Population Status of the American Crocodile (*Crocodylus acutus*) in the Tempisque Great Wetland, Guanacaste, Costa Rica, 2009-2010

Juan Rafael Bolaños Montero

(cocodrilo1@gmail.com)

Abstract

To determine the status of the crocodile (*C. acutus*) population in the Tempisque River, Guanacaste, Costa Rica, I studied the whole influence area of the river, rather than just its navigable segment. Every contributor river, small lagoon and related wetland were taken into account, in what I named here as the Tempisque Great Wetland (TGW). I partially examined the effect of some climatic factors, as well as the historical use of land. I estimated the population size as 2315 individuals, and a total of 1951±25.26 (84.3%) non-hatchling crocodiles; split in 292 (15.0%) in the Upper Basin, 1262 (64.7%) for the Lower Basin, and 397 (20.4%) for the Marshes Area. Relative density is 4.56, 8.79 and 23.08 ind/km respectively. Estimated general relative abundance was 8.68 ind/km. General size structure estimated was 386 (16.7%) recruits, 454 (19.6%) juveniles, 648 (28.0%) sub-adults, and 463 (20.0%) adults. Sex ratio was 3.3:1 (male:female).

Introduction

Studies about the state of the populations of crocodiles (*Crocodylus acutus* Cuvier 1807) are nowadays more frequent in Costa Rica, with pronounced interest in the populations of the Pacific coast (Sasa and Chaves 1992; Bolaños *et al*. 1997; Piedra 2000; Porras-M 2004); as much as to determine the population of the Tempisque River as the most important among all others in the country. Information exists regarding the size and sex distribution of this population (Bolaños *et al*. 1997; Sánchez 1992, 2001). Nevertheless, these studies have been carried out only in the navigable river channel, with an approximate total length of 50 km from its mouth in the Gulf of Nicoya, to the place known as La Cutacha, upstream at a height of the Hacienda El Viejo.

During the last 15 years, repeated accident occurrence with crocodiles, reports of crocodiles in places where they had not been sighted before, as well as reports of high numbers of individuals in several Tempisque's contributors, like the Bebedero, Charco and Cañas Rivers; besides the worrying crocodile visit in aquaculture ponds in the counties of Cañas and Bagaces (Bolaños, in prep.), have attracted attention towards the possibility that the actual evaluations of the population of crocodiles in the Tempisque river have been showing underestimated results, if considered that the studied population was always the same relatively small fraction of the real population of crocodiles of what I call here as the Tempisque Great Wetland (TGW), from the High Basin of the river in the birth of the Tempisquito River, down to the Gulf of Nicoya in the Toro Island; including its most important contributors and adjacent wetlands along its trip towards the sea.

The present study establishes an integral conception of the habitat of the crocodile in the Tempisque River, as well as an improved conceptualization and better estimation of the status of its crocodile population.

Materials and Methods

Study Area

It is possible to split the TGW into Upper Basin, Lower Basin and Area of Marshes, since each of them is clearly differentiated by conditions of soil genesis, geomorphologic gradient, water regime and green coverage.

The Upper Basin is characterized by soils of volcanic origin (Cabrera 2007) where the clear water runs on a stone bed where the river has washed cannons of up to 6 m deep in the stone, with a range in altitude from up to 90 m asl at the bridge of the Inter-American Highway on the Tempisquito River, down to 30 m asl along the community of Guardia (Cabrera 2007). This condition determines the existence of a system of gradients, by means of which the connection is established between long ponds of up to 600 m long and with a 30 m average width. There exists an average threshold of 30 m of area of damping forest coverage in both margins of the watercourses, with secondary forest mostly, with a canopy of approximately 10 m high in species as espavel (*Anacardium excelsum*), jobo (*Spondias mombin*), gallinazo (*Schizolobium paraibum*), ceibo (*Ceiba pentandra*), tempisque (*Sideroxylon capiri*) among others. During the achievement of the study, I observed local proper fauna, like coyote (*Canis latrans*), nutria (*Lutra longicaudis*), iguana (*Iguana iguana*), garrobo (*Ctenosaura similis*), guatuza (*Dasyprocta punctata*), pizote (*Nasua narica*), mapache (*Procyon lotor*), urraca (*Calocitta formosa*), martín peña (*Tigrisoma mexicanus*), garza real (*Ardea alba*), tamandúa (*Tamandua tetradactyla*), mono congo (*Alouata paliata*), mono cariblanco (*Cebus capuchinus*), boa (*Boa constrictor*) among others. There is an extensive use of land to raise cattle for meat, with wide extensions of area covered by pastures (Peters 2001). The urban pressure on the water river beds is here of low impact, with the unique reference to the small town of Irigaray.

The Lower Basin is considered from the community of Guardia, 30 m asl down to 0 m asl, at the mouth of the river in the sea. The river's water runs here in a sedimentation substratum of alluvial origin, which goes by a lot slower than it uses to go in the High Basin, without the presence of rapids along the river bed. The waters here are cloudy, as a result of the sedimentary effect of waters running on soil. The river has here a 50 m average width and the average depth is of between 6 and 8 m during the rainy season. Meanwhile, during the dry season, the width of the river and its average depth is 20 m and from 2 to 4 m respectively, with the frequent existence of deep large ponds. From La Cutacha to its end in the sea, the river reduces the speed of its current, acquires more width and depth and allows, thanks to the fact that the tides affect up to this sector, the navigation by crafts of low openwork like boats and tourist longboats. In this area the shores of the river are of light slopes, with green coverage basically of bushes, except in the area protected by the Palo Verde National Park, where the forest coverage is from primary and secondary forest composed by proper forest species of the area (Sánchez, 2001) and from swamp and mangrove forest. The agricultural activities as the raising of rice, sugar cane and watermelon or cantaloupes are taken up to the very margin of the river, without respect of the damping area required by Law 276 for protection of the watercourses. Along the river, every year the companies dedicated to the production of these goods accustom to "clean" the shore of the river with heavy machinery up to a 50 m margin from shore, they keep and maintain the dike that must protect them from the winter floods, jeopardizing the crocodile nesting banks already established. There also exist water authorizations granted by Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento (SENARA) for the irrigation of cultures in the Low Basin of the Tempisque. During the dry season (ENE-ABR) this water extraction goes as far as to reduce the water volume in a very significant way (Alvarado *et al*. 2008), to the point in which the inhabiting fauna migrates in search of water and life in the internal area of the territory, in the areas of cultivation. The Low Basin of the Tempisque presents a strong impact for urban pressure, owed to the growth of cities like Guardia, Liberia, Filadelfia, Santa Cruz, Bagaces, Cañas, Bebedero, Comunidad, Belén, Bajo Tempisque. Some of the faunistic species sighted during the achievement of the work were raccoons (*P. lotor*), pizotes (*N. narica*), coyote (*C. latrans*), garza real (*A. alba*), martin peña (*T. mexicanum*), iguana (*I. iguana*), garrobo (*C. similis*), mono cariblanco (*C. capuchinus*), mono congo (*A. paliata*), chocuaco (*Cochlearius cochlearius*), garza azul (*Egretta caerulea*), cigüeñón (*Mycteria americana*), garza bueyera (*Bubulcus ibis*).

As Area of Marshes I classified to what would represent a species of attached wetland inside the TGW adjacent to the Tempisque river in the field of its Lower Basin and in the side of the Peninsula de Nicoya. This area gets completely connected every year with the main river bed of the Tempisque during the rainy season, product of the floods; but it remains in a relative separation during the months of the dry season, only connected across minimal courses of water of the El Charco and Bolsón Rivers, as well as other small meanders that drain the area, thus connecting the lagoons Mata Redonda, Corral de Piedra and Sonzapote with the rest of the marsh and with the main river channel.

Since the beginning of the colonization of the Guanacaste Province in 1821, it has been experienced a sensitive decrease of the green coverage, and a large area has been transferred from wilderness to the development of pastures for cattle raising, both in the Upper Basin and in the Lower Basin (Peters 2001). Further on, the advent of the mechanization in the cultivation, supported by the creation of the Irrigation District of Moracia, made possible the incorporation of more grounds of the Lower Basin plains, as well as the replacement of some areas of extensive cattle for cultivation like rice, sugarcane, sorghum, cotton and corn (Peters 2001). At present the basic cultivation is rice and sugarcane, watermelon and cantaloupe, which occupy large extensions of land, up to the very margin of the water courses, and which minimize the water volume of the Tempisque River, determining that with a normal environmental water volume, only 31% of the whole of profiles of depth fulfill with the requests of *C. acutus* (Alvarado *et al*. 2008).

The development of the livestock business, and then the expansion of the agricultural border, promoted in the area the improvement of the road network and general routes of communication, to ease the supply of inputs and products extraction to the available markets (Peters 2001); as a result, the additional labor force brought with it a strong urban development, which expanded the limits of the existing establishments and propitiated the establishment of more urban centers for the development of the area. Under these circumstances, the habitat provided by the rivers, estuaries, swamps and attached wetlands, turned out to be submitted to the joint effect of these factors, and led to a reduction of the space available for the species that inhabit this habitat, to the overcrowding of their populations, and to an inconspicuous condition of life, in which there was more and more frequent and normal to meet a crocodile, and crocodiles were pressed to be mobilized up to places that earlier they had not dared to visit, in search for water and their natural preys.

During the 1990s it initiated the development of aquaculture in the area, with the consolidation of companies favored by the Irrigation District of Moracia, dedicated to the production of tilapia in the counties of Cañas and Bagaces, which establishments induced positively the food offer for the native fauna and relieved the scarcity that should have happened as a result of the negative effects aimed in the previous paragraph.

Table 1. Sampling segments in the area within the established cartographic land marks.

Segment	Location	m asl
Upper Basin		
Corobicí River	10° 27' 11.1" N 85° 07' 44,6" W	29
Interamericana - Tenorio	10° 26' 00.2" N 85° 09' 24.2" W	21
Tempisquito River		
Interamericana - Ahogados	10° 48' 56.1" N 85° 32' 37.3" W	90
	10° 44' 00.5" N 85° 31' 32.9" W	75
Los Ahogados River	10° 48' 10.0" N 85° 30' 02.1" W	66
Ahogados - Tempisquito	10° 44' 00.5" N 85° 31' 32.9" W	75
Colorado River	10° 39' 43.3" N 85° 31' 37.2" W	60
Colorado - Tempisque	10° 38' 08.5" N 85° 33' 46.8" W	42
Tempisque River		
Irigaray - Guardia	10° 43' 14.6" N 85° 31' 09,8" W	66
	10° 34' 13.6" N 85° 35' 20.8" W	39
Lower Basin		
Tempisque River		
Segment A	10° 12' 44.6" N 85° 14' 05.0" W	0
Níspero - Puerto Humo	10° 18' 59.2" N 85° 21' 09.7" W	0
Segment B	10° 18' 59.2" N 85° 21' 09.7" W	0
Pto. Humo - Pto. Chamorro	10° 20' 31.1" N 85° 21' 59.3" W	8
Segment C	10° 20' 31.1" N 85° 21' 59.3" W	8
Pto. Chamorro - Bolsón	10° 21' 53.8" N 85° 24' 36.6" W	7
Segment D	10° 21' 53.8" N 85° 24' 36.6" W	7
Bolsón - Puente Pelón	10° 25' 20.1" N 85° 24' 08.0" W	9
Bebedero River	10° 22' 11.4" N 85° 11' 50.9" W	11
Bebedero - Tempisque	10° 15' 08.4" N 85° 14' 20.6" W	1
Tenorio River	10° 22' 11.4" N 85° 11' 50.9" W	11
Bebedero - Interamericana	10° 27' 59.6" N 85° 09' 44.1" W	34
Blanco River	10° 22' 11.4" N 85° 11' 50.9" W	11
Bebedero - Puente bajo	10° 23' 24.4" N 85° 12' 38.1" W	12
Cañas River	10° 21' 11.3" N 85° 08' 05.0" W	17
Hotel - Bebedero	10° 20' 04.7" N 85° 12' 04.4" W	
Tempisque River		
Palmira - Filadelfia	10° 30' 47.8" N 85° 34' 08.8" W	21
	10° 25' 19.5" N 85° 31' 42.7" O	17
Tempisque River		
Las Bombas - El Pelón	10° 26' 37.2" N 85° 26' 14.9" W	17
	10° 25' 48.1" N 85° 24' 37.1" O	9
Marshes Area		
Mata Redonda Lagoon	10° 19' 58.7" N 85° 24' 50.3" W	4
	10° 18' 47.8" N 85° 24' 42.5" O	3
El Charco River	10° 20' 26.7" N 85° 25' 29.2" W	9
	10° 20' 48.2" N 85° 24' 29.8" O	7
Bolsón River	10° 22' 08.2" N 85° 25' 41.3" W	8
	10° 21' 53.7" N 85° 24' 37.8" W	7

The Working Segments

I determined the study area based in available information in the cartographic sheets 1:50000 of the National Geographical Institute; numbers 003 Murciélago, 004 Ahogados, 006 Carrillo Norte, 065 Belen, 066 Tempisque, 067 Cañas, 021 Talolinga, and 022 Abangares; with support in reviews realized in Google Earth. I proceeded to evaluate thru actual surveys in the field, the best possibilities of both day and night action, as well as the importance and relevancy of inclusion of the segments; according to the knowledge acquired thru years of work in the rivers and marshes of the studied area, and of the dynamics of the populations of crocodiles in every place. This way, according to my best criterion, I chose to make direct observations in the following study segments.

Related to climate, the National Meteorological Institute (2010) has two small meteorological stations in the study area, Llano Grande in Liberia and Taboga in Cañas. According to information gotten from this source in series of time of 20 years between 1989 and 2008, Table 2 delivers information about the behavior of some climatic factors at both stations.

Table 2. Average daily climatic parameters (standard deviation in brackets) by meteorological station and season, for 2008.

Parameter	Season	Llano Grande	Taboga
Humidity (%)	Dry	62.39 (4.37)	65.21 (5.34)
	Rainy	83.27 (4.94)	82.72 (5.34)
Rainfall (mm)	Dry	7.5 (17.86)	17 (34.01)
	Rainy	283.3 (212.52)	253.97 (159.81)
Maximum Temperature (ºC)	Dry	34.65 (1.16)	33.18 (1.25)
	Rainy	31.43 (0.97)	31.76 (0.79)
Minimum Temperature (ºC)	Dry	21.5 (1.11)	23.31 (1.43)
	Rainy	22.21 (0.65)	22.64 (0.93)

Data Collection

I made as much as 22 field trips of an average of 3 nights each, between December 2008 and October 2010. Sometimes I could make observations both day and night. In every case, I did the field work during nights with no moon light, in order to prevent from affecting crocodile sighting in the river. I used a 3.5 m inflatable boat AVON and a 15HP Yamaha engine, in the usually navigable rivers like Tempisque from the ocean to the Bridge at Hacienda El Viejo, and the Bebedero River, from its confluence with the Tempisque River, up to the town of the same name. I worked the Blanco River using the same boat, but with a 2.5 HP motor in the first section from Bebedero, and continued then by rowing when it was necessary to remove the engine in order to go on. In the rest of segments of the Upper Basin, where there are frequent rapids and areas of very low depth and cobbled floor, I required to use a 3.2 m inflatable boat AIR brand, and worked sliding stream down, rowing from the beginning point. This was also the way I did the Cañas River and the Lagoon of Mata Redonda. Every time it was needed, I walked at the water body to come closer the animal and to observe it straight or to capture it, so that the depth was not a factor preventing me from doing an observation or capture. Five of the field trips were dedicated exclusively to the apprehension of the crocodiles that would provide with information about the sex rate in the TGW. I used a 6V and 10A RAYOVAC head lamp, as well as a Garmin ETREX GPS to trace the routes and monitoring of the trips.

Size structure was done by means of visual estimation, whenever it was possible to observe the complete animal, or for extrapolation when I could only observe its head on the surface of the water, according to which the length of the head fits 6.6 times in the entire size of the crocodile, in accordance with performed measurements I made in up to 275 crocodiles of all the different sizes. According to this, individuals were placed in a size classification every 0.5 m between SIZE I and SIZE IX, this is, from “X≤ 0.5 m” to “4≤X≤ 4.5 m”. Whenever it was not possible to determine any measurement of the animal, and as it gets used in this type of studies, I checked the observation as “eyes only” (King *et al.* 1990). Then these classes were added up into groups representing actual stages in the natural growing up of the crocodile, as hatchlings, recruits, juvenile, sub-adult and adult. The class “hatchling” (≤0.5 m) appears in the remarks table because it exists as such, and its report turns out to be important to demonstrate a working and dynamic population, nevertheless, its number will not be considered for further analysis in this study, since the survivorship percentage in this class is about 5%, and its incorporation to the active population is as improbable as that.

Trying to maintain parallelism with earlier studies performed in the main river bed of the Tempisque during the past 19 years, I kept the division of the observations in four segments, in order to be able to make segment counts when the climate conditions demand so. Statistical tests were done using SPSS, version 15 for Windows.

Results

I designed this work to estimate the real size of the population of the TGW, determining the structure of its population for sizes and for sex. I established for the first time the distribution of the crocodiles along the diverse water courses, and made an estimation of the relative abundance of crocodiles in the whole wetland. In the hope to construct a sufficient factual foundation to sustain some management lines to wisely handling the actual problem being faced by civil population and environmental authorities related to crocodiles in the TGW, in such a way that they allow to preserve this crocodiles population, at the same time relieve the pressure that they allege to suffer. I analyzed my field observations considering historical information of meteorological nature, as well as information relative to the green coverage of the area of study, the agricultural and cattle practices in the place, and the town-planning pressure in the area.

Thinking that the work segments are a representative partial vision of the existing reality in the whole study area, I estimated the whole population using sampled values gathered, with the information obtained in every class of habitat as it is the case.

Table 3. Crocodile counts in the Tempisque Great Wetlands by area and segment. Counts were corrected for area not surveyed (Correc. km), and then for visibility bias (Correc. visib.). H= hatchlings, R= recruits, J= juveniles, SA= sub-adults, A= adults, EO= eyes only.

Area/Segment Size category (m)	H <0.5	R 0.5-1.0	J 1.0-1.5	SA 1.5-2.0	SA 2.0-2.5	A 2.5-3.0	A 3.0-3.5	A 3.5-4.0	A 4.0-4.5	Eyes Only	Counts	Correc. km	Correc. visib.
Upper Basin													
Corobicí R.			4	3			4			2	13	13	14
Tempisquito R.		5	6	3	5	8	1			1	29	52	56
Los Ahogados R.	10	6	2	6	7	1					32	56	60
Colorado R.	4	4	5	2	4	3	1				23	23	25
Irigaray - Guardia	65	31	27	15	5	5				13	161	178	192
Sub-Total	**79**	**46**	**44**	**29**	**21**	**17**	**6**	**0**	**0**	**16**	**258**	**323**	**347**
Lower Basin													
Tempisque - main channel													
Níspero - Humo	15	33	8	8	18	10	18	2	2	9	123	123	140
Humo - Chamorro	6	21	8	10	5	1	11	1		2	65	65	74
Chamorro - Bolsón	22	18	14	16	38	24	33	4	4	5	178	178	202
Bolsón - Puente Pelón	25	13	3	3	12	13	18	8	3	11	109	109	124
Bebedero R.	4	27	26	16	11	6	3		1	5	99	99	113
Tenorio R.	5	6	7	6	4	5	10			4	47	47	53
Blanco R.		8			2	1	1			2	14	30	34
Cañas R. - Cañas	11	2	5	1	2	9	3	1		4	38	67	76
Palmira - Filadelfia		3	26	3	10	5	1			4	52	62	70
Las Bombas - Pelón		16	68	47	44	3	4			8	190	538	612
Sub-total	**88**	**147**	**165**	**110**	**146**	**77**	**102**	**16**	**10**	**54**	**915**	**1317**	**1497**
Marshes Zone													
Mata Redonda Lagoon	20	6	24	3	25	6	4			25	113	283	314
Charco R.	3	3	4	2	3	2	2	0	0	2	21	21	23
Bolsón R.	7	7	9	5	7	4	4	1	0	4	48	120	133
Sub-Total	**30**	**16**	**37**	**10**	**35**	**12**	**10**	**1**	**0**	**31**	**182**	**424**	**471**
Totals	**197**	**209**	**246**	**149**	**202**	**106**	**118**	**17**	**10**	**101**	**1355**	**2064**	**2315**
Totals (size categories)	**197**	**209**	**246**	**351**		**---------------- 251 ----------------**				**101**			

These observations were done along the different segments of work, the length of those segments is presented in Table 4.

Table 4. Total river distances and survey lengths.

Area/Segment	Surveyed (km)	Total (km)	Area/Segment	Surveyed (km)	Total (km)
Upper Basin					
1. Corobicí River	6	6	10. Bebedero River	20.5	20.5
2. Tempisquito River	9	16.22	11. Tenorio River	18.2	18.2
3. Los Ahogados River	6	10.5	12. Blanco River	3.3	7
4. Colorado River	7	7	13. Cañas River	10	17.5
5. Tempisque River Irigaray - Guardia	22	24.37	14. Tempisque River Palmira - Filadelfia	14.5	17.27
Sub-total	**50**	**64.09**	15. Tempisque River Las Bombas - El Pelón	6	17
Lower Basin			**Sub-total**	**118.6**	**143.57**
6. SEGMENT A - Tempisque Níspero - Puerto Humo	22	22			
7. SEGMENT B - Tempisque Pto. Humo - Pto. Chamorro	7.7	7.7	**Marshes Zone**		
			16. Mata Redonda	4	10
8. SEGMENT C - Tempisque Pto. Chamorro - Bolsón	7.7	7.7	17. Charco River	2.2	2.2
			18. Bolsón River	2	5
			Sub-total	**6**	**17.2**
9. SEGMENT D - Tempisque Bolsón - El Pelón	8.7	8.7	**Total**	**174.6**	**224.86**

The field work considered a fraction of 78% of the whole potentially workable kilometres. Segments from 1-5 (Upper Basin) represent 29% of the surveyed area with visibility of 93%; segments 6-15 (Lower Basin) represent 68% of the surveyed area with visibility of 88%, and segments 16-18 (Marsh Zone) represent 3% of the surveyed area with visibility of 90%.

I could only work 35% of the available Marshes Zone habitat, due to the difficulties imposed by the environment to actually make effective observations, with too many vegetation in the edge of the water, and a profuse aquatic flora or tifa (*Typha domingensis*), lotus (*Nymphaea* sp)., choreja (*Eichhornia crassipes*), elodea (*Elodea canadensis*) and gamalote (*Paspalum fasciculatum*), which seriously difficult the transit of any type of craft, and even the researcher himself whenever I decided to get to the water trying to improve my possibilities. On the other hand I covered more than 75% of the sampleable potential habitat of the Upper Basin and Lower Basin, and in general more than 75% of the available habitat in the TGW.

A proportional distribution of the "eyes only" among the size classes results in a distribution of: hatchlings 364 (15.7%), recruits 386 (16.7%), juveniles 454 (19.6%), sub-adults 648 (28.0%) and adults 463 (20.0%).

Given that hatchlings are not considered to be a part of an effective and stable population, then substrating them from the gotten numbers, the entire number of crocodiles estimated in the TGW added up to n = 1951 crocodiles, ± s=25.96.

Distributed by area with 292 (15.0%), 1262 (64.7%), and 397 (20.4%) individuals, according to Upper Basin, Lower Basin and Area of Marshes respectively; for a general relative abundance of 8.68 ind/km; and partial for area of 4.56 in the Upper Basin, 8.79 in the Lower Basin and 23.08 in the Area of Marshes.

I captured 25 small crocodiles during the general observation field trips, every time it meant no extra difficulties to grab and manipulate them while accomplishing the general objectives of the survey. Furthermore, I carried out five field trips with the only aim of capturing as many crocodiles as possible in every one of the three environments studied. Among some other complementary targets, the purpose of these captures was to get information to estimate the population sex rate. I captured a total of 72 crocodiles, 55 males and 17 females, for a general sex rate of 3.3:1 male:female. In the High Basin I captured 12 crocodiles, 3 females, for a sex rate of 3:1 male:female. In the Low Basin I captured 52 crocodiles, 12 turned out to be females, for a sex rate of 3.33:1 male:female. I captured 8 crocodiles in the Area of Marshes, 2 of which were females, for a sex rate of 3:1 male:female. The size of capture was between 75 and 352 cm. I avoided sexing individuals of a smaller size due to the difficulties in determining sex in hatchlings and small recruits, as well as the risk injury they would run trying to sex them (Allsteadt and Lang 1995).

Table 5. Comparison of 1989-1994 (early) and 2003-2008 (late) periods with respect to meteorological station. Values are Student-t and probability. Mean (and estimated deviation) values are also provided for rainfall and minimum temperature.

	Years	Llano Grande	Taboga
Humidity		t= 0.005 p= 0.996	t= -1,635 p= 0.105
Rainfall	1989-94 2003-08	110.14 (125.47) 160.25 (181.92) t= -1,924 p= 0,057	113.07 (106.33) 160.82 (171.98) t= -2 p= 0.048
Max. Temp.		t= 1.015 p= 0.312	t= 0.439 p= 0.662

On a 20-year time series between 1989 and 2008, for the climatic factors precipitation, temperature and moisture, I run a statistical analysis to contrast between the first six and last six years of the series, considering only 4 summer months in each of two existing meteorological stations in the studied area. I did this, trying to determine the effect of the climate on the skewed sex rates in the TGW, and the chosen months are these in what eggs incubate. I found significant values just for precipitation at both meteorological stations; and for the minimal values of temperature at the Taboga station, in Cañas (Table 5).

It can be seen that there has been a significant increase of up to 50.11 mm in the precipitation levels between the first and last years of the series; nevertheless, although it is true that the increase in the precipitation favors the general conditions of the crocodile's habitat, it is not proven that precipitation influences somehow the sex definition during the incubation time.

On the other hand, a highly significant change has been acquainted, of 0.66°C during this 20 years time span in the minimum temperature, in the Taboga meteorological station. In spite of this, the compared averages as can be seen in Table 6, do not even reach 24°C, therefore they do not qualify as temperatures to incubate crocodile eggs, and could not be associated this variable to the sex rate encountered.

Discussion

The crocodile population along the navigable main river channel, represents 23% of the whole estimated population for the Tempisque Great Wetlands; I verified that in effect, the real size of the local population of crocodiles has been underestimated, as a product of a limited conception of what should be the objective habitat.

The Area of Marshes constitutes a nursery for the individuals of lesser sizes, and a refuge area for crocodiles of medium total length (Sánchez 2001). Some adult crocodiles rejected from the main river channel during the season of courtship and mating, use to visit this place, and sometimes they remain there indefinitely. Lara (1990) reports as better relative abundance 5.9 ind/km for the marsh crocodile (*C. moreletii*) in a marsh segment in secondary forest, in the Petén area, Guatemala, and he argues reasons similar to those of Sánchez (2001). Casas-A and Méndez-DC (1992) report 12.3 ind/km, for a study on *C. acutus* done in 1989, in the Cuitzmala River, Jalisco, Mexico. Barahona-B and Bonilla-C (1999) report 2.16 ind/km for Orinoco Crocodile (*C. intermedius*) in the Arauca area in Colombia. Sánchez (2001) accounts for a relative abundance of 18.3 ind/km in the Tempisque river, on the navigable main river bed; right after his Sánchez *et al.* (1993) report of a relative abundance of 2.3 ind/km , scarcely in an 8 years time span. This present study, of a more integral character from the spatial point of view, seems to agree more with the last observation of Sánchez, if it is considered that there have been visited areas of diverse environmental characteristics, and the hatchlings have been excluded definitely from the analysis. It might be speculated that important events have happened during this time, to justify, along with normal changes that usually happen in any natural environment, for a jump of up to almost four times in the growth of this population, unwillingly of what it would be expectable given the loss of habitat due to the advance of the agricultural border and of the urban pressure. Porras-M (2004) reports 5.58 ind/km of *C. acutus* in the Tusubres River, in the Central Pacific coast of Costa Rica, in the area of coverage of the Playa Hermosa Wildlife Refuge, with important agricultural activity in the area, and the constant alertness of the wildlife rangers; without mentioning that according to personal information under analysis, apparently the most pristine and rainy areas affect negatively the relative abundance of *C. acutus*. As a corollary, given the existence of a report of a relative abundance of 2.28 for the Sierpe and Térraba Rivers (Bolaños *et al.* 1997), and under this former assumption, this datum is not a good reference to compare for the occasion, since the environmental conditions in the South Pacific coast of the country (Very Humid Tropical Forest) are a lot different from those found in the North Pacific coast (Tropical Dry Forest); and the impact of man is also different in both regions. Cedeño *et al.* (2006) report relative abundances from 0.13 to 2.69 ind/km for C. acutus; and of between 0.87 and 7.57 ind/km for C. moreletii, in the state of Quintana Roo, Mexico. Rainwater and Platt (2009) report 0.49 ind/km for *C. acutus* in the keys of Blackbird and Calabash, in Turneffe Atoll, in Belize. Sasa and Chaves (1992) and Piedra (2000) found in the Tárcoles River, in the Central Pacific Ocean, relative abundances of 19.2 and 32.02 respectively; comparison that must be carefully done, considering that the Tárcoles River in the segment where these studies were done, passes by the edge of the Carara National Park and also considered the Guacalillo protected mangrove. Besides, and this is more important, the tourist activity with crocodiles was born and it has developed in this place, and the tourist guides provide the animal of a special protection and feeding; without mentioning that the hatchlings class was part in these studies, and depending on the season, a large number of eyes can be seen in the river during the nights when the bloom has just taken place.

The size structure presents a peak in the class of sub-adults with 28%, and then fall down up to 20% in the adults class. The classes of lesser size, although with a high absolute frequency, are relatively speaking, of low profile, since the samplings were done almost always during the second semester of the years of field observation, and present hatchlings show a very low survivorship during the first two months of age. As for the recruits (17%) and juvenile (20%), although they were also observed in fair amount, it turns out to be very probable that they prefer to inhabit the small adjacent wetlands to the river, areas of cultivation and proper and abundant channels of irrigation in the TGW, to avoid the contact with their major size congeners and to hide better than their natural predators, until the time of having a more competitive size to introduce themselves openly before their community.

On having compared the results obtained in previous studies with the present one, it turns out to be clear that the percentage contribution of "recruits" to the population grew scarcely moderately in 6%, followed by an average growth of 8% "juvenile" in the class. In both cases the increase happened during the first 8 years of the interval, and stayed approximately stable during the space of 7 remaining years up to the present study. This might be reflecting that the nests quantity in the field increased the same way as the reproductive females stock increased in the wild during the first period. Apparently this condition remained constant during the second period.

Table 6. Comparative distribution (%) by size according of the TGW crocodile population in different years. * Sánchez *et al*. (1996); ** Sánchez (2001).

Class	1993*	2001**	2008
Recruits	12	18	18
Juveniles	14	24	7
Sub-adults	5	8	23
Adults	7	17	32

Of the same way, the quantity of "sub-adults" increased lightly from 5% to 8% during the first lapse, to advance in a change of 20% for the second period, in which the surviving recruits of the first period reached sizes of up to 2.5 and 3 m. The same relation is observable in the class of "adults", which reached an increase of 10% in the first period, and 3 more points during the second, consistent with the fact that during this stage of its lives, the crocodiles approach more its asymptotic size, and its yearly growth is perceptibly slower than the one shown by individuals of lesser sizes.

In general, the evidence points towards a population in plain growth, as demonstrated by the absolute numbers, and although it should not have been an object of this study, it would be necessary to expect that the dispersion of this population should happen of a homogeneous form in the whole area of the TGW, and according to the proper characteristics of different habitat recounted, with a better expectation in the Lower Basin of the river, because of the aquaculture companies cited.

Cedeño *et al*. (2006) reported percentages of 6.25, 34.3 and 53.1 for juvenile, sub-adult and adult respectively in the *C. acutus* population in Quintana Roo in Mexico, which demonstrates an increasing tendency towards the individuals of larger sizes, which joined to the low relative abundance might indicate a population being harvested in its individuals of lesser sizes, what marks the disappearance of these classes of size.

The fragmentation of the habitat product of the economic activities, along with the human increase in the river as a product of the boom of the tourist activities, and of the fact that human settlements seek always to be established next to the water courses; the loss or migration of the considered species "natural preys" for the crocodile, and the disappearance of some of the species that normally would prey on crocodiles during their first weeks, like coyote (*C. latrans*), puma (*Panthera concolor*), garrobo (*C. similis*), pizote (*N. narica*), martín peña (*T. mexicanus*) and real heron (*A.alba*) among others, have brought as a result that the loss of nests and of hatchlings owed to natural depredation has diminished, and that for his part, due to its proximity with man, crocodiles have changed their everyday menu towards other species that previously were not occupying its interest, like dogs, ducks, pigs, calves, and even humans when the occasion has allowed it. Additional to this, the successful establishment of the aquaculture industry has meant a constant food provision in the form of tilapia (*O. niloticus*) in all the watercourses in the area; and with this, it is reasonable to hope that the implicit reduction in the competition for food, have brought a consistent increase in the numbers of the populations of the species that feed on this fish, crocodiles one of them.

Although places exist with similar relative abundance inside the limits of our borders, and although the existing habitat presents conditions the same way adapted for the development of a numerous population of crocodiles, according to the stereotype of which places more retired and less invaded by the man present better characteristics for the development of a better population of crocodiles, nevertheless, they do not exhibit higher values and do not even be equal to what I found.

The Tárcoles River, in the Central Pacific coast presents the higher relative abundance in Costa Rica, motivated possibly by its proximity with the National Park CARARA, and for the incidence of a wide and awkward tourist activity that deals with staying awake and feeding to the crocodiles in the river. A relatively pristine area as the Sirena and Corcovado Rivers, in the Corcovado National Park, as well as the Matina, Pacuare and Sucio Rivers, in the Caribbean and North areas respectively, present values of low relative abundance (Bolaños, unpubl.), although the habitat conditions are ideal for occurring of a crocodiles population in accordance with the brought for the bibliographical references (Thorbjärnarson 1989).

Table 7. Relative crocodile abundance in several rivers of Costa Rica. *Porras-M (2004).

	2004	2005	2007	2009
Tarcoles	9.22 *	-	-	9.5
Terraba	-	-	-	2.07
Sirena	1.42	-	-	-
Corcovado	0.83	-	-	-
Matina	-	-	2.3	-
Pacuare	-	-	1.3	-
Sucio-Sarapiqui	-	2.9	-	-

Interestingly, the relative abundance in Tempisque practically has been quadrupled in a period of 18 years, with a valuation average of growth of 3.59 for the period between 1993 and 2009; the same area in which the urban and agricultural pressure increased during this time span, accompanied by the development of the road network and its consequent habitat fragmentation in the upper and low basins of the river (Cabrera 2007).

In conditions like the existing one, to attend such an important development of the resident population, where the migratory effects are practically despicable due to the relative isolation of the area as regards to the populations of the Central Pacific coast and of the external area of the Nicoya Peninsula (Porras-M 2004), and where it has not been possible to determine for the route of the analysis of the variables of climate any significantly detrimental change, must be thought about the existence of some important exogenous factor that should have affected positively in the growth of this population of crocodiles, promoting the environment load capacity to provide sustain for this induced growing population. This still not investigated evidence, but observed in the different courses of water of the Lower Basin and Area of Marshes of the TGW, points according to field observations, towards an artificial increase in the natural offer of food, with the constant organisms escape from the ponds of culture of the aquaculture companies established in Cañas and Bagaces, with direct access to the main rivers of the basin, as the propitiator of an artificially supported growth of the crocodiles population. This observation has not been scientifically evaluated, and constitutes a truth which dimension has yet to be established.

The sex rate found is distant by much from the brought one for Joanen and McNease (1980) as the ideal for a healthy population of crocodilians of 1:2 male:female. A sex ratio like the one found in this study, bears witness to the existence of a males' overpopulation that becomes problematic at the moment of initiating the courtship and mating season; the advent of more fights for the possession of the suitable places for mating and for the females in the river, result in more disabled and rejected reproductive crocodiles of the places of courtship; more crocodiles in search of refuge, strolling around for the wetland in search for a provisional place of refuge and feeding. With an increasing population like that of the TGW, it would mean also the sudden appearance of individuals of big sizes in places in what earlier they had not been sighted; more crocodiles with their high hormonal load, and in places that are not its territory; there would be more crocodiles annoying and scared with major readiness to defend themselves or to attack at all times. This has happened every time and more frequently during the last years. It is important to highlight that frequent crocodiles denunciations exist in invasion to places next to the people's houses, and also they are protagonists in the denounces about domestic animals attacked by crocodiles. Individuals with 3 or more meters of entire size, which is the size that has turned out to be consistently involved in accidents with human beings as it is possible to see in Table 8, they constitute 24% of the entire population.

Table 8. Some documented crocodile attacks on humans in Costa Rica.

Date	Size (m)	Sex
	Fatal	
3 Sep 1995	4.5	M
8 Apr 1997	5	M
1 May 1998	3	F
6 May 1999	Various crocodiles	
16 Jun 2002	3	-
11 Apr 2005	4	M
8 Apr 2007	6	M
5 May 2007	6	M
3 Mar 2008	3	F
3 Apr 2008	4	-
11 May 2010	3.5	F
17 May 2010	4	M
	Non-Fatal	
Apr 1996	3	-
Sep 2002	3.5	M
Sep 2002	3	-
7 Mar 2006	3	M
19 Sep 2006	2.5	M
19 Sep 2006	3	-
22 Feb 2007	4	M
6 Mar 2007	3	M
30 Mar 2007	4	M
22 Jan 2008	2.5	M
19 Sep 2008	3	M
17 Jan 2009	3.5	M
5 Feb 2010	4.5	M
11 May 2010	3.5	-
19 Apr 2011	4.5	M

Casas and Méndez (1992) surmise a sex rate of 1:1 M:F for their study in the Cuitzmala River, in Jalisco, Mexico; waiting for a behavior similar to the exhibited one by the species in the state of Florida, and reported like that by Kushlan and Mazzotti (1989). Cedeño-V. *et al*. (2006) found a similar relation of sexes of 1:1, so much for *C. moreletii* as for *C. acutus* in its study in the state of Quintana Roo, in Mexico. Porras-M (2004), informs a sex rate of 1:1 in three rivers of the Costa Rican Central Pacific coast. Sánchez (2001) speculates about the existence of 114 females and 38 males in the area corresponding to the navigable river bed of the Tempisque River, for what according to its criterion it would be a relation of sexes of 1:3 M:F, such as which Joanen and McNease (1980) suggest it for a healthy crocodilids population. In the estuary La Ventanilla, in Oaxaca, Mexico, García-Grajales *et al*. (2007) reported a sex rate of 3:1 M:F, similar to the one found in this study, and also deserving a deeper analysis.

Additionally, the sex rate found in this study, reflects what is already apparent in the distribution of sizes reported for this population over the course of time, where the number of smaller sizes crocodiles exhibited an important increase during the first half of the period of studies, but then it established and maintained for the second half; while on the other hand, the reproductive class showed an important increase along the whole period (Table 9), this might be demonstrating the fact that the increasing numbers of the two upper classes of the structure of sizes of the population, is sustained mostly in the increase of the males quantity over that of females, with the consequence then, that the nests of every year are being laid by a relatively constant stock of reproductive females, and then, the increase in the lower classes of the scale has stagnated, which is observed relatively constantly during the second part of the period.

Thorbjärnarson (1997) analyzes an important slant phenomenon in favor of the females in the different reports of sex rates for studies realized in crocodilids. It indicates that in general terms there should to be a tendency to which slant is brought in favor of females in case of crocodiles, as in the species *C. niloticus*, *C. novaguineae* and *C. porosus*. Thorbjärnarson (1997) points out that the skew sampling affects straight in the determination of precise reasons of sex, and establishes three potential error sources in the achievement of the samplings, distinguishing mortality in both sexes, separated habitat selection for each sex, and lacking in skill to determine the sex of the juvenile individuals. I would aim even at one more source of slant, which would be related straight on one hand to the capacity or the determination of the investigator to gain access to the most difficult spaces where it is known that there are crocodiles, and on the other hand with the decision to really capture the animals who are in conditions of difficult apprehension or who infuse sufficient fear as to discourage its potential captor.

In case that distinguishing mortality exists, which has not been studied in *C. acutus,* the current condition of the population of crocodiles of the TGW would be even the same one found during this study, and needs in this moment to establish correctional policies to return to the normality, in whose case should carry out as soon as possible a study that specially determines the occurrence of this phenomenon to establish correctional policies by size class, if it is possible to do such a thing, of course in its sizes of hatchling and recruit. As regards the second one and third slant sources, bearing in mind these remarks, I chose the apprehension environment of individuals carefully to prepare the possible environment preference on the part of both sexes; it was also decided not to sex crocodiles from the two lower size classes. I tried to be especially careful of not falling down in any of the possible causes of slant discussed.

Conclusions

The observed growth of the population of crocodiles in the TGW to have almost quadrupled in the space of 18 years; in conditions that normally would aim towards the decrease of its numbers as a result of the urban pressure on the wild areas, the expansion of the agricultural border, and of the more important human use of the water courses; induces to think that in this moment there should exist in the wild, a population that goes too far the normal possibilities of support of the wetland, not to be for the existence of a hypothetical exogenous factor, which artifitially propitiates this particular fact.

Considering the impact of the populations of crocodiles on the human populations and human activities, joined the existing growth in the population of crocodiles of the TGW, it turns out to be pertinent to design and to deal with politics of control that trend to diminish the number of crocodiles in the TGW, in the best interest of conservation of the species, and of the safety of the settlers of the region. Considering the skewed sex rate, it turns out to be logical to think that it would proceed the selective removal of males from their respective niches and in a proportional way to the individuals quantity for sub area, up to finding a more balanced sexes rate.

As an element intimately tied to the problem of quantities of crocodiles in the area, and of conflict between crocodiles and human beings, the atypical sex rate must be analyzed in a closer context, to determine the associated factors to this malady, and to propose solutions that return the indicator up to more normal values in wild populations.

It is necessary to determine the magnitude of the effect of the aquaculture farms on the load capacity of the wetland in which they are operating, across the organisms escape from their cultivation ponds; as well as the importance of implementing the possibility of exercising effective control on this escape, with the interest to induce in an immediate way a better balance in the populations of crocodiles and of other species in the ecosystem of the TGW, independently that this factor influences or not the condition of the population of local crocodiles. The real load capacity of the TGW as for crocodiles refers, it will be possible of determining once successfully gotten this balance.

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