Herpetological Conservation and Biology 21(1):30–52.
Submitted: 12 August 2025; Accepted: 29 December 2025; Published: 30 April 2026.

# The First Island-Wide Assessment of the American Crocodile *(Crocodylus acutus)* in Jamaica: Population Status, Habitat Use, and Conservation Priorities

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*Abstract.*—**The American Crocodile *(Crocodylus acutus)* is the most widely distributed New World crocodile, inhabiting lowland and coastal wetlands of the Americas. Despite its broad range, populations face multiple stressors, and survey data remain limited in many areas, including Jamaica, where habitat loss and illegal hunting pose significant threats. We conducted the first island-wide assessment of *C. acutus* in Jamaica to evaluate encounter rates, distribution, size-class structure, and nesting activity. Additionally, we analyzed habitat use to identify Crocodile Conservation Units (CCUs), the most important areas for the conservation of *C. acutus*. Over two years (2020-2022), we conducted 105 spotlight surveys across 35 sites and extracted 1,974 geolocations from historical and current data. Our results confirm crocodile presence across the historical South Coast range, with small, scattered populations on the North Coast. We encountered non-hatchling crocodiles at a rate of 2.5 crocodiles/km (1,049 crocodiles/427.2 km) with relative abundance varying across different habitats. Sewage ponds, mangrove swamps, and rivers supported the highest encounter rates, and juveniles (27%) and hatchlings (14%) were the most frequently observed. Our findings demonstrate the ability of *C. acutus* to adapt and persist in a changing environment, inhabiting artificial wetlands and disturbed landscapes. We identified seven CCUs that encompass critical natural and artificial habitats, 81.2% of which fall within protected areas. To ensure the long-term survival of *C. acutus* in Jamaica, we recommend a combination of strategies, including protecting critical habitats (CCUs), long-term education programs, stronger law enforcement, and further research.**

*Key Words*.—artificial habitats; crocodylian; conservation; crocodile conservation units; encounter rates; habitat analysis; natural history; protected areas

## Introduction

Crocodylians are widely distributed, large-bodied predators, that inhabit all types of freshwater habitats across lowlands (commonly below 1,000 m elevation) in the tropics, sub-tropics, and some temperate regions (Martin 2007). Crocodylian conservation and management programs are becoming increasingly important as wild populations decline, due to threats such as habitat loss and human-crocodylian conflict (Somaweera et al. 2020). The American Crocodile *(Crocodylus acutus)* is one of the current 26 crocodylian species described globally, and the most widely distributed New World crocodile (Somaweera et al. 2020; Rainwater et al. 2022). The species ranges from the southern tip of Florida (USA), across the Pacific and Atlantic coasts of southern Mexico, through Central America and northern South America, and throughout parts of the Caribbean (Thorbjarnarson 2010). *Crocodylus acutus* is considered a coastal species found in brackish sections of rivers, coastal lagoons, and Mangrove Swamps (Thorbjarnarson 2010; Mauger et al. 2012). The species also inhabits inland wetlands and marine habitats around offshore atolls and islands and exhibits adaptability to disturbed and artificial habitats (Thorbjarnarson 2010; Mauger et al. 2012). *Crocodylus acutus* populations significantly declined from the 1930s to the 1960s due to overexploitation for their skins, which was exacerbated by habitat loss and fragmentation (Mazzotti 1999; Rainwater et al. 2022). Global efforts, such as being placed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975, have led to the recovery of the species (Thorbjarnarson et al. 2006). This includes its down-listing to Vulnerable by the International Union for Conservation of Nature (IUCN) on its Red List (Balaguera-Reina et al. 2015a; Rainwater et al. 2022). Population ecology studies of *C. acutus* have been conducted in parts of its range, including the U.S. (Florida), Belize, Colombia, Cuba, Dominican Republic, Mexico, Haiti, Ecuador, and Venezuela (Thorbjarnarson 2010; Rainwater et al. 2022); however, *C. acutus* remains threatened and understudied in some countries, including Jamaica (Mauger et al. 2012; Rainwater et al. 2022).

Jamaica is the third largest island in the Greater Antilles. *Crocodylus acutus* is one of many understudied native species in the country, where its distribution is relatively well known but the population size and status are not (Wilson 2011). Thorbjarnarson et al. (2006), Thorbjarnarson (2010), and Rainwater et al. (2022) listed Jamaica as a high priority for action, recommending an island-wide population evaluation and habitat assessment to develop a crocodile conservation plan for the country. The earliest accounts of crocodiles in Jamaica from the 17th Century suggest an abundant population with little information on their status or ecology (Mazzotti et al. 2012). The population started to decline during the 1960s due to hunting and mass removal for commercial exhibits (Mazzotti et al. 2012; Leslie Garrick, unpubl. report). In response to the declining population, *C. acutus* was placed under the Third Schedule of the Wild Life Protection Act (WLPA) in 1971, which is mandated by the National Environment and Planning Agency (NEPA 2008; https://www.nepa.gov.jm/sites/default/files/2019-11/wild-life-protection-act.pdf). Despite legal protection, Leslie Garrick (unpubl. report) in the earliest known study, concluded that most Jamaicans greatly dislike crocodiles and think swamps are worthless habitats. Over time, crocodile management has progressed, but the threats have not subsided. The Jamaican government faces myriad challenges enforcing legislation aimed at protecting *C. acutus* and its habitats, which include those that fall within the natural protected area system of the country (Wilson 2011). This system comprises nine types of protected areas, designated under five legislations, governed by three agencies, one being NEPA/Natural Resources Conservation Authority (NRCA). Under the IUCN Protected Area categories, protected areas of Jamaica can be best described as Habitat/species Management Area (IV), Protected Landscape/Seascape (V), or Protected Area with sustainable use of natural resources (VI). The lack of clarity in protected area designation and the direction of legislation and policy, however, has greatly hindered management structures in the national protected areas system of Jamaica (Henwood and Otuokon 2015).

A small, mainly coastal, portion of the island provides habitat for crocodiles. The loss and fragmentation of coastal wetlands pose significant threats to the species. Between 1996 and 2016, Jamaica lost over 770 ha of mangroves due to anthropogenic activity and climate change (Castano Isaza et al. 2019). As a result, the availability of natural crocodile habitats, including suitable nesting sites, has declined (NEPA 2008). Illegal hunting is another major threat. Reports of crocodiles being hunted for their meat, particularly the tail, date back to the early 2000s. Initially linked to Asian immigrants purchasing crocodile meat for consumption, this illicit practice has more recently expanded into local communities, driven by the misguided belief that crocodile meat has aphrodisiac properties (NEPA 2008; Wilson 2011; Beauchamp et al. 2019). Crocodiles also face additional pressures, including persecution, roadkill, illegal removal from the wild, and direct and indirect feeding (NEPA 2008; Wilson 2011; NEPA 2020a). Although crocodile attacks on humans are relatively rare (14 non-fatal and four fatal attacks recorded from 1764 to 2022), negative interactions often stem from misconceptions, ingrained fears, and unsafe practices (Mazzotti et al. 2012; NEPA 2020a; https://crocattack.org/). Despite these challenges, crocodiles play an important role in Jamaica, contributing to eco-tourism and holding national significance, appearing on the Coat of Arms of the country as a symbol of the island's native fauna. They may also play an important ecological role as ecosystem engineers, influencing habitat dynamics and as indicator species for healthy ecosystems (Mazzotti et al. 2012; NEPA 2020a; Somaweera et al. 2020).

Previous surveys of *C. acutus* in Jamaica have been small-scale and, in some cases, incomplete, which has limited their conservation value. The first attempt at an island-wide survey in 2004 reported that crocodiles primarily inhabit several wetlands along the south coast of the island, from Holland Bay in the east to the Negril Morass in the west (Kelly 2007; NEPA 2008). Contemporary surveys confirm small, isolated crocodile populations along the north coast of Jamaica; however, it is unclear whether these are original or newly established populations, as early reports by Lynn and Grant (1940) and Leslie Garrick (unpubl. report) noted their absence along this coast.

Hypotheses for the occurrence of *C. acutus* along the northern coast of Jamaica include natural dispersion and release of captive crocodiles in the parish of Trelawny (Mazzotti et al. 2012).

In a spatial ecology study in Jamaica by Beauchamp et al. (2019), six crocodiles were tagged with satellite transmitters in 2011 in the parish of St. Catherine. Tracking data showed that home-ranges varied from 5.1 km$^2$ to 58.8 km$^2$ and that habitats used were primarily wetland forest and open water. Between 2015 and 2019, NEPA reported that the Greater Portmore sewage ponds had a notably higher crocodile population count than that of natural habitats, such as Black River and Salt River (NEPA 2020b). Kelly (2007) similarly reported that Greater Portmore, including these sewage ponds and the canal network, had one of the largest crocodile populations. Artificial and disturbed habitats are becoming increasingly important across the range of the species as observed at the El Cajon Reservoir, Honduras, the cooling canals of Turkey Point Power Plant in Florida, USA, and sewage treatment ponds in Ambergris Caye, Belize (Gaby et al. 1985; Brandt et al. 1995; Espinal and Escobedo-Galván 2011; Boucher et al. 2020).

*Crocodylus acutus* nesting records in Jamaica date back as early as 1981 (Leslie Garrick, unpubl. report), and since then nesting has been observed across six south coast parishes, spanning St. Thomas to St. Elizabeth. Crocodiles have been observed nesting on beaches, along riverbanks, and more recently within artificial habitats, along canal banks and sewage ponds. Nesting in Jamaica has been recorded as early as February and as late as June, and the clutch size can vary from eight to 40 eggs (NEPA 2020a; Lawrence Henriques, pers. comm.). Data are limited, however, on *C. acutus* nesting characteristics and success, parental care, and hatchling survival rates with only Leslie Garrick (unpubl. report) having examined these aspects in the country. The introduced Small Indian Mongoose (*Herpestes auropunctatus*) was listed as the only egg predator, aside from humans. *Crocodylus acutus* are typically hole-nesting species but are also known to build mound nests (Thorbjarnarson 1989; Grigg 2015). In Jamaica, both nests were observed, with mound nests recorded along beaches and hole nests on elevated riverbanks. Regarding parental care, hatchlings remained with the mother for up to 1 mo in shallow nursery habitats before dispersing into more open water (Leslie Garrick, unpubl. report).

In terms of habitat conservation priorities, Thorbjarnarson et al. (2006) identified three Crocodile Conservation Units (CCUs) for Jamaica, which are defined as areas where substantive crocodile populations exist (Thorbjarnarson et al. 2006). These were the Portland Bight Protected Area, Manatee River (Milk River) and Black River; however, more data were required to rank Jamaica in the Florida-Greater Antilles bioregion. This would require research on the extent of crocodile occurrence and the status of habitat in the country (Thorbjarnarson et al. 2006). The Black River, which had a limited protected area at the time, was later declared a protected area measuring 204.82 km$^2$ in size in 2021 (https://www.nepa.gov.jm/sites/default/files/2022-02/THE-NATURAL-RESOURCES-CONSERVATION-BLACK-RIVER-PROTECTED-AREA-ORDER-2021.pdf).

Because past studies on the *C. acutus* population in Jamaica are limited and have not adequately addressed the island-wide population, our goal was to conduct the first complete island-wide assessment of *Crocodylus acutus* in Jamaica. Our objectives were to determine the population status by analyzing encounter rates, distribution, size-class structure, and nesting activity, and to conduct a habitat analysis using historical and current data to identify critical conservation areas. Assessing the population will be critical in guiding conservation priorities for this threatened species and its habitat.

## Materials and Methods

***Study area***.—Jamaica is an island country (10,991 km$^2$) in the Caribbean, consisting of three counties subdivided into 14 parishes (Forestry Department 2015). The island has a tropical climate, with a distinct dry season (December-March) and a wet season (April-November). Mean monthly temperatures range from 24° to 27° C and can get as low as 19° C at night during the coolest months (Climate Studies Group, Mona 2017). We conducted field surveys for *C. acutus* at 35 sites across Jamaica from March 2020 to March 2022 (Fig. 1). Site selection was based on three criteria: (1) crocodile presence; (2) accessibility; and (3) security risk. During the first year, we conducted preliminary surveys by walking through crocodile habitats, establishing new survey routes and evaluating existing ones. We used DJI Mavic Pro drone (DJI, Shenzhen, Guangdong, China) to assist in mapping survey routes. Survey routes covered a total of 123.2 km, providing a representative sample

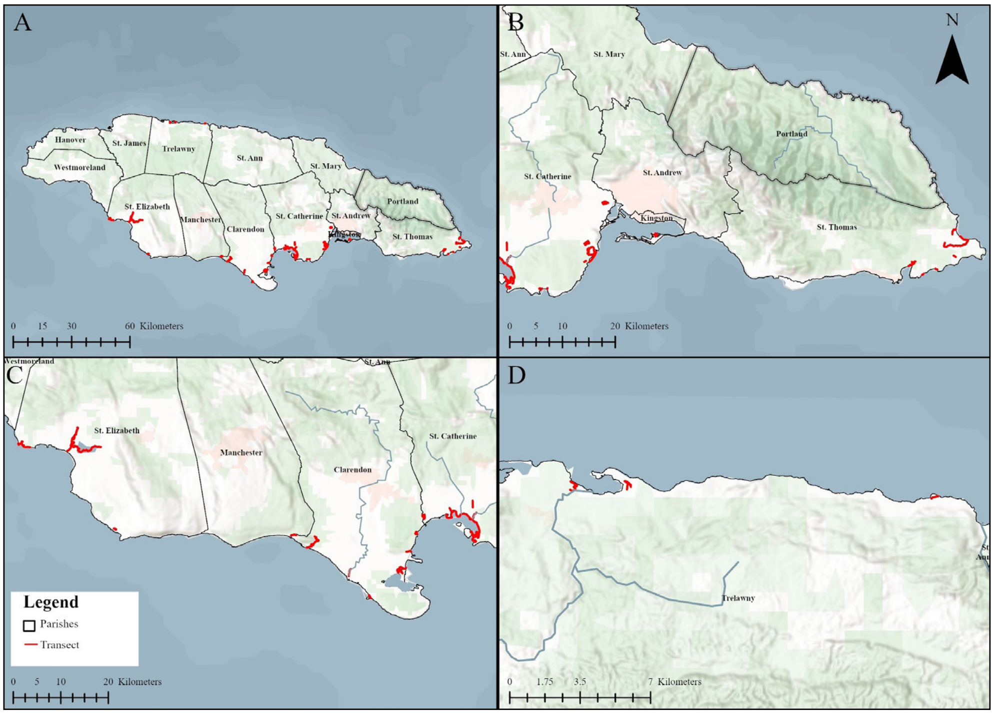


**Figure 1**. (A) Map of Jamaica showing the study areas and survey routes highlighted in red across the island. (B) Parishes of St. Thomas, Kingston, St. Catherine. (C) Parishes of St. Catherine, Clarendon, Manchester, St. Elizabeth. (D) Parish of Trelawny. (Map created using ArcGIS software by Esri. Basemap from Esri World Topographic Map, with data from Esri, U.S Geological Survey [USGS], National Oceanic and Atmospheric Administration [NOAA], Garmin, and other contributors).

of the island-wide population. We conducted surveys in six parishes along the south coast and one parish on the north coast. Twenty-seven survey sites fell within natural Protected Areas designated by the NRCA/NEPA and human disturbance in the form of residential, commercial and road development, as well as industrial, agricultural, and fishing activities varied across sites.

***Data collection***.—We assessed the island-wide population of *C. acutus* by determining encounter rates (number of crocodiles/km), distribution, size-class structure, and nesting activity. Nocturnal eyeshine surveys and nesting assessments were the primary methods we used (Cherkiss et al. 2004). To analyze species distribution over time, we used the NEPA Wildlife Incident Database (NEPA, unpubl. data), which provided a 14-y dataset (2008–2022). Additionally, we reviewed literature on the biology and management of *C. acutus* in Jamaica from 1982 to 2022.

***Nocturnal eyeshine surveys***.—We conducted Nocturnal Eyeshine Surveys by motorboat, canoe, jon boat, car, or on foot, beginning at least 30 min after sunset. To optimize detection, we avoided fieldwork during full moons and adverse weather conditions whenever possible. All vessel types were operated at a moderately slow and consistent speed throughout each survey. The survey team consisted of a primary and secondary observers responsible for detecting crocodiles while additional team members operated the watercraft or vehicle. We detected crocodiles in water and on banks using a 200,000-candle power spotlight and an LED headlamp. We determined survey lengths using a handheld GPS calculated on Garmin BaseCamp, with different routes ranging from 0.4 to 27 km in length. For dead-end routes, we recorded observations only on the way back to avoid double counting individuals. Traveling to the end of each route before dusk allowed for safe navigation in daylight and ensured that all counts were made after dark, when eye-shine detectability was highest. Although crocodiles may have been disturbed on the outbound leg, this approach minimized double counting and ensured that crocodiles were surveyed under comparable conditions.

At the start and the end of each survey, we collected environmental data, including: (1) water temperature (measured by a thermometer in °C); (2) salinity (measured with an optical refractometer, scale 1–100 parts per thousand; ppt); (3) air temperature; and (4) wind speed (both air temperature and wind speed measured by a Kestrel 3000 pocket weather meter in °C and mph; Nielsen-Kellerman, Boothwyn, Pennsylvania, USA). We also recorded the dominant habitat in the immediate vicinity of each observed eyeshine. For natural pond surveys, we collected environmental data for each pond, whereas for sewage and aquaculture pond surveys, we recorded only air temperature and wind speed. For each crocodile observation, we slowly approached the animal to estimate its size and record a GPS waypoint of its location. We categorized individuals into four size classes: (1) hatchling/class I (< 0.60 m total length; TL); (2) juvenile/class II (0.60 to < 1.5 m TL); (3) sub-adult/class III (1.5 to < 2.25 m TL); and (4) adult/class IV (≥ 2.25 m TL) based on Cherkiss et al. (2011) categories. When size estimation was not possible, we recorded individuals as eyeshine only (EO). Survey effort was influenced by environmental conditions, time constraints, and funding availability. Over the 2-y period, we surveyed 22 sites a total of four times, once during the wet season and once during the dry season each year. The survey frequency of the remaining 13 sites varied: 10 were surveyed once, two were surveyed twice, and one was surveyed three times, during either the wet or dry season, or both. We assessed natural and artificial wetlands, including mangrove swamps, rivers, ponds, coastal lagoons, bays, canals, coastline, sewage ponds, and aquaculture fish ponds.

***Nesting activity***.—From 2020 to 2022, we used multiple methods to search known and suspected nesting habitats, increasing the likelihood of nest detection, particularly during the nesting and hatching season (February-September). We recorded nests during nesting assessments, through wildlife incident reports received by NEPA, and opportunistically during eyeshine surveys. We identified nesting activity by the presence of hatchlings in a waterbody or nest evidence, such as eggshells, signs of digging by a crocodile, or an open (excavated) nest cavity (Mazzotti et al. 2022). We categorized nests as either hole or mound construction and determined causes of nest failure, including predation, human disturbance, and flooding (Mazzotti 1989).

***Habitat analysis***.—We compiled crocodile locality data using a Wildlife Incident Database administered by NEPA over a 14-y period (2008–2022). Of the 824 incident reports recorded from 2008 to 2022, we selected 407 for analysis after excluding unconfirmed reports, records without location data, and incidents involving captive crocodiles. We categorized each incident as a sighting, a relocation, an attack, an illegal capture, illegal hunting, vehicle collision, or drowning. In addition, we reviewed literature on the biology and management of *C. acutus* in Jamaica from 1982 to 2022, including peer-reviewed papers, unpublished technical reports, and data from previous field studies. These records provided critical information on crocodile presence in areas where we did not detect individuals during surveys or where surveys were not conducted. We extracted coordinates and locality data for sightings and nests from these documents and compiled them into a spreadsheet. We then categorized all historical and wildlife incident data by date, season, location (GPS), parish, type of incident, habitat type, and size class (where applicable), while also noting any additional relevant information. Each record represented an observation, though in some cases, depending on the incident type, a single record documented multiple individuals.

***Data analysis***.—We used encounter rate as an index of relative abundance, calculating it for each location as the total number of non-hatchling crocodiles sighted per kilometer of survey route travelled (Bayliss 1987). We excluded hatchlings due to their low survival rate compared to other life stages, which is mainly due to predation and osmotic stress (Platt and Thorbjarnarson 2000b; Grigg 2015). We also excluded artificial survey sites (sewage ponds and fish ponds) from environmental analyses involving salinity and water temperature, as these data were not collected at these sites. We tested data normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests, depending on the sample size. We assessed differences in encounter rates across years, seasons, parishes, and habitat types using Mann-Whitney U and Kruskal-Wallis tests. To identify correlation between encounter rates and environmental variables (salinity and water temperature), we conducted a Spearman's Rank Correlation analysis (Mauger et al. 2012; Fowler et al. 2013; Hilevski and Velasco 2020; Flores-Escalona et al. 2021). All analyses were performed using Microsoft Excel and IBM SPSS Statistics (Version 22). We considered results statistically significant at $P \leq 0.05$ and compared encounter rates with those reported in other *C. acutus* studies across the region.

We analyzed size-class distribution analysis based on four categories: (1) hatchling; (2) juvenile; (3)

sub-adult; and (4) adult, following methods used by Flores-Escalona et al. (2021). We assessed size-class distribution differences across the two habitat types, natural and artificial, using a Chi-squared Contingency Test. We examined statistical relationships between size-class categories and environmental variables (salinity, air temperature, water temperature) using the Kruskal-Wallis Test. We described nesting data based on location, habitat type, substrate, and hatchling observations (Mazzotti 1989; Cherkiss et al. 2011).

We compiled spatial information as discrete points from historical records, survey data, and nesting observations, standardizing them to the projected coordinate system of Jamaica using ArcGIS Pro 3.1.0 (Esri, Redlands, California, USA). To measure the spatial distribution of the areas historically and currently occupied by the species, we calculated the Extent of Occurrence (EOO) using the Minimum Convex Polygon (MCP) method, following IUCN guidelines (IUCN Standards and Petitions Committee 2022). We refined our MCP by adjusting it to national boundaries and topography of Jamaica, using an elevation ranging from -8.3 m to 104 m, based on our compiled geolocation dataset. No occurrences were recorded above 104 m, and the adjustment minimized overestimation of the EOO of the species (IUCN Standards and Petitions Committee 2022). We divided crocodile geolocation data into two groups: pre-2013 period (2004–2012) and post 2013-period (2013–2022) to align with the land cover datasets of Jamaica (https://www.forestry.gov.jm/publiccontent). We projected and analyzed pre-2013 geodata over the 1998 land cover dataset and post-2013 geodata over the post-2013 dataset to assess habitat use over time. While this division may have not been the most accurate, no objective method existed to separate geo-data between the two land cover groups. To evaluate the importance of mangrove habitat for the species, we incorporated mangrove land cover into our analysis. We also examined the EOO and geolocation data in relation to natural protected area boundaries.

To define regional habitat priorities for *C. acutus* in Jamaica, we delineated Crocodile Conservation Units (CCUs). Selection of CCUs was guided by information on the species range, protected area boundaries and the crocodile geolocation data. In areas with fewer geolocations, we prioritized protected area boundaries and species range to ensure that important wetland habitats were not excluded or fragmented. Because *C. acutus* is primarily a coastal species, we incorporated nearby coastlines into CCU delineations. We created CCU polygons in Google Earth Pro (Google LLC, Mountain View, California, USA) and exported them as shapefiles into ArcGIS Pro and projected them onto the 2013 land cover dataset. We adapted the CCU selection criteria from Thorbjarnarson et al. (2006), Balaguera-Reina et al. (2017), and Rodriquez-Cordero et al. (2019), ranking each CCU using a scoring system based on seven variables, with a maximum score of 32 points (Table 1). These seven variables represent key factors in the long-term conservation of the species.

## Results

***Nocturnal eyeshine surveys***.—We conducted 105 nocturnal eyeshine surveys at 35 sites. We observed 1,220 crocodiles along 427.2 km of survey routes, and of these, 1,049 were non-hatchlings. No crocodiles were observed at six sites, including all north coast locations (Braco, Martha Brae, Oyster Bay). The overall encounter rate was 2.5 crocodiles observed per km, with the highest encounter rate recorded at Flashes (80.4 crocodiles/km; Appendix Table). The distribution of encounter rates across all surveys was positively skewed, due to a small number of sites exhibiting very high values compared to the other sites (mean = 6.32 ± [standard deviation] 16.13; range of values, 0.00–111.30). Encounter rates did not differ significantly between the two survey years ($U$ = 1,316, df = 1, $P$ = 0.728) or between seasons (wet season 1, dry season 1, wet season 2, dry season 2; $H$ = 0.36, df = 3, $P$ = 0.947; Fig. 2). Significant differences in encounter rates were detected between St. Catherine and the parishes of Trelawny, St. Andrew, St. Elizabeth, St. Thomas, and Clarendon ($H$ = 36.47, df = 6, $P$ < 0.001). St. Catherine had the highest mean encounter rate and exhibited significant variation between survey sites ($H$ = 26.60, df = 11, $P$ < 0.001; Fig. 2). Two mangrove swamps had the highest and third-highest encounter rates (Flashes and Manatee Bay, respectively), while the Hellshire sewage ponds had the second highest encounter rate.

Survey sites were categorized into natural (bay, river, mangrove swamp, coastal lagoon, coastline, pond), artificial (sewage pond, fish pond, canal), and mixed habitats. Encounter rates differed significantly between natural and artificial habitats ($U$ = 1,178, df = 1, $P$ = 0.022), with artificial habitats (mean rank = 60.12, n = 25, $P$ = 0.022) exhibiting higher encounter rates than natural habitats (mean rank = 45.14, n = 72, $P$ = 0.022; Fig. 2). Mixed habitats were excluded

**Table 1.** Criteria used to prioritize Crocodile Conservation Units (CCUs) based on seven variables. Percentage values are used for variables based on land cover; all other variables use counts or categorical values.

| Variable | Description | Classifier | Value |
|---|---|---|---|
| Population size (estimate) | Estimate size of non-hatchling crocodile population based on number of geolocations | < 50 | 1 |
| | | 50–100 | 2 |
| | | 101–500 | 3 |
| | | 501–1000 | 4 |
| | | > 1000 | 5 |
| Population studies | Number of population studies conducted, past and current | 0 | 1 |
| | | 1–10 | 2 |
| | | 11–20 | 3 |
| | | 21–30 | 4 |
| | | > 30 | 5 |
| Habitat quality | Areas classed as 'buildings and other infrastructure,' 'bauxite extraction,' 'quarry' | > 80% | 1 |
| | | 60%–80% | 2 |
| | | 40%–59% | 3 |
| | | 20%–39% | 4 |
| | | < 20% | 5 |
| Mangrove areas | Percentage of total mangrove cover | < 10% | 1 |
| | | 10%–20 % | 2 |
| | | 21%–30% | 3 |
| | | 31%–40% | 4 |
| | | > 40% | 5 |
| Nesting habitat | Number of nests reported in area based on historical and current data | 0 | 1 |
| | | 1–5 | 2 |
| | | 6–10 | 3 |
| | | 11–15 | 4 |
| | | > 15 | 5 |
| Illegal hunting | Reports of illegal hunting | Yes | 1 |
| | | No | 2 |
| Protected areas | Total area under the protected area system | < 20% | 1 |
| | | 20%–40% | 2 |
| | | 41%–60% | 3 |
| | | 61% –80% | 4 |
| | | > 80% | 5 |
| Total (highest score) | | | 32 |

from this analysis due to the small sample size. We determined size-class for 63% (763) of the observed crocodiles, classifying 27% (n = 327) as juveniles, 14% (n = 171) as hatchlings, 12% (n = 146) as sub-adults, and 10% (n = 119) as adults. The remaining 37% (n = 457) were categorized as eye-shine only (EO). Crocodiles displayed generally wary and skittish behavior. Estimating size was challenging when animals submerged from a distance or were hidden by dense vegetation. Crocodiles of all size-classes were observed in both natural and artificial habitats, but size-class distribution varied with habitat type ($\chi^2 = 0.23$, df = 3, $P < 0.001$; Table 2). Hatchlings and adults were more abundant in artificial habitats, whereas juveniles and sub-adults were more abundant in natural habitats. Most crocodiles were observed in sewage ponds (37%), mangrove swamps (27%), and rivers (21%).

Encounter rates were not correlated with salinity ($P = 0.310$) or water temperature ($P = 0.760$). Mean salinity was 13.1 ± 14.74 ppt (range of values, 0–49.9 ppt; n = 85), with 60% of non-hatchling crocodiles

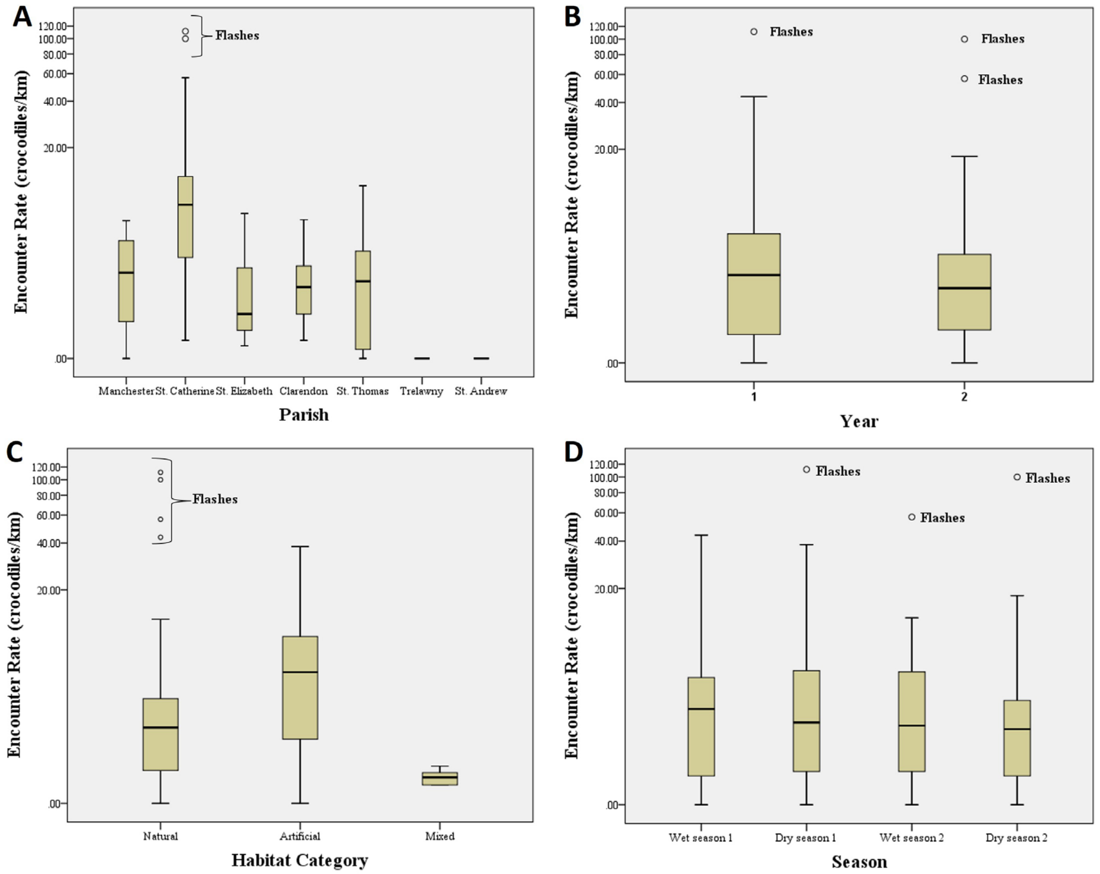


**FIGURE 2**. Median encounter rates (crocodiles/km) of the American Crocodile *(Crocodylus acutus)* by: (A) parish; (B) year; (C) habitat category: and (D) season. Boxes are the interquartile range (25th-75th percentiles), the horizontal line within each box indicates the median, and whiskers extend to the range of the non-outlier values. Outliers are represented by open circles and labelled by survey site. Note that the y-axis uses a non-continuous scale (axis break) to display extreme values.

occurring in habitats with salinity between 0–20 ppt, 28% in 20–40 ppt, and 4.7% in > 40 ppt. Water temperature ranged from 23°–33.4° C. We found significant differences in environmental variables between size classes for salinity, water temperature, and air temperature (Table 3). Juveniles were found in significantly more saline environments (17.70 ± 13.93 ppt) than all other size classes: hatchlings (4.95 ± 12.99 ppt), sub-adults (11.62 ± 13.84 ppt) and adults (8.16 ± 12.88 ppt). Among all size classes, we observed hatchlings in the least saline habitats.

**TABLE 2**. Size-class distribution for the American Crocodile (*Crocodylus acutus*) across natural and artificial habitats in Jamaica.

| Size-class category | Natural habitat (n = 692) | Artificial habitat (n = 528) | Total (n = 1,220) |
|---|---|---|---|
| Hatchling/Class I | 67 | 104 | 171 |
| Juvenile/Class II | 218 | 109 | 327 |
| Sub-adult/Class III | 82 | 64 | 146 |
| Adult/Class IV | 51 | 68 | 119 |
| Eyeshine only (EO) | 274 | 183 | 457 |

***Nesting activity***.—Twenty-three nests were recorded at 13 sites across four south coast parishes and one north coast parish (Fig. 3). The single north coast record confirms crocodile presence in that region, where no crocodiles were observed during eyeshine surveys. Nesting occurred within the reported nesting season of February-June, and hole nests were the only type recorded. Nests were found in both natural and artificial habitats: 35% along shoreline beaches; 30% on sewage pond banks; 13% along canal banks; 13% along riverbanks; 3% on roadsides; and 3% on a farm. All nests were located near a water body. Marl (sewage pond, roadside, river; 44%) was the dominant substrate, followed by sand (shoreline beach; 39%) and peat (canal

**Table 3**. Size-class distribution for the American Crocodile *(Crocodylus acutus)* observed by mean ± standard deviation (n, range) of environmental variables.

| Environmental variables | Hatchlings | Juveniles | Sub-adults | Adults | Statistical tests |
|---|---|---|---|---|---|
| Water temperature (°C) | 26.50 ± 2.16 | 27.21 ± 2.28 | 27.11 ± 2.4 | 26.61 ±1.96 | $H$ = 12.67, df = 3, |
| | (92, 23–32) | (239, 23–32) | (80, 23–32) | (57, 23–32) | $P$ < 0.001 |
| Air temperature (°C) | 27.36 ± 1.79 | 27.43 ± 1.67 | 26.97 ± 1.78 | 26.90 ± 1.62 | $H$ = 9.67, df = 3, |
| | (144, 24–31.8) | (322, 23–30.9) | (138, 23–31.8) | (118, 20–30) | $P$ = 0.020 |
| Salinity | 4.95 ± 12.99 | 17.70 ± 13.93 | 11.62 ± 13.84 | 8.16 ± 12.88 | $H$ = 78.74, df = 3 |
| | (79, 0–50) | (231, 0–51) | (85, 0–51) | (58, 0–36) | $P$ < 0 .001 |

and farm; 17%). Multiple nests were recorded at the Hellshire and Greater Portmore sewage ponds, Amity Hall, Font Hill 2, and South Holland, with the Hellshire sewage pond site being reused annually throughout the sampling period. Female crocodiles with hatchlings were observed on four occasions in a small pond (Oyster Bay), a river (Longville Farm), and sewage pond (Hellshire and Greater Portmore). All nests, except for Salt River, were identified by an open cavity with eggshells. Nest success was difficult to determine, as there were no visible signs of nest failure or predation. Hatchlings were observed in water bodies near 10 nesting sites, aligning with the nesting period. There were 23 cases where hatchlings were recorded during eyeshine surveys, though the location of the nests could not be determined. Hatchlings were observed all year-round across six habitat types, along the habitat fringe (88.1%), in mangrove roots (4%), or in open water (7.9%). The number of hatchlings per survey ranged from one to 31 individuals.

***Habitat analysis***.—We reviewed 28 documents from 1983 to 2022, and of these, four were peer-reviewed journal articles, and the remaining documents were unpublished data classified as technical reports (n = 21), proceedings (n = 1) and management plans (n = 2). We also reviewed the NEPA Wildlife incident database and the island-wide survey data including nesting data. We extracted and compiled 1,974 geolocations. The EOO, based on the Minimum Convex Polygon (MCP), covered an area of 2,716.7 km$^2$, representing approximately 24.7% of the land area of Jamaica. The EOO encompassed all 14 parishes and included scattered geolocations far inland, with the majority of occurrences clustered

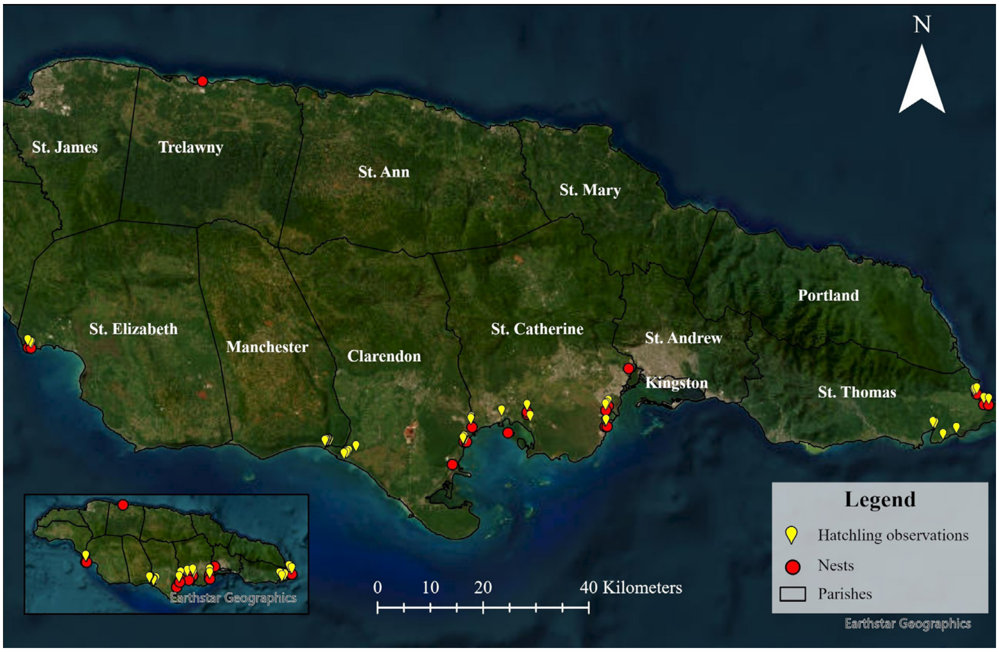


**Figure 3**. Location of nesting areas and hatchling observations of American Crocodiles (*Crocodylus acutus*) from 2020–2022 island-wide across Jamaica. Observations recorded in five parishes along south coast and one parish along north coast. (Map created using ArcGIS software by Esri).

along coastal wetland areas and in and around water channels extending inland. We found crocodiles in 17 land cover categories (based on the 2013 redefined land cover classification) across all parishes except St. Ann on the north coast. Crocodile presence was confirmed on two offshore cays, collectively known as the Goat Islands, located off the coast of St. Catherine Parish. The range of *C. acutus* was concentrated along the south coast, representing 98.2% of the geolocation data, with the highest occurrences recorded in the parishes of St. Catherine (n = 1,047), St. Elizabeth (n = 252), and Clarendon (n = 238).

We analyzed 213 geolocations for the pre-2013 period. The dominant habitat types (> 10%) included a Field category (herbaceous crops, fallow, cultivated vegetables), Buildings and Other Infrastructures, Mangrove Forest, Plantation (tree crops, shrub crops, sugar cane, banana), and Herbaceous Wetland. For the post-2013 period, we found 1,760 geolocations in the dominant land cover categories of Buildings and Other Infrastructures, Mangrove Forest, and Herbaceous Wetland, in addition to Water Body. Overall, the highest percentage of crocodiles was found in human-disturbed landscapes (Buildings and Other Infrastructures; 29.63%), followed by Mangrove Forest (21.04%), Herbaceous Wetland (14.82%), and Water Body (13.60%; Fig. 4, Table 4). We found differences in the landscape indices between the 1998 and 2013 land cover data with eight new categories in the 2013 classification: Secondary Forest; Fields (pasture, human disturbed, grassland); Quarry; Fields (bare land); and four Hardwood Plantation categories (eucalyptus, mahoe, mahogany, and mixed). The 2013 Secondary Forest category incorporates 75% of the 1998 Fields and Secondary Forest category and 75% of the Bamboo and Secondary Forest category. (Forestry Department 2015). The 1998 Water Body category included only lakes, excluding other wetland systems, leading to underrepresentation in the pre-2013 results. This category had one of the highest values in the 2013 datasets, which provided a more accurate identification of water bodies. According to the EUBSP Mangrove Assessment Verification Report (Forestry Department, unpubl. data), Mangrove Forests comprised 1.3% of the total land cover of Jamaica. Crocodiles were present in 27 of the 109 defined mangrove areas, representing 68% of the total mangrove land cover. Crocodile geolocations occurred across 21 natural protected areas, including three Protected Areas, two Marine Parks, one Environmental Protection Area, and 15 Game Reserves/Sanctuaries. Ten of the Game Reserves overlapped with other protected areas.

***Crocodile conservation units (CCUs)***.—We identified seven CCUs covering an area of 1274.4 km$^2$ (26.5% of the EOO), with all CCUs overlapping with sections of the EOO. Of the total CCU area, 556 km$^2$ (43.5%) fell outside the EOO boundary. This discrepancy was primarily due to the EOO being clipped to the coastline of Jamaica, whereas some CCUs extended into adjacent marine environments, including bays and nearshore areas. The CCUs did not include all crocodile geolocations, but only those located in areas identified as most important for the long-term conservation of the species. We evaluated each CCU against seven key habitat variables based on our criteria (Table 5), and all seven contained wetland habitats and were located along the south coast, spanning St. Thomas, St. Andrew, Kingston, St. Catherine, Clarendon, Manchester, and St. Elizabeth parishes (Fig. 5). The CCUs included 69.1% of the Mangrove Forests on the island, representing 45 of the 109 defined mangrove areas, and 214.94 km$^2$ (16.8%) of disturbed areas (infrastructure, quarry, bauxite extraction). Of the total CCU area, 81.2% fell under national protection, comprising 15 natural protected areas (three Protected Areas and 12 Game Reserves/Sanctuaries).

The Portland Bight CCU ranked first overall, having the largest total area and mangrove habitat, the highest number of geolocations, the greatest number of population studies (42 of 85 studies), and the highest number of reported nests (32 of 61 nests). Holland Bay-Pera and Bowden Bay, which ranked second and fifth, respectively, had no disturbed areas. Bowden Bay was the smallest and the only CCU to have no nesting reports. This CCU, along with Font Hill, contained no protected areas. The Black River CCU, ranked second, was the only CCU established from an existing protected area boundary (Table 5).

## Discussion

***Population ecology***.—Crocodiles in Jamaica are still present in habitats where they have historically been found, primarily along the south coast. Although we did not find crocodiles during eyeshine surveys on the north coast, a single nest recorded in that region confirms their presence and suggests that crocodiles may occur at low densities, consistent with earlier reports describing this subpopulation as small (NEPA 2008; Mazzotti et al. 2012). Despite

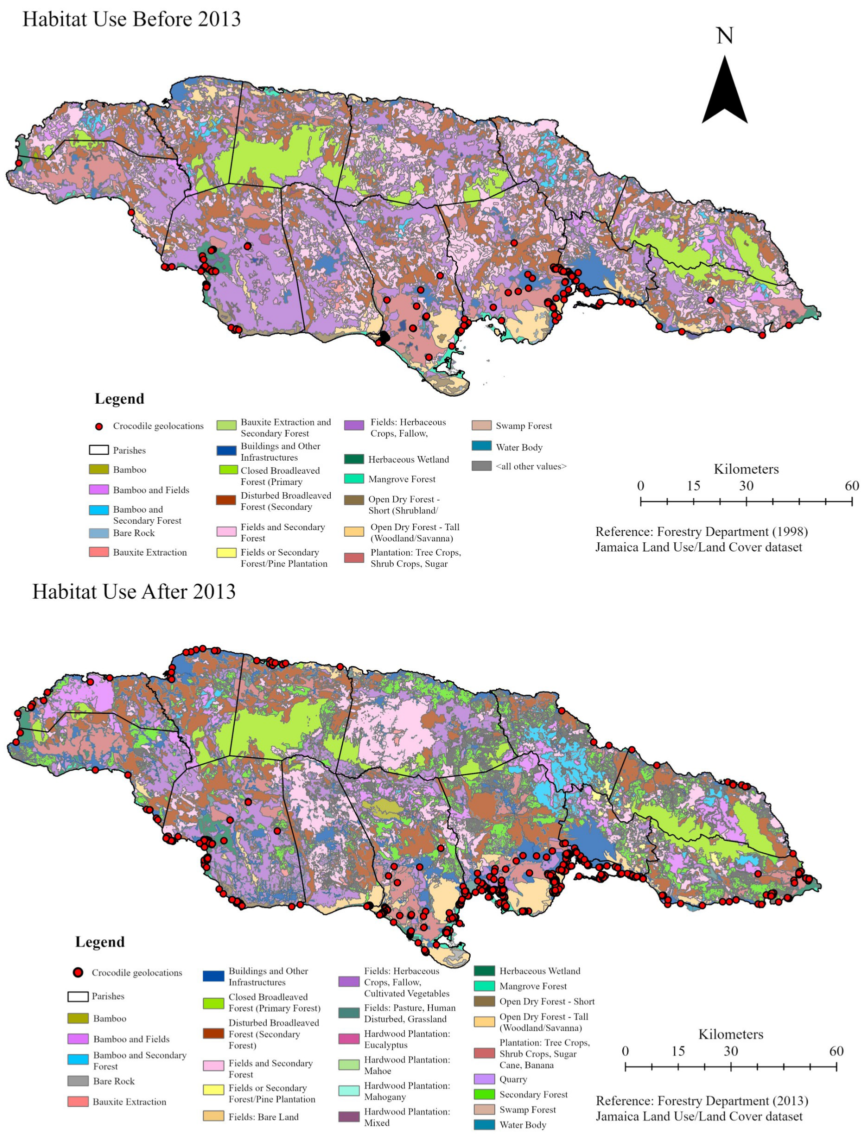


**Figure 4**. Geolocations of the American Crocodile *(Crocodylus acutus)* for the pre-2013 period overlaid on the 1998 land cover classification and post-2013 period overlaid on the 2013 land cover classification. (Map created using ArcGIS software by Esri)**.**

threats such as illegal hunting and habitat destruction, which have worsened in recent decades (Wilson 2011; Mazzotti et al. 2012; Beauchamp 2019; NEPA 2020a), *C. acutus* continues to occupy a range of habitat types. The overall encounter rate across all survey sites was 2.5 crocodiles/km, with the highest encounter rates recorded in Mangrove Swamps (80.4 crocodiles/km) and sewage ponds (18.5 crocodiles/km). These findings are in line with Beauchamp et al. (2019), who demonstrated crocodile preference for wetland forests (referred to as Mangrove Swamps). One such site, the Flashes, exhibited the highest encounter rate (80.4 crocodiles/km) reported for the species in the literature to date, and corroborated Kelly (2007) survey results. In our surveys juveniles were frequently observed along the periphery of this swamp, where their eyeshine created a visual effect resembling city lights. According to the population model of Messel (1982), originally developed for Saltwater Crocodiles (*C. porosus)*, large juveniles and sub-adults may aggregate in shallow or marginal habitats to avoid territorial conflicts with dominant adults. With the exception of the Flashes, encounter rates for *C. acutus* in Jamaica are similar to those reported in other countries, such as Belize and Costa Rica (Platt and Thorbjarnarson 2000b; Platt et al. 2004; Escobedo-Galván 2005; Rainwater and Platt 2009; Mauger et al. 2012). There was some variation

**Table 4**. Land-cover categories in which crocodile geolocations were recorded for the pre-2013 and post-2013 periods. Values of 0.00 indicate that no geolocations were recorded for that habitat type during that period. Cells marked with a dash (–) indicate that the category did not exist in that dataset. The symbol % = percentage of area of geolocations.

| | Pre 2013 | Post 2013 | Pre 2013 | Post 2013 | All records | |
|---|---|---|---|---|---|---|
| | Area (km$^2$) | % | Area (km$^2$) | % | Area (km$^2$) | % |
| Bare Rock | – | – | 0.00 | 0.41 | 0.00 | 0.33 |
| Bauxite Extraction | – | – | 0.00 | 0.10 | 0.00 | 0.08 |
| Buildings and Other Infrastructures | 0.01 | 24.53 | 0.07 | 30.95 | 0.09 | 29.63 |
| Disturbed Broadleaf Forest | – | – | 0.00 | 0.03 | 0.00 | 0.03 |
| Fields and Bamboo | – | – | 0.00 | 0.14 | 0.00 | 0.11 |
| Fields and Secondary Forest | 0.00 | 2.12 | 0.01 | 2.88 | 0.01 | 2.72 |
| Fields: Bare Land | – | – | 0.00 | 0.37 | 0.00 | 0.29 |
| Fields: Herbaceous Crops, Fallow, Cultivated Vegetables | 0.01 | 25.33 | 0.01 | 4.74 | 0.03 | 8.97 |
| Fields: Pasture, Human Disturbed, Grassland | – | – | 0.00 | 0.14 | 0.00 | 0.11 |
| Herbaceous Wetlands | 0.01 | 10.28 | 0.04 | 16.00 | 0.04 | 14.82 |
| Mangrove Forest | 0.01 | 17.47 | 0.05 | 21.97 | 0.06 | 21.04 |
| Open Dry Forest–Tall | 0.00 | 2.02 | 0.01 | 2.49 | 0.01 | 2.39 |
| Plantation: Tree Crops, Shrub Crops, Sugar Cane, Banana | 0.01 | 12.19 | 0.00 | 1.22 | 0.01 | 3.47 |
| Quarry | – | – | 0.00 | 0.14 | 0.00 | 0.11 |
| Secondary Forest | – | – | 0.01 | 2.44 | 0.01 | 1.94 |
| Secondary Forest and Fields | 0.00 | 0.53 | – | – | 0.00 | 0.11 |
| Swamp Forest | 0.00 | 0.64 | 0.00 | 0.14 | 0.00 | 0.24 |
| Water Body | 0.00 | 4.89 | 0.04 | 15.85 | 0.04 | 13.60 |
| Total | 0.06 | | 0.23 | | 0.29 | |

**Table 5**. Crocodile Conservation Unit criteria calculations for the American Crocodile (*Crocodylus acutus*) in Jamaica. Population size is an estimate and Habitat quality is the percentage of human landscape.

| Name | Area (km$^2$) | Rank | Population size | Population studies | Habitat quality | Mangrove areas (%) | Nesting habitat | Illegal hunting | Protected areas (%) |
|---|---|---|---|---|---|---|---|---|---|
| Portland Bight | 898.03 | 1 | 1,227 | 42 | 7.20 | 6.38 | 32 | Yes | 95.47 |
| Holland Bay-Pera | 29.35 | 2 | 67 | 7 | 0.00 | 47.78 | 9 | Yes | 79.52 |
| Font Hill | 5.51 | 3 | 140 | 7 | 0.05 | 38.23 | 13 | Yes | 0 |
| Milk River-Canoe Valley | 13.79 | 3 | 146 | 5 | 0.83 | 27.41 | 3 | Yes | 73.02 |
| Black River Lower Morass | 204.82 | 4 | 92 | 14 | 5.31 | 6.84 | 1 | Yes | 100 |
| Bowden Bay | 0.92 | 5 | 51 | 3 | 0.00 | 54.98 | 0 | Yes | 0 |
| Ferry-Palisadoes | 121.99 | 6 | 137 | 7 | 26.09 | 5.55 | 3 | Yes | 41.39 |

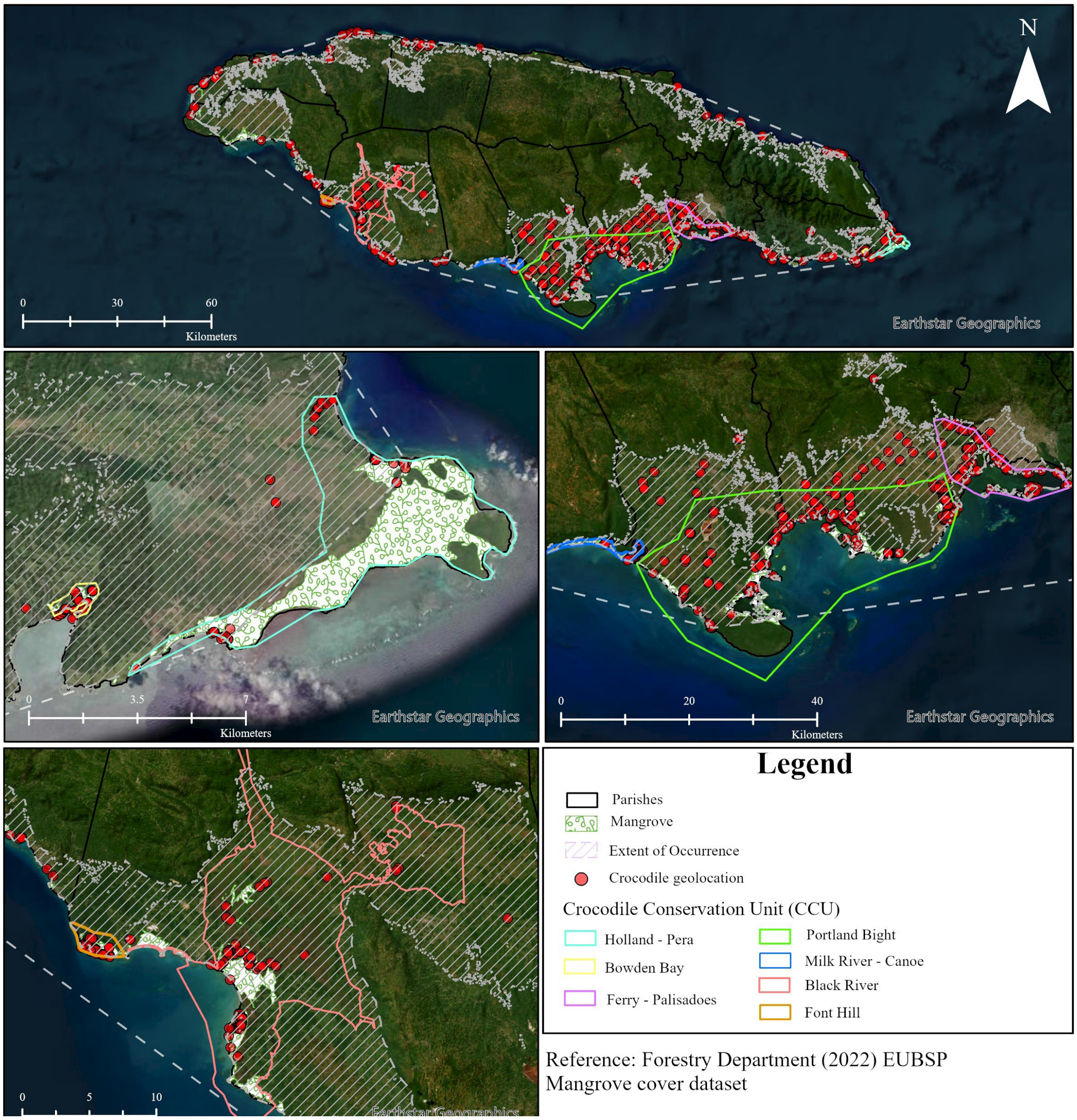


**Figure 5.** Crocodile Conservation Units (CCUs) defined for Jamaica. The CCU boundaries are represented by different colors. Distribution of crocodile geolocations and mangrove cover in relation to the CCU boundaries are shown. Extent of occurrence (EOO) based on a Minimum Convex Polygon (MCP). (Map created using ArcGIS software by Esri).

among habitat types, and for coastline habitat, low encounter rates were common (Martinez-Ibarra et al. 1997; Cherkiss et al. 2011). High encounter rates in sewage ponds are not unique to Jamaica, as similar findings have been reported from Ambergris Caye, Belize (Marisa Tellez, pers. comm.).

*Crocodylus acutus* in Jamaica inhabit a wide range of habitats, occupying both natural and artificial wetlands. Crocodiles were observed in mangrove swamps, rivers, canals, aquaculture ponds and, notably, sewage treatment facilities. Thorbjarnarson (1989) reported that the species can adapt to artificial habitats, and our results strongly support this. In fact, artificial habitats exhibited significantly higher encounter rates (mean rank = 60.12) than natural habitats (mean rank = 45.14), contradicting historical accounts that emphasized the presence of the species in natural wetlands along the south coast (Kelly 2007; NEPA 2008; Mazzotti et al. 2012; Leslie Garrick, unpubl. report). The three sewage treatment facilities exhibited high encounter rates (9.8 to 18.5 crocodiles/km); however, we caution that these results may be affected by detectability bias due to reduced vegetation cover, open water conditions, and altered crocodile behavior. Crocodiles in sewage ponds were less wary and more exposed, making them easier to detect. These sites supported all size classes, successful nesting, and were part of a larger and diverse wetland network in the parish of St. Catherine, which also recorded the highest number of reported human-crocodile interactions (NEPA Wildlife Database; NEPA, unpubl. data). The Portmore area, within this parish, illustrates the adaptability of *C. acutus* to urbanization. Despite extensive wetland loss since the 1960s, crocodiles use the intricate canal system to move between sewage ponds, natural wetlands like the Flashes and Great Salt Pond, and the coastline.

Literature on crocodiles in artificial wetlands is limited, but existing studies suggest that such habitats can provide protection from wind and wave exposure, nesting sites, and abundant food during prolonged dry seasons (Gaby et al. 1985; Cerrato 1991). In Jamaica, prey availability in sewage ponds appears limited to wading birds or fish entering during floods, and individuals likely move between wetlands to meet foraging needs (pers. obs.). Use of these sites reflects a trade-off between sheltered habitats and resource abundance, especially in anthropogenic landscapes (Mauger et al. 2012). Additionally, we think that crocodiles use sewage ponds as a refuge from illegal hunting, which is reportedly rare at these facilities. Even during construction work at the Greater Portmore facility (2019–2022), crocodiles remained in the area and recolonized the ponds once construction was completed (NEPA Wildlife Database; NEPA, unpubl. data; pers. obs.). Crocodile presence in sewage ponds may also be influenced by the nutrient-rich waters, discarded food waste, and the presence of domestic animals, often released or dumped by residents, although such practices are declining with improved enforcement (pers. obs.).

Population trends over time could not be determined because most earlier studies did not use standardized survey methods. Encounter rates observed in natural habitats, such as Black River, Holland Bay (North and South), and Salt Island Creek, were < 2 crocodiles/km. These results contribute new baseline data for survey sites previously studied in Jamaica (Kelly 2007; NEPA 2008; Mazzotti et al. 2012). Evaluating population trends requires further investigation using standardized survey methods over multiple years. The *C. acutus* size-class structure we observed was similar to that reported by Kelly (2007) and others (Cherkiss et al. 2011; Hilevski and Velasco 2020), with most observations consisting of juveniles and hatchlings. Size estimates were obtained for 63% of individuals encountered, with larger crocodiles more likely to submerge at a distance or seek refuge in vegetation, behavior consistent with increased wariness in adult crocodiles (Lander 2003). Such behavior may result from negative experiences associated with habitat modification and hunting (Webb and Messel 1979; Espinal and Escobedo-Galván 2011). Black River and sewage pond facilities harbored some of the largest crocodiles observed. In Black River, adults appeared to dominate the main channel and were frequently observed beneath active bird rookeries along the mangrove fringe, taking advantage of opportunistic foraging (Thorbjarnarson 1989; Nell and Frederick 2015). The largest known wild crocodile found in Jamaica (4.17 m TL; known as Terrorist) was observed in Black River during the study period and was reportedly caught illegally and killed in 2022 (Joseph Swaby, pers. comm.).

The presence of crocodile hatchlings and yearlings at multiple locations confirms successful reproduction and recruitment across both natural and artificial habitats. Freshwater and low salinity sites, including rivers and sewage ponds, were important nursery habitats, providing shelter in the form of reeds, algae mats, and mangrove prop roots. Although sewage ponds often lack dense vegetation, extended maternal presence may offer compensatory protection (pers. obs.). Environmental conditions fell within the range reported for this species (Mazzotti 1983; Thorbjarnarson 1989). We did not find a correlation between encounter rates and salinity or water temperature in natural habitats. The average salinity varied by size class, with hatchlings found in low salinity areas (mean = 4.95 ppt), conditions that support early-stage survival (Mazzotti 1983; Thorbjarnarson 1989), while juveniles and sub-adults occupied more brackish or more saline waters (mean = 17.70 ppt and 11.62 ppt, respectively). These results support the hypothesis of size-class segregation by salinity (Gaby et al. 1985).

***Nesting activity***.—Our findings confirm that *C. acutus* continues to nest at historical sites along the south coast of Jamaica. Nesting activity occurred in both artificial and natural habitats, highlighting the ability of the species to adapt to human disturbances. With coastal development reducing the availability of secluded sandy beaches, crocodiles are utilizing artificial habitats for nesting. Similar trends have been reported in Florida by Mazzotti et al. (2022), where nesting activity has expanded onto banks and levees of canals and ditches. Nesting activity was characterized by hole nests near water bodies along beaches, roadside, farmland, and the banks of sewage ponds, canals, and rivers. Most nests occurred along the south coast, including one on the offshore Little Goat Island, where hatchlings were observed in shallow seawater. One nest was confirmed in the north coast parish of Trelawny. Locating nests was a challenge, and we often relied on reports and observations during population surveys. Nest predation was not directly observed, but *Herpestes auropunctatus*, previously identified by Leslie Garrick (unpubl. report) as a nest predator, remains a threat (Damion Whyte, pers. comm.). Illegal egg harvesting was also reported (NEPA Wildlife Database; NEPA, unpubl. data; Lawrence Henriques, pers. comm.).

The varied distribution of nests may represent a bet-hedging strategy, where female crocodiles collectively increase reproductive success by nesting in multiple habitat types across the range of the species to buffer against different environmental conditions (Hairston and Fox 2013; Mazzotti et al. 2022). Incubation conditions varied between sites. In natural habitats, such as beaches, nests were resistant to flooding but vulnerable to desiccation, whereas nests in marl substrate offered the reverse problem (Mazzotti et al. 1988, 2022; Mazzotti 1989). Beach nests may also be more exposed to wave action, wind, and hypersalinity (Mazzotti et al. 2022), while artificial sites face more human disturbances due to surrounding development and human activity.

Parental behavior was observed during nesting. There were two cases of females visiting nests consistently during incubation (Devante Cooper, Damion Whyte, and Charles Moodie, pers. comm.). Tail drags, excavated nests, eggshells, and hatchling presence confirmed females transporting hatchlings to a water source. Defensive nest behavior, although previously documented (NEPA Wildlife Database; NEPA, unpubl. data), was not observed during the study period, consistent with other reports from Florida (USA) and Haiti where nest defense is rare (Ogden 1978; Thorbjarnarson 1988; Charruau and Hénaut 2012; Balaguera-Reina et al. 2015b). Non-aggressive behavior may reflect an adaptive response to increasing human presence near nesting sites. Nonetheless, human-crocodile conflict continues to occur. A hotel in Trelawny requested that hatchlings and a female crocodile be relocated due to guest safety concerns, despite the animal being over a kilometer away from the buildings. A similar case occurred on a farm in Clarendon, where fear amongst staff prompted calls for the removal of crocodiles from a river on the property (NEPA Wildlife Database; NEPA, unpubl. data; pers. obs.).

Artificial habitats supported repeated nesting. At the Hellshire sewage ponds, 31 hatchlings were observed during a single survey. Females at these sites were frequently observed near hatchling pods. We often encountered solitary hatchlings, though, in Mangrove Swamps, rivers, and canals, which may indicate that maternal care is limited for extended periods (Thorbjarnarson 1988; Kushlan and Mazzotti 1989; Platt and Thorbjarnarson 2000a; Charruau and Hénaut 2012) or that early hatchling dispersal can occur when habitats adjacent to the nest are unsuitable, such as areas exposed to wave action or hypersaline conditions (Ogden 1978; Mazzotti 1983; Thorbjarnarson 1989).

***Habitat analysis***.—Our study presents the first comprehensive habitat analysis of *C. acutus* conducted in Jamaica. Over an 18-y period (2004–2022), crocodiles were recorded in all parishes except St. Ann; however, in 2023, the relocation of an adult male from a coastal residential area in St. Ann confirmed the presence of *C. acutus* in all 14 parishes. The species demonstrated the ability to extend its range inland, with confirmed records up to 20.8 km from the coastline and at elevations of 104 m. The majority of observations (98.2%) were concentrated on the south coast, while north coast populations only began appearing after 2013. The increase in observations over time may reflect improved public reporting, local crocodile population growth, or greater human-crocodile interactions where natural habitat has been reduced. Frequent encounters in human-impacted landscapes mirror regional trends (Balaguera-Reina et al. 2015a) and highlight the ability of the species to utilize disturbed locations, often near human habitation, where they consume food waste and encounter prey (Thorbjarnarson 1989; Amarasinghe et al. 2015; Pooley 2016; Pooley et al. 2017; Sandoval-Hernández et al. 2022). Another contributing factor may be the loss of natural habitat, as human-impacted land use increased by 60% between 1998 and 2013 (Forestry Department 2015). Mangrove forests, herbaceous wetlands, and water bodies made up the other main habitats for *C. acutus*, although given that 2013 is the most recent land cover dataset, future studies should reassess habitat use with updated land cover data to determine whether these patterns persist.

We identified seven CCUs along the south coast, spanning 1274.4 $km^2$ and covering 26.5% of the species EOO. These CCUs include key habitats, such as coastal wetlands, rivers, canals, artificial ponds (sewage and aquaculture) and offshore cays. Approximately 81.2% of the CCU area overlaps with existing protected areas, a relatively high value compared to similar studies (Thorbjarnarson et al. 2006; Rodriquez-Cordero et al. 2019). We did not identify any CCUs on the north coast, where crocodile populations appear small and scattered, and suitable habitat is limited.

Several CCUs align with zones previously recommended for habitat/species management areas (West Harbor to Cockpit Salt Marsh, Amity Hall to Cabarita, the Black River Morass including Parottee, Font Hill, and Canoe Valley) by Kelly (2007) and identified under the three CCUs (Portland Bight Protected Area, Manatee River [Milk River], and Black River) by Thorbjarnarson et al. (2006). These areas continue to represent conservation priorities for *C. acutus*. The largest CCUs, Ferry-Palisadoes, Portland Bight, and Black River, have the highest levels of human disturbance, with diverse land uses, while the smaller CCUs, Holland Bay-Pera, Bowden Bay, Milk River-Canoe Valley, and Font Hill remain relatively undisturbed. The CCUs exist in isolation and maintaining ecological connectivity between them is important. Crocodiles can use the coastline, marine environments, and terrestrial landscapes as dispersal pathways (Clark and Sues 1989; Sandoval-Hernández et al. 2022).

***Conclusion***.—Our study provides the first island-wide assessment of *C. acutus* in Jamaica, confirming its widespread distribution across both natural and artificial habitats. Crocodiles are mainly concentrated along the south coast, with the highest encounter rates in sewage ponds, mangrove swamps, and rivers. The Flashes exhibited the highest encounter rate reported for *C. acutus* in the region. The size-class structure dominated by juveniles and hatchlings, with confirmed successful nesting in both natural and human-impacted landscapes, suggests ongoing reproductive success. We identified seven potential CCUs, covering 26.5% of the EOO of the species and encompassing a range of habitats essential to all life stages.

Despite a myriad of stressors, including illegal hunting and habitat loss, *C. acutus* populations continue to persist across much of their historical range, although localized declines may be occurring in some areas. Further research is needed to determine actual population trends. Tourism-driven coastal development has historically contributed to wetland loss in Jamaica, particularly on the north coast. With limited space remaining, development pressure is likely to shift towards the south coast, home to the largest remaining mangrove forests and crocodile populations in Jamaica. The construction of the first large-scale all-inclusive resort on the south coast in 2001 removed approximately 20 ha of pristine coastal wetland and requests for crocodile relocations from the area continue (NEPA Wildlife Database; NEPA, unpubl. data). Continued expansion of tourism infrastructure into this region will exacerbate habitat loss and human-wildlife conflict.

As large, charismatic predators, crocodiles have the potential to serve as flagship species for wetland conservation (Thorbjarnarson et al. 2006; Mazzotti et al. 2009). This is particularly relevant for the mangrove forests of Jamaica, the second most used habitat by crocodiles in this study, 69.1% of which falls within CCU boundaries. Adopting a flagship approach may help strengthen and diversify efforts to reduce further loss of this threatened habitat (Hamilton and Casey 2016; Thompson and Rog 2019). Achieving meaningful protection, however, will require addressing significant structural challenges. Many protected areas lack adequate funding, enforcement, and public engagement. Institutional barriers and ambiguous regulations further undermine effective conservation (Leverington et al. 2010; He and Cliquet 2020). Redefining protected areas under IUCN categories and legislating effective regulations are essential steps forward.

Our results underscore the resilience of *C. acutus* and its ability to adapt its feeding, mating, and nesting behavior to modified environments. While several studies have documented the ability of this species to persist in disturbed habitats (Gaby et al. 1985; Brandt et al. 1995; Espinal and Escobedo-Galván 2011; Mazzotti et al. 2022; Sandoval-Hernández et al. 2022), their use of artificial wetlands, particularly sewage ponds, remains understudied and warrants further research. As coastal development intensifies, human-crocodile interactions are likely to increase. The CCUs identified in our study represent high-priority habitats and should be integrated into national legislation to ensure the long-term conservation of *C. acutus* in Jamaica and its wetland ecosystems.

**Table 6**. Recommendations to improve American Crocodile (*Crocodylus acutus*) conservation and management in Jamaica. The actions are listed in no particular order.

| Recommendation | Description |
|---|---|
| Education and Community Engagement | Develop long-term public education programs to address misconceptions about crocodiles and promote safe coexistence. Target all demographics including fisherfolk who are frequently at risk due to unsafe fishing practices. |
| Community-based Warden Groups | Establish more game warden community groups to monitor crocodile activity, educate, foster local stewardship and provide livelihood opportunities. |
| Legislation and Enforcement | Strengthen enforcement of the recently amended Wild Life Protection Act, ensure on the ground routine monitoring and consider further revisions to explicitly prohibit feeding of wild crocodiles. Improve interagency coordination among NEPA, Jamaica Constabulary Force (JFC), Game Wardens, and environmental organizations. |
| Ecotourism | Establish responsible ecotourism ventures, such as crocodile river tours. Canoe Valley (Manchester), Cockpit Salt Marsh (Clarendon), Font Hill (St. Elizabeth), and Holland Bay (St. Thomas) have been recognized as potential sites. |
| Protected Area Management | Manage protected areas in accordance with IUCN guidelines, integrating CCUs into the national protected area system. Designate small, less-disturbed CCUs (Holland Bay-Pera, Bowden Bay, Milk River-Canoe Valley, and Font Hill) under IUCN Category IV (habitat/species management area) to protect and actively manage critical crocodile habitat. Larger, multi-use CCUs (Portland Bight, Ferry-Palisadoes, and Black River) can be placed under Category VI (protected areas with sustainable use of natural resources), and core wetland sub-zones established to receive the highest level of protection. |
| Research and Monitoring | Conduct further research on population size, nesting ecology, adaptation to artificial wetlands and spatial ecology. Develop a standardized, long-term population monitoring framework for Jamaica to support conservation priorities, and to ensure consistent data collection and analysis of population trends overtime. |

***Recommendations***.—To improve crocodile conservation and management in Jamaica, we recommend several priority actions (Table 6). These include strengthening education and community engagement, establishing more game warden groups, enhancing enforcement and legislative support, expanding eco-tourism opportunities, improving protected area management, and conducting further research needed to guide long-term conservation planning. These measures will help ensure the continued existence of crocodiles on the island.

*Acknowledgments*.—Funding and support for this research was provided by the National Environment and Planning Agency (NEPA)/Natural Resources Conservation Authority (NRCA) of the Government of Jamaica, the University of Florida Croc Docs, CrocFest, the University of the West Indies, and the Jamaica Conservation Partners Grant. This research was permitted by NEPA and approved by the Mona Ethics Committee of the University of West Indies. We thank everyone who participated in the surveys and provided information and other assistance: Damany Calder, Ricardo Miller, Monique Curtis, Justin Saunders, Lawrence Henriques, Jan Pauel, Byron Wilson, Joe Wasilewski, Joey Brown, Marisa Tellez, Damion Whyte, Savannah Boan, J. Charles Swaby, Eric Garraway, NEPA staff and Game Wardens, the Caribbean Coastal Area Management Foundation (C-CAM), Holland Bay Crocodile Sanctuary, Hope Zoo, Urban Development Corporation, Jamaica Swamp Safari, as well as volunteers, community members, and fishermen who assisted with boat transportation including Boat Captains: Charles Moodie, Lando James, Ralph Pusey, Earl Thompson, and Barrington Clarke. We appreciate the Urban Development Corporation (UDC), the National Water Commission (NWC), and the Central Wastewater Treatment Company (CWTC) for site access and the Forestry Department for providing land cover data.

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# Appendix

**Appendix Table**. Summary of non-hatchling American Crocodiles *(Crocodylus acutus)* observed during the sampling period from 2020–2022 in Jamaica. Encounter rate (number of crocodiles observed/km of survey route) was used as an index of relative abundance. The abbreviation N/V means a site not visited. Header abbreviations are HC = habiat category (Nat = natural, Art = artificial, Mix = mixed), TNER = Total of non-hatchlings encountered at site, TLSR = Total length of survey route (km), WS-20 = wet season 2020, DS-20 = dry season 2020-21, WS-21 = wet season 2021, DS-21 = dry season 2021-22, TER = total encounter rate.

| | | | | | | Crocodiles / km | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Survey site | Parish | HC | Habitat type | TNER | TLSR | WS-20 | DS-20 | WS-21 | DS-21 | TER |
| Alligator Hole River | Manchester | Nat | River | 18 | 6.4 | 3.1 | 6.3 | 1.9 | 0.0 | 2.8 |
| Amity Hall | St. Catherine | Art | Canal | 9 | 2.4 | 3.8 | N/V | N/V | N/V | 3.8 |
| Black River 1 | St. Elizabeth | Nat | River | 21 | 34.8 | 0.5 | 0.3 | 0.8 | 0.8 | 0.6 |
| Black River 2 | St. Elizabeth | Nat | River | 17 | 38.4 | 0.9 | 0.3 | 0.3 | 0.2 | 0.4 |
| Boggy Pond | Clarendon | Nat | Mangrove Swamp | 6 | 4.4 | 0.9 | 0.9 | 1.8 | 1.8 | 1.4 |
| Bowden Bay | St. Thomas | Nat | Bay/river/ Mangrove Swamp | 41 | 12.8 | 5.0 | 2.5 | 2.2 | 3.1 | 3.2 |
| Bowers River | St. Catherine | Nat | River | 8 | 2.4 | N/V | 3.3 | 3.3 | N/V | 3.3 |
| Braco | Trelawny | Nat | Mangrove swamp | 0 | 0.4 | 0.0 | N/V | N/V | N/V | 0.0 |
| Cockpit River | Clarendon | Nat | River | 9 | 7.2 | 2.8 | 0.6 | 0.6 | 1.1 | 1.3 |
| Coquar Bay | St. Catherine | Nat | Mangrove swamp | 9 | 1.1 | 8.2 | N/V | N/V | N/V | 8.2 |
| Dalvey | St. Thomas | Art | Canal | 0 | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Flashes | St. Catherine | Nat | Mangrove swamp | 193 | 2.4 | 43.5 | 111.3 | 56.5 | 100.0 | 80.4 |
| Font Hill 1 | St. Elizabeth | Nat | Mangrove swamp | 51 | 22.0 | 2.9 | 1.5 | 2.7 | 2.2 | 2.3 |
| Font Hill 2 | St. Elizabeth | Nat | Mangrove swamp | 69 | 16.4 | 4.1 | 7.1 | 3.7 | 2.0 | 4.2 |
| Great Pond Treasure Beach | St. Elizabeth | Nat | Pond | 1 | 1.7 | N/V | 0.6 | N/V | N/V | 0.6 |
| Great Salt Pond | St. Catherine | Nat | Coastal lagoon | 11 | 8.1 | N/V | 1.4 | N/V | N/V | 1.4 |
| Greater Portmore Sewage Pond | St. Catherine | Art | Sewage pond | 185 | 18.8 | 12.8 | 9.8 | 8.7 | 8.1 | 9.8 |
| Hellshire sewage ponds | St. Catherine | Art | Sewage pond | 37 | 2.0 | 12.0 | 38.0 | 6.0 | 18.0 | 18.5 |
| Longville fish farm | St. Catherine | Art | Fish pond | 29 | 8.0 | 3.5 | 4.0 | 5.5 | 1.5 | 3.6 |

**Appendix Table,** continued

| Survey site | Parish | HC | Habitat type | TNER | TLSR | Crocodiles/km WS-20 | DS-20 | WS-21 | DS-21 | TER |
|---|---|---|---|---|---|---|---|---|---|---|
| Manatee Bay | St. Catherine | Nat | Mangrove swamp | 5 | 0.4 | 12.8 | N/V | N/V | N/V | 12.8 |
| Martha Brae area | Trelawny | Nat | Pond/river | 0 | 1.4 | 0.0 | N/V | N/V | N/V | 0.0 |
| Milk River | Clarendon | Nat | River | 58 | 22.8 | 2.3 | 3.3 | 1.9 | 2.6 | 2.5 |
| North Holland | St. Thomas | Art | Canal | 12 | 6.4 | 0.6 | 0.0 | 2.5 | 4.4 | 1.9 |
| Oyster Bay | Trelawny | Nat | Mangrove swamp | 0 | 1.9 | N/V | N/V | 0.0 | N/V | 0.0 |
| Palisadoes AA | Kingston | Nat | Mangrove swamp | 0 | 0.5 | 0.0 | N/V | N/V | N/V | 0.0 |
| Palisadoes RJYC | Kingston | Nat | Mangrove Swamp | 0 | 2.4 | 0.0 | N/V | 0.0 | N/V | 0.0 |
| PBPA Coastline | St. Catherine | Mix | Coastline/ canal | 44 | 108.0 | 0.4 | 0.3 | 0.6 | 0.3 | 0.4 |
| Pera | St. Thomas | Nat | Mangrove swamp | 4 | 1.6 | 5.0 | 2.5 | 2.5 | 0.0 | 2.5 |
| Rio Minho | Clarendon | Nat | River | 5 | 1.9 | N/V | 2.6 | N/V | N/V | 2.6 |
| Rocky Point | St. Thomas | Nat | Mangrove swamp | 16 | 2.0 | 11.1 | 5.6 | 11.1 | 1.9 | 8.0 |
| Salt Island Creek | St. Catherine | Nat | River | 14 | 8.4 | 0.5 | 1.9 | 1.4 | 2.9 | 1.7 |
| Salt River | Clarendon | Nat | River | 15 | 3.3 | 3.6 | N/V | 6.4 | 3.6 | 4.5 |
| Soapberry Sewage plant | St. Catherine | Art | Sewage Pond | 120 | 12.4 | 6.1 | 11.0 | 12.9 | 8.7 | 9.7 |
| South Holland | St. Thomas | Mix | Mangrove swamp/ canal | 19 | 36.8 | 0.3 | 0.7 | 0.5 | 0.5 | 0.5 |
| West Harbor | Clarendon | | Mangrove swamp | 23 | 24.0 | 1.8 | 0.3 | 1.2 | 0.5 | 1.0 |