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Impact of Anthropogenic Activities on the Abundance of *Crocodylus suchus* (Saint-Hilaire 1807) within the Nazinga Game Ranch, Burkina Faso

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Abstract

In Burkina Faso, human activities are practiced in Nazinga Game Ranch (NGR) which is colonized by West African crocodiles *Crocodylus suchus* (Geoffroy Saint-Hilaire 1807) decades ago. This study which aims to estimate impact of anthropogenic activities on abundance of *C. suchus* has been conducted in NGR reservoirs. For data collection, *C. suchus* populations were counted morning, afternoon and night from October 2015 to May 2017 in 11 reservoirs. Binoculars were used for remote observations and spotlight was used by night. According to the size of the sites and its accessibility, direct observations were carried out on foot or by canoe. Every time we observed crocodiles, they were numbered and added information such as their size, their behavior, geographical coordinates and the type of habitat were collected. Human activities were noted after direct observations. The R software version 3.5.3 was used for data analysis. A total of 1849 crocodiles including hatchlings, juveniles, subadults and adults were counted in these 11 reservoirs of the NGR. They were more abundant in reservoirs than rivers with highest abundances in Akalon, Akwazena, Kalieboulou and Barka. Crocodile showed very high visibility at night their abundances showed important correlation with human activities and environmental factors such as roads, fishing, tourism, moon phases and "died crocodiles" and in NGR.

Keywords

Crocodylus suchus, Abundance, Human Activities, Protected Area,

Burkina Faso

1. Introduction

The establishment of protected areas constitutes a keystone conservation strategy as protected areas are today the most natural areas that give refuge to wild animals [1] [2] [3]. Among the various pressures encountered, human activities that influence the distribution of animals are of increasing concern. In this situation, protected areas appear to be the main shelter for the conservation of wildlife [4].

The West African crocodile (*Crocodylus suchus*) is the only crocodilian currently found in Burkina Faso. This species is only recently recognized, having been separated from the Nile crocodile (*C. niloticus*) [5]. *Crocodylus suchus* is smaller than the *C. niloticus* and less inclined to attack humans or livestock [6]. Recent surveys indicate that *C. suchus* is declining or is about to became extinct throughout much of its range.

In Burkina Faso, data on the biology, ecology, and behavior of *C. suchus* are scarce, which currently hinders extensive conservation planning. Most of the limited information available consists only of presence/absence records [7] [8] [9]. In some areas of Burkina Faso, *C. suchus* is persecuted by humans because they prey on livestock, a form of human crocodile conflict [10] [11]. Crocodiles are fully protected by the national legislation in Burkina Faso, and are listed under CITES Appendix I nationally, but there is no monitoring to ensure compliance with these laws.

In most reservoirs in Burkina Faso, activities carried out there around. Despite the provisions and regulations in force for the protection and conservation of crocodiles, several threats could affect their population. Indeed, the uncontrolled clearing for the acquisition of arable land, the overgrazing, the illegal exploitation of the crocodile for its skin and its meat, the anarchic fishing constitutes a danger for these reptiles. In addition to these activities, gardening, water sampling, laundry and the making of traditional bricks are common practices around reservoirs. These activities are not without consequences on the crocodiles abundance.

In this work, we assessed the impact of human activities on the abundance of crocodiles in one of Burkina Faso protected areas. A better knowledge of the faunal populations, in particular the crocodiles of the Ranch is essential, in order to establish actions of conservation of the biodiversity. Thereby this paper aimed at describing abundance, distribution, and impact of human activities on the crocodiles in the NGR.

2. Methodology

Study area

The Nazinga Game Ranch (NGR) was created in 1975 and lies in southern Burkina Faso (11˚1'/11˚18'N and 1˚18'/1˚43'W). Covering an area of 98,100 ha, its southern limit runs along the border between Burkina Faso and Ghana (Figure 1). The main management objectives are to protect and conserve wildlife by controlling human impacts. In NGR, the dry season runs from October to May and the rainy season from June to September [12] [13], with a mean annual rainfall of 900 mm. The monthly average temperature ranges between 18.1˚C and 38.4˚C.

NGR is drained by the Sissili River, an intermittent river, and the Dawevele and the Nazinga rivers, its two seasonal tributaries. From 1979 to 1989, eleven reservoirs were created to supply wildlife with permanent water in the dry season (Table 1). Three are not built on a river and thus function as maintained

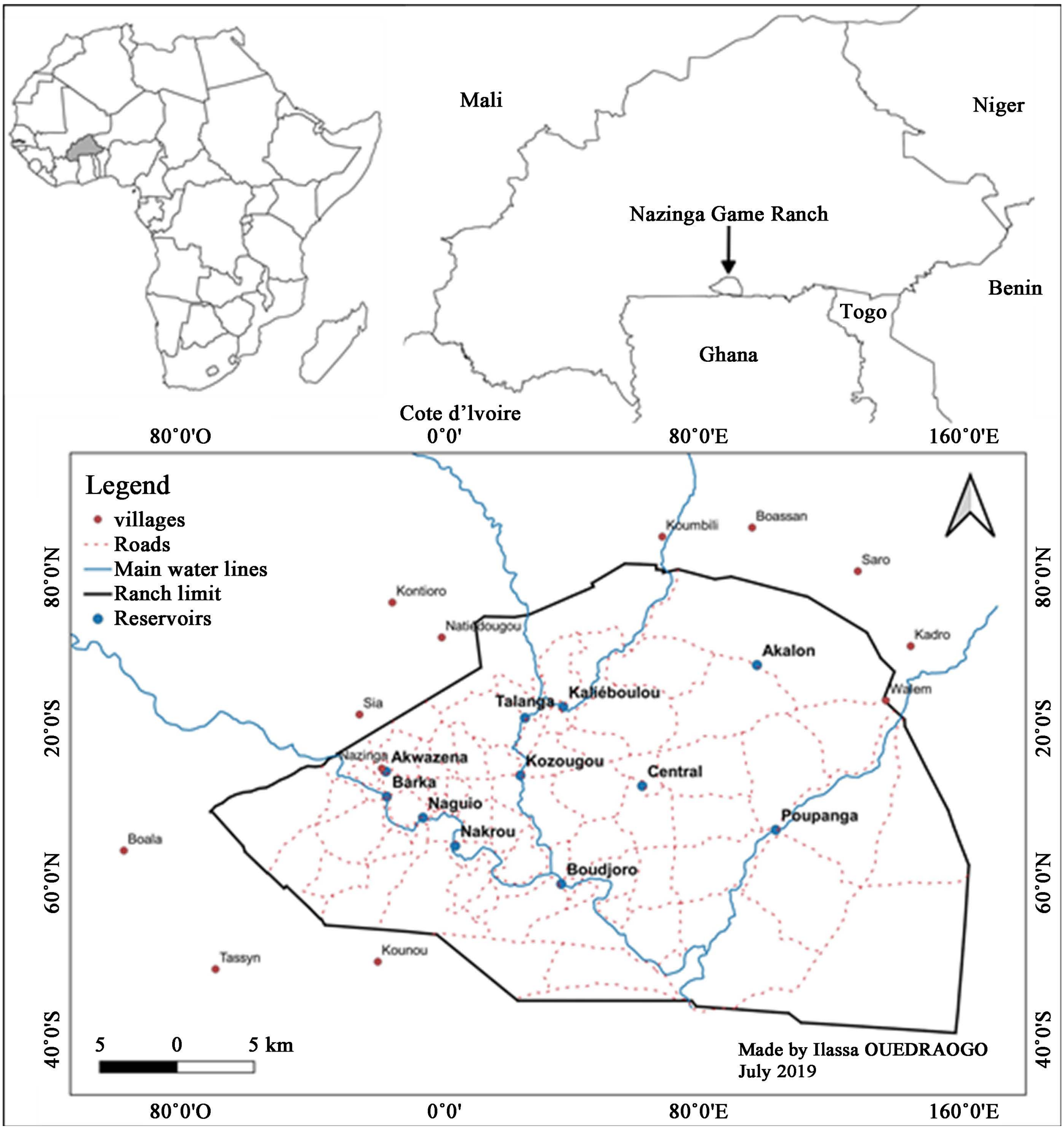


Figure 1. Map of study area highlighting the surveyed reservoirs.

Table 1. Characteristics of the 11 reservoirs in the Nazinga Game Ranch.

Reservoirs	Date	HD (m)	MFA (ha)	Fishing
Akalon	1986	2.50	18	No
Akwazena	1977	2.75	7	No
Barka	1983	3.25	20	Yes
Barrage central	1987	3.00	21	Yes
Bodjoro	1985	3.25	24	Yes
Kalieboulou	1987	4.50	60	Yes
Kozougou	1981	2.00	21	Yes
Naguio	1983	3.00	21	Yes
Nakourou	1981	2.00	18	Yes
Poupanga	1986	2.00	21	Yes
Tanlanga	1984	3.00	18	Yes

ponds (Akwazena, Akalon and Barrage Central). Human habitation, agriculture, cattle breeding, and deforestation are forbidden around the ranch, but fishing is allowed from December to May. Three types of fisheries are practiced in the NGR: commercial fishing is carried out on the basis of a partnership with a fishmonger, subsistence fishing is practiced by local residents, and customary fishery is carried out 90% by women and framed by men, with authorization from NGR administration. NGR is divided into two zones: a conservation and ecotourism area that includes the Akwazena, Barka, Naguio, Nakourou Kozougou, and Talanga reservoirs, and the hunting zone that includes the Kalieboulou, Barrage Central, Akalon, Poupanga and Bodjoro reservoirs. Barrage Central, Poupanga, and Talanga are the NGR non-perennial reservoirs and their banks are bare. Akalon and Akwazena are the water reservoirs that are not located on a river. And in the dry season there is a significant decrease in the amount of water from these pools. Kalieboulou is the largest water reservoir on the ranch with an area of 60 ha. The reservoirs Barka, Naguio, Nakourou, Bodjoro are located on the same river that flows in the rainy season. Renovation work on the Talanga reservoir dike was underway during our survey.

Surveys of crocodile abundance and distribution

To analyze crocodile abundance and distribution in NGR, we implemented diurnal and nocturnal spotlight surveys [14] [15] [16]. In each reservoir, we conducted two diurnal and one nocturnal survey. We surveyed for crocodiles during the day first from 7 - 12 h and then again from 15 - 18 h, and at night from 19 - 23 h. For each survey, we noted date, start and end time, surveyed distance, reservoir and any additional important remarks. We searched for crocodiles on foot along the bank or by canoe according to the size and accessibility of the reservoir. We used binoculars to facilitate the counting of crocodiles from a distance before they fled into water from the banks or submerged as the boat approached. For each crocodile sighted, we classified it into one of four categories: hatchlings (<0.5 m), juveniles (0.5 - 1.0 m), subadults (1 - 1.50 m), adults (>1.5 m), and as "eyes only" (EO) when we were unable to more precisely determine size. During crocodiles surveys, detectability parameter were also reported. These are the weather and climatic conditions such as: presence/absence of rain or fog; presence/absence of the moon; indications concerning the water level and indications of the presence of crocodiles (tail traces, legs, burrows, droppings and nests crocodiles).

Description of human activities and environmental characteristics

We collected information about human activities through direct observations in the field, during three focus groups, and via interviews with population. Field trips were undertaken to confirm the accuracy of population assessment. Human activities were defined visually by means of field protocol Human activities sites fell within a continuum ranging from low to very high intensity. Observations consisted to report information's about the frequency of tourism, density of habitations, intensity of poaching and fishing and the presence of roads around each river. Each of these parameters will be assigned to low, moderate or high depending on the intensity. Three major categories were defined and codified as: No = 0; Low = 1; Moderate = 2 and High = 3 (Table 2).

Habitats type (river section, reservoir or pond) were also reported and zone type (conservation or hunting zone). The ranch is divided into two zones: hunting zone and a conservation zone Conservation zone is site was human impact is low and were characterized by a nearly negligible population density and preserved natural riparian vegetation. These were created with the goal of protecting and conserving the wildlife for limited hunting and fishing and maintaining the ecological integrity of the area [17]. Hunting area is an area where human activities such as fishing, hunting and tourism can be practiced.

Data analyses

We used R version 3.5.3 software (R Core Team, 2014) to map crocodile

Table 2. Codification of the pressure from human activities.

Pressure	Pressure intensity (code)			
	No = 0	**Low = 1**	**Moderate = 2**	**High = 3**
Fishing	No fishing activity	Number of fishermen less than 15/day/site for 6 months	Number of fishermen between 15 and 50/day/site for 6 months	More than 50 fishermen/day/site for 6 months
Habitation	No habitation	Human settlements far than 1 km	Human settlements between 0.5 and 1 km	Human settlement at 0.5 km maximum
Traffic (Roads)	No roads to the river	River accessible only by small roads	River accessible by dirt road used only by guides	River accessible by dirt road used by guides and villagers
Poaching	No traces of poaching	One case of poaching trace already observed or reported	Two to five cases of poaching traces observed or reported	More than five cases of poaching already observed or reported
Tourism	No tourism	less 50 tourists/day/site	Between 50 and 100 tourists/day/site	More than 100 tourists/ day/site

distribution, and conduct all analyses. We fitted a generalized linear model (GLM) to data to identify anthropogenic variables (habitations, poaching, fishing, road, tourism, and hunting area) are responsible for crocodile abundance and determine the relationship between detectability factors (water level, presence/absence of rain, presence/absence of moon and presence index) and crocodile count data. To calculate crocodile's abundance in each site, individuals were counted during each period of survey and the maximum abundance for each size class is considered. Maps were made to show the crocodiles distribution within the NGR using always the software QGIS (Quantum Geographic Information System) version 2.18.2.

3. Results

Abundance of crocodiles

According to the counting results, *C. suchus* is not equitably distributed over the different reservoirs of the NGR. **Figure 3** present the variation of crocodile total abundance within sites (**Figure 2(a)**) and the median of number of viewed crocodiles per survey (**Figure 2(b)**). It appears that the crocodile total abundance varied significantly between sites (p-value = 0.0123 or the Kruskal-Wallis rank sum test). Then, Akalon showed the highest median (289 specimens). This is statistically higher than site like Kozougou, Bodjoro and Barrage central. Akalon is followed by Akwazena (99.5), Kalieboulou (87.0), Barka (71.5), Naguio (71.5), Talanga (44.5), Nakourou (36.0), Kozougou (35.0), Bodjoro (22.0) and B. central (20.0). In the Poupanga we did not observe any individuals of crocodiles, but only indicators of presence such as the droppings, footprints of the tails marks and burrows.

Population size structure

Among the 1849 individuals of crocodiles we counted, they were respectively 13%, 21%, 14%, and 7% of hatchlings, juveniles, subadults and adults. 45% of viewed crocodiles were classified eyes only and were excluded for this size class analysis. **Figure 3** presents the size structure of all reservoirs visited. The median number of hatchings (07 individuals) is lower than juveniles (16) and Sub-adults (08) while adults have the lowest median. in term of proportions we have respectively 22%, 39%, 24% and 15% of hatchings, juveniles, Sub-adults and adults.

The general pattern in **Figure 4** is confirmed for each site following the size class pyramid in **Figure 4**. Then, juvenile is always the most abundant size class. Then from juvenile to adult we have normal decrease for all site except for Barrage central. Remarkable patterns are observable in this Barrage central were sub-adults is the lowest abundant size class and in Talanga were hatchings is the lowest abundant size class. Proportions of adults plus sub-adult are higher, from 40 to 46% in Talanga, Akalon and Akwazena. In the opposite site like Bodjoro shows up to 70% of juveniles plus hatchings.

Influence of anthropogenic factors

Generalized Linear Models (GLM) has been used to predict the impact of

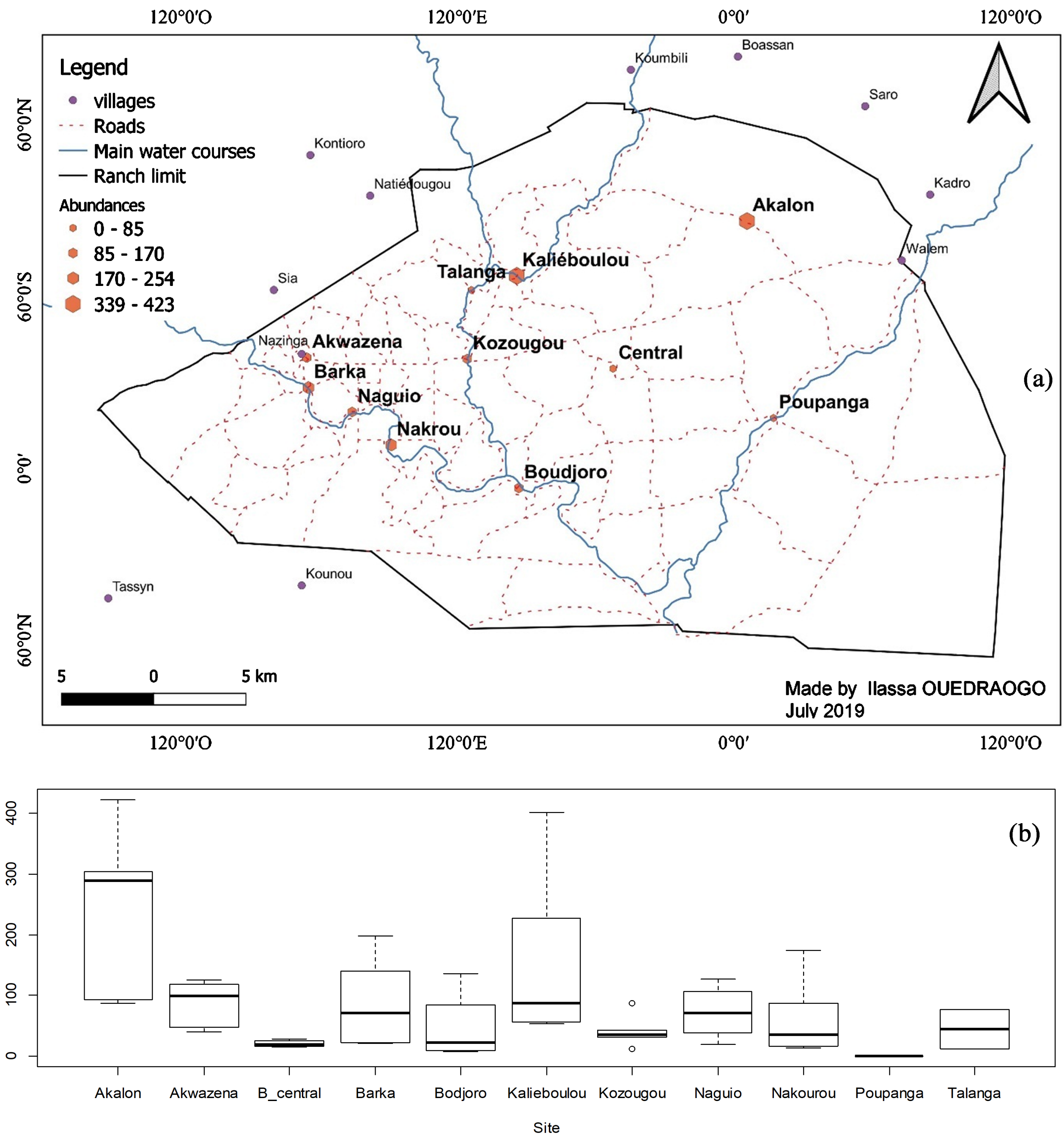


Figure 2. Abundance of crocodiles per sites.

anthropogenic factors on crocodile abundance in the ranch (Table 3). With explanatory factor (fishing, tourism, habitations, traffic and poaching) and the count data of the crocodiles was used as response factors in the models. This analysis showed that the coefficient estimates differed in terms of anthropogenic activities on crocodile population abundance. These factors are likely to influence crocodile abundance in the different sites of Ranch ($p < 0.0001$). There are negative correlations not significant between fishing (−26.68); habitations (−12.39); traffic (−62.40) and poaching (−1.94) with the crocodile abundance.

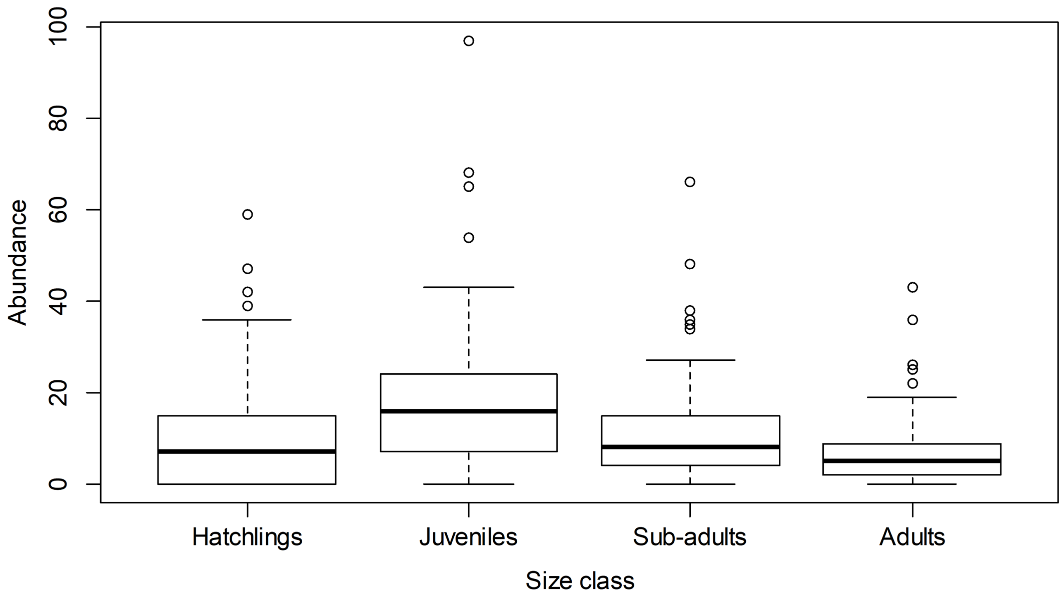
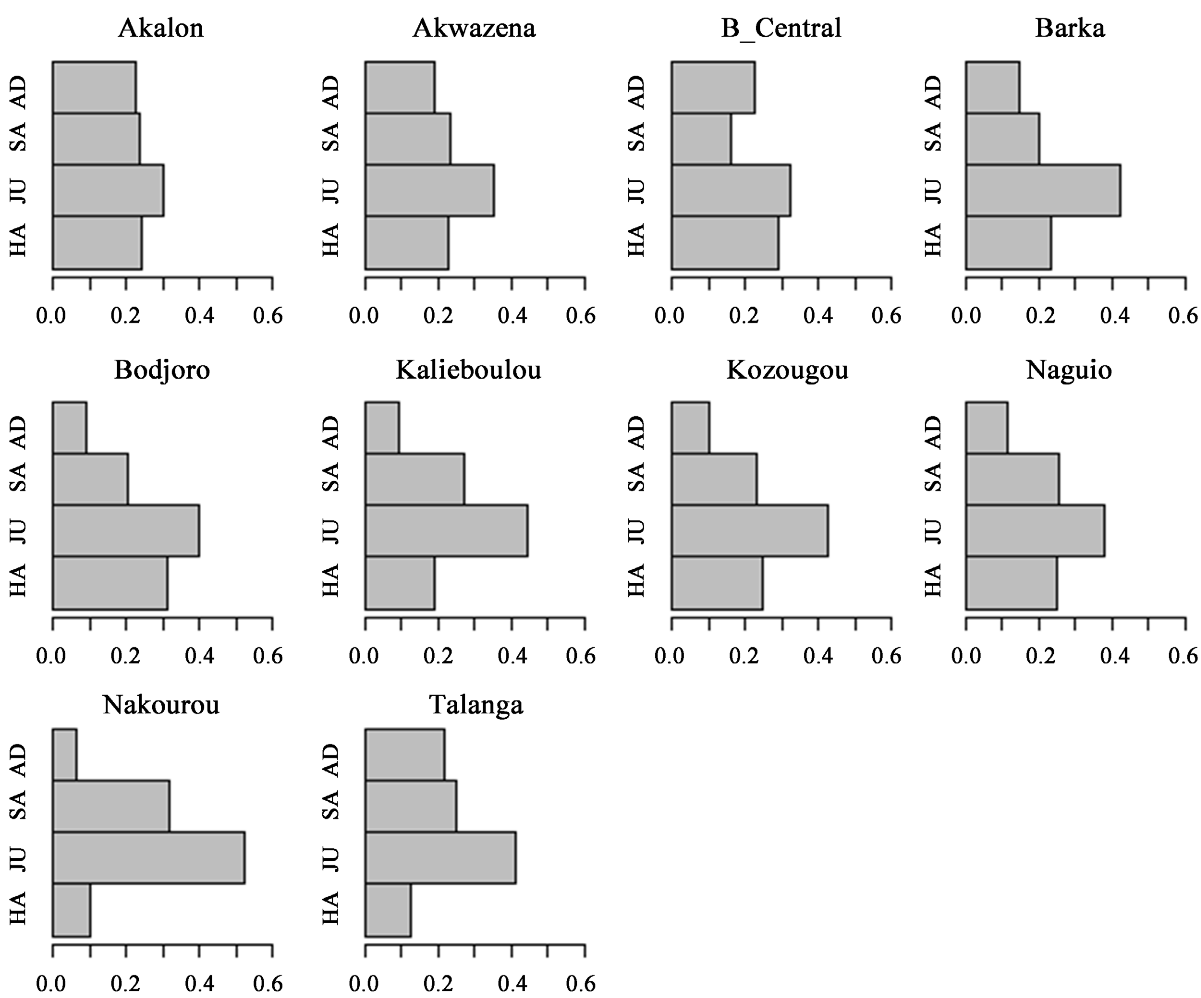


Figure 3. Abundance of crocodiles per size class.



HA: hatchlings; JV: juvenile; SA: subadult; AD: adult, B_central: Barrage central.

Figure 4. Pyramids of the crocodile size class according to sites.

Table 3. Influence of human activities on crocodile abundance.

Coefficients:	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	−139.113	90.054	−1.545	0.12973
Fishing	−26.683	14.259	−1.871	0.06813
Tourism	119.425	44.192	2.702	<0.0001**
Habitations	−12.395	63.486	−0.195	0.84612
Traffic (roads)	−62.409	23.553	−2.650	0.01123*
Poaching	−1.949	83.761	−0.023	0.98154

Signif. codes: 0 "***" 0.001 "**" 0.01 "*".

Table 4. Influence of detectability parameters on crocodiles abundance during monitoring.

Coefficients:	Estimate	Std.Error	Z value	Pr (>|z|)
(Intercept)	81.728	110.522	0.739	0.464
P/A of moon	−53.073	43.901	−1.209	0.233
P/A of rain or fog	−1.085	43.939	−0.025	0.980
Water level	26.471	29.813	0.888	0.379
Presence indices	−23.577	39.148	−0.602	0.550

P/A: presence/absence.

On the other hand, tourism (119.42) has a strong positive correlation on the abundance of crocodiles on the ranch.

Influence of detectability parameters

The crocodile abundance data along with the detectability parameters data were analyzed fitting generalized linear models in R. The count data of the crocodiles was used as response factors in the models (Table 4). The GLM analysis showed that the coefficient estimates differed among detectability parameters. The model did not show any significant relationship between detectability parameters and crocodile abundance. But negative correlations exist between P/A of moon (−53.07); P/A of rain (−1.08) and indices (−23.57) with crocodiles survey.

Effect of survey period and habitat type

Figure 5(a) shows the variation (per survey) of crocodile abundance according to the monitoring periods (morning, afternoon and night). Statistical analysis showed that crocodiles are better observable at night than during the day ($p < 0.00001$ for Kruskal-Wallis rank sum test). Their abundance did not change significantly between the morning and the afternoon surveys, but difference between these two periods and night count was statisticaly significant (respectively $p < 0.0003$ for Wilcoxon rank sum test).

Based on type of habitat (reservoir or river), variation of crocodile abundance was not statistically significant (p-value = 0.1343 for the Mann-Whitney U test). But, as shown in Figure 5(b) abundance is higher in the reservoirs than in the river with respective median of 87 and 48 individuals.

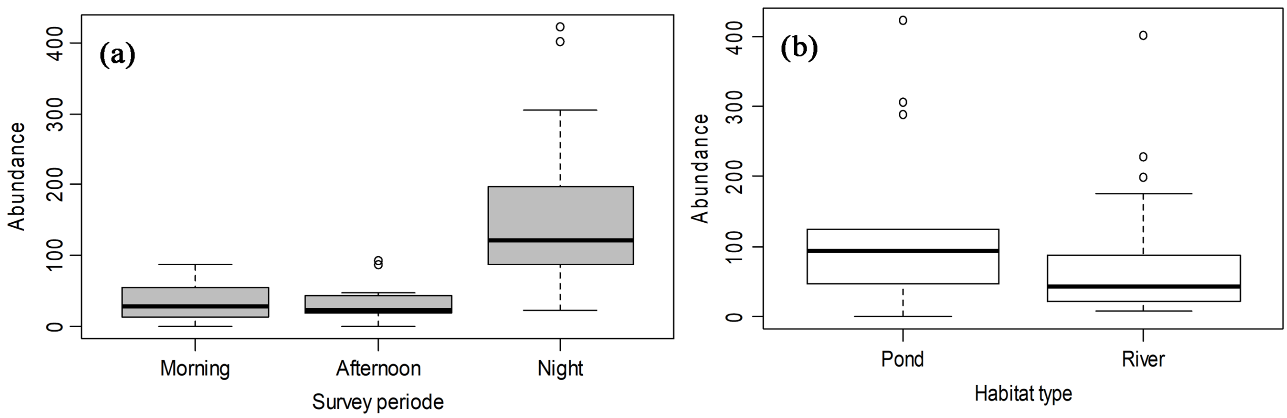


Figure 5. Abundance of crocodiles according to the Survey period (a) and habitat type (b).

4. Discussion

According to interviews persons, including local inhabitants and Ranch staff, suggest that two or three crocodile species existed in the Ranch. While some works of [6] and [7] on the distribution of crocodiles in the NGR which affirmed also the existence of two or three species of crocodiles. However, our surveys only detected one species *Crocodylus suchus* and it is almost certain that prior records of other species are a case of mistaken identity by the local people. In Burkina Faso, in addition to *Crocodylus suchus*, *Osteolaemus tetraspis* and *Mecistops cataphractus* were found in the Comoe, Bougouriba and Volta Noir (Mouhoun) rivers by Waitkuwait [18]. This result of presence of a one species is in opposition to several studies in Africa which attest to the existence of three species. It's the case in Benin with the works of [19] [20], the Côte d'Ivoire [21].

Crocodiles abundance was not uniform among the different sites. Particularly highest median was found in some rivers such as Akalon (289 specimens), Akwazena (99.5), Kalieboulou (87.0), Barka (71.5) and Naguio (71.5). This could be explained by nature of reservoirs. There is virtually no fishing activity in the reservoirs like Akalon and Akwazena, therefore, crocodiles that like quiet environments are not disturbed. In these reservoirs crocodiles are easily observable during the day and the night. In the reservoirs there is very little vegetation and the shores are exposed this allows easy counting of crocodiles according to works [22]. While Kalieboulou, is largest water reservoir of NGR (60 ha), with a significant amount of water all year long. So, despite fishing activities in Kalieboulou and Barka, crocodile individuals are strongly present. On Barka River (20 ha), the high number of crocodiles observed could be explained by the presence of fish. According to fishermen this part of the Ranch is the richest in fish. Many crocodiles adapt better to change in their environment and to human disturbance as long as some essentials like, amount of prey and quality of water as reported by [22] [23].

Results show that Barrage Central, Talanga and Kozougou have relatively low crocodile populations compared to other reservoirs on the ranch. This can be attributed to several factors. The Barrage central and Talanga reservoirs are not perennial. Depending on the rainfall, these reservoirs lack enough water around April. As for Kozougou reservoir is crossed by the main road of the Ranch. On the banks of this reservoir are two local fishing groups of more than 38 people. They fish for a period of more than 6 months each year. These elements could be factors of disturbance of crocodiles. In Poupanga no individual of crocodile has been observed but only indicators of presence. Indeed, during the entire period of study, the dam of this reservoir was broken. And there was virtually no water in this reservoir after the rainy season. The presence indices observed concerned droppings and traces of the legs and body in the existing puddles in this reservoir.

The size-class distribution of *C. suchus* was analyzed in 11 sites in NGR. On average, the most abundant size classes over the period of this study were the juveniles. This average was of more than 45% in all reservoirs. Most of our reservoirs are covered with vegetation at the banks, except the Barrage central and Poupanga, which could partly explain Juveniles abundances, because Juvenile crocodiles may select habitats based on availability both of insects and of sheltering vegetation [24]. [25] found a higher number of juveniles of Nile crocodile at Pongolapoort Dam, compared with sub-adults and adults, with a population structure similar to that NGR. This result is fairly consistent with other studies [26] [27] who had met more juveniles than subadults in their works. However, the percentage of crocodiles in the different size classes differ from some other studies [28]. In general, sub-adults may have been sighted more frequently because these size classes are easier to detect or more approachable [14]. In a population where juveniles dominate, it is a viable population that is able to sustain itself, like mentioned [25]. The difference between size class may be due to the fact that most adult animals tend to be vary more and therefore less easily countable than younger animals [29] and the fact that they often submerge when a spotlight approach. It was noted that other factors influence the size and structure of the crocodile population. Sometimes the presence of fishermen on the sites affects the monitoring. They seem to be aware of crocodile's favorite pilgrimage sites as well as the proximity of their distribution to preferred fishing areas. As crocodiles regularly feed on fish caught in the nets, fishermen believe that they are destroying their fishing gear and hindering fishing efforts according to [8]. The body size was not estimated in 45% of the sighted crocodiles, because these individuals were either sighted from too far or almost totally submerged in water.

Census survey of *C. suchus* had been conducted in eleven different rivers in Nazinga Game Ranch. Nocturnal surveys of the different reservoirs confirmed the abundance of crocodiles, though most individuals detected were juveniles. Night surveys yielded greater counts of crocodiles in the reservoirs compared to diurnal surveys. This can be explained by the fact that the night crocodiles come out of the water to feed themselves. Crocodiles are mainly nocturnal animals which implies that they are mainly active during night. According to [15], activity peak of crocodiles is during the night. This period, the reflection of their eyes at light allows detection at sometimes large distances. Also, at night they can be approached more easily, which allows better identification. According to [30] a large percentage of the population of crocodiles would be basking on various banks night, depending on the time of the year.

Crocodiles were less visible in reservoirs than rivers. This could be explained by the fact that in reservoirs, fishermen spend all the day on the water and disturbed crocodiles. Indeed, because of their noise, crocodiles hiding before being sighted by the survey team. So, there is competition between crocodiles and fishermen as reported by [8]. For crocodiles feed on many fish species and are perceived by freshmen as major competitors. This result can be compared to those of [10] who stated that Nile crocodiles are widely distributed throughout sub-Saharan Africa, and are found in a wide variety of habitat types, including large lakes and rivers. For [31] the crocodiles have a preference for some habitat types.

The results from the Linear Models show that the number of crocodiles in an area might be affected by the number of habitations, fishing, roads, tourism and hunting area. Fishing has effects on crocodile health, resulting in fishing net injuries and drowning of juveniles. Death juvenile crocodiles were found on the banks of reservoirs Barrage central, Kozougou and Talanga with pieces of fishing net between the legs. This is confirmed by the work done by [20] in Benin. Roads lead habitats loss and fragmentation. The presence of roadside next to the reservoirs causes sometimes deadly accidents of some crocodile that cross the road. This was testified by the administration's agents during the interviews.

These studied disturbance factors are not the only factors affecting crocodile abundance and distribution. Observation of human disturbance of crocodile in the study area revealed that most of the animals sighted were found in undisturbed habitats. Even if crocodiles are not concerned with hunting, the results show that the reservoirs in the hunting area are less abundant in crocodile than those in the conservation area except for Akalon. This reflects the fact that crocodiles need quiet areas. This demonstrates the positive influence of protected areas for conservation of this crocodile [32]. GLM analysis showed a correlation between different environmental factors. These factors can have positive or negative influence on crocodile monitoring. The positive correlation between habitats and roads may be due to the fact that they are protective factor for these reptiles. The presence of habitat in a locality reduces the poaching of crocodiles. Anthropogenic activities have significant influence on crocodiles abundance [33] [34]. A combination of different parameters and anthropogenic factors could have a major impact on crocodiles abundance.

5. Conclusion

In Nazinga Game Ranch, *Crocodylus suchus* was encountered in all aquatic habitats, with a strong dominance of juvenile crocodiles over other age classes. Its global abundance varies according to the anthropic activities carried out in the reservoir and the quantity of water. Contrary to expectations, some anthropogenic activities, notably fishing, found to positively correlate with the abundance of crocodile population. Although this does raise concern, the increase in smaller size classes, indicates good structuring of crocodile population. As a result, crocodile population in NGR is still protected. This study has provided first data on number of crocodiles in NGR. These data can be used with future works to determine the trend of crocodile populations. The census has also provided information on their distribution in the different rivers according to the impact of human.

Authors Contribution

Ouedraogo Ilassa: conception; sampling design, data analysis and first manuscript writing. Oueda Adama and HEMA M. Emmanuel: supervisor, data analysis, validation and manuscript editing and review. Oueda Adama: Formal analysis, review and editing, Project administration, Supervision, Validation. Hema Mr. Emmanuel, allowed us to get in touch with the people in charge of the Nazinga Game Ranch for the monitoring of the crocodiles and gave us practical advice on the field. Matthew H. Shirley, allowed us to do a training course in Ivory Coast on the techniques of observation and capture of crocodiles and also by his corrections of the manuscript. All the work was done under the supervision of Gustave B. KABRE who was the director of the laboratory.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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