ETHNO-ZOOLOGICAL RELATIONSHIPS AND POPULATION ECOLOGY OF THE AMERICAN CROCODILE (*Crocodylus acutus,* Cuvier 1807) AND THE SPECTACLED CAIMAN (*Caiman crocodilus fuscus,* Cope 1868) IN THE HIGH BASIN OF MAGDALENA RIVER, COLOMBIA

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Over-exploitation of crocodilians as food and/or economic resource in national and international markets has been historically evident (Messel *et al.*, 1995). Habitats have also been impacted in the quest for crocodile's skins being some species vanished locally and regionally throughout their range in Colombia (Medem, 1981; Balaguera-Reina & González-Maya, 2010; Thorbjarnanrson *et al.*, 2006). Along with this historical reduction of wildlife populations comes a decreasing in the interactions between local people and crocodilians (ethno-zoological relationships), losing people empirical knowledge vital to achieve natural resources management at different scales and conservation of the biodiversity (Balaguera-Reina & González -Maya, 2010; Balaguera-Reina, 2012). Added to that, lack of knowledge regarding interactions among species and their surroundings (biological and physical habitat) limit to carry out conservation and management initiatives on crocodilians. In the upper basin of the Magdalena river, for instance, the most recent official information was taken more than 20 years ago (Medem, 1981; Barahona,*et al*, 1996). These elements have contributed to species such as *Crocodylus acutus* and *Caiman crocodilus fuscus* are classified at the national and international level at some level of vulnerability because of its conservation status (Rodriguez-Melo, *et al*., 2002; Sanchez-Paez, *et al*., 2004). Thereby, we determined the ethno-zoological relationships and the population ecology of *C. acutus* and *C. c. fuscus* in the upper Magdalena basin, assessing bio-ecological knowledge and spatial and social relationships of local residents with these species. In addition, we assessed, in a preliminary way, the ecological patterns of these populations analyzing the suitability habitat, relative abundance, size, habitat and population structure, as well as the relationship with the biotic and abiotic factors that may influence the presence of individuals in the study area.

MATERIALS AND METHODS

Study area

The upper basin of the Magdalena has an extension of 54.785 km^2. It includes Huila and Tolima departments as a whole and some extensions from Cauca and Cundinamarca department. It is characterized by a vegetable formation dominated by dry tropical forest with temperatures above 24°C and precipitations between 700 and 2,000 mm per year (Espinal, 1985; Murphy & Lugo, 1986)

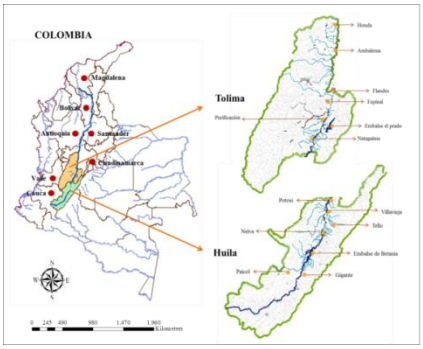


Figure 1. *Geographic location of the upper basin of the Magdalena river. Source: IGAC, 2007*

Methods

<u>*Ethno-Zoological assessment*</u>: From February to March 2015 we carried out interviews and semi-structured surveys to local residents following the snowball technique (Ortega-Huerta & Medley, 1999), assessing the bio-ecological knowledge and spatial and social relationships between people and crocodilians. The quantitative data were analyzed using descriptive statistics and a logistic regression using the Software IBM SPSS Statics 19 (IBM, 2010), whereas the qualitative data were analyzed using the program NVivo.10 (Nvivo, 2012).

Habitat suitability: Taking into account the coverage mapping developed by IDEAM, *et al.,* (2007; scale: 1:500,000) and by the IGAC (2007; scale: 1:500,000), we analyzed crocodiles habitat suitability in the upper basin of the Magdalena river, using the software ArcGIS 10.1 (ESRI, 2012). This information was adjusted using both departmental boundaries (Huila and Tolima) and isobaths at 1,000 m above the level sea. The first one was used to delimit the study area and the second one was based on the highest altitude reported by villagers where *C. c. fuscus* can be found. Based on this new area, we estimated habitat suitability taking into account water bodies extension buffering them 1 km (Balaguera-Reina, *et al*., 2015). We also analyzed biomes, climates, land-cover, and ecosystem present in this area.

Population ecology: From July to August 2015, we carried out spotlight surveys (Chabrek 1969) on each sampling area selected (Bethany viewpoint, Bethany dam, Juncal Lake, and Villavieja, Ambalema, and Honda municipalities). Sighted individuals were grouped into size classes according to Seijas (1988) on the case of *C. acutus* and Ayarzaguena (1983) on the case of *C. crocodilus*. Those individuals that were hidden before estimating its size were recorded as "eyes only". This information was analyzed using frequency histograms. We calculated relative abundance (Ind/km) per sampling area, department, and month (De la Ossa, *et al*., 2013). Moreover, population size was estimated using the method defined by Messel, *et al.,* (1981). Each observation was georeferenced taking into account water and environmental temperature and relative humidity as abiotic factors. These data were analyzed using a PCA (principal component analysis). We also classified the location where crocodiles were found in one of the following categories: open water, shallow water at the edge, mud, beach, under trees, edged vegetation, on land vegetation, and on fallen logs or rocks. The information obtained was analyzed using histograms and a 2 x 8 simple contingency table. Finally we carried out hypothesis testing using ANOVA and Duncan and Tukey post-hoc analyses to determine the relationship between relative abundance, size classes, categories of habitat, and abiotic factors per month, department and sites sampled.

RESULTS

Ethno-Zoological assessment: A total of 97 surveys and nine interviews were conducted in 30 towns in Huila and Tolima departments and in the limits of Cundinamarca Department. Interviewees were 98 % men between 23 and 75 years (85%) (15% remaining refers to people who preferred do not say their ages). The majority of interviewees had high bio-ecological knowledge species (57% about *C. acutus* and 53% about *C. c. fuscus*), since all villagers reported to meet crocodilians and 84% of them claims to be able to differentiate American crocodiles and spectacled caimans through physical characteristics such as the shape of the head-snout (37%), the size of the body (26%), among others. They sight spectacled caimans (98%) and American crocodile (60%) mainly in the evenings (60%) and afternoons (68%), respectively. Likewise, respondents raised a variety of food items ranging from fish (76% for caimans and 60% for crocodiles) to human beings (3% for caimans and 10% for crocodiles). About nests, 40% of people knows how to recognize them, highlighting that crocodiles prefers hollow type nests, while caimans prefers to build nests type mound. Regarding to hatchlings and yearlings (small individuals), 68% of interviewees recognized *C. c. fuscus* hatchlings, however, 87% of interviewees had never seen *C. acutus* hatchlings. It is important to highlight that the environmental regional agency (Corporación Autónoma Regional del Alto Magdalena-CAM) in the late 2014 reported 14 *C. acutus* hatchings in Villavieja (Huila) as well as adults. We found that the bio-ecological knowledge was not statistically related with the interviewee ages (Logistic regression $p > 0.05$ for both species).

On the other hand, the level of social relationship human-crocodile was low, with a 66% for *C. c. fuscus* and 88% for *C. acutus*, a statistically significant relationship was not found between age and this aspect for both cases (R. logistics > 0.05). The majority of interviewees reported no-use of these species (51% for caiman and 80% for crocodile), followed by those who use them for feeding (38% and 8%, respectively). In terms of time-space relationship, 74% and 23% of interviewees reported to have had direct contact with caimans and crocodiles, respectively, mainly because by non-directed catch (57% for *C. c. fuscus* and 48% for *C. acutus*). On the other hand, 25% (in the case of caimans) and 36% (in the case of crocodiles) of interviewees reported

direct or indirect hunting. Likewise, 41% of the persons interviewed reported some type of affectation by the caimans; and 13% by crocodiles. The main impact caused by caimans and crocodiles to interviewees is fishing nets damaging (73% and 59%, respectively), followed by attacks (22% for caimans and 29% crocodiles). In addition, 41% of residents identified medical, ecological, or cultural belief/uses around the crocodilians. Likewise, 40% of the total of evaluated people claimed to feel some kind of fear for these reptiles. However, most of the interviewees (60%) commented on not fearing them, because they consider those animals' runs when humans are around and only defend themselves if they are disturbed. 48% of interviewees stated crocodiles bring benefits to humans as food and money. In contrast, 84% said there is not benefits to other animals by the presence of crocodilians, because they consider that these reptiles eat them. However, 16% did recognize the benefits associated with the ecological component and ecosystem balance.

A total of 140 areas where crocodiles can be found in the area were reported by interviewees distributed among rivers (53%), streams (21%), lakes (14%), dams (10%) and lagoons (2%). These reports were presented at altitudes between 201 and 905 m. above the level sea; the lowest places were found in the municipality of Honda (Tolima Department) and the highest place was in Los Cauchos in Guadalupe municipality (Huila Department).

Habitat suitability: Cartographic analysis showed that Huila and Tolima departments have a territorial area of 42.493,07 km^2 and the potential habitat where crocodilians can be found based on the isobaths at 1.000 m and the 1 km buffer around the water bodies represent the 27,4% of it. We found 13 types of land-cover on this potential area, being grasslands and pastures (6.069,34 km^2, 52,05%) the most dominant followed by secondary forest (1.943,85 km^2, 16.67%). In addition, there were four types of biomes, being the sub-xerophytic tropical zone-biome from the upper Magdalena the most dominant (6.403,94 km^2; 50, 17%), followed by low oro-biomes of the Andes (5.052,34 km^2; 47,11%). In terms of weather conditions, there were eight kinds of climate, the one with more dominance was the warm-dry climate (65.6%) followed by the dry climate (15.7%). In the case of ecosystem units we recorded 29 from which pastures of the oro-biome low Andes ecosystem (4181,53 km^2, 35,86%) along with the sub-xerophytic tropical ecosystem (1866,96 km^2, 16,01%) were the most dominant.

Analysis of population attributes:

A total of 192,48 km were assessed throughout six sampling routes (16 ± 11 km). A single sighting was obtained from *Crocodylus acutus*, which means that this species has a relative abundance of 0.005 Ind/km in the upper Magdalena. The report took place in the month of August, at the mouth of the river Baché in the sector of Villavieja. The individual had a total length of 65 cm (class II).



Figure 2. *Crocodylus acutus observed in Villavieja (Huila).*

In the case of *C. c. fuscus*, it presented a relative abundance of 2,6 Ind/km in the upper basin of the Magdalena River. We the highest relative abundance between departments was recorded in Huila Department (3,2 Ind/km). Regarding time, July had the highest relative abundance value (3,1 Ind/km). The most abundant sector for both months was Laguna El Juncal. The ANOVA showed that there were no significant differences in the abundance

values between months (p = 0,987) and Department (p = 0,761). However, there are statistically significant differences between the different sites sampled (p = 0,041), being the Laguna el Juncal the sector presenting the greatest difference regarding to the other points of sampling, according to Duncan's test.
We sighted a total of 505 individuals, of which 106 belong to class I, 75 to class II, 13 class III, and 311 individuals in the category of "only eyes". Huila and July had the highest number of sightings.

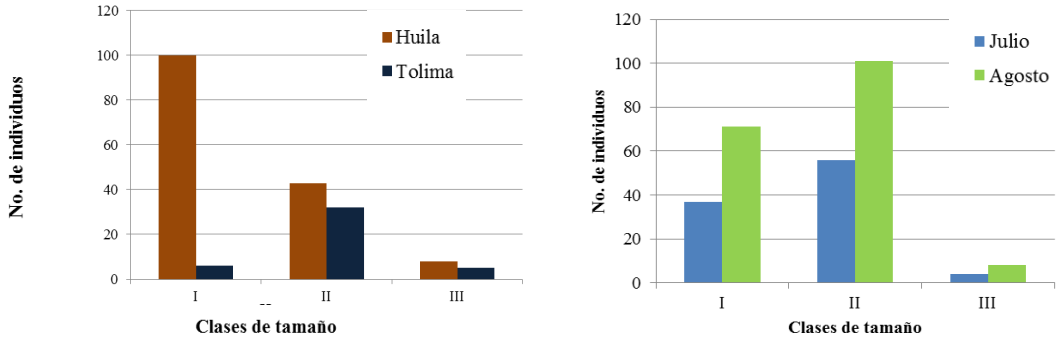


Figure 3. *Distribution of class sizes by Department (left) and month (right).*

On the other hand, it may suggest that the upper basin of the Magdalena river has a population of 153,0 ± 36.6 individuals, with a visible fraction (*p*) of 28%. In terms of departments, Huila presented one larger population size (184.3 ± 42.3 Ind) than Tolima (52.6 ± 8.2 Ind). In relation to the sites, the Laguna del Juncal presented the largest population size (316,0 ± 29.7 individuals; *p*= 43%).

Regarding the abiotic data, we got an environmental and water temperature of 27.4 ± 1.9°C and 25.4 ± 1.8°C, respectively, and a value of relative humidity of 66.4 ± 9.4%. Most of the individuals were reported in the middle of each variable categories: 356 individuals were sighted between 24 and 27.9°C of environmental temperature, 386 individuals were sighted between 24 and 27.9°C of water temperature and 248 individuals were sighted between 60-69% of relative humidity. The principal component analysis (PCA) showed that in general terms, the factors that are more related to the presence of individuals are the relative humidity and the water temperature.

From 505 records of caimans, 124 were sighted on edged vegetation, followed by shallow water and open waters, with 106 and 84 individuals, respectively. In contrast, habitats where individuals were observed the lowest were beach with three individuals and on tree trunks fallen or rocks with 5 caimans. The contingency table, threw a value of Chi-square of 2,000 and a p-value of 0.175 which means that we failed to reject the null hypothesis, which means the presence of caimans in the study area is independent of the these types of habitat.

DISCUSSION

The bioecological features reported by villagers coincide with ecological patterns reported for the species, reaffirming the high knowledge they have about them. However, there are key elements that may limit conservation processes of these species such as sexual segregation related to activities carried out every day, element that can bring great impact, as the decrease of conveying culturally the natural relationship human-crocodile (Balaguera-Reina & Gonzalez-Maya, 2010). In addition interviewees reported low contact with *C. acutus*, which can generate a significant cultural loss by the population of the upper Magdalena river basin, since this is a characteristic species of the area and some interviewees reported not meeting them or know their ecological and/or physical characteristics. It is also relevant to say that the reduction in contact with wildlife helps to increase the mystification of these, which can affect drastically conservation planning.

The majority of interviewees commented that there is no utility for any of the two species. The reasons may be linked to the decline of populations and therefore of the encounters, as well as the legal implications that poaching and illegal trade of wildlife (Rojas-Briñez, 2011). Two key elements in the possible recovery of

natural populations considering that the upper basin of the Magdalena River was an area of frequent hunting and currently caimans and crocodiles are reduced in the area.

The use of crocodilians meat is an activity that can be defined as livelihoods in most of the regions of the country, which has increased alarmingly in recent years because of the rising demand for food by people who have migrated to wild or rural areas (Morales-Betancur, *et al.,* 2013). Even as respondents affirmed, raised spectacled caiman meat has become the first choice of food facing the shortage of fish obtained in their daily work, as a result of the decline in fish production in the basin of the Magdalena (Morales-Betancur, *et al.,* 2013).

The absence of hatchlings and yearlings of *C. acutus* as interviewees reported may reflect how impacted populations could be, since in addition to being listed in the "Critically endangered" for Colombia and "Vulnerable" globally (Ponce-Campo *et al.,* Ross, 1998; IUCN, 2004), did not have an official record of their presence in the Huila Department for more than 30 years, from studies conducted by Medem in 1981.

On the other hand, in the case of landscape analysis, was observed a dominance of ecosystems impacted with lower states of conservation, being pasture and secondary landscape coverage the most dominant representing 66.7% of the analyzed area. Very similar feature was reported by Balaguera-Reina (2012) in the Cienaga de Zapatosa and Costilla, (Department of Cesar, Colombia). This item reaffirms the fact that the crocodilians today face fragmentation and habitat loss as one of the most important threats causing a decrease in wild populations or even generating local vanishing (Cavanzo-Ulloa 2004; Alvarez del Toro 1974; Varona 1987).

At the population level, this study becomes the first approach of the past 20 years, to the population ecology of *C. acutus* and *C. c. fuscus* in the upper basin of the Magdalena River (Medem, 1981; Barahona *et al.,* 1996). Although the time was considerably short, the frequency histogram reflects a population structure of *C. c. fuscus* apparently exploited, due to the low number of class III individuals reported and the absence of class IV. This lack makes reproductive and population replacement processes difficult (King *et al.* 1990), since breeding active spectacled caimans belongs to these classes. Similarly, according to the approaches of Ayarzaguena (1983), the population in the study area can be a population "over-exploited".

However, the constant contact of the crocodilians with fishermen, hunters, and boats, encourage individual behavioral changes, since organisms become more "shy" and hard-to-spot (Medem, 1981). This can support, the absence of sightings of individuals of great size. In previous works such as the national census of the Crocodylia (1994-1997), a record of *C. acutus* was also obtained, where is indicated, in general terms, that *C. acutus* populations still are very fragmented, being frequently sight isolated individuals; there is also the possibility that are restricted, in inaccessible places. This confirms the low presence of individuals from several years ago.

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