

Does Crocodile Conservation Matter in Sacred Natural Sites of Benin (Western Africa)?

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Abstract

Crocodiles are protected species present in Sacred Natural Sites (SNS) in Benin. The impact of SNSs on the conservation of crocodylians in Benin were carried out by (i) assessing the extent to which anthropogenic activities affect crocodylians' population, and (ii) analysing the impact of social and religious changes for the conservation of crocodylians over a timescale. The characteristics of the crocodile population and habitats in 11 SNSs during daytime and night were also provided. Semi-structured interviews with 330 respondents were conducted and land use/land cover changes with 2000 and 2020 remote sensing data were analysed. The West Africa crocodile (*Crocodylus suchus*) was recorded in 81.8% SNS and consisted of 61.5% hatchlings, 15.6% juveniles, 11.85% subadults, and 11.1% adults (N= 135 crocodiles). With increasing degradation of natural ecosystems and increasing settlements/agricultural lands, there has been a significant decrease in crocodile abundance and extirpation (18.2% SNSs). Communities perceived crocodiles as sacred, a link with ancestors, the god of fertility, and a way to preserve water. Nevertheless, respondents also perceived the negative impact of introduced religions (70.9%) and no longer worshiped sacred crocodiles (52.7%) due to religious prohibition. Raising awareness, and participatory management of SNSs with the communities would help to mitigate the threats.

Keywords: Community-based conservation, Endogenous beliefs, Remote sensing, Sacred Natural Sites, Totems

Introduction

Seven crocodile species grouped in three genera (*Crocodylus*, *Osteolaemus*, and *Mecistops*) are found in Africa (Somaweera et al. 2020). They are subservient to aquatic ecosystems in protected and unprotected areas including sacred natural sites (SNSs) provided that the ecological parameters of the habitat are liveable (Aust et al. 2009). Carnivorous and greatly feared, badly perceived, and enduring negative media reporting when conflicts occur, crocodylians are responsible for more deaths than any other animal in Africa and human-crocodile conflicts are well documented (Chomba et al. 2012, Lamarque et al. 2009, Utete 2021). Promoting crocodile conservation within communities

is challenging and arguments are diverse including economic (product and by-product trade, ecotourism), ecological (maintaining the productivity and diversity of wetlands), cultural and intrinsic values (van der Ploeg et al. 2011). Conservation based on increasing awareness of economic values through direct exploitation is currently hardly conceivable in the wild. In general, crocodiles register a high mortality rate from egg to maturity as less than 1 % of crocodiles survive to adulthood (Adan 2000, Letnic 2004). In poor countries, ecotouristic importance increasingly put forward does not result in general as basic infrastructures lack. The ecological values claimed in many studies are not scientific evidence-based but speculative hypotheses (Somaweera et al. 2020). Cultural and intrinsic

values are therefore the avenues to explore for species conservation.

In many cultures, crocodiles represent divine creatures worshiped by communities in SNSs (Brackhane et al. 2019, Eniang et al. 2020, Rakotondrabe & Girard 2021). Thus, the impact of traditional beliefs for crocodile conservation is a new avenue for research. By assigning sacred status to crocodylians that cannot be threatened for spiritual purposes, communities have contributed to maintaining the species in a secured habitat and thus ensuring their survival for decades (Diawuo & Issifu 2015). The West African crocodile (*Crocodylus suchus*) is likely the most worshiped crocodylian in Africa (Pooley 2016) with a distribution range from Egypt, Ethiopia, Ghana, Benin to Burkina Faso (Arhin 2008, Bio Ouré et al. 2020, Hekkala et al. 2011, Hekkala et al. 2020, Kpéra et al. 2014, Ouedraogo et al. 2020). This conservation role of SNSs for the biodiversity explains the underlying cultural values that connect humans and nature (Caleb et al. 2020). Nevertheless, the small size of SNSs is a limiting factor for their effective conservation value (Avtzis et al. 2018). Most of them do not benefit from official recognition from the central government and are left to the sole efforts of communities.

In Benin, the inclusion of SNSs in the legislation of natural resources conservation has been observed (Inter-ministerial decree number 0121 of 16 November 2012 governing the sustainable management of sacred forests in Benin). However, effective measures fail to be implemented. Benin has widely distributed SNSs that account for important species like crocodiles (Agbo & Sokpon 1998). Traditionally managed through taboo systems by spiritual leaders, the SNSs were peaceful places for crocodylians where they could feed, grow and reproduce over a long period. Thus, their presence has been reported in SNSs in northern Benin where they coexist with communities of various socio-cultural groups including the Baatombu, Mokoles, and Boos who tolerated them (Kpéra 2002, Kpéra et al. 2012, Kpéra et al. 2014). Moreover, in Benin,

the assumption that "*ponds with crocodiles never dry up*", has favoured crocodiles to be regarded early as sacred in dry regions (Kpéra et al. 2014). However, while about twenty years ago, Kpéra (2002) mentioned the peaceful coexistence between communities and crocodylians in SNSs, the author's publication 10 years later reported threats to populations of sacred crocodylians (Kpéra et al. 2012). The situation seems to have subsequently worsened since, in 2020, two information reviews tackled the subject. Online newspapers published on www.agencebeninpresse.info by "Agence Benin Presse" dated 4 February 2020 titled "*The sacred caimans of Sinende threatened with extinction*" and another one published on www.laperchedunord.info by "La Perche du Nord" dated 3 February 2020 titled "*The last refuge of the sacred caimans of Sinende threatened*" mentioned that the sacred crocodiles of Sinende district were threatened and even extinct in some places. The use of "caiman" is a mistake of non-specialists as to date only crocodiles are recorded in Benin. This information has emphasized a scientific interest in SNSs in the context of important deforestation (rate: 3.10%) in northern Benin (Djaouga et al. 2021). Moreover, to better understanding the threats, habitat changes around the sacred crocodiles' refuges deserve to be analysed, for example, thanks to remote sensing data and the use of the Google earth engine (Djaouga et al. 2021, Rahmi et al. 2022).

Previous studies on crocodylians in SNSs addressed the way communities deal with their presence in agropastoral dams with a focus on ecosystem services and the interaction with stakeholders involved in the use of water resources (Kpéra 2002, 2015). Therefore, we still lack data on the species, their abundances, population trends, taboo systems, habitat dynamics, and threat factors of crocodylians in SNSs that can provide a baseline for conservation strategies and actions plan.

The study aims to provide insight into the impact (benefits/erosion) of SNSs on the conservation of crocodylians in Benin. Specifically, we aimed (i) to assess the extent

to which anthropogenic threats impact the crocodylians' population in the Beninese SNSs by analysing crocodylians' population status and mapping land use and land cover change around the SNS, and (ii) to analyse the impact of social and religious changes for the benefits of traditionally managed SNSs and the conservation of crocodylians over a timescale.

Conceptual Framework

Sacred natural sites and taboo systems

SNSs are expressions of traditional beliefs of communities consisting of important reservoirs and focal points of biodiversity, found in terrestrial or aquatic ecosystems and removed from everyday access and use (Dudley et al. 2009). They are all types of natural features (forests, rivers, etc.) from a small area (individual tree, animal) to whole landscapes (Hariraveendra et al. 2020, Rakotondrabe & Girard 2021, Verschuuren et al. 2010). Beliefs about SNSs are perpetuated by traditional ecological knowledge (TEK). TEK represents all types of experience, unique to an indigenous people of specific geographical areas, acquired over a long time of direct human contact with the environment (Usher 2000). In SNSs, the worship of ecosystem components has been a tradition of many world religions (Avtzis et al. 2018, Daye & Healey 2015, Mukul et al. 2012, Tiimub et al. 2020, Wild & McLeod 2008). Informal institutions ordinarily known as taboos prohibit the use of natural resources (Caillois 1959). They are unwritten codes that regulate human behaviour and social restriction applied by communities to control the depletion of common resources (Colding & Folke 1997). Taboos are the worldwide oldest measures by which nature is respected in its own right by mankind. In the current study, all the traditional resource management systems like totems, myths, and other norms were ascribed to taboos. Taboo systems are classified into (i) Segment, (ii) Temporal, (iii) Method, (iv) Life history, (v) Specific-species, and (vi) habitat taboos (Sharma et al. 2021). For instance, specific-species taboos comprise a total interdict of species as foods and other

plausible reasons at all times and space for all members of a human community (Coldin & Folke 1997). Then, taboos promote species population growth in their ecosystems.

In Benin, taboo systems vary depending on the regions; the north, the centre, and the south (Agbo & Sokpon 1998). Likewise, depending on the SNSs, the taboos are more or less strict, ranging from a total ban on resource exploitation (fetish forests) to partial (Cemetery forests). In addition to the other associated taboos, the animal and plant species that confer sacred status are immediately taboos.

Ostrom's theory of common-pool resource

SNSs are endogenous forms of conservation around the world (Dudley et al. 2009). Their use by communities is determined by the respect for the endogenous standards they have imposed on themselves for several generations. Thus, although SNSs are perceived as assets belonging to the whole community, their access and uses are regulated. SNSs are not open-access resources for communities. In general, they are managed by spiritual leaders based on a mode of governance well-known by the entire community. However, the communities surrounding each SNS share various forms of link which show the interdependence between the members. These characteristics of the SNSs make them a common-pool resource. The common-pool resource (CPR) alludes to a natural or man-made asset system that is large enough to make it expensive to keep out potential beneficiaries from getting benefits from its use (Ostrom 1990). Communities may be able to manage the non-private property efficiently by developing and enforcing stable systems of informal norms (Ostrom 2000). The theory underlying this study followed this logic. Scientific theory explains a phenomenon of interest to the researchers as results assist in making intelligent and practical decisions (Nachmias & Nachmias 2000). Therefore, the theoretical framework underpinning the study is Ostrom's (1990) theory of common-pool resource that advocates management by local actors through social norms and institutional

arrangements designed on eight principles namely:

1. *Clearly defined boundaries: Individuals or households who have rights to withdraw resource units from the CPR (SNS in this case) must be clearly defined, as must the boundaries of the CPR itself.*
2. *Congruence between appropriation and provision rules and local conditions: Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material and/or money.*
3. *Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying the operational rules.*
4. *Monitoring: Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.*
5. *Graduated sanctions: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.*
6. *Conflict-resolution mechanisms: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.*
7. *Minimal recognition of rights to organize: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.*
8. *For CPRs that fire parts of larger systems: Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.*

However, SNSs are being tested by the influence of development projects,

modernization, and changes in religious systems (Dudley et al. 2009, Malhotra et al. 2001, Rutte 2011). Therefore, are spiritual leaders able to respect/apply these eight principles and preserve the SNSs from these rapid changes? This study aims to determine to which extent changes in social and religious systems affect the governance of SNSs.

Materials and Methods

Study area

The study was held in seven districts (Ouassa-Péhunco, Banikoara, Nikki, Kalalé, Segbana, Kandi, and Sinendé) extended from 9°80 – 10°00N latitude and 1°20 – 3°80E longitude located in the eastern part of the Soudanian and northern Soudano-guinean zones in Benin (Fig.1) from December 2019 to August 2020 during rainy and dry seasons.

The area is characterized by 900 mm to 1150 mm of annual rainfall, 24.5°C – 33.5°C of temperature, and a dry tropical climate with a single six months dry season an average. The tropical ferruginous soils were the most widespread with a strong agricultural potential where the vegetation cover is mainly tree and shrub savanna (Adomou 2011). Waterways and gallery forests are habitats for crocodiles, the aquatic target species. All eleven SNSs were located at gallery forests, the current conditions of which have been assessed.

The population is dominated by Baatombu, Mokole, Boo, and Fulani socio-cultural groups unevenly distributed between the villages, and the main religions are Muslim followed by Christianity and animist (INSAE 2016a, 2016b).

Sampling

We prospected eleven SNSs having housed sacred crocodiles (Kpéra 2002) located in Ouassa-Pehunco, Banikoara, Nikki, Kalale, Segbana (1 SNS for each), Kandi (2 SNSs), and Sinende (4 SNSs). They consist of seven SNSs river sections (63.6 %), two natural ponds (18.2 %) and two agropastoral dams (18.2 %). The microhabitat specificities noted

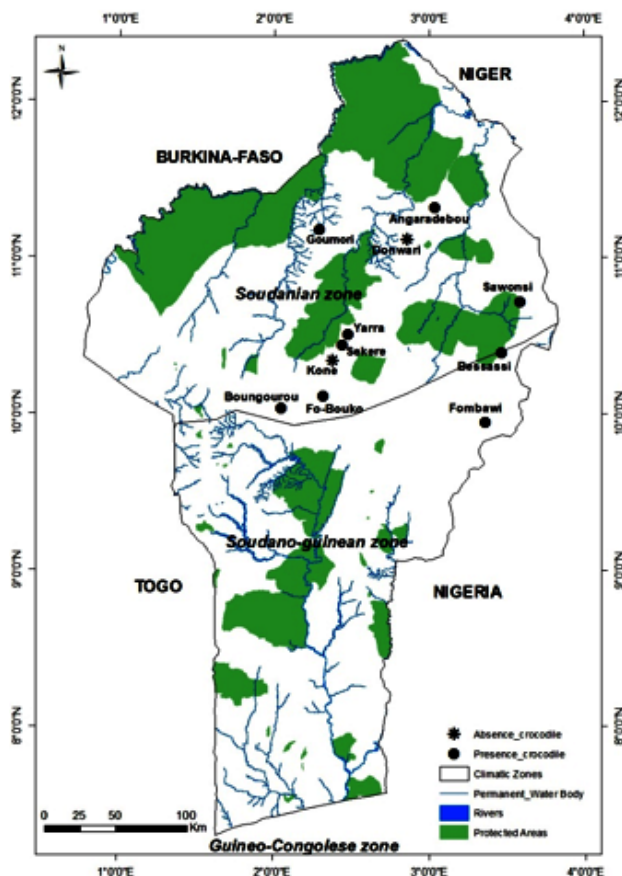


Figure 1 Map showing all the sacred natural sites sampled in this study where crocodiles were present or absent. A total of 11 sacred sites were sampled in 7 districts. The map was constructed in ArcGis 10.4.1

in the ecology of crocodiles relate to the type of water point, the seasonality, and the presence of rocky banks (table 1).

We conducted semi-structured interviews (Santos et al. 2020) with 330 respondents (30 per SNS) selected within the communities. The surveys in a given locality were carried out in the same period as the surveys at the associated SNS and were therefore spread over the dry season and the rainy season from

December 2019 to August 2020. We used snowball or chain referral sampling which is one of the most popular sampling methods in qualitative research. The technique is based on networking made among people who share or know of others who possess the characteristics of research interest (Biernacki & Waldorf 1981). This non-probabilistic technique is effective even if it is likely to present biases. Starting with an agreeable respondent, he was

TABLE 1

Number of crocodiles counted for two size classes during the night and the characteristics of their habitats

	Ang.	Donwari	Goumori	Sawonsi	Bessassi	Koné	Sekere	Fo-Bouko	Yarra	Fombawi	Boung.
hatchlings	0	0	0	15	21	0	35	0	12	0	0
non-hatchlings	6	0	9	17	13	0	34	5	14	7	7
d (m)	468	32	228	166	125	70	150	76	125	812	100
sites' similar characteristics	Presence of water points, settlements close to the site (<1km), crocodiles are the main species of the site and there sacred										
sites' dissimilar characteristics	River, temp.	Dam, temp.	River, temp.	River, temp.	river, rocky bank	Dam, temp., rocky bank	APD, perm.	River, temp.	River, temp.	APD, perm.	River, temp., rocky bank

Note: Temporary (Temp.), Permanent (Perm.), Angaradebou (Ang.), Boungourou (Boung.)

asked to suggest the following respondent that fit the research criteria. The latter was asked to recommend the following and so forth. The selection of respondents was based on (a) the willingness to participate and (b) being a resident of the village.

The questions were mainly related to the perception of respondents about the (1) sacred crocodile population size in 2000, 2010, and 2020; (2) sacred crocodile population trend, (3) main causes of the sacred crocodile population trend, (4) taboo systems, (5) reasons of crocodile worship, (6) benefit of the SNS, (7) impact of socio and religious changes for SNSs.

The "Executive Management of Water, Forests and hunting" of the "Ministry of living environment and sustainable development" granted permission to pursue this research (#N° 097/DGEFC/PF-CITES/SA in 2019 and #N°005/DGEFC/PF-CITES/SA in 2020). No biological material was collected. In each locality, before starting, we showed the authorization and explained the objectives of the research to the authorities and respondents. After recording the verbal consent of the voluntary respondents, we delivered the questionnaire individually in the local language or French.

Impact of anthropogenic threats on crocodylians

Current population status of crocodylians

We established crocodiles' population structure with daytime surveys on foot by the end of the dry season and the beginning of the first rains (Prasad et al., 2018). We classified the sightings as hatchling (total length TL \leq 40cm), juvenile (40cm \leq TL < 110cm), sub-adult (111cm < TL \leq 180cm), adults (TL > 180cm), and eyes only (EO, crocodiles that could not be classified because apart from the eyes, all their body was immersed (Balaguera-Reina et al. 2018, Saragih et al. 2020)). We established the encounter rate with night-time spotlight counts (Tellez et al. 2017). We spent all night and all day in each site during dry and rainy seasons then two days and two nights for

the prospection, not including the interviews. We recorded the crocodile population trend over the timescale of 2000-2010-2020 (mapped in ArcGis10.4), anthropogenic threats, and benefit/erosion of SNSs through ethnozoological surveys carried out using semi-structure questionnaire addressed to all the respondents. Ethnozoology which is a discipline using human communities' knowledge about animal species accumulated through oral traditions, deals with the animal richness that communities may use for beneficial purposes. Respondents classified the crocodylians population within Unknown, Extinct, rare (<10 non-hatchlings), common (between 10-30 non-hatchlings), and abundant (>30 non-hatchlings).

Land use and land cover changes around the SNSs

Each SNS' degradation was assessed by Land Use Land Cover (LULC) change analysis over a radius of 1 km between 2000 and 2020. This diachronic analysis required the planimetric data that are:

- the topographic background of the National Geographic Institute (IGN) of 2018;
- 30 m spatial resolution Landsat 2000 and 2020 images uploaded in GeoTIFF format to the earthexplorer.usgs.gov platform;
- and GPS survey data as ground control points.

The processing of satellite images was done with QGIS Remote sensing 2.18 software. A colour composition with Landsat 7 bands 4, 3, and 2 and Landsat 8 bands 5, 4, and 3 was used for vegetation analysis given its effectiveness. The Landsat 8 was launched on the 11th February 2013, so the combination with Landsat 7 launched on the 15th April 1999 was useful for the images from the year 2000. The comparison of the classifications made it possible to detect changes in the state of the vegetation. The superimposed classification based on the assumption that the spectral signature of each pixel is representative of the class of vegetation in

which it is found was used and all the pixels of each satellite image were classified according to the Random Forest algorithm which is a decision tree (Rahmi et al. 2022). The Gearthview extension of QGIS, the Google Earth Pro software, and the ground control points were also used for the evaluation of the quality of the classification (Guzman et al. 2022, Jonah Dias et al. 2022). After validation of the classification, ten land occupation units were retained (dense forest, gallery forests, open forest and woodland savannahs, tree and shrub savannahs, plantation, agricultural land, settlements, rocky ground, wasteland, and water body). The classified images were then vectorized to proceed with their layout.

The analysis of the changes in the state of the vegetation was made through the calculation of the evolution report of the units between 2000 and 2020 (Percentage unit of 2020 - Percentage unit of 2000). The areas of the vegetation classes were calculated by crossing the vegetation maps in 2000 and 2020 using the Groupstat function of the vector menu of the QGIS remote sensing 2.18 software.

Perception of communities on crocodile population trends over a timescale in SNSs

Factorial component analysis (FCA) in the FactoMineR package (Le et al. 2008) was used to reveal the link between the perception about crocodile population trends and the SNSs on the one hand (a) and between the perception about crocodile population trends and the main causes of the trend on the other hand (b).

Impact of social and religious changes on the benefits of SNSs and crocodiles' conservation

We recorded the perception of communities regarding the anthropogenic threats, importance of SNSs (spiritual, ecologic, touristic, economic, and renowned), and impact of the introduced religions (Christian and Islam) on sacred crocodylians. Additionally, we recorded the benefit/erosion of SNSs, taboo systems, and attitudes toward sacred crocodylians.

The Relative Frequency of citation (RFC) was used to point out the perception about

the benefit/erosion of traditionally managed SNSs for the conservation of crocodylians over a timescale. The keywords used were spiritual, economic, food products, by-product, touristic, and other [renown of the village, and ecologic (crocodile ponds did not dry-up, Specific-species taboos)]. The impact of introduced religions was also appreciated using the keywords Strong, Medium, Low, and Non-existent.

The RFC was calculated using the formula $RFC = FC / N$ where FC is the number of respondents mentioning a specific answer and N is the number of respondents participating in the survey (Vitalini et al. 2012). As for the Khi-sq independence test, it was used to reveal the link. Then, we classified the taboos recorded within the taboos systems (Sharma et al. 2021).

Results

Impact of anthropogenic threats on crocodylians

Current population status of crocodylians

Nine SNSs (81.8%) housed sacred crocodiles. Both hatchlings and non-hatchlings were recorded in 36.4% SNSs (table 1). The population structure of the West African crocodile -*Crocodylus suchus*-, the only species recorded, consisted of 61.5% hatchlings, 15.6% juveniles, 11.85% subadults, and 11.1% adults (total day counts = 135 crocodiles). Except the hatchlings, the proportions of the last three size classes are not significantly different (Khi-sq = 1.7885, df = 2, p-value = 0.4089). Depending on the season, the number of sightings varied both during the day (135 sightings in dry season to 19 sightings in rainy season, 85.9 % decrease) and the night (195 sightings to 24 sightings, 87.7 %). The SNS of Sekere was the most populated with 69 crocodile sightings over 195 total crocodile sightings (table 1). The sacred water points stretch over an average of 202.6 ± 70.9 m (table 1).

Land use and land cover changes around the SNS

A total of 10 LULC classes were recorded from the maps of the eleven SNSs (Bio Ouré_ Supplementary_ figure_ 1a, 1b, 1c, 1d). Four classes were missing or did not change namely Wastelands in 8 SNSs, dense forests in 9 SNSs, Water bodies in 10 SNSs, and Rocky ground in 11 SNSs during the dry season (table 2). On average, from 2000 to 2020, dense forests, open forest and woodland savannah, tree and shrub savannah, water bodies and gallery forests of the SNSs have decreased. Adversely, settlements, agricultural lands, plantations, and wasteland have increased (table 1). Additionally, water bodies were missing in

81.8% SNSs. Only the SNSs of Sekere and Fombawi were permanent because they were developed as agropastoral dams.

Perception of communities on crocodile population trends over a timescale in SNSs

We recorded the perceptions of men and women of 3 age categories (Youngs "<18 years", adults "18–60 years" and old people "> 60 years"). Respondents consisted of Muslims (74.9%), Christians (24.2%) and Animists (0.9%) of four ethnic groups including Baatombu (51.2%), Boo (25.8%), Fulani (13.9%) and Mokolé (9.1%). However, among Muslims and Christians, some respondents still resorted to animistic practices.

TABLE 2
Land Use Land Cover change between 2000 and 2020 around the eleven Sacred Natural Sites

	Ang.	Donwari	Goumori	Sawonsi	Bessassi	Koné	Sekere	Fo-Bouko	Yarra	Fombawi	Boung.	Average
DF	0	0	0	0	0	0	0	0	0	-6,42	-2,97	-0,9±2,1
GF	-8,2	-2,9	-13,4	-2,5	0,2	-1,4	-0,8	-3,75	-0,13	-1,03	-1,29	-3,2±4,1
OFWS	0	-6,5	0	-7,9	0	0	-1,7	-4,29	-0,17	-9,29	4,25	-2,3±4,1
TSS	-23,4	-4,0	-0,3	-50,7	-57,3	-0,5	0,01	-17,36	-1,49	-14,69	-34,71	-18,6±20,8
PL	-1,9	0	5,6	15,2	-1,6	2,2	3,77	0	29,71	6,03	-48,28	1,0±18,8
AL	30,1	-5,3	5,6	43,3	45,3	-8,4	-4,02	19,96	-3,12	22,39	82,42	20,7±28,2
SlT	3,2	18,6	2,4	2,6	11,8	8,1	0,22	5,43	-24,80	3,03	0,68	2,9±10,7
WL	0,3	0	0	0	1,6	0	0	0	0	0	0,12	0,2±0,5
WB	0	0	0	0	0	0	-0,4	0	0	0	0	-0,04±0,1
RG	0	0	0	0	0	0	0	0	0	0	0	0

Note: Dense forest (DF), Gallery Forest (FG), Open Forest and woodland savannah (OFWS), Tree and Shrub Savannah (TSS), plantation (PL), Agricultural land (AL), Settlements (SLT), Rocky ground (RG), Wasteland (WL) et Water bodies (WB) Angaradebou (Ang.), Boungourou (Boung.)

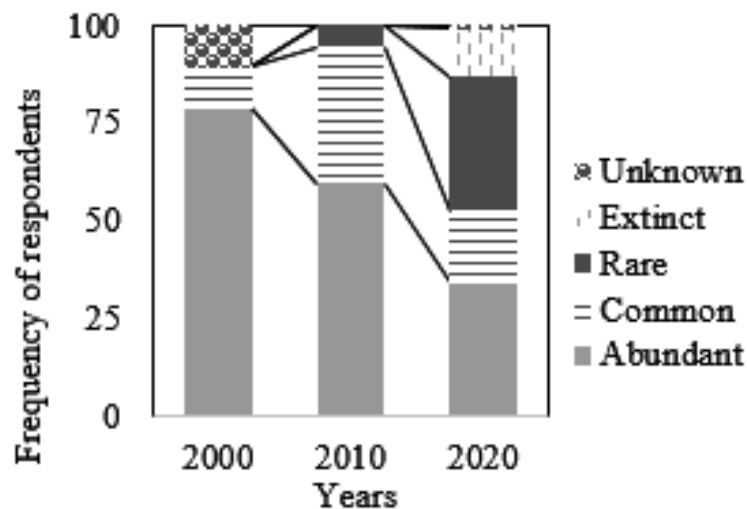
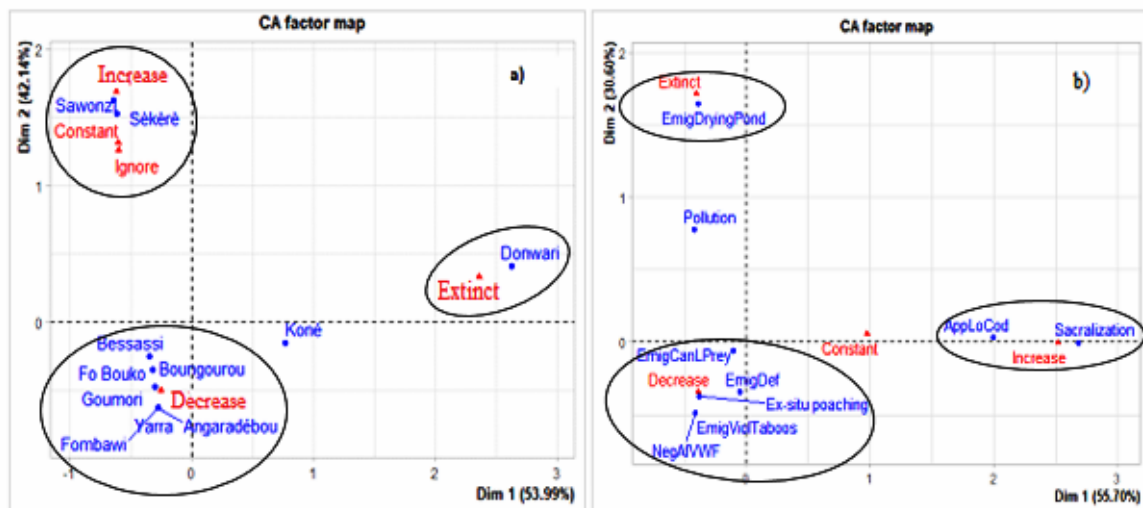


Figure 2 Respondents' perception of sacred crocodile population sizes in SNS



Emigration of crocodiles due to the drying up (EmigDryingPond), Emigration due to violation of taboos (EmigViolTaboos), Emigration due to deforestation (EmigDef), Emigration and cannibalism due to lack of prey (EmigCanLPrey), Pollution, Poaching occurred outside the SNSs (Ex-situ poaching), Application of local code sanctions (AppLoCod), Sacralization (Sacralization), Negligence of SNS after creation of village water facilities (NegAFVWF)

Figure 3 FCA biplot crocodile population trends and SNS (a) and their main causes (b)

Respondents perceived a significant decrease in sacred crocodylians' abundance from 2000 to 2020. Besides, crocodylians were extirpated in 2020 at Donwari and Kone, and the perception of "rare" increased up to 33.9 % in 2020 (Fig. 2).

Respondents perceived a decrease in crocodile population size in the majority of SNSs (Fig.3). The chi-sq test revealed a link between respondents' perception about population trends and the causes (DF= 48, Chi-sq= 615.45, p <0.001) plotted in Fig.3b. Poaching occurred outside the SNSs and emigration due to drying-up, deforestation and

lack of prey were the main causes of crocodile population size decline whereas application of local codes and respect of taboos favoured the increase of crocodile population (Fig. 3b). Only the SNS of Sekere had a written local code, the only copy of which available from the traditional chief could not be found. Apart from this written local code of the SNS of Sekere, none of the SNSs including Sekere have legal status as SNS. Also, none of the sites belong to a network like the Indigenous and Community Conserved Areas (ICCA) for example. Concerning conflicts, informal resolution methods are generally not applied.

TABLE 3

Classification of taboos recorded from respondents during ethnozoological survey within taboo systems

Taboos and beliefs on the SNSs	Taboo systems	SNSs
Prohibition on killing crocodiles	Specific-species taboos	All SNSs
Prohibition on killing some animal species	Specific-species taboos	All SNSs
Prohibition on cutting specific woody species	Specific-species taboos	Boungourou
Prohibition of fishing at specific periods of the year	Temporal taboo	Boungourou
Prohibition to cross the SNSs with a dead person	Segment taboo	Boungourou
Prohibition of accessing for menstruating women	Segment taboo	All SNS
Prohibition to use some equipment (metal)	Method taboo	Bessassi
Ban on communities from raising goats	Method taboo	Boungourou
Prohibition on selling fish caught (only consumption)	Method taboo	Yarra

Impact of social and religious changes for the benefits of SNS and crocodylians conservation

Reasons for crocodiles' worshipping

Behind the sacred, communities revered crocodiles for the underlying benefits gained when taboo systems were applied. Crocodiles were perceived as:

- An incarnation of the ancestors and a way to be connected to the ancestors,
- Mythical species having the power to ensure the protection of the village,
- Having the power to grant them favours,
- God of fertility and health especially witchcraft, craziness, and health crises,
- Having the power to ensure water sustainability in the SNSs and to remedy droughts,
- Taboo animals that cannot be injured, killed and eaten.

The RFC revealed that recorded benefits of SNSs were spiritual (100%), the renown of the village (46.7%), and ecologic (32.7%, crocodile ponds did not dry-up, Specific-species taboos) but not economic (0%) and almost touristic (1.2%).

Taboo systems and benefits for crocodile conservation

All the respondents and local laws mentioned only crocodiles within the sacred river or dams as sacred, but not outside. All respondents were aware of the SNS boundaries. However, these limits were not marked. The taboo systems summarized in the table 3 bring out the first principle of Ostrom's theory especially "Clearly defined boundaries" and is also related to the principle 2 of Ostrom's theory in the context of the current study by describing the traditional norms of resource access by community.

Traditional beliefs and practices within the social and religious groups

The RFC revealed that the negative impact of introduced religions was perceived as strong by 70.9% of respondents, medium by 11.2%, low by 16.7%, and non-existent by 1.2%. Of over 202 respondents who no longer resorted

to sacred crocodiles, the main cause was religious prohibition (86.1%).

Discussion

SNSs are common pool resources managed by informal norms and have been of interest for crocodile conservation in northern Benin. The survival of sacred crocodiles became challenging due to threats related to the direct impact on crocodile, their environment, and social and religious changes. Communities have failed to properly manage the SNSs because in general, the sanctions were no longer applied to those who violate the norms and communities were becoming Muslims and Christians.

Impact of anthropogenic threats on crocodylians in the Beninese SNS

The threats on sacred crocodiles are reported both outside the limits of SNS and inside the limits. The boundaries of the SNS continue to be reduced due to various degradations and require clear marking of the boundaries using concrete blocks and woody fences. This will already fulfill the first principle for the governance of CPR defined by Ostrom. However, while the clear demarcation of boundaries is quite fundamental, it is not a sufficient condition for the preservation of SNS and sacred crocodiles.

After Ostrom's first principle, the second part discussed the spatiotemporal variation of sacred crocodile populations with regard to natural but especially anthropogenic causes in relation to Ostrom's other principles. The crocodylian sightings showed seasonal variations, lower in the rainy season (Behangana et al. 2017). The variations depend on water level which can account for up to 61% (Calverley & Downs 2014) and the scattering of crocodiles in the rainy season when water levels rose and related streams filled. The results indicated that the dry season was more appropriate to approximate the effective population size of crocodiles in a given area.

By the end of the dry season, the presence of

a high proportion of hatchlings and juveniles in 45.5% SNSs is an indicator of a viable crocodylian population (Wallace *et al.* 2013). The absence of hatchlings and juveniles in low-populated SNSs (Angaradebou, Goumori, Koné, Fo-Bouko, Fombawi, Donwari) indicated that reproduction was no longer taking place and reflects the first level of threat. Additionally, respondents perceived a decrease in crocodiles' population sizes within almost all the SNSs (81.8%). Thus, these SNSs were no longer ideal refuges for the long-term survival of sacred crocodiles in the states they were in. Likewise, some of the SNSs where viable populations of crocodiles were recorded, were also facing a crocodile population decrease. The decrease and decline of the crocodile population happened as a result of mainly anthropogenic threats.

LULC changes analysis revealed that the SNSs have been degraded over timescale by the conversion of natural habitats like gallery forests, dense forests, Open Forest and woodland savannah, Tree and Shrub Savannah, and water bodies. The SNSs prospected were located in rural districts in northern Benin that had among a high rate of deforestation due to the high rate of human population growth that created increasing land demands for agriculture (cotton production) and settlements (Kouta & Toko Imorou 2019). During the dry season when herbaceous fodder is no longer available, herdsmen heavily exploit woody fodder. These repeated practices have likely contributed to accelerating the process of spatial change of forest ecosystems over time by disrupting the growth but also the reproductive capacity of targeted woody species. Regarding Bogaert *et al.* (2004), spatial changes recorded in natural ecosystem classes were mainly fragmentation, shrinking, perforation, and creation. The observed changes were the result of a regressive ecosystem process. Additionally, respondents mentioned some main threats including poaching occurred outside the SNSs, drying-up of water bodies, and lack of prey in the SNSs. The destruction of gallery forests has a negative impact on water bodies surrounded by creating filling up and unsuitable habitats

for aquatic animal species. The four SNSs with higher population sizes have permanent water bodies (Sèkèrè) or limited periods of dryness (Yarra, Bèssassi, Sawonzi).

Impact of social and religious changes on the benefits of SNS and crocodiles' conservation

In various African sociocultural groups, communities resort to crocodiles as sacred species. For example, among Zulu tribes in South Africa and Luhya tribes in Kenya, crocodiles are sacred animals that symbolize fierce fighter, human beings, and the incarnation of ancestors and to kill a crocodile is tantamount to killing a human member (Mandillah & Ekosse 2018). Similar beliefs are held in Okwa, Boki LGA, Ukwa, Odukpani LGA (Cross River state), and Amadung, Ikot Abasi LGA (Akwa Ibom state) of Nigeria (Eniang, *pers. obs.*, 2020). Communities resort to crocodiles within the study area for the same reasons. Beyond this spiritual importance for communities, these taboos and prohibitions play a fundamental conservation role, especially for species such as crocodiles whose products and by-products are of interest. But the original reasons which conditioned the sacralisation of species or their habitats were above all of spiritual order and not any direct desire for the conservation of species (Jimoh *et al.* 2012). Thus, conservation strategies for SNSs should include the preservation of the beliefs that carry them. Likewise, any practice of any kind that weakens this spiritual bond undermines this effective strategy of endogenous conservation.

The link between the increase in crocodile populations and the application of local code sanctions is an illustration of this. The fifth principle of Ostrom's theory recommends sanctions proportional to the seriousness of the violation committed (Ostrom, 1990). The traditional leaders who should ensure the application of sanctions have increasingly little influence due to the introduced religions which are taking over. Implicitly, conflict resolution is also compromised. Threats linked to illegal crocodile harvesting have been reported at all sites. But, the application of sanctions

has generally not been reported except for a single case at the Sekere SNS alone. Those responsible for the SNS should find the mechanism for a proportional application of the sanctions provided in order to deter those in violation. But, the rules should already be established and adopted for example in a local code written in a participatory manner then supervised in application (Principle 2, 3 and 4). These principles are already lacking in almost all SNSs. Another level of conflict in the SNS other than that described by Ostrom (1990) opposes in the present case the resource itself (sacred crocodiles) to the local populations. It will be necessary to further research on human-crocodile conflicts in SNS in order to propose efficient mechanisms for their management.

The specific-species taboos centred on crocodiles was a taboo system common to all the SNSs that particularly protected the species. But in addition, other taboo systems like the prohibition on cutting woody species helped to conserve the entire ecosystem of the SNSs. These beneficial conservation practices were being phased out due to the conversion of communities to introduced religions that demonize endogenous beliefs and threaten the effectiveness of taboos as a conservation tool (Adu-Gyamfi 2011, Alohu et al. 2016, Jimoh et al. 2012, Van der Ploeg et al. 2011). Directly or indirectly, the introduced religions followers have encouraged the violation of social norms grouped within Ostrom's eight principles that contribute to SNSs conservation. Over eleven SNSs prospected, crocodiles were extinct in two SNSs and their populations were decreasing in the remaining ones. Then, SNSs are becoming vulnerable like what is observed around the world (Alohou et al. 2019, Wild & McLeod 2008). One of the urgent measures would be to include the SNSs in a protected area system such as ICCA for international legal recognition.

Ostrom (1990) points out that the governance of common goods is all the more effective when these goods belong to a larger system. The involvement of other institutions at higher levels could help improve the management

of sacred forests. For example, the inclusion of these sacred forests in the ICCA database will allow their wider recognition. Thus, local communities will have to submit to both local and general regulations. Local regulations continue to be transmitted orally from one generation to another across all SNSs traveled. The requirements of this local regulation deserve to be secured in a written document to be formalized at the local administration level in order to avoid the loss of certain important aspects during oral transmission. Since 2012, Beninese legislation provides in Interministerial Order No. 0121/MEHU/MDGLAAT/DC/SGM/DGFRN/SA of November 16, 2012 setting the conditions for sustainable management of the sacred forest in the Republic of Benin, the management of sacred forests by a committee called the "Local Committee for the Management of Sacred Forests". The SNS in this study surrounded by plants with varying levels of degradation should indeed have a local management committee. But apart from a traditional leader, none of the SNS visited had a committee set up.

Conservationists regard the often-small size of SNSs as a factor limiting their conservation value. Even small-size SNSs have considerable conservation relevance, they would contribute most to species conservation if incorporated into networks (Avtzis et al. 2018). Taboos impose limitations on certain activities and prescribe management regimes that contribute to securing important resources for the community as recorded during interviews. However, during the rainy season when the water level of the SNSs overflows, crocodiles disperse. Not having a sacred status outside SNSs, they can therefore be killed in these surrounding habitats which for the most part were once gallery forests now degraded and replaced by farms. Being carnivorous species, with the impoverishment in prey reported by communities in recent years at the sacred water points, crocodiles were forced to go further beyond the limits of the SNSs. In doing so, they got killed. In addition, these SNSs that were once connected to other vast

natural aquatic ecosystems were increasingly being converted into ecological islands by the destruction of the gallery forests that formed the natural corridor.

Conclusion

Communities' perception of SNS is changing with the conversion to introduced religions, thus increasing the once-feared sacred crocodile's threats. Poaching and the degradation of the SNSs have resulted to sacred crocodile's extinction in some sites. Contemporary changes in social and religious systems are leading to the depletion of natural resources in the SNSs. Hence, sparing SNSs from depletion may depend on the will of the communities to respect the taboos as restrictive measures that protect their goods and Ostrom's eight principles. The future of SNSs may depend on the capacity of communities to maintain the taboo as norms in the use of resources.

Local authorities and forest administrations should:

- sensitize introduced religious leaders to overcome their negative perceptions towards traditional practices for a positive conservation impact,
- determine the geographic data of the SNSs,
- elaborate a participatory conservation plan for the SNSs,
- restore the natural ecosystem mainly the gallery forests using local tree species,
- identify and secure the nesting sites of sacred crocodiles,
- mitigate the threat factors recorded in the SNSs,
- apply the measures of the decree n°0121 of date 16 November 2012 governing the sustainable management of SNSs in Benin,
- include the SNSs in a protected area system such as ICCA.

Beninese legislation has defined the framework for sustainable management of sacred forests which can be applied to SNSs in general. It

clearly shows the establishment of a local management committee whose composition and responsibilities of the members are specified. This committee will be able to carry out the procedures for the registration of the SNS in the ICCA database. These are preliminary steps to guarantee national and international recognition.

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Conflict of Interest

The authors declare none.

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