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Effect of vegetation and abiotic factors on the abundance and population structure of *Crocodylus acutus* (Cuvier, 1806) in coastal lagoons of Colima, Mexico

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***Abstract.*—Crocodile populations are affected by their environment, and disturbance of that environment leads to changes in their physiology and behavior. Using nocturnal spotlight counts, the influences of vegetation type and several abiotic factors on populations of *Crocodylus acutus* were evaluated in Colima, Mexico. Six interconnected lagoons with a known presence of crocodiles were selected, and the largest (Laguna de Cuyutlan) was divided into four sections. Differences in crocodile density and size classes among these lagoons were determined, and the effects of abiotic factors and vegetation type on the density and distribution of crocodiles were identified. Salinity could influence the crocodile populations, since low crocodile densities were observed in lagoons with high salinity. Average densities of crocodiles of 0.2–8.3 individuals/km and 0–5.9 ind/km were recorded during the rainy and dry seasons, respectively. The average densities of crocodiles of size classes I, II, and III ranged from 0.3–1.7 ind/km, whereas those of size classes IV and V ranged from 0.1–1.8 ind/km. Population densities of crocodiles were associated with factors such as salinity (<1%), and since the hatchlings and juveniles are the most vulnerable to conditions of high salinity, they are drawn to sites of lower salinity, such as those with aquatic and mangrove vegetation. This suggests that *C. acutus* can find refuge and food in the mangrove vegetation and water at ambient temperatures of 3.9–6.3 ºC. Variations observed in both the water and ambient temperatures probably did not affect the normal thermoregulation processes of the crocodiles, since they can adopt a strategy of thermoconformity in response to even minor variations in temperature. There were significant differences (*P* <0.05) among the lagoons in terms of salinity, aquatic and mangrove vegetation, and water and ambient temperatures. The coastal lagoons of Colima provided suitable habitats for crocodile distribution, but increased salinity led to the movement of crocodiles towards areas supplied with freshwater.**

Keywords. American Crocodile, depth, habitat, Pacific, salinity, wetlands

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Introduction

The American Crocodile, *Crocodylus acutus*, has the widest species distribution of its genus on the American continent. It is found from southern Florida to Colombia on the Atlantic side, and from Mexico to Peru on the Pacific side of the continent (Brandt et al. 1995). The species inhabits shallow waters and, while it prefers freshwater, the American Crocodile can tolerate high salinities and use saltwater routes to move to reproduction, feeding, nesting, and refuge areas (Lang 1987; Thorbjarnarson et al. 2006; Mazzotti et al. 2007; Cupul-Magaña 2012). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) lists *C. acutus* in Appendix II, the International Union for the Conservation of Nature (IUCN) lists the species as Vulnerable, and the Official Mexican Norm 059-SEMARNAT-2010 considers it a species subject to special protection (DOF 2010).

Large specimens can be found at great depths in Costa Rica, and high water salinity levels lead to a greater dispersion of the animals (Mauger et al. 2012).

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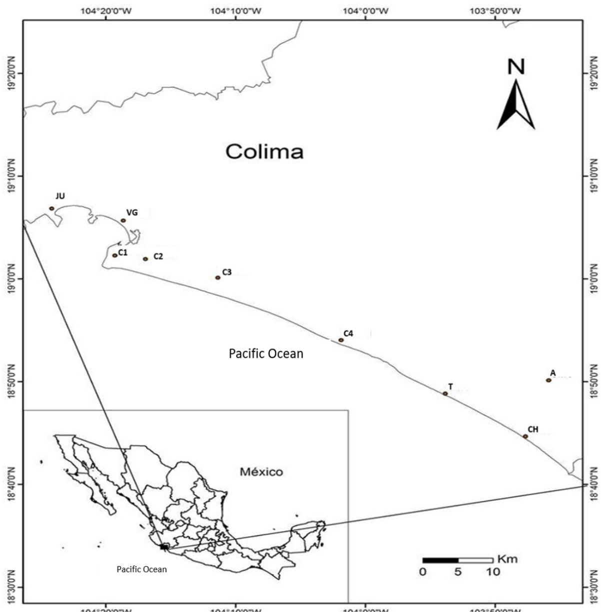

Fig. 1. Selected sites in the study area. Acronym definitions and characteristics of the sites are given in Table 1.

Relationships between low crocodile densities and increased water temperature, high salinity, and poor vegetation cover have been reported in Ecuador (Carvajal et al. 2005). However, Cherkiss et al. (2011) did not find a relationship between water or air temperature and crocodile densities in Florida, although these authors did observe that all crocodile size classes preferred protected canals and ponds of low salinity surrounded by vegetation. The distribution of American Crocodiles in Colombia is influenced mainly by resource availability (Balaguera and González 2008). It is therefore important to determine the relationships between these variables and crocodile densities in Mexico, compared to other populations of this species.

While García-Grajales and Buenrostro-Silva (2014) did not analyze salinity values on the coast of Oaxaca, Mexico, these authors determined that high crocodile densities were associated with mangrove vegetation since the crocodiles preferred to stay hidden among the mangrove roots. This finding coincides with previous reports from Jalisco and Veracruz, where the density of crocodiles *C. acutus* (Cupul-Magaña 2012) and *Crocodylus moreletii* (González-Trujillo et al. 2014) decreased in modified habitats unless a strip of vegetation was present near the water bodies. In Nayarit, Mexico, Hernández-Hurtado et al. (2011) reported high densities of all sizes of *C. acutus*, which were associated with sites of low salinity, depths exceeding 1 m, and six types of vegetation, conditions in which the crocodiles presented greater dispersion and benefited from a higher availability of food and shelter.

The coastal area of Colima, Mexico, has undergone changes due to extensive construction of infrastructure. Over a period of 13 years, 145.40 ha of mangrove have been lost, out of a total area of 494.02 ha, which has modified the physical and biological structure of the coastal ecosystems (Jiménez-Ramón et al. 2016). While it is likely that a consequent modification of the crocodile habitat could have occurred, the biotic and abiotic variables related to the density and distribution of American Crocodile populations that inhabit the area are unknown. Therefore, the objective of the present study was to evaluate the state of the crocodile populations in Colima, Mexico, and to determine which habitat variables influence the abundance, structure, and distribution of this species. A greater crocodile abundance was expected at lower salinities, as well as a greater density of adult crocodiles in areas with higher temperatures, and higher numbers of hatchlings and juveniles in areas with a greater presence of aquatic vegetation.

Materials and Methods

Study area. The coastal zone of the state of Colima, which comprises the study area, presents annual temperatures ranging between 20 and 28 ºC and mean annual precipitation of 947.8 mm. The rainy season begins in June, and precipitation events can be torrential, especially at the end of August and the beginning of September, while the rains begin to decrease in November (Arévalo et al. 2016). This region supports vegetation communities of low elevation dry deciduous forest, scrub forest, and mangrove forest. Lagoons with a known presence of crocodiles were selected for this study, based on information provided by the local environmental authorities and communities established close to each lagoon. Six lagoons were selected, with the largest (Laguna de Cuyutlán) divided into four sections that communicated directly with each other (see Fig. 1 and Table 1 for lagoon abbreviations). The dominant vegetation found in the selected lagoons is mangrove forest comprising the species *Rhizophora mangle* and *Laguncularia racemosa*, with secondary vegetation such as *Acacia* sp., and floating vegetation such as *Typha domingensis* and *Echhornia crassipes*. It should be noted that some lagoons are permanently connected to the ocean (JU, C1, C2, C3), while others are connected for only part of the year (VG, T, CH), and some are completely disconnected from the ocean (C4 and A).

Sampling data. Night visits were made twice during the rainy season (once in June 2014 and once in November 2015) and twice during the dry season (once in March 2015 and once in May 2016). The nocturnal spotlight technique, as proposed by Messel et al. (1981) and Thorbjarnarson et al. (2000), was used to determine the relative population density, reported as individuals per km (ind/km). From a 25 hp outboard motor boat, either a 500-lumen headlamp or a handheld torch was used to illuminate the water surface, the lagoon edges, below the mangrove vegetation, and the emergent vegetation. The individuals counted were grouped into size classes I to V

Table 1. Identification key of study sites and environmental variable value averages for each site during the two seasons. **Ta:** water temperature; **Tai:** ambient temperature; **Sal:** salinity; **P:** depth.

Key	Lagoon/Estuary	Latitude	Longitude	Sal (psu)	Ta (°C)	Tai (°C)	P (m)
JU	Juluapan	19°06'50"	104°24'23"	24.9	28.7	25.9	1.9
VG	Valle de las Garzas	19°05'17"	104°18'20"	2	28.9	27	1.3
C1	Cuyutlán Vaso I	19°02'13"	104°19'18"	32.3	28.8	25.4	1.6
C2	Cuyutlán Vaso II	19°01'12"	104°15'30"	32.1	28.2	25.4	1.1
C3	Cuyutlán Vaso III	19°00'15"	104°12'53"	30.1	31.3	28.3	1.1
C4	Cuyutlán Vaso IV	18°54'05"	104°01'53"	0.5	30.4	27.1	0.8
T	Tecuanillo	18°48'49"	103°53'52"	0.5	26.4	25.4	1.4
CH	Chupadero	18°45'01"	103°48'08"	0.6	29.3	24.8	1.4
A	Amela	18°50'21"	103°45'49"	0.3	31.2	27.4	3.5

according to total body length, which was estimated by calculating the distance from the base of the eyes to the end of the snout of the crocodile and multiplying by ten (Platt and Thorbjarnarson 2000).

Temperature and salinity were recorded at every km traveled on the lagoons. These parameters were measured with a multiparametric PCSTestr35 (OAKTON, Vernon Hills, Illinois, USA), with a salinity meter accuracy of ±1.0% FS and automatic temperature compensation. Depth was measured with an aluminum leveling rod 10 m in length, graduated in centimeters. Vegetation type was the only biotic factor recorded; each lagoon was visited during the day in order to describe the species of flora present, which were grouped into four vegetation types based on the classification by Ramírez-Delgadillo and Cupul-Magaña (1999). The distance covered by each vegetation type along the shore of each lagoon for each km traveled was measured with a GPS brand Garmin model e-trex 10, in order to determine a relationship between the vegetation data and the presence of crocodiles.

Data analysis and statistics. To determine the degree of association between crocodile density, abiotic factors (water temperature, ambient temperature, depth, and salinity), and vegetation, a non-metric multidimensional scaling analysis (NMDS) was performed in the program PAST version 3.08 (Hammer et al. 2001), using the average value of each variable obtained in each selected lagoon. A dissimilarity matrix was obtained using the Bray-Curtis coefficient (Hammer et al. 2001). This analysis creates a stress coefficient, for which a value below 0.1 indicates that the groups formed differ in their compositions. To corroborate the groups obtained, a dendrogram was created using the Bray-Curtis coefficient (Hammer et al. 2001). This dendrogram provided a correlation coefficient which indicated the similarity among the lagoons, with values close to 1 indicating greater similarity.

Differences in crocodile density between seasons, lagoons, and size classes were estimated with a Kruskal-Wallis test ($P < 0.05$). This same analysis was used to evaluate differences in crocodile densities between the lagoons that were connected to each other, and between lagoons that were either always connected to the ocean, connected for only part of the year, or completely disconnected from the ocean. Differences between abiotic factors per season and per lagoon were evaluated with a Kruskal-Wallis test ($P < 0.05$), and a Tukey test ($P < 0.05$) was used to identify where differences occurred. This same analysis was used to evaluate differences in vegetation per type and per lagoon. All of these analyses were performed using the software package PAST version 3.08 (Hammer et al. 2001).

Results

The study was conducted in a total of six lagoons that collectively represented a surface area of approximately 9,545 ha, and were located along 76.6 linear km of the coastline of Colima state. Significant differences were found in the crocodile densities in these lagoons in both seasons ($P = 0.0001$); the Tukey test indicated that the differences occurred between the lagoons with greater crocodile density (A and VG) and those with lower density (C1, C2, and T). The NMDS analysis and the dendrogram integrated the data from both seasons and generated a stress coefficient of 0.06 and a correlation coefficient of 0.92. There was a separation between the lagoons connected to the ocean (JU, C1, C2, and C3) as one group, and those that were either not connected to the ocean or only connected for part of the year (VG, CH, and T) as another group (Fig. 2). However, the dendrogram showed that lagoon C4 was similar to the group of lagoons not connected to the ocean, while lagoon A was dissimilar to all the others (Fig. 3).

Crocodiles were observed at the nine study sites during both seasons. Relative frequencies ranged from 0.2–8.3 ind/km and 0–5.9 ind/km during the rainy and dry seasons, respectively (Fig. 4). There were significant differences in density in the A and CH lagoons during the two periods ($P = 0.0001$), but no differences were found between size classes ($P = 0.4$).

The density of individuals in the lagoons connected to the ocean (JU, C1, C2, C3) was lower than in those not connected to the ocean or connected for only part of the year ($P = 0.006$). Densities of 0 to 1 ind/km in size classes I, II, and II, and of 0 to 0.4 ind/km in size classes IV and V, were recorded in the lagoons connected to the ocean for

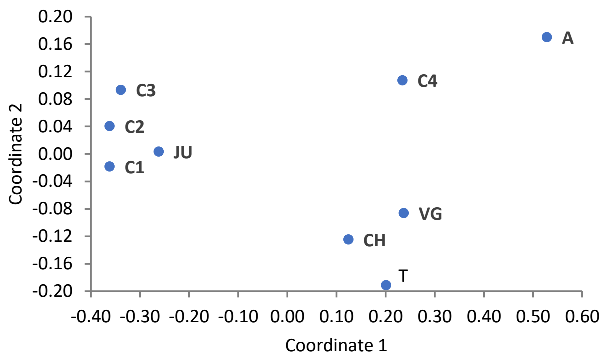

Fig. 2. Non-metric Multidimensional Scaling (NMDS) analysis showing the formation of two groups, by taking into account the crocodiles observed, water salinity, temperature, depth, and the four vegetation types present. Acronym definitions and characteristics of the sites are given in Table 1.

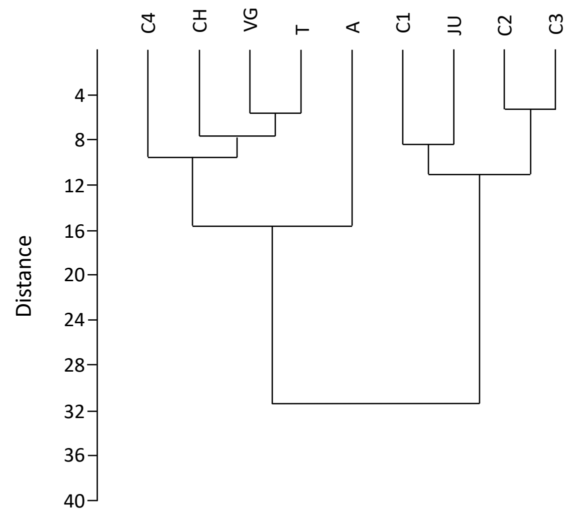

Fig. 3. Dendrogram considering the crocodiles observed, water salinity, temperature, depth, and the four vegetation types present. Acronym definitions and characteristics of the sites are given in Table 1.

only part of the year (Table 2). Eight species of flora were identified on the shores of the sampling sites, all of which were included in the vegetation classification proposed by Ramírez-Delgadillo and Cupul-Magaña (1999). *Rhizophora mangle* and *L. racemosa* were classified as mangrove forest species, *T. dominguensis* and *E. crassipes* as aquatic vegetation, *Acacia* sp. and *Guazuma ulmifolia* as secondary vegetation, and *Batis maritima* and *Cocos nucifera* as pasture-agricultural vegetation. Of the 78.5 linear km traveled, mangrove vegetation was present in eight of the nine lagoons, representing an overall presence of 72%. Site A did not present mangrove vegetation; however, 61% of the banks of this lagoon presented aquatic vegetation and 39% presented secondary vegetation. Of the total crocodile population, 55.4% was recorded in the lagoons where mangrove vegetation occurred, while the remaining crocodiles were recorded in aquatic vegetation (Table 3). There were significant differences in crocodile density between vegetation types ($P = 0.003$). The Tukey test showed that the mangrove vegetation differed significantly ($P < 0.05$) in this regard from the other vegetation types.

Salinity ranged from 0.2–27% during the rainy season, and from 0.4–35.3% during the dry season. There were significant differences in this parameter between the two seasons ($P = 0.001$) and between the averages of lagoons ($P = 0.0002$); and differences were also detected ($P < 0.05$) between the lagoons connected to the ocean (JU, C1, C2, C3) and those that were not connected to the ocean (VG, C4, T, CH, A). Water temperature ranged from 25.8–32.1 ºC during the rainy season, and from 27.9–31.8 ºC during the dry season, with a significant difference found between the two seasons ($P = 0.0002$). The ambient temperature ranged from 22.1–29.3 ºC during the rainy season, and from 26.3–28.2 ºC during the dry season, also with a significant difference between the two seasons ($P = 0.0002$). The depth range was 0.9–3.5 m during the rainy season and 0.6–3.6 m during the dry season; but there was no significant difference between the two seasons ($P = 0.7$) in this regard, although there were differences ($P = 0.0005$) in depth between lagoons. Lagoon A differed significantly ($P < 0.05$) from the other lagoons (JU, VG, C1, C2, C3, C4, T, CH).

Discussion

Density

The crocodile density ranges found in this study (0–8.3 ind/km) during the two seasons in the nine lagoons can be considered low. This is due to the influences of salinity, ambient temperature, water temperature, and

Table 2. Crocodile population structure expressed as relative density (individuals/km) and percentages (%) for each lagoon, in the two study seasons. **Only eyes** indicates individuals for which the size could not be determined.

	Size classes											
Lagoon	**I**		**II**		**III**		**IV**		**V**		**Only eyes**	
	I/km	%	I/km	%	I/km	%	I/km	%	I/km	%	I/km	%
JU	0	0	0.9	22.4	0.7	15.3	1.1	34.1	0.3	10.6	0.6	17.6
VG	0.5	7.2	1.8	26.4	1.7	24.1	0.8	12	0.4	6	1.7	24.1
C1	0	0	0.1	1	0	0	0	0	0	0	0	0
C2	0.3	35.3	0.2	29.4	0.3	35.3	0	0	0	0	0	0
C3	0.2	7	1	32.8	0.7	21.5	0.6	20.4	0.4	11.3	0.2	7
C4	0.6	27	0.6	29.1	0.5	22.7	0.3	12.1	0.1	4.3	0.1	5
T	0	0	0	0	0	0	1.8	1	0	0	0	0
CH	1	30.3	0.3	7.9	1	31.6	0.4	13.2	0.4	11.8	0.2	5.3
A	0.9	13	0.4	5.7	1	15	1.8	26.8	1.5	22	1.2	17.5

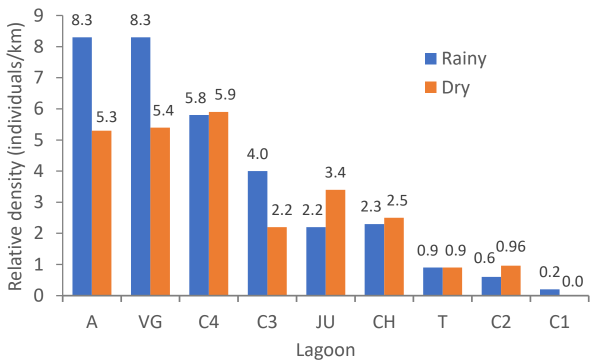

Fig. 4. Average relative *Crocodylus acutus* density in the studied lagoons during the two (rainy and dry) study seasons. Acronym definitions and characteristics of the sites are given in Table 1.

the mangrove vegetation, which varied depending on the connection with the sea in lagoons JU, C1, C2, and C3. This density level can be compared to four other similar studies in different parts of Mexico.

In Chamela-Cuixmala, Jalisco, García et al. (2010) recorded 20.4–32.5 ind/km, classifying this density as high and attributing it to variables such as water depth (0.5 m) and mangrove vegetation cover.

In Boca Negra, Jalisco, Cupul-Magaña et al. (2002) reported 51.2 ind/km and classified this density as high, attributing it to the fact that the area provided the crocodile population with refuge and feeding areas through the presence of mangrove vegetation.

In Palma Sola, Oaxaca, García-Grajales and Buenrostro-Silva (2014) reported a density of 70 ind/km, classifying this value as high and attributing it to the presence of the mangrove vegetation which provided an important refuge area for the crocodiles.

In San Blas, Nayarit, Hernandez-Hurtado et al. (2011) reported densities of 0.36–4.31 ind/km, which were within the ranges found in this study, with the highest densities found in sites with depths greater than 1 m, slow currents, low salinities (4.92–11.03%), high elevations, and six vegetation types, including mangrove swamp.

Thorbjarnarson et al. (2006) designated an area of 22,790 ha as a bioregion of the coast of Colima and Jalisco. They considered the vegetation type as an important variable and estimated a population of between 500 and 1,000 crocodiles. That assessment does not coincide with the results of this study, since in less than half of that area (9,945 ha belonging to the coast of Colima), 506 crocodiles could be observed. However, the difference may be due to the fact that the previous study did not include any of the specific lagoons examined in the present study.

Population Age Structure

The age structure observed in the present study (Table 2) suggests that the populations of crocodiles in Colima are in good health, since the highest percentage of the population belonged to classes I, II, and III, which are classified as juveniles and subadults (Seijas 2011). According to Calverley and Downs (2014), a population structure where the largest number of crocodiles is represented by juveniles and subadults can indicate a positive trend, whereas a population where the largest number of crocodiles is adults indicates a population in decline. In this study, fewer size class III crocodiles were found in lagoons JU, VG, C4, and C3 (Table 2), probably due to dispersion behavior (Cedeño and Pérez 2010; Hernández-Hurtado et al. 2011; García-Grajales and Buenrostro-Silva 2014). This suggests that size class IV and V crocodiles dispersed towards the vegetation because of their territorial behavior, and remained there in refuge without moving towards the open areas of the lagoon (Carvajal et al. 2005; Balaguera and González 2008).

Vegetation Types

In this study, mangrove was the predominant vegetation and it was where the highest percentage of crocodiles was recorded. This suggests that *C. acutus* finds refuge and food in the mangrove vegetation in Veracruz. González-Trujillo et al. (2014) reported the density

Table 3. Linear extents (km) and percentages of vegetation types found in each lagoon.

Lagoon	Mangrove km (%)	Aquatic vegetation km (%)	Secondary vegetation km (%)	Pasture-agriculture km (%)
JU	6 (100)	0	0	0
VG	1.5 (50)	0	0	1.5 (50)
C1	6 (100)	0	0	0
C2	15.5 (97)	0	0	0.3 (3)
C3	16 (100)	0	0	0
C4	4 (67)	2 (33)	0	0
T	0.564 (100)	0	0	0
CH	7 (100)	0	0	0
A	0	11 (61)	7 (39)	0

of *Crocodylus moreletii* was related to vegetation type, with mangrove hosting the largest number of crocodiles and attributed this to the vertical structure of the mangrove, which provides suitable shelter. For *C. acutus* in Oaxaca, García-Grajales and Buenrostro-Silva (2014) recorded the largest number of crocodiles in the mangrove vegetation and attributed this to the fact that crocodiles prefer to remain hidden among the roots of the mangroves. In Ecuador, Carvajal et al. (2005) stated that, in addition to providing refuge for the crocodiles, the mangrove vegetation also provides food resources in the form of invertebrates and vertebrates that also inhabit the mangrove.

However, in Florida, Cherkiss et al. (2011) report that mangrove is the habitat used least by *C. acutus* crocodiles, since the largest number of individuals was observed in artificial ponds, canals, and streams, which offer more protection and this species can easily adapt to anthropogenically created or transformed habitats. In the present study, the Amela (A) lagoon is the largest and has the most abundant aquatic vegetation where the highest densities of crocodiles were recorded.

Abiotic Factors: Salinity, Connection to Ocean, Depth, and Temperature

Salinity was an important factor in crocodile abundance in the different water bodies. The lagoons with the highest salinity formed one group and those with lowest salinity formed another group (Table 1; Figs. 2 and 4). Salinity could negatively affect the crocodile populations, particularly the young (classes I and II) and juveniles (class III), because high salinity causes the individuals of this species to dehydrate, unlike *C. porosus* in Australia which has two glands in the palate that allow it to expel excess salt (Richards et al. 2004). The salinity-sensitivity of this species was reflected in crocodile densities, since the lowest values were recorded in the lagoons with high salinity (Fig. 3). Hernández-Hurtado et al. (2011) also reported a decrease in crocodile density when salinity increased (24.76–35.85%). An increase in crocodile density was observed here from the northern (C1) to the southern (C4) sites sampled within the Cuyutlán Lagoon (C1, C2, C3, and C4). At the latter site, salinity had decreased to concentrations of 0.4–0.7% and juvenile and adult crocodiles (classes I, II, and III) were dominant (Table 2). This could be due to the fact that hatchlings and juveniles are the most vulnerable to high salinity concentrations, which would prompt them to seek out sites of lower salinity (Richards et al. 2004).

Dispersion of crocodiles towards different areas in search of freshwater has been reported (Dunson and Mazzotti 1989). A preference of crocodiles for areas with salinity below 1% has also been observed (Espinosa et al. 2012). The effect of salinity on crocodiles in classes I and II could be fatal, since hatchlings and juveniles have little tolerance for high salinity (Lang 1987). While some of the highest salinities in this study were observed at lagoon C2, a large number of hatchlings were recorded there (Fig. 3). However, these animals would die rapidly due to dehydration if they did not move to sites with lower salinity; and this was reflected in the relative densities of classes IV (0 ind/km) and V (0.5 ind/km) [Richards et al. 2004; Hernández-Hurtado 2010].

While lagoon JU was permanently connected to the ocean, crocodiles of all classes, other than class I, were observed there, and they were also observed very close to the mouth of the Miramar Creek. The crocodiles in size classes I, II, and III can avoid the high salinity of the lagoon by finding refuge up this freshwater creek during the rainy season, where they can reach adult sizes. Individuals of *C. acutus* have been reported up this creek (at elevations up to 1,220 m asl) between Guerrero and Oaxaca (Casas-Andreu et al. 1990).

Temperature variations ranged from 3–6 ºC (Table 1) in the two study seasons. Carvajal et al. (2005) reported that high temperatures (40 ºC) influenced the distribution of crocodiles, which preferred lower temperatures; whereas Espinosa et al. (2012) reported that low temperatures (14.42 ºC) influenced the distribution of crocodiles, which were observed in areas with higher temperatures. Lang (1987) reported a positive correlation between water temperature and crocodile density, as water and air temperatures influence the body temperature of crocodiles with implications for their physiological processes. The relatively minor temperature variations observed during this study probably did not affect the normal crocodile thermoregulation processes. This could be due to the fact that crocodiles living in environments with little temperature variability adopt a strategy of thermoconformity. In order to control this physiological process, the crocodiles spend a large part of the day and night in the water regulating their body temperature, a process in which water depth can play an important role (Campos and Magnusson 2012; Grigg et al. 1998; Lang 1987).

The depths observed in the present study ranged from 0.6–1.92 m (Fig. 3), with significant differences in depth among the lagoons. Lagoon A differed significantly from the others, presenting both the greatest depths and highest crocodile density. However, the depths recorded in all of the lagoons were sufficient for the crocodiles to move, reproduce, and feed (Fujisaki et al. 2009). Calverley and Downs (2014) stated that variations in depth could affect the number and distribution of crocodiles. Hernández-Hurtado et al. (2011) recorded the greatest number of crocodiles at depths of over 1 m, which corroborated the finding by Campbell et al. (2010) of a high correlation between water depth and the distance traveled by crocodiles towards feeding areas. Fujisaki et al. (2009) reported that depth had a direct influence on adults during the reproductive period, since both males and females seek water depths of over 1 m in order to mate.

Lagoon A had no similarities with any of the other lagoons during both seasons. This lagoon was characterized by having mostly aquatic vegetation and abiotic factors that remained rather constant, with water temperature variations of 1 ºC, air temperature variations of 2 ºC, as well as the greatest depths, and freshwater available throughout the year. The distribution and state of health of the crocodiles at this location were dictated by the low variation in the abiotic factors and aquatic vegetation that provided refuge and food. Moreover, in this case, intraspecific relationships had a greater influence on the population (Lang 1987; Grigg et al. 1998; Balaguera and González 2008; Cherkiss et al. 2011).

Conclusions

In the present study, the abiotic and biotic factors evaluated, including salinity, ambient temperature, water temperature, and mangrove vegetation, were found to have close relationships with the population dynamics of the crocodiles in the State of Colima, and changes in these variables may influence the distribution of *C. acutus* populations. High salinities may restrict the crocodiles to sites that are supplied with fresh water, either constantly or for some part of the year. These high salinities can have direct effects on organisms, particularly in the early stages of their development. Continued monitoring of these variables, as well as the populations of crocodiles, should contribute to our understanding of the behavior of these populations of crocodiles prior to modification of their habitat, as well as determining the characteristics of the habitat they prefer. These are priorities for contributing to the improved management and conservation of this species.

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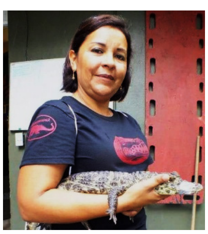

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