First successful nest for the Vulnerable American crocodile *Crocodylus acutus* population on the west coast of Florida, USA

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Abstract The American crocodile *Crocodylus acutus* occurs across the Americas, with its northernmost distribution being in South Florida, USA. This species has undergone severe declines across its range and is categorized globally as Vulnerable on the IUCN Red List and as Threatened on the U.S. Federal Endangered Species List. Long-term monitoring studies in the USA have documented a shift in American crocodile nesting activity and an expansion of its range throughout the southern and eastern coasts of South Florida. However, no successful American crocodile nests have been recorded until now on the west coast of South Florida. Here we document the American crocodile nest monitoring conducted during 1997–2021 at Rookery Bay National Estuarine Research Reserve and the first successful nest from the west coast of South Florida for *C. acutus*. Marco Airport and McIlvane Marsh are the two main American crocodile nesting areas identified at the Reserve, with 92 nests and 3,586 eggs recorded during 1997–2021. We found most nests at Marco Airport (95.7%) and only four nests (4.3%) at McIlvane Marsh. To date, none of the nests found at Marco Airport have produced successful hatchlings. In contrast, hatchlings have been produced at McIlvane Marsh since nests were first documented there in 2020. We discuss the implications of our findings in terms of the future conservation of the species.

Keywords Conservation, crocodylian, *Crocodylus acutus*, Florida, nesting ecology, threatened species

The American crocodile *Crocodylus acutus* is a coastal crocodylian that occurs across the Americas from southern Florida, USA, to northern South America and the insular Caribbean (Thorbjarnarson et al., 2006). This species has undergone severe declines in the past because of overexploitation and habitat loss. Hence it has been categorized since 1994 as Vulnerable globally on the IUCN Red List (Rainwater et al., 2022) and Threatened locally by the U.S. Fish & Wildlife Service (USFWS, 2007). Conservation measures developed in the last 5 decades in most regions across its range have facilitated the recovery of American crocodile populations in several countries (Rainwater et al., 2021). However, habitat loss because of agricultural and residential development and illegal hunting are ongoing threats (Rainwater et al., 2021).

Long-term monitoring studies in the USA from the early 1970s to the present documented a shift in American crocodile nesting activity and an expansion in its range throughout the western, southern and eastern coasts of South Florida (Mazzotti et al., 2022). However, no successful American crocodile nests have been recorded until now on the west coast of South Florida. In the last 2 decades unsuccessful nests (nests that did not produce successful hatchlings, mainly because of infertile eggs or early embryonic death) have been reported on the west coast of South Florida on Sanibel and Marco islands as well as in Rookery Bay National Estuarine Research Reserve (LeBuff, 2016; Mazzotti et al., 2022). Here we report the results of American crocodile nest monitoring during 1997–2021 at the Rookery Bay Reserve, and the first successful *C. acutus* nest from the west coast of South Florida.

The Rookery Bay Reserve lies at the northernmost of the Ten Thousand Islands on the Gulf Coast of Florida (Fig. 1). The Reserve, which was established in 1978 to protect its undisturbed habitats and monitor listed species and other wildlife, incorporates 445 km^2 of land and water. Approximately 162 km^2 comprise primarily mangrove forests/wetlands, saltwater and freshwater marshes and upland habitats such as coastal hammocks and cypress sloughs, and the remaining area encompasses open-water habitats (FDEP, 2013). These habitats are vital for hundreds of plant and animal species, including $>$ 70 federally and state-designated threatened and endangered species, including the American crocodile (FDEP, 2013). The first American crocodile nest at the Reserve was recorded in 1997 at Marco Airport, triggering the monitoring programme.

We conducted surveys for crocodile nests by motorboat, car and foot during 1997–2021 across the Reserve in April and May (i.e. the egg-laying period) and monitored nesting habitats in June–August (i.e. the hatching period) as recommended for South Florida (Mazzotti, 1989). We noted

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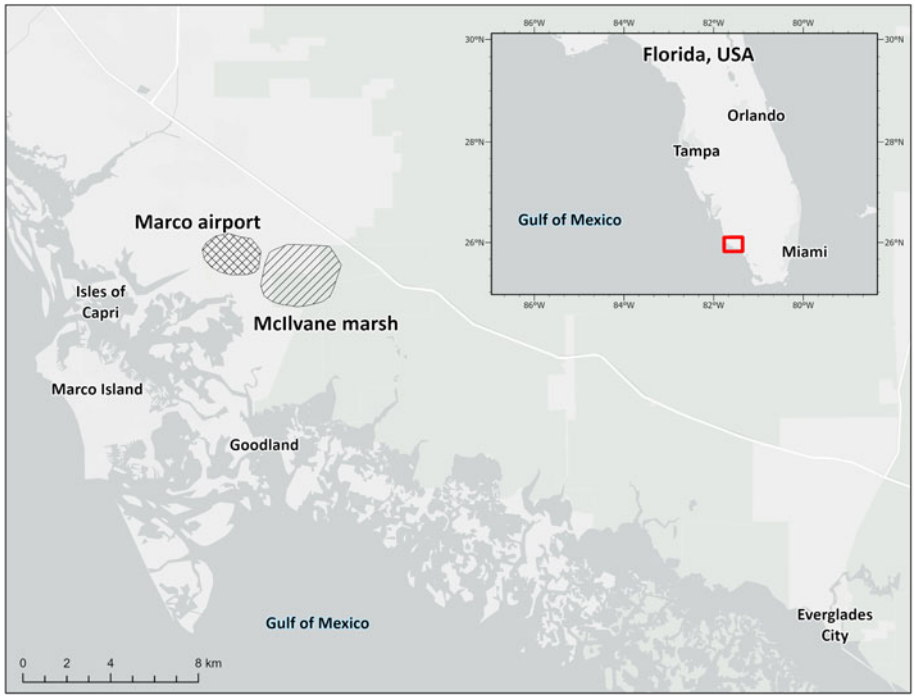

FIG. 1 The locations of Marco Airport and McIlvane Marsh, in the Rookery Bay National Estuarine Research Reserve, Florida, USA, where the American crocodile *Crocodylus acutus* was recorded nesting during 1997–2021.

nesting activity (tail drags, digging or scraping) and the presence of eggs or hatchlings whenever possible. We categorized nests as holes or mounds (Murray et al., 2019) and as either isolated, near other nests or with multiple clutches within the same mound. We identified hatched nests by the presence of an open hole, evidence of digging or hatched eggshells. We considered eggshells at an excavated nest as evidence of a successful nest. We considered nests as unsuccessful when the hatching period (August) had passed and no hatchlings had emerged (Mazzotti et al., 2022).

We identified two nesting areas (Marco Airport and McIlvane Marsh; Fig. 1) across the Reserve and recorded 92 nests and 3,586 eggs during 1997–2021, with a mean of 3.7 ± SD 1.6 nests per year. We found most nests at Marco Airport (95.7%), and only four nests (4.3%) at the McIlvane Marsh area, starting in 2020. We found nests during April–May and excavated them in September when no signs of activity from the female or hatchlings were present. Most nests found at both Marco Airport and McIlvane Marsh were communal (two clutches adjacent to each other). In the first year of monitoring (1997) we recorded five nests with a total of 256 eggs (51.2 ± SD 5.9 eggs per nest). We found the maximum number of nests in a single year (seven nests) in 2004 (mean clutch size = 40.0 ± SD 14.8 eggs per nest) followed by six nests in both 2003 (46.0 ± SD 17.8 eggs per nest) and 2008 (44.5 ± SD 10.6 eggs per nest, based on two nests only). During 2009–2019, the number of nests found at the Reserve dropped to 2–3 but mean clutch size during this time remained similar (42.5 ± SD 10.7 eggs per nest). None of the nests found until 2019 (all at Marco Airport) produced successful hatchlings.

The first documented American crocodile at McIlvane Marsh was observed in 2013 but nesting activity was not documented there until 2019. However, because of logistical issues we could not monitor McIlvane Marsh in 2019. We recorded the first two successful nests at McIlvane Marsh in 2020. These were hole nests situated adjacent to each other (3 m apart) and the approximate hatch dates were 28 June and 3 July. We captured and marked 16 hatchlings from these two nests, which were on average 29.4 ± SD 1.3 cm in total length, 14.8 ± SD 0.6 cm in snout–vent length and 78.7 ± SD 7.0 g in mass. We recovered 12 whole eggshells from the nest hatched on 3 July and only fragments of eggshells from the nest hatched on 28 June, with this fragmentation probably resulting from depredation. A camera trap deployed on the latter nest showed the female American crocodile digging up hatchlings and vultures feeding upon the eggs and embryos, implying that not all of these eggs were depredated. In 2021 we found two successful nests at the same location that hatched approximately on 6 July. We captured and marked 20 hatchlings, which were on average 28.4 ± SD 1.5 cm in total length, 14.1 ± SD 0.8 cm in snout–vent length and 69.0 ± SD 11.0 g in mass. We also recovered 14 eggshells from the first nest and 20 eggshells from the second. Upon digging further into the nests, we found two dead hatchlings in the first nest and eight dead hatchlings in the second. We suspect successful nesting at McIlvane Marsh began in 2019 based on the above nesting observations, three juveniles captured during spotlight surveys in 2020 (51.5 ± SD 0.8 cm in total length, 26.7 ± SD 0.4 cm in snout–vent length and 300.0 ± SD 34.6 g in mass) and the remnants of old eggs found when digging up nests in 2020.

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The Reserve has been recorded recently as a so-called cold-spot for American crocodile nesting, meaning that this area demonstrates a low but consistent number of nests across time (Mazzotti et al., 2022). However, the reason why no viable eggs or alive hatchlings were observed over > 20 years remains a matter for investigation. Some potential hypotheses are a lack of reproductive males and the effects of temperature, humidity, salinity and/or root mass on the eggs. Further research will help us better understand the variables affecting the nesting ecology of American crocodiles in this northernmost part of their range. Since 2019, efforts to remove invasive flora across the Marco Airport area have been implemented. These efforts not only include removing flora that shades out and degrades historical crocodile nesting sites, but also adding sand to nest sites with the aim of enhancing the attractiveness of the site and increasing its use. Although no nests have ever been confirmed as hatching at Marco Airport, spotlight surveys at this site should be included within the Reserve nest monitoring programme to provide data on the actual population inhabiting the area. These surveys could also help us to confirm whether any other nests not recorded in the nesting surveys are present in the area and have produced hatchlings.

The local recategorization of the American crocodile from Endangered to Threatened in the USA has been related to the increase in the number and success of nests (Mazzotti et al., 2007). Human-made habitats such as those found at the Reserve and McIlvane Marsh have provided important *C. acutus* nesting habitats in areas such as Cape Sable, Turkey Point Power Plant and Crocodile Lake National Wildlife Refuge (Mazzotti et al., 2022). The continued success of American crocodile nests at a new location in Florida would be another step towards the recovery of this threatened species.

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Conflict of interest None.

Ethical standards Crocodiles were handled under USFWS permit number and IACUC #202109072, and this research otherwise abided by the *Oryx* guidelines on ethical standards.

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