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SOME HYDROCHEMICAL AND HYDROLOGICAL CHARACTERISTICS OF CROCODILIAN HABITATS.

Stefan Gorzula

División de Cuencas e Hidrologia, C.V.G. Electrificación del Caroni
C.A. (EDELCA),
Apartado 62413, Caracas, Venezuela.

Jorge Paolini

Centro de Ecologia, Instituto Venezolano de
Investigaciones Cientificas (IVIC),
Apartado 1827, Caracas, Venezuela.

and

John Thorbjarnarson

Foundación para la Defensa de la Naturaleza (FUDENA),
Apartado 70376, Caracas 1071–A, Venezuela.

ABSTRACT

Hydrochemical data were gathered from seven Paleosuchus trigonatus localities; 15 Caiman crocodilus crocodilus localities, and seven Caiman crocodilus (Llanos) localities. The mean temperatures (^{o}C)*, conductivities* $(\mu mhos)$ *and total cations* $(\mu eq\ l^{-1})$ *were 22.4/6.6/49.3, 29.1/48.5/215.8, and 32.4/125.6/-1,052.2 respectively. Hydrological data were processed for 27 Crocodylus intermedius localities and 16 P. trigonatus localities. Mean annual rainfall (mm) and runoff (mm) were 1,797/-734 and 2,422/1,441 respectively. Correlations between conductivity and cations indicate ecological relationships between habitats and crocodilians. Hydrochemical and hydrological data could be used for survey planning, ecological studies, site selection for reintroductions and environmental impact assessment.*

KEY WORDS: –Caiman–*Crocodylus*–habitat–hydrochemistry–hydrology–*Paleosuchus*–Venezuela.

INTRODUCTION

Effective management and conservation plans for crocodilians require a detailed knowledge of the geographical distribution of the species under consideration. In Venezuela, a country of almost 1,000,000 km^2, no records of crocodilians exist for about 72% of the area, although most of it probably contains crocodilian populations (Gorzula, 1987). At present, an extensive survey of crocodilians in Venezuela is a short term research priority.

In general, most studies to date define crocodilian habitats on the basis of subjective descriptors. However, survey planning would be greatly facilitated, if measurable and mapable habitat data could be effectively applied. This paper examines some hydrochemical and hydrological data which may help to define more precisely the habitats of three of the five crocodilian species that occur in Venezuela: the Spectacled Caiman, *Caiman crocodilus*, the Orinoco Crocodile, *Crocodylus intermedius* and Schneider's Smooth-fronted Caiman, *Paleosuchus trigonatus*.

METHODS

Nomenclature

Medem (1983) recognized the existence of various demes in the nominal subsepecies *Caiman crocodilus crocodilus* and discussed the unpublished revision of the late Karl P. Schmidt (Chicago Natural History Museum), who intended to describe the form from the Llanos of Venezuela and Colombia as a new subspecies, *Caiman c. humboldti*. The Llanos form is a fast growing, large subspecies; females attain total lengths of upto 1.80 m and males attain total lengths upto 2.70 m. The subspecies from the Guayana Shield is slow growing and much smaller; females and males seldom exceed total lengths of 1.50 m and 1.70 m respectively. In order to distinguish these two probale subspecies, this paper refers to *C. crocodilus* from the Venezuelan Llanos as *C. crocodilus* (Llanos) and *C. crocodilus* from Venezuelan Guayana as *C. c. crocodilus.*

Study sites and hydrochemical data

Water samples for *P. trigonatus* habitats were collected from seven localities in the Gran Sabana and Rio Carrao areas. Samples for *C. c. crocodilus* habitats were taken from 15 localities in the El Manteco region (Gorzula, 1978) and in areas southwest of Ciudad Guayana. *C. crocodilus* (Llanos) habitat water samples were obtained from seven sites in the Venezuelan Llanos on the Masaguaral and Terecay ranches (Fig. 1)

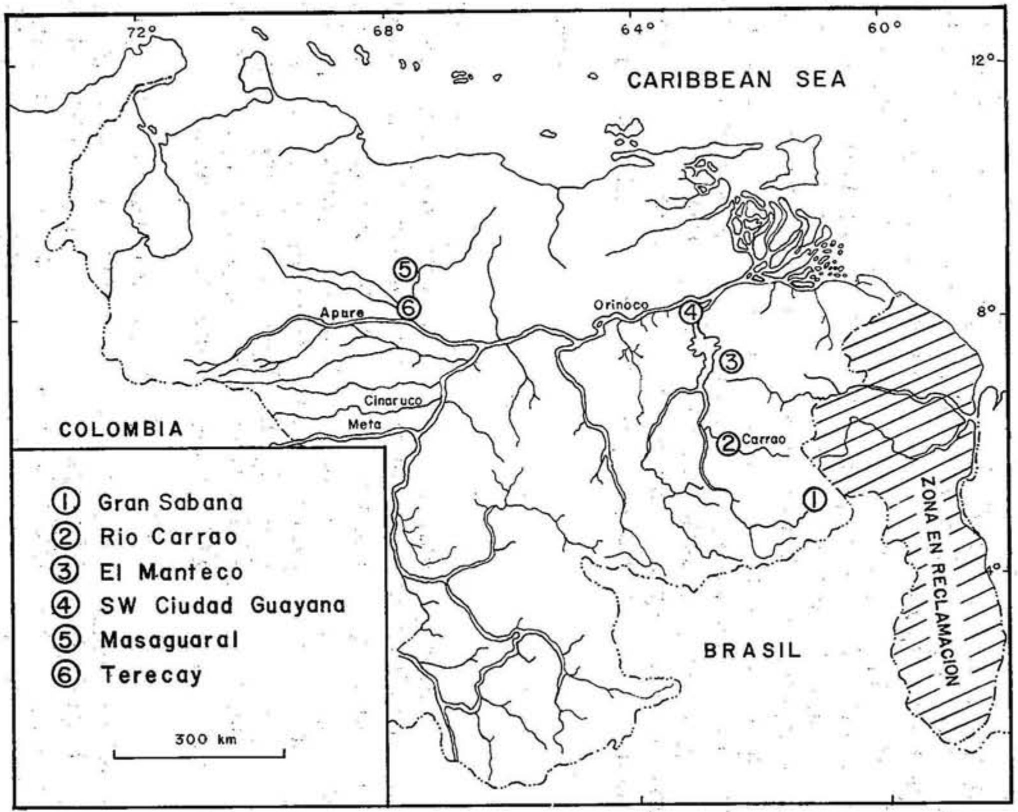

Fig. 1 Map of Venezuela showing the six principal areas where hydrochemical data were gathered for *Palesosuchus trigonatus* (1 & 2), *Caiman crocodilus crocodilus* (3 & 4), and *Caiman crocodilus* (Llanos) (5 & 6).

The samples were directly collected in 0.25 *l* plastic bottles. Air and water temperatures, pH and conductivity measurements were carried out in the field. Laboratory samples were filtered through membrane filters or precombusted glass filters and analysed as described by Paolini *et al.* (1983).

Hydrological data

The exact positions of 27 *C. intermedius* and 16 *P. trigonatus* localities were obtained from previous publications (Godshalk, 1982a; Franz *et al.*, 1985; Gorzula & Paolillo, 1986; Ramo & Busto, 1986), direct observations by two of us (SG and JT) and personal communication with other researchers.

Geographical coordinates and elevations were calculated from 1 : 100, 000 and 1 : 25, 000 scale maps of Venezuela (Cartografia Nacional, Ministerio del Ambiente y de los Recursos Naturales Renovables). Catchment areas above each locality were calculated from maps of scales 1 : 1, 500, 000 to 1 : 25, 000 depending on the size of the river basin.

Rainfall and runoff data were taken from COPLANARH (1972) and the EDELCA data base. Flow rates were estimated from the existing data for the river basin or interpolated from data for adjacent basins.

RESULTS AND DISCUSSION

Hydrochemistry

Table 1 shows the means and standard deviations of the eight parameters measured for habitats of *P. trigonatus, C. c. crocodilus* and *C. crocodilus* (Llanos).

	Paleosuchus trigonatus	*Caiman crocodilus crocodilus*	*Caiman crocodilus (Llanos)*
Number of samples	7	15	7
Water Temperature(°C)	22.4 ± 0.34	29.1 ± 2.69	32.4 ± 1.51
pH	4.2 – 6.7	5.2 – 7.0	5.7 – 9.3
Conductivity (μmhos)	6.6 ± 2.0	48.5 ± 13.3	125.6 ± 54.9
Total cations (μeq l^{-1})	49.3 ± 19.2	215.8 ± 77.8	1,052.2 ± 755.1
Ca^{+++} (ppm)	0.26 ± 0.12	1.16 ± 1.05	9.73 ± 10.56
Mg^{++} (ppm)	0.07 ± 0.05	0.55 ± 0.31	2.96 ± 1.66
Na^{+} (ppm)	0.41 ± 0.34	1.89 ± 0.96	16.07 ± 17.13
K^{+} (ppm)	0.48 ± 0.23	1.17 ± 0.83	4.25 ± 2.08

Table 1: Some hydrochemical parameters of *Paleosuchus trigonatus, Caiman c. crocodilus* and *Caiman Crocodilus* (Llanos) habitats; means ± S. D. are shown; ranges given for pH.

The data for pH showed an apparent increase in acidity with decreasing conductivity and cation content. However, most pH values for all three habitats were in the general range of 5 – 7. The data for all other parameters almost separated out into three distinct groups indentifiable with the three crocodilian habitats.

The differences in mean temperatures of the three crocodilian habitats may partly be explained by the effect of altitudinal gradients. The localities *P. trigonatus* are highland sites (450 to 940 m above sea level) while all other localities are in lower altitudes (< 300 m). Most of the temperature measurements for *C. c. crocodilus* localities were taken at night when the waters were cooling, whereas those for the other two crocodilian habitats were measured during the day. Therefore, the temperature range reported for *C. c. crocodilus* habitats is probably an underestimate. The temparatures of lagoons and ponds have a greater diel variation than rivers. Adjacent vegetation can also affect temperature and small rivers in forests will be cooler than similar sized rivers in savannas of the same altitude. Factors other than altitude could also affect the water temperatures of crocodilian habitats.

Figure 2 shows the relationship between total cations and conductivity for the crocodilian habitats and an additional 17 rivers from the Venezuelan Llanos and Venezuelan Guayana. Total cations are proportional to the conductivity ($r=0.8158$; $P< 0.05$).

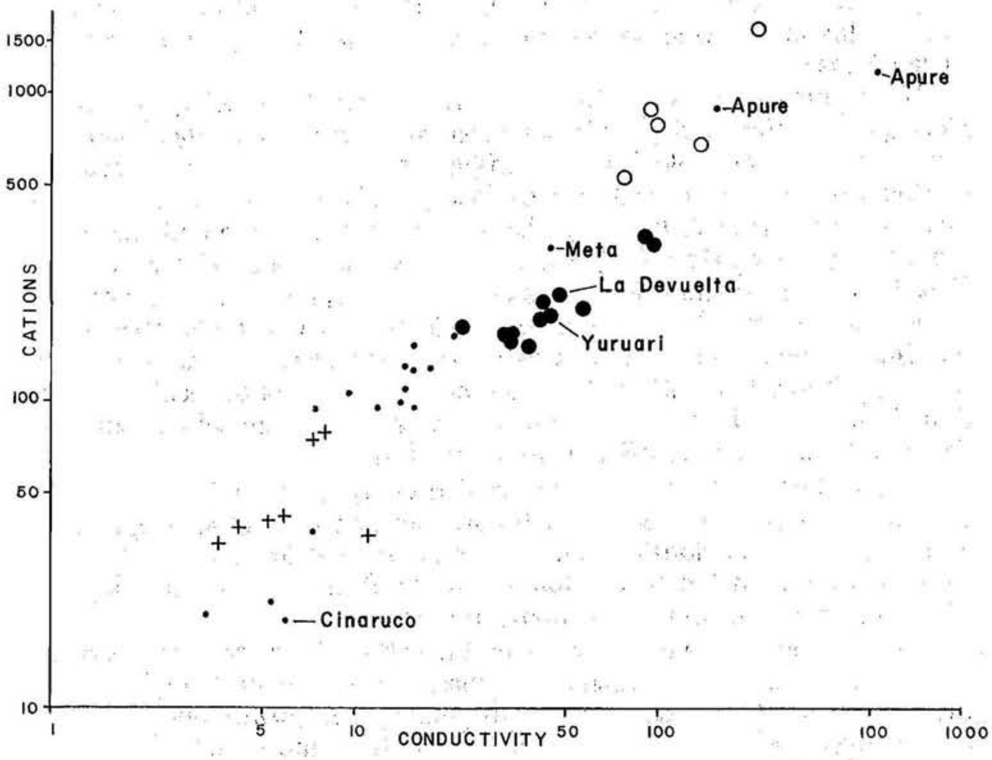

Fig. 2. **Plot of total cations (μ eql^{-1}) against conductivity (μmhos) for habitats of *Paleosuchus trigonatus* (crosses), *Caiman crocodilus crocodilus* (black circles), *Caiman crocodilus* (Llanos) (open circles), and a series of Venezuelan rivers (dots).**

It should be noted that all of the *P. trigonatus* habitats were rivers while most of the *Caiman* habitats were lagoons. The two *C. c. crocodilus* habitats which were flowing water (Yuruari & La Devuelta) fell within the hydrochemical range of the lagoon localities. Likewise, the hydrochemical characteristics of the two sites on the Apure river were within the upper range reported for *C. crocodilus* (Llanos) habitats.

The grouping of the hydrochemical characteristics for the three crocodilian habitats may be explained by the basic geology and geomorphology of the study areas.

The Gran Sabana is an area of Precambrian quartzites dominated by sand-stone table-mountains (Schubert *et al.*, 1986) and the waters which drain these mountains are acidic with a very low concentration of cations (Grupo Cientifico Chimanta, 1986). The El Manteco and Ciudad Guayana sites are within an area of Precambrian igneous-metamorphic rocks (Schubert *et al.*, 1986). The Venezuelan Llanos is an alluvial floodplain which receives nutrient rich waters from the Venezuelan Andes.

If the distributions of the three crocodilians were solely due to biogeography and if the hydrochemical characteristics of their habitats have no direct ecological relationship, then one would not expect to find these species outside the defined geological areas. This, however, is not the case. *P. trigonatus* has been reported from the Llanos in the Rio Cinaruco (Godshalk, 1982b). The headwaters of this river (Fig. 1) are palm swamps within the Orinoco floodplain and it does not receive waters from the Andes. The hydrochemical characteristics of the Cinaruco were similar to *P. trigonatus* habitats in the Gran Sabana (Fig. 2). Thus, two different geological and geomorphological situations have given rise to rivers with the same hydrochemical characteristics and the same crocodilian is found in both.

Within the lowlands of the Venezuelan Guayana both *C. c. crocodilus* and *P. trigonatus* occur over the same general geological area, and have also been occasionally found to occur sympatrically (Gorzula & Paolillo, 1986). In the latter situation, it is not known whether this is a permanent or a seasonal phenomenon.

Nevertheless, the overall data suggest that there is an ecological relationship between the hydrochemical characteristics of the habitat and the crocodilians that occur therein. In general, *P. trigonatus* appears to inhabit oligotrophic waters; *C. c. crocodilus* is found in mesotrophic habitats and *C. crocodilus* (Llanos) occurs in the eutrophic floodplains.

Hydrology

Tables 2 and 3 respectively show the coordinates, elevation above sea level, catchment area, annual rainfall, annual runoff, and estimated flow-rate for *C. intermedius* and *P. trigonatus* localities.

Table 2: Hydrological characteristics of rivers with *Crocodylus intermedius.*

Locality	Coordinates	Elevation (m)	Catchment (km^2)	Mean Rainfall (mm)	Annual Run off (mm)	Flow rate (m^3s^{-1})
Orinoco 1	0624N-6711W	40	—	—	—	—
Orinoco 2	0837N-6214W	5	1,123,000	2,550	926	33,000
Orinoco 3	0755N-6434W	10	—	—	—	—
Caura 1	0737N-6452W	10	48,100	2,950	1,800	2,745
Caura 2	0623N-6436W	150	28,435	2,950	2,040	1,840
Cuchivero	0720N-6549W	35	14,520	2,440	1,135	520
Guaniamo	0704N-6547W	35	6,350	2,440	1,135	230
Ventuari	0415N-6625W	100	34,030	3,250	1,745	1,880
Cinaruco 1	0634N-6485W	70	3,930	1,950	405	50
Cinaruco 2	0632N-6814W	60	5,445	1,950	405	70
Capanaparo 1	0656N-6720W	40	17,700	1,800	185	105
Capanaparo 2	0656N-6807W	50	14,820	1,800	185	90
Arauca	0702N-7110W	125	—	1,900	460	—
Apure	0800N-6811W	45	58,240	2,200	780	1,320
Manapire	0751N-6611W	40	7,250	1,300	100	23
Rabanal	0819N-6710W	45	18,450	1,100	300	175
Guarico	0856N-6724W	105	7,865	1,100	300	75
Camatagua	0948N-6654W	300	1,815	1,100	300	17
Chirgua	0856N-6755W	70	3,025	1,150	510	50
Portuguesa	0815N-6738W	55	52,030	1,300	510	840
Guanare	0820N-6808W	40	6,960	1,600	1,035	230
Cojedes	0900N-6825W	60	7,865	1,200	510	130
Camoruco	0922N-6845W	110	605	1,200	510	10
Tucupido	0857N-6950W	135	393	1,700	1,035	13
Bocono	0847N-6952W	130	1,695	1,700	1,035	55
Tinaco	0926N-6825W	100	1,240	1,200	510	20
San Carles	0920N-6833W	105	1,996	1,200	510	32

Apart from a single elevation of 300 m (Table 2), the localities for *C. intermedius* were at low elevations on the Orinoco floodplain, whereas *P. trigonatus* localities showed a wide altitudinal range from 50 – 1, 340 m (Table 3).

Table 3: Hydrological characteristics of rivers with *Paleosuchus trigonatus.*

Locality	Coordinates	Elevation (m)	Catchment (km^2)	Mean Rainfall (mm)	Annual Run off (mm)	Flow rate (m^3s^{-1})
Ginaruco	?? - ??	50	17,700	1,800	185	105
Uruyen	0542N-6226W	480	155	2,400	1,660	8
Cuyuni	0643N-6105W	110	31,160	2,000	750	740
Botanamo	0652N-6052W	100	7,560	1,600	750	180
La Escalera	0554N-6125W	1,340	5	3,200	1,660	0.25
Carrao	0614N-6247W	450	7,585	2,500	1,660	400
Kukenan 1	0455N-6123W	820	5,060	2,000	1,610	260
Kukenan 2	0455N-6112W	830	3,015	2,000	1,610	155
Yuruani 1	0458N-6115W	830	1,480	2,000	1,610	75
Yuruani 2	0503N-6107W	840	1,240	2,000	1,610	65
Jaspe	0456N-6106W	940	21	1,850	1,610	1,10
Yureba	0403N-6601W	130	38	2,800	1,680	2
Puruname	0325N-6618W	100	1,930	3,300	1,610	100
Baria	0105N-6625W	150	1,285	3,000	1,720	70
Mawarinuma	0050N-6612W	150	245	3,000	1,720	13
Yagua	0332N-6646W	120	2,955	3,300	1,610	150

Catchment areas and estimated flow rates for the habitats of both species were somewhat inconclusive. It seems that *C. intermedius* occurs in "large rivers", but we do not have adequate information to separate the localities which represent resident breeding populations from those used partially or seasonally by individual crocodiles. In the case of *P. trigonatus* many (if not all) of the localites may be represented by "surplus" males while the true populations exist in side creeks. Studies in the Manaus area show that *P. trigonatus* inhabits small forest streams (Magnusson, personal communication).

With regard to rainfall and runoff there seems to be a reasonable degree of separation. *C. intermedius* localities had lower rainfall (mean 1, 797 ± 644 mm) and much lower runoff (mean 734 ± 526 mm) than those of *P. trigonatus* localities (rainfall mean 2, 422 ± 591 mm; runoff mean 1, 441 ± 453 mm).

CONCLUSIONS

P. trigonatus, *C. c. crocodilus* and *C. crocodilus* (Llanos) habitats may be differentiated on the basis of hydrochemical characteristics while *P. trigonatus* and *C. intermedius* habitats may be separated on the basis of hydrological characteristics.

A system of classifying crocodilian habitats based on hydrochemistry and hydrology would have several applications in management and conservation.

i Hydrological and geomorphological data could be gathered and processed prior to field-work, and used to establish areas that should be given survey priority.

ii Censuses could relate densities to measurable physical and chemical parameters, which in turn may help in explaining differences in population dynamics, carrying capacity, etc.

iii When reintroduction of a species to areas where it is assumed to have occurred previously are planned, the optimum sites could be selected easily.

iv A concise knowledge of the hydrochemical and hydrological requirements of crocodilian species would enable environmental impact assessments of large scale water resource projects such as dams and canalizations.

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