explaining the recovery of this threatened species, describing its natural history, emphasizing the need for respect, and minimizing fear of the species (Smithem and Mazzotti 2008).

Acknowledgments We thank the many field biologists who worked with us over the years, often under harsh field conditions, to collect these data. We thank the U.S. Geological Survey (Greater Everglades Priority Ecosystem Science), National Park Service, FWS, U.S. Army Corps of Engineers, FWC, South Florida Water Management District, Miami Dade Natural Areas Management, Florida Department of Environmental Protection, Florida State Parks, Deering Bay Golf Course and Florida Power and Light Company for their support of this project and for providing access to data and study sites. We are especially grateful to R. Curry, D. Jennings, S. Klett, P. Moler, L. Hord, J. Maguire, R. Skinner, R. Whethy, J. Wasilewski, and R. Wilcox from those agencies for their commitment to research and monitoring of crocodiles in Florida. K. Hines, M. Brien, A. Litt, R. Harvey, and K. Rice helped with preparation of this manuscript. All permits and approval for research on this endangered species were obtained from permitting agencies and are available for inspection upon request to the senior author. Use of trade, product, or firm names does not imply endorsement by the U.S. Government or the authors.

References

Abadia, G. 1996. *Population dynamics and conservation strategies for Crocodylus acutus in Bahia Portete, Colombia. In Crocodiles: Proceedings of the 13th Working Meeting of the Crocodile Specialist Group*, 176–183. Gland: IUCN–The World Conservation Union.

Alleman, R.W., D.W. Black, S.E. Formati, L.K. Gulick, and J.A. VanArman. 1995. *An update of the Biscayne Bay surface water improvement and management plan*. West Palm Beach: South Florida Water Management District, Planning Department.

Bayliss, P. 1987. Survey methods and monitoring within crocodile management programmes. In *Wildlife management: Crocodiles* *and alligators*, ed. G.J.W. Webb, S.C. Manolis, and P.J. Whitehead, 157–175. Sydney: Surrey Beatty & Sons.

Brandt, L.A., F.J. Mazzotti, J.R. Wilcox, P.D. Barker, G.L. Hasty, and J. Wasilewski. 1995. Status of the American crocodile (*Crocodylus acutus*) at a power plant site in Florida, USA. *Herpetological Natural History* 3: 29–36.

Brien, M.L., M.S. Cherkiss, and F.J. Mazzotti. 2008. American crocodile, *Crocodylus acutus*, mortalities in southern Florida. *Florida Field Naturalist* 36: 55–82.

Cherkiss, M.S. 1999. Status and distribution of the American crocodile (*Crocodylus acutus*) in Southeastern Florida. MSc thesis, University of Florida.

Cherkiss, M.S., J.A. Frost, and F.J. Mazzotti. 2008. An evaluation of human–crocodile interactions in south Florida. Final Report, Contract No. DO899447. Florida Fish and Wildlife Conservation Commission.

Cott, H.B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (*Crocodylus niloticus*) in Uganda and Northern Rhodesia. *Transactions of the Zoological Society of London* 29: 211–356.

Dugan, B.A., A.S. Rand, G.M. Burghardt, and B.C. Bock. 1981. Interactions between nesting crocodiles and iguanas. *Journal of Herpetology* 15: 409–414.

Fish, J.E., and M. Stewart. 1991. *Hydrogeology of the surficial aquifer system*. Denver: U.S. Department of the Interior, U.S. Geological Survey.

Gaby, R., M.P. McMahon, F.J. Mazzotti, W.N. Gillies, and J.R. Wilcox. 1985. Ecology of a population of *Crocodylus acutus* at a power plant site in Florida. *Journal of Herpetology* 19: 189–198.

Hornaday, W.T. 1875. The crocodile in Florida. *The American Naturalist* 9: 498–504.

Hornaday, W.T. 1904. *The order of crocodiles and alligators. The American natural history.* New York: Charles Scribner.

Hutton, J. 1989. Movements, home range, dispersal and the separation of size classes in Nile crocodiles. *American Zoologist* 29: 1033–1049.

SAS Institute, 1988. Cary, NC: SAS Institute Inc.

King, F.W., H.W. Campbell, and P.E. Moler. 1982. Review of the status of the American crocodile. In *Crocodiles: Proceedings of the 5th Working Meeting of the Crocodile Specialist Group*, ed. D. Dietz and F.W. King, 84–98. Gland: IUCN–The World Conservation Union.

King, F.W., M. Espinosal, and C.A. Cerrato. 1990. *Distribution and status of the crocodilians of Honduras. In Crocodiles: Proceedings of the 10th Working Meeting of the Crocodile Specialist Group*, 313–354. Gland: IUCN–The World Conservation Union.

Kushlan, J.A. 1982. The status of crocodilians in South Florida. In *Crocodiles: Proceedings of the 5th Working Meeting of the Crocodile Specialist Group*, ed. D. Dietz and F.W. King, 99–107. Gland: IUCN–The World Conservation Union.

Kushlan, J.A., and F.J. Mazzotti. 1989a. Historic and present distribution of the American crocodile in Florida. *Journal of Herpetology* 23: 1–7.

Kushlan, J.A., and F.J. Mazzotti. 1989b. Population biology of the American crocodile. *Journal of Herpetology* 23: 7–21.

Lang, J.W. 1975. The Florida crocodile: Will it survive? *Museum of Natural History Bulletin* 46: 4–9.

Lazcano-Barrero, M.A. 1989. *Report on the status and conservation of the American crocodile population in Cuixmala, Jalisco*. Mexico: University of Florida.

LeBuff, C.R. 1957. The range of *Crocodylus acutus* along the Florida Gulf Coast. *Herpetologica* 13: 188.

Mazzotti, F.J. 1983. The ecology of *Crocodylus acutus* in Florida. PhD thesis, Pennsylvania State University.

Mazzotti, F.J. 1989. Factors affecting the nesting success of the American crocodile. *Crocodylus acutus*, in Florida Bay. *Bulletin of Marine Science* 44: 641–646.

Mazzotti, F.J. 1999. The American crocodile in Florida Bay. *Estuaries* 22: 552–561.

Mazzotti, F.J., and M.S. Cherkiss. 2003. *Status and conservation of the American crocodile in Florida: Recovering an endangered species while restoring an endangered ecosystem*. Fort Lauderdale: University of Florida, Fort Lauderdale Research and Education Center.

Mazzotti, F.J., L.A. Brandt, P.E. Moler, and M.S. Cherkiss. 2007a. American crocodile (*Crocodylus acutus*) in Florida: Recommendations for endangered species recovery and ecosystem restoration. *Journal of Herpetology* 41: 121–131.

Mazzotti, F.J., M.S. Cherkiss, M.W. Parry, and K.G. Rice. 2007b. Recent nesting of the American crocodile (*Crocodylus acutus*) in Everglades National Park, Florida, USA. *Herpetological Review* 38: 285–289.

Moler, P.E. 1992a. American crocodile population dynamics. Tallahassee: Florida Game and Fresh Water Fish Commission. Final Report, Study No. 7532.

Moler, P.E. 1992b. American crocodile nest survey and monitoring. Tallahassee: Florida Game and Fresh Water Fish Commission. Final Report, Study No. 7533.

Moore, J. 1953. The crocodile in Everglades National Park. *Copeia* 1953: 54–59.

Neill, W.T. 1971. *The last of the ruling reptiles*. New York: Columbia University Press.

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

Platt, S.G., and J.B. Thorbjarnarson. 2000. Status and conservation of the American crocodile, *Crocodylus acutus*, in Belize. *Biological Conservation* 96: 13–20.

Read, M.A., J.D. Miller, P.I. Bell, and A. Felton. 2004. The distribution and abundance of the estuarine crocodile, *Crocodylus porosus*, in Queensland. *Wildlife Research* 31: 527–534.

Rodda, G.H. 1984. Movements of juvenile American crocodiles in Gatun Lake, Panama. *Herpetologica* 40: 444–451.

Seijas, A.E. 1988. Habitat use by the American crocodile and the spectacled caiman coexisting along the Venezuelan coastal region. MSc thesis, University of Florida.

Smith, H.M. 1896. *Notes on Biscayne Bay, Florida, with reference to its adaptability as the site of a marine hatching and experiment station. In The report of the U.S. Commissioner of Fish and Fisheries for 1895*, 169–191. Washington DC: GPO.

Smithem, J.L., and F.J. Mazzotti. 2008. Risk perception and acceptance of the American crocodile (*Crocodylus Acutus*) in South Florida. *Florida Scientist* 71: 9–22.

Thorbjarnarson, J.B. 1988. The status and ecology of the American crocodile in Haiti. *Bulletin of the Florida State Museum Biological Science* 33: 1–86.

Thorbjarnarson, J.B. 1989. *Ecology of the American crocodile, Crocodylus acutus. In Crocodiles: Their ecology, management, and conservation: A special publication of the Crocodile Specialist Group of the Species Survival Commission*, 228–258. Gland: IUCN–The World Conservation Union.

Webb, G.J.W., A.R.C. Britton, S.C. Manolis, B. Ottley, and S. Stirrat. 2000. *The recovery of Crocodylus porosus in the Northern Territory of Australia: In Crocodiles: Proceedings of the 15th Working Meeting of the Crocodile Specialist Group*, 195–235. Veredero: IUCN–The World Conservation Union.

Woodward, A.R., and W.R. Marion. 1978. An evaluation of factors affecting night-light counts of alligators. *Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies* 32: 291–302.

Wyman, J. 1870. On the existence of a crocodile in Florida. *American Journal of Science and Arts* 49: 105.