SRAS Final Report
Conservation of Crocodile Species in agro-pastoral dams in Benin

Akpénin Mariano J.E. Aloukpe
University of Abomey-Calavi, Zogbadjé, Abomey-Calavi, Benin (jeaneudesaloukpe@gmail.com)

Abstract

The study aimed to record agropastoral dams inhabited by crocodile species in Benin. It was conducted during the dry season (October to December) using direct and indirect observations and ethnozoological surveys. A distribution map was created based on GPS coordinates of crocodile presence/absence points. The study of biophysical and biochemical data, as well as parameters such as reservoir seasonality and bank type, allowed for the determination of the characteristics and typology of the water reservoirs. Analyses were then used to classify the agropastoral dams according to their features. Factors influencing crocodile abundance and distribution were identified through nocturnal counts. Threats and conflicts were determined through direct observations, supplemented by ethnozoological surveys conducted with 150 people. Of the 38 water points studied, crocodiles were found in only seven reservoirs (18.42%). Five crocodiles and their footprints were observed at the Doumé dam, and only the West African crocodile (*Crocodylus suchus*) was observed, with an average density of 0.98 crocodiles per hectare of reservoir surveyed. The local population estimates the average crocodile population at 27 individuals in Doumé (Savalou), 8 in Kaboua (Savè), and 5 in Kilibo (Ouèssè). Species are differentiated by snout shape (100%), size (30%), and color (63.33%). Two types of human-crocodile interactions were observed: peaceful cooperation and conflict. Threats to crocodile populations include the filling in of water reservoirs, water pollution from agricultural waste and pesticides, human activities around agropastoral dams, and poaching of crocodiles for their meat. It is essential to involve local communities in the design and implementation of action-research projects that benefit both humans and crocodiles to ensure the conservation of crocodiles in agropastoral dams.

Introduction

Crocodiles act as keystone species and often serve as indicators in monitoring and restoration programs for aquatic ecosystems (Fukuda et al., 2011; Fergusson, 2010; Mazzotti et al., 2007, 2009). The lack of knowledge regarding crocodile population dynamics and their ecology has enabled large-scale illegal exploitation of these animals across African countries. Of the seven African crocodile species, three are present in Benin. These include the West African crocodile (*Crocodylus suchus*), the dwarf crocodile (*Osteolaemus tetraspis*) and the African slender-snouted crocodile (*Mecistops cataphractus*). All three species are listed in Appendix I of CITES (fully protected animals), and their conservation statuses on the IUCN Red List (IUCN, 2017) are "Endangered", "Vulnerable", and "Critically Endangered", respectively. Although these crocodile species enjoy full protection under Beninese law, they are still heavily poached (Kpéra et al., 2011).

This study aimed to provide relevant ecological data and offer insights into the current situation of crocodiles, their ecological preferences, and the role played by hydro-agricultural infrastructures in their conservation. The general objective of this research was to evaluate the role of hydro-agricultural management schemes in the conservation of crocodile species within the Sudano-Guinean zone of Benin. Specifically, the study aims to: (1) determine the distribution, abundance, and population structure of crocodiles in hydro-agricultural management schemes in Benin, (2) identify factors that favor the presence of crocodiles in hydro-agricultural management schemes in Benin, (3) determine the threats and human-crocodile conflicts at the level of hydro-agricultural management schemes in Benin.

Materials and Methods

The study was carried out in seven (7) municipalities in southern Benin (Figure 1).

We systematically surveyed each of the hydro-agricultural management schemes (AHA) documented in the 2008 Hydrographic Atlas, which was updated on-site in collaboration with municipal technical services, Territorial Agricultural Development Agencies (ATDA), and local community surveys.

The presence of crocodile species was assessed using both direct and indirect observation methods. Direct observations were carried out using binoculars during the daytime (Adugna et al., 2017), while indirect observations relied on searching for presence indices such as feces, burrows, footprints, nesting sites, and vocalizations/signs (Shirley and Eaton, 2012). The standard method of nocturnal spotlight counting using high-brightness LED headlamps was deployed to detect crocodiles (Webb and Smith, 1987) to estimate abundance. Crocodiles present along the banks and in the water were systematically counted at each site, with species identified based on phenotypic characteristics. Surveyed surface areas were delineated via tracking with a GPS unit.

Counted individuals were grouped into four abundance categories adapted from Santiapillai and de Silva (2000) as follows:

- Probably Extinct: Crocodiles historically occurred in the environment but have vanished.
- Rare: < 10 crocodiles.
- Common: $10 - 30$ crocodiles.
- Abundant: > 30 crocodiles.

For *C. suchus* and *M. cataphractus*, population structures were categorized into age classes following Santiapillai and de Silva (2000), Kpéra (2002), and Yollou (2005):

- Size < 0.5 m = Hatchling
- Size 0.5 m $- 1$ m = Juvenile
- Size 1 m $- 2$ m = Subadult
- Size > 2 m = Adult.

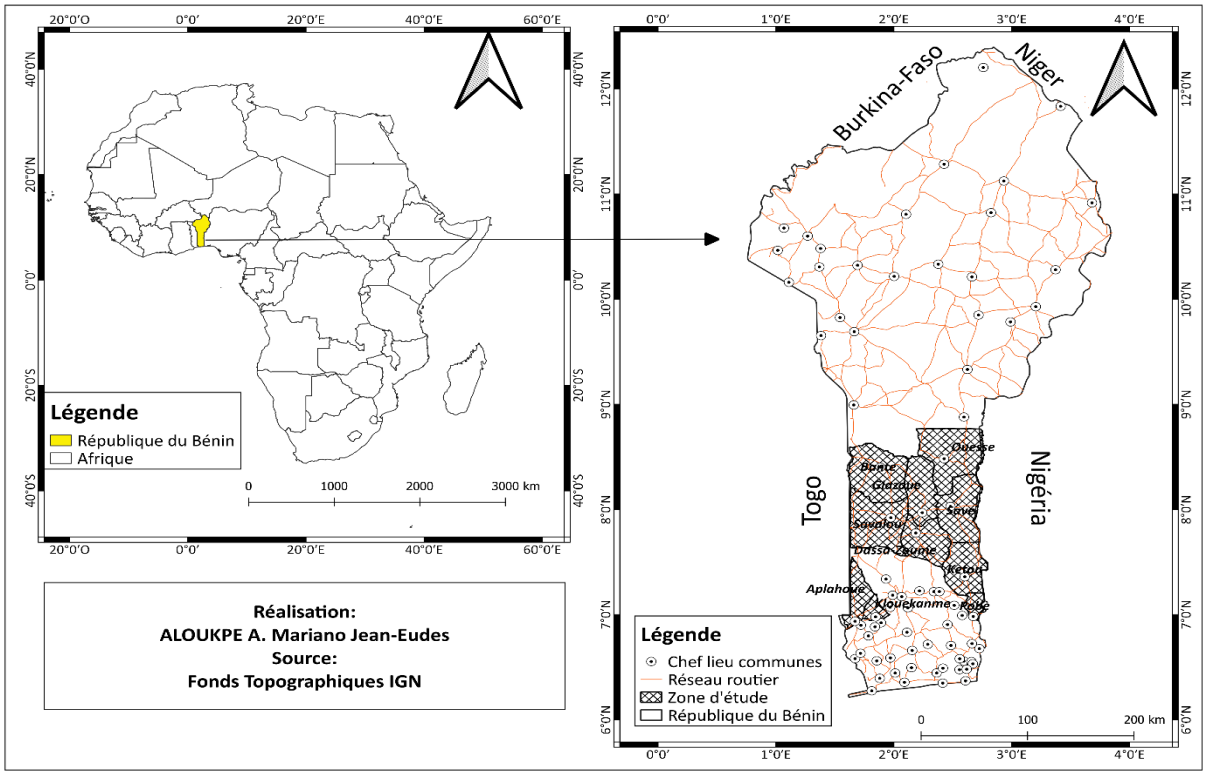


Figure 1. Geographical location of the municipalities of seven (07) municipalies in Southern Benin (Ouèssè, Bantè, Glazoué, Savè, Savalou, Dassa-Zoumé, Pobè, Kétou, Aplahoué, and Klouékanmé) (Produced by: ALOUKPE Mariano, 2020).

For dwarf crocodiles (*O. tetraspis*), the specific framework adopted by Hèdégbètan et al. (2015) was applied:

- Size < 0.5 m = Hatchling.
- Size $0.5 - 0.9$ m = Juvenile.
- Size $0.9 - 1.5$ m = Subadult.
- Size > 1.5 m = Adult.

Size estimation for crocodiles spotted out of the water was performed via direct observation. For individuals whose bodies were submerged, total length was estimated based on head length. A head-to-body length ratio of $1:7$ was assumed for *C. suchus*, and a ratio of $1:5$ or $1:5.5$ was applied for *M. cataphractus* (Shirley and Eaton, 2012).

Crocodile density (D, in crocodiles/ha), representing the total number of individuals (n) per unit surface area of the water body (S, in hectares), was calculated using counting data (Sai et al., 2016) via the formula:

$$D = \frac{n}{S}$$

The colonization rate (T) represents the percentage of water reservoirs harboring crocodiles (p) relative to the total number of surveyed water reservoirs (P). It was determined using the formula:

$$T = \frac{p}{P} \times 100$$

Biotic parameters (aquatic plant coverage rate, proportion of bank vegetation) and abiotic parameters (pH, temperature, turbidity) were measured to determine colonization factors and establish a reservoir typology integrated with socio-ecological surveys. Threat factors and conflicts were assessed at each site using ethnozoological interviews guided by questionnaires, alongside field observations. Direct field surveys focused on detecting indices like traps, resource extraction, and carcasses. Crocodile tolerance and disturbance levels were measured via flight distance (the distance at which a crocodile flees when encountered out of the water) and safety distance (the distance at which the animal halts after fleeing) (Tureau, 2018).

Results

Crocodile Habitat Characteristics

The Collines Department contained 84.21% of the inspected hydro-agricultural management schemes. Out of 34 functional management schemes, 32 maintained permanent water bodies with an average pH of 7.16 ± 0.06, an average temperature of $31.55°C \pm 0.37$, and water surfaces dominated by white water lilies (*Nymphaea alba*). These hydro-agricultural points were heavily utilized by local communities for drinking water, dishwashing, laundry, bathing, and livelihood activities such as market gardening, fishing, and livestock watering.

Crocodile Distribution

Ethnozoological surveys indicated crocodile presence across seven hydro-agricultural management schemes. *C. suchus* was the sole species physically encountered during field observations. However, respondents reported the presence of the *C. suchus* and *M. cataphractus* with citation frequencies of 56.67% and 20%, respectively.

Local identification criteria relied on snout shape (100%), size (30%), and skin color (63.33%). In contrast, *O. tetraspis* was not reported within these managed structures, despite being accurately described as a small-sized species by respondents. Diachronic distribution maps for 2020, 2015, 2010, and 2005 were compiled to trace spatial patterns (Figure 2). The global colonization rate was established at 18.42% across the 38 management schemes.

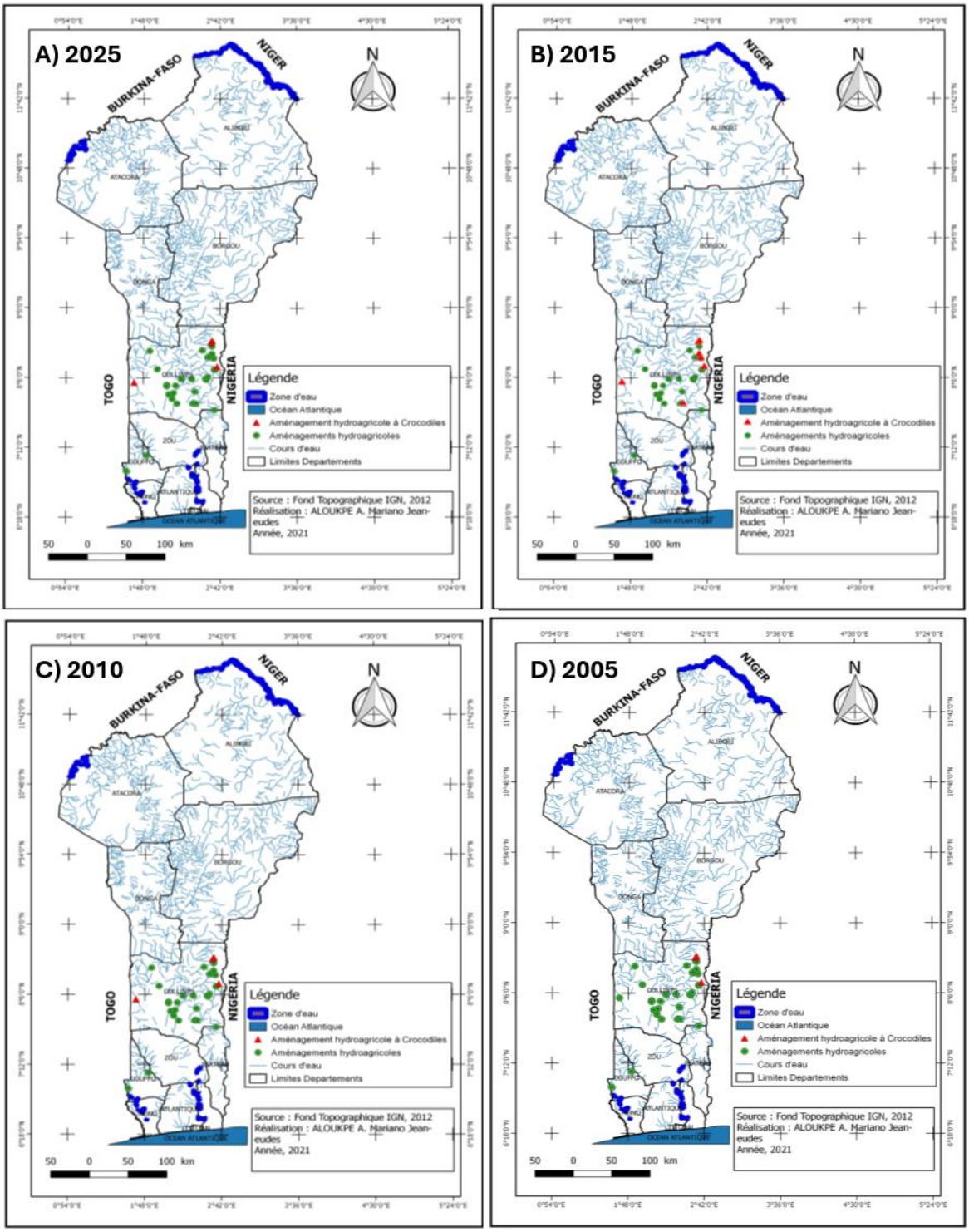


Figure 2. Spatialization of hydro-agricultural management schemes in the study area in A) 2025, B) 2015, C) 2010 and D) 2005.

Abundance and Density

In general, crocodile populations are rare throughout the study zone. Nocturnal surveys yielded a count of only 5 subadult crocodiles, exhibiting an average size of $1.5\ \text{m} \pm 0.1$, restricted entirely to the Doumé reservoir (Savalou). No individuals were detected during daytime counts. Approximately 77.33% of respondents reported a perceived decline in crocodile numbers across various management schemes, except for the Doumé reservoir, where an upward trend was noted. The direct ecological density calculated for the Doumé reservoir was 0.98 crocodiles/ha, whereas interview data suggested a higher relative local density estimate of 5.4 crocodiles/ha (Figure 3).

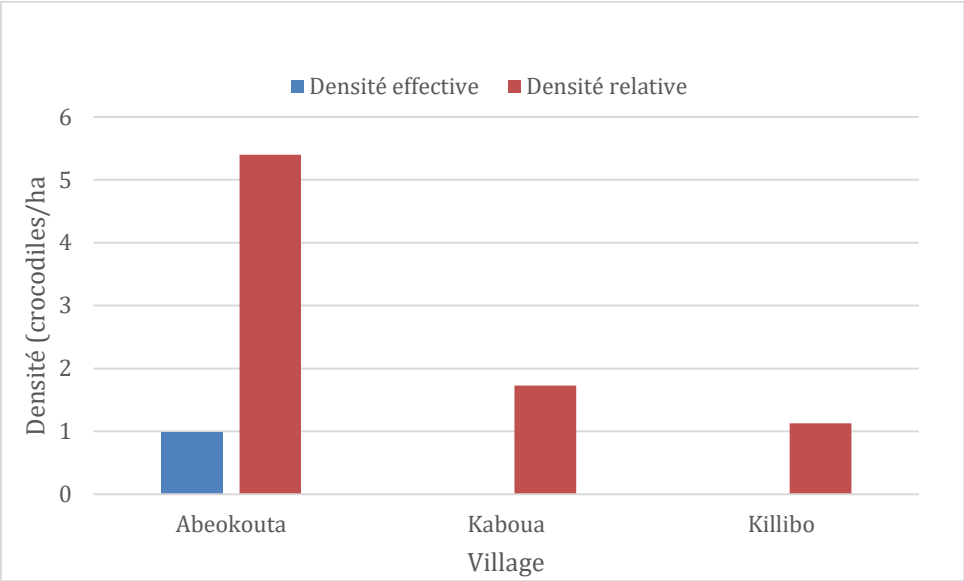


Figure 3. Crocodile density per hectare in each crocodile village.

Ecological Drivers and Typology of Reservoirs

Principal Component Analysis (PCA) was applied to model relationships between environmental parameters. The correlation circle (Figure 4) showed that Axis 1 explained 19.94% of the total variance and was heavily tied in its positive quadrant to water turbidity (Tu) and aquatic plant cover (Cpa). This axis reflects the **water quality** of the hydro-agricultural management schemes. Axis 2 accounted for 16.05% of the variance, illustrating an inverse relationship between reservoir surface area (S, positively correlated) and crocodile presence (Pc, negatively correlated). This axis represents **surface area and crocodile presence**. Axis 3 (not displayed) captured 13.08% of the variance.

The first factor plane explained only 49.066% of the total cumulative variance, which is statistically weak. This implies that field-measured biophysical descriptors alone cannot fully account for crocodile distribution. Hierarchical cluster analysis (Figure 5) categorized the water bodies into three clear groups based on field parameters:

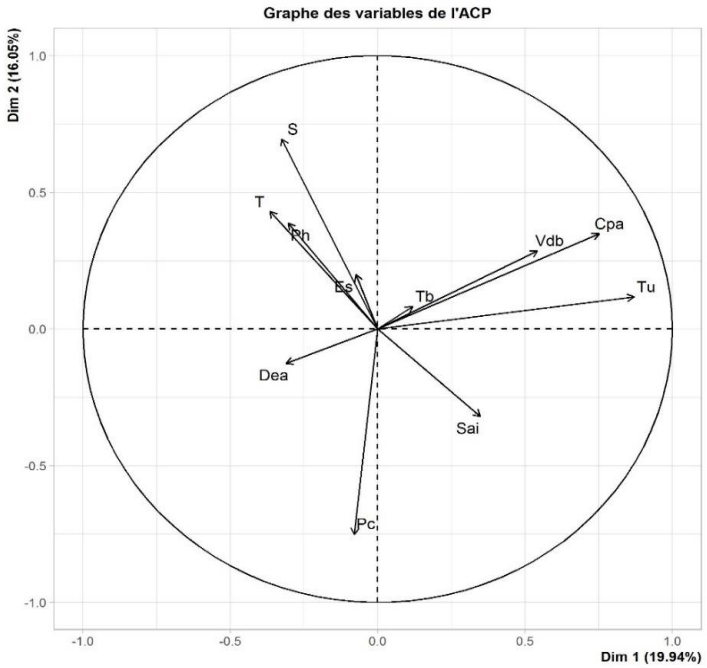


Figure 4. Factorial map of principal components.

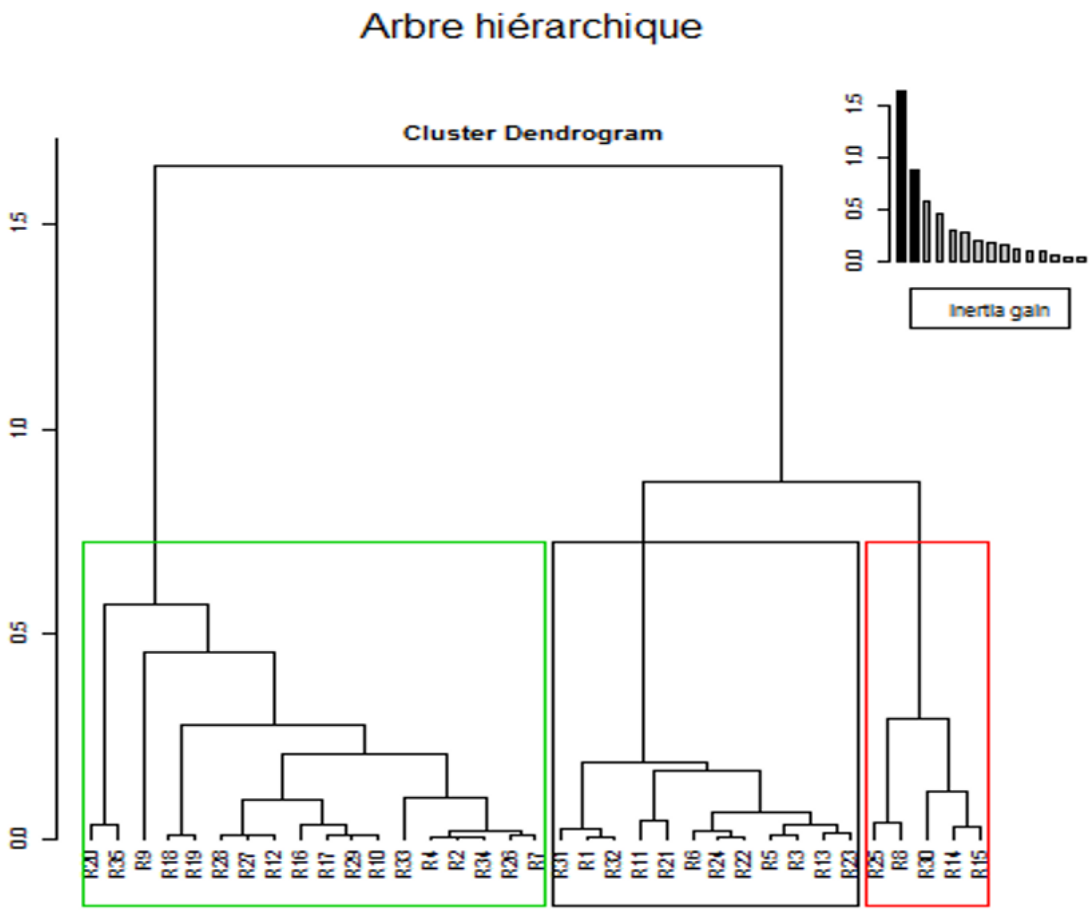


Figure 5. Hierarchical cluster tree of water reservoirs in the study zone. Group 1 (Green) comprises the largest number of schemes, both colonized and uncolonized. Characterized by high bank vegetation density, small surface areas, and short water-to-settlement distances. Group 2 (Black) includes permanent reservoirs that do not harbor any crocodiles. Characterized by clear water (low turbidity) and sparse aquatic plant cover. Group 3 (Red) exclusively consists of large-surface, permanent reservoirs colonized by crocodiles. Characterized by high water turbidity and dense aquatic plant cover.

Anthropogenic Threats and Human-Crocodile Conflicts

Despite the proximity of these managed water points to human households, crocodiles maintained total peace and solitude. Broadly, crocodiles did not cause injuries or damage to local populations. Every single respondent confirmed a peaceful cohabitation between human communities and local crocodiles, citing the following drivers: "Crocodiles are protected by the government; We do not eat this type of animal, and meat is rarely part of our standard meals; We are not traditional fishing communities, and we lack the specialized nets required to catch crocodiles; The crocodiles do not bother us."

The specific threat factors highlighted by local participants include poaching (16%), siltation and filling in of water points (98.67%), destructive agricultural practices near banks (79.33%), pollution from chemical inputs (40.67%), complete drying up of water points (34.67%), intensive livestock grazing (20.67%). These identified threats varied markedly depending on the specific locality.

Discussion

Crocodile Distribution and Ecology

The geographic allocation of water points and their seasonal hydrology heavily dictate crocodile presence across the landscape. Out of 38 reservoirs, seven (7) schemes were successfully colonized by crocodiles post-construction. This aligns with Bathiono (2007), who posits that crocodiles exploit nearly all forms of wetlands, rivers, tributaries, and natural pools. Artificial lakes and irrigation dams are frequently colonized following installation. Consequently, artificial depressions from sand mining, borrow pits from road construction, and roadside borrow-puddles serve as vital anthropogenic habitats (Kpéra, 2002).

The recorded colonization rate (18.42%) is vastly lower than the 88% reported by Kpéra (2008) in Northern Benin. Platt et al. (2006) and Cedeño-Vázquez et al. (2006) emphasize that crocodile establishment depends tightly on water permanence. This is supported by our findings, as local populations observe that these reptiles preferentially occupy large hydro-agricultural reservoirs that maintain permanent water volumes. During the dry season, low-water conditions force crocodiles to concentrate within these permanent bodies, drastically increasing localized densities and providing optimal conditions for population counts (Kpéra, 2002).

Local knowledge systems recognize three species based on snout morphology, total body size, and skin coloration, mirroring the ethnozoological classification documented by Kpéra (2002). The physical confirmation of *C. suchus* as the sole species observed reinforces its status as the dominant crocodile in West African wetlands, with historically strong representations across Benin (Kpéra, 2008; Yollou, 2005).

Conversely, the complete absence of *M. cataphractus* and *O. tetraspis* confirms their localized rarity. Ecologically, *M. cataphractus* requires dense gallery forest cover (Erard, 2003), while *O. tetraspis* is confined to marshy swamps—habitats fundamentally distinct from the open hydro-agricultural dams surveyed. Additionally, the competitive dominance and broad ecological preference of *C. suchus* may actively exclude *M. cataphractus* from these modified water structures (Shirley and Eaton, 2012). Since *M. cataphractus* is not strictly nocturnal, it should have been detected during daytime observations if present (Shirley and Eaton, 2012). Given that these two absent species are typically sympatric, it is reasonable to conclude they do not inhabit the immediate study zone (Kpéra, 2008).

The high frequency of *Nymphaea alba* provides structural benefits valued by crocodiles, as floating vegetation cools water temperatures, buffers oxygen levels via daytime photosynthesis, and offers vital camouflage against human disturbance (Leslie and Spotila, 2001).

The low absolute counts (only 5 subadults in Doumé compared to 132 individuals observed by Kpéra (2008) in the W Transboundary Biosphere Reserve) restrict deep statistical modeling of population dynamics. This deficit is likely caused by the intensive crypsis and camouflage behaviors used by young juveniles to evade apex predators. Multi-season, long-term studies spanning both wet and dry cycles are strongly recommended to refine demographic trends.

Conservation Status and Contemporary Threats

The presence of local taxonomies indicates a deeply rooted, long-term cohabitation. State protection via Law 87-014 is strongly supported by informal endogenous community protections. This dual institutional structure maintains excellent relations between humans and crocodiles. Crucially, zero crocodile attacks on humans were reported, contrasting sharply with Northern Benin, where Kpéra (2015) identified frequent attacks on people, livestock, and domestic dogs. Local communities access the banks daily without fear of wildlife conflict, confirming Mitchell's (2007) observations of low conflict in Gabon and findings in Burkina Faso detailing high crocodile docility around human settlements (Bathiono, 2007; Ouédraogo, 2020).

The primary hazards facing crocodiles stem from habitat degradation rather than direct exploitation (Garba, 2007). Severe siltation is structurally shrinking the holding capacity of these reservoirs. Without rapid management intervention and mechanical dredging, these vital permanent sanctuaries risk complete seasonal drying in the near future.

Globally, crocodile declines are heavily linked to expanding agricultural and anthropogenic activities (Fukuda et al., 2014; Botha et al., 2011; Treves et al., 2009). Encroaching agricultural fields utilize intense chemical fertilizers and synthetic pesticides right up to the water margins. While adult crocodilians tolerate moderate chemical bioaccumulation, their nesting substrates and porous eggshells are highly vulnerable to lethal chemical contamination (Chareau et al., 2013). This matches Treves et al. (2009), who demonstrated a negative correlation between market gardening and hatchling recruitment. Furthermore, the recent emergence of systemic pansteatitis in apex aquatic predators highlights their extreme vulnerability to intensive pesticide runoff (Du Preez et al., 2018). These upstream agricultural practices directly undermine juvenile survival, threatening the long-term demographic viability of the entire regional population.

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