POPULATION ECOLOGY OF THE AMERICAN CROCODILE (Crocodylus acutus; Cuvier, 1807) AND SPECTACLED CAIMAN (Caiman crocodilus fuscus; Cope, 1868) IN THE EMBALSE DE URRÁ, CÓRDOBA.

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Introduction

Crocodilian species in Colombia have been affected by overexploitation and habitat loss, particularly the *Crocodylus acutus* and *Caiman crocodilus fuscus* species. In Colombia, between the years of 1950 and 1980, the exploitation of around 400,000 crocodile skins per year took place. The International Union for Conservation of Nature's threatened species red list has reported that the *C. acutus* species is currently in a vulnerable state (VU) while the *C. c. fuscus* species is catalogued in a low risk. Because of this the Convention on International Trade in Endangered Species included *C. acutus* a *C. c. fuscus* in its appendices I and II.

Crocodilian protection and conservation efforts are greatly important since Crocodilian's role as predator contributes to the maintenance and control of aquatic and terrestrial communities (Ross, 1969). Additionally, Crocodilians participate in nutrients cycling by means of their depositions and feeding remains which get incorporated in the aquatic medium and promote the growth and development of several vegetable species which make part of the trophic chain. (Van der Ploeg *et al*, 2011).

Because of the previously exposed, it is essential that studies get carried out in areas from which there is not much available information. This information includes ecology and ethno-zoological relationships of the crocodilian species, which contributes to future conservation and handling plans.

Methods

Ethno-zoological evaluation: Between July and August 2015, we carried out semi-structured surveys applying the "snowball" technique, consisting of locating people with knowledge of crocodile species present in the area (Fig. 1). These surveys sought to evaluate aspects related to: bio-ecological knowledge (differences between species, eating and reproductive habits), social relations (beliefs, conflicts and perception) and finally, spatial relation (distribution) with crocodilians in the Urrá reservoir (Montería, Córdoba).



Figure 1. Execution of semi-structured interviews with locals.

Habitat analysis: Using ArcGis 10.3 software (ESRI, 2012) and the mapping proposed by the IGAC (2007), the zoning limits were adjusted and a 1 km buffer was developed to determine the effective habitat of the species. Subsequently, information was extracted in relation to biomes, climates, coverages and ecosystem units (Balaguera-Reina et al., 2015)

Population structure: Based of the information provided by the surveys and reports of Urrá S.A. E.S.P., six areas were selected: Frasquillo, Chivogado, Angostura, Las Claras, Puerto Nuevo, Gaita and finally, Tucurá (Fig. 2). Samplings were carried out between August 16 and 21 (2015), making night trips by boat at maximum speed of 7 km/h between

19:00h and 2:00h during the new moon phase in order to make sightings (Ulloa and Sierra, 2002; Balaguera-Reina et al., 2007). Besides, a direct visual counting technique was applied (Chabreck, 1966) using halogen lamps to detect the reflection of the light caused by the *tapetum lucidum* present on the outer surface of crocodile's eyes. After detection, the animal was approached at approximately two meters of distance in order to determine its species, estimate its size, and record varied environmental characteristics (including georeferencing, relative humidity, water temperature and ambient temperature).

Also, the data record was grouped by size classes according to groups established by Ayarzagüena (1983) for *C.c. fuscus* and Seijas (1986; 2011) for *C. acutus*. After this, a population structure analysis was performed using frequency histograms (Ayarzagüena, 1983; Velasco and Ayarzagüena, 1995), determination of abundance values (N=R/LT) and determination of the visible fraction by the method proposed by king *et al* (1990) (Ayarzagüena, 1983; Velasco and Ayarzagüena, 1995).

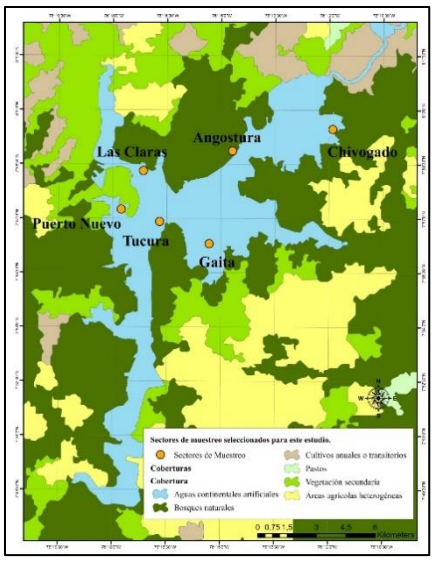


Figure 2. Study area, Urrá reservoir

On the other hand, registered information of the abiotic factors was used for the elaboration of the principal component analysis (PCA) using the R studio software version 3.3.3 (R Foundation, 2017). Additionally, an analysis of variance (ANOVA) between the variables of water temperature, ambient temperature, and humidity relative to the factors "classes" and "habitat types" was implemented in order to determine any type of statistical relationship between these variables.

Spatial analysis: The geo-referenced records and the cartographic analysis were overlapped in order to obtain the type of coverage in which crocodilian species are found by forming a buffer of 100 meters to each of the records and then generating the cut in the cartographic information base of the IDEAM (2007) (Scale 1: 500000) for the extraction of the cover types that supports the species. Finally, to determine the attributes of special distribution by the species, the closest neighbor analysis was used with ArcGis 10.3 software.

Logistic issues that limited fieldwork

This work faced difficulties during its execution which led to producing a single sample. Among the most important of these difficulties there was an incident on September 15, 2015, where the National Army generated alerts about illegal insurgence conflicts in the study area. This report was sent to the El Bosque Univeristy Biology Direction which led to the definitive suspension of field work and the withdrawal of said work. This was done with the intent of protecting the life and integrity of the researchers.

Results

According to the retrieved information, all sightings could be determined to belong to *Caiman crocodilus fuscus* individuals. Because of this reason the following results can only be associated to this species.

Ethno-zoological evaluation: A total of 75 surveys were carried out involving people from 26 zones adjacent to the reservoir. From these surveys it was determined that in relation to bio-ecological knowledge, the majority of respondents had a medium knowledge (73 %) (Fig. 3), some were capable of identifying important ecological aspects such as sightings, others were able of differentiating between crocodile species (60 %), identify their tracks (79 %), identify their diet (89 %) and mentions some reproductive aspects (91 %) of the species (Fig. 4).

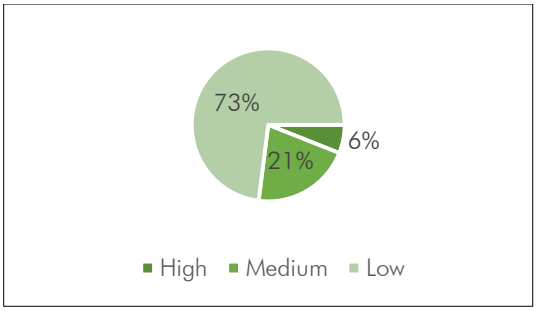


Figure 3. Level of bio-ecological knowledge by the locals.

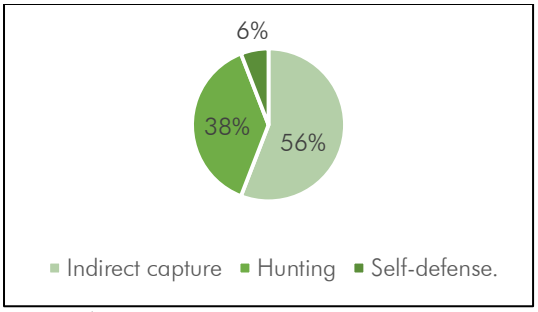


Figure 4. Types of encounter with crocodile species.

Regarding ethno-zoological aspects, 45 % of respondents said they had direct contact with the species *C.c. fuscus* being the most frequent cause (56 %) the non-directed capture of sub-species with fishing nets. The second most frequent type of encounter is related to hunting (38 %), since locals occasionally use the subspecies as food. Additionally, the lowest type of encounter (6 %) is related to acts in self-defense due to attacks produced by crocodiles. Finally, in relation to spatial distribution of crocodiles in the study area, respondents identified eight exclusive sites for *C.c. fuscus* and one for *C. acutus*.

Habitat analysis: Potential habitat covered a total of 179 km^2, of which 41 % belongs to the coverage of *artificial continental waters* (73.1 km^2), 40 % to *natural forests* (71.5 km^2), 12 % *secondary vegetation* (22.66 km^2), 6 % to *cover heterogeneous agricultural* areas (10.37 km^2) and finally 1 % of annual or transient crops (1.93 km^2). On the other hand, only two types of biomes were reported: *The Magdalena and Caribbean "Helo-biome"* being predominant with a 59 % (106.75 km^2) extension followed by the *tropical humid Zono-biome of the Magdalena and Caribbean* with an extension of 41 % (72, 74 km^2). Additionally, a single type of climate is reported being this *warm humid*. Regarding the types of ecosystems, 9 types were registered, the most dominant being *Continental waters of the Magdalena and Caribbean helobiome* (73.01 km^2), *Natural forests of the tropical humid zonobiome of the Magdalena and the Caribbean* (44.88km^2) and *Natural forests of the Magdalena and Caribbean helobiome* (14.83 %).

***Population structure*:** Despite the information provided by the local population, in the six sectors where the transects were executed, only records for the sub-species *Caiman crocodilus fuscus* were reported (Fig. 5). Related to the relative abundances, a value of 2.85 ind./ km was obtained being the sum of the transects of 5.82 km^2 and a total of 148 records classified by size classes, while 116 could only be registered as "eyes" since it was not possible to estimate his size.

Regard to the population size estimate (N), it was obtained that the population of the sampled areas was 103.17 ± 13.04 and according to the frequency histogram with an N = 148 (m=191 y s=0.755) the most representative class was class II (n = 84; 57 %), followed by class I (n = 42; 28 %), class III (n = 15; 10 %) and class IV (n = 7; 5 %) (Fig. 6).



Figure 5. Exemplary of the species *Caiman crocodilus fuscus*

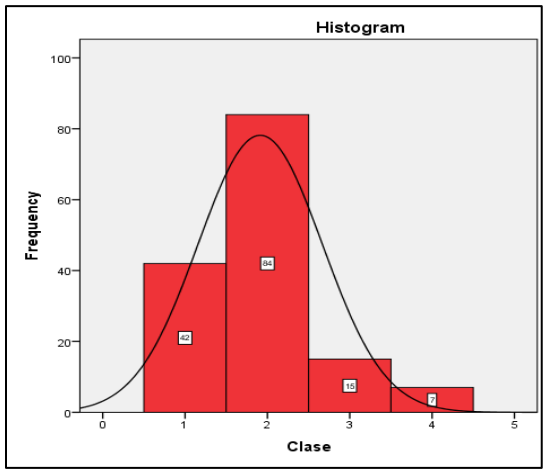


Fig 6. Histogram of frequencies for species *C. c. fuscus*.

In regards to abiotic factors, it was found that the relative humidity with the highest number of individuals (66 ind.) was between 87 % and 90 %; regarding water temperature, the range with the highest number of registered individuals (77 ind.) was between 30.6 ° C and 31.5 ° and, finally, with respect to environmental temperature, the range with the highest number of crocodiles (49 ind.) was between 25.6 ° and 26.5 ° C. On the other hand, the results obtained by ANOVA determined that there are no significant differences between water temperature and size classes ($p = 0.992$), while there are differences with the habitat factor ($p < 0.001$). In relation to the ambient temperature, it was obtained that none of the factors presented, and finally, with respect to relative humidity, the values for the factors of class ($p = 0.648$) and habitat ($p = 0.368$) also do not present any type of statistical significance. Complementing the above, the PCA allowed to show that the presence of organisms is more related to the relative humidity and water temperature.

Spatial analysis: In the Chivogado locality individuals were found distributed in the types of coverage *Artificial inland waters* (85 %; area: 0.44 km2) and *Natural forests* (15 %; area: 0.079045 km2). For the Angostura sector, crocodilians were distributed in the types of coverage *Artificial inland waters* (56 %) and *Natural forests* (44 %). Regarding Las Claras; *artificial continental waters* (62 %), *natural forests* (20 %) and *secondary vegetation* (18 %) were reported in the coverage. In addition, in the Puerto Nuevo sector, the layers of *artificial continental waters* (62 %), *natural forests* (5 %) and *secondary vegetation* (33 %) were presented. Finally, in the Tucura-Gaita sector, the coverage of *artificial continental waters* (74%), *natural forests* (20%) and *secondary vegetation* (6%) were recorded.

Discussion

It was observed that, most of the population has a basic knowledge of the sub-species *C. c. fuscus;* as expected due to the frequency with which the sub-species is sighted in the reservoir. These was verified with the results obtained by ethno-zoological surveys. Namely, the identifying aspects comprised were morphology, dietary composition, reproductive aspects, and others. Also, in regards on the *C. acutus* species, scarce knowledge is reported by locals since sightings are done by people whose economic role forces them to move farther away to areas such as "Río Manso" or "Río verde", where this species is present.

Additionally, a high percentage of respondents had an affirmative answer regarding the sightings of the spectacled caiman. Therefore, it was possible to evaluate the perception of the locals in front of the crocodiles, observing a remarkable sense of fear because they consider these animals dangerous. However, despite this fear, a very low percentage of respondents said that within the dietary component of the species was the human. This may be due to the bad reputation and myths created around the species for different reasons, mainly due to unintentional encounters in nesting times, given the territoriality of these species (Medem 1981).

Another relevant factor to consider is the conflict between crocodylids species and the human population. This is mainly generated by the rupture of fishing nets (Balaguera-Reina, 2008) because the crocodylids are frequently trapped in them and in order to be released they must be broken. In addition to this, another of the affectations is the loss of farm animals which generates discomfort to the inhabitants and contributes to generate a negative and unfavorable image of these species (De la Ossa et al. 2013, pp. 168).

Regarding the habitat, it was observed that the predominant coverage in the area was that of *artificial continental waters*. The development of hydroelectric activities such as the construction of dams and flooding of areas generates a problem given that these do not foresee the impacts that they will have on possible nesting areas (Morales-Betancourt and Lasso, 2013, pp.289), In addition, geological nature of basins determines the physical-chemical characteristics of water and sediment load, directly affecting the permanence of the characteristic biota of the area (Bustamente-Fernández, 2008). On the other hand, the second most extensive coverage in the reservoir was that of natural forests, favoring the presence of *C.c fuscus* since they are favorite territories for the establishment of nesting areas (Allsteadt, 1994).

Pertaining the population structure of *C. c. fuscus*, it is not possible to state the population state of the species at the study area, given that the obtained dataset does not represent the sampling effort required to determine an aspect such as this. Finally, all the monitored areas showed clustered distribution patterns. This type of occurrence occurs due to

requirements of sub-species according to habitat conditions, since in places where abundant plant cover persists, low anthropic intervention and availability of amphibious sites, there will be a greater presence of *C.c. fuscus* (Cabrera et al 1997)

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