COMPARATIVE ANALYSIS OF HABITATS OCCUPIED BY *Caiman crocodilus* IN FLOODABLE PLAINS OF VENEZUELA

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RESUMEN

Se describen habitats primarios y secundarios ocupados por *Caiman crocodilus* (baba) en 514.096 hectáreas de llanos inundables venezolanos subdivididas en 6 regiones ecológicas. Se efectuaron censos nocturnos y se estimó la superficie de los cuerpos de agua. Los habitats primarios se clasificaron en caños, ríos y lagunas; los secundarios en préstamos (excavaciones) y módulos (diques), describiendo su formación vegetal y cobertura de vegetación acuática. Se practicó ANOVA a los datos, con el censo como variable numérica y como variables clasificadoras la región ecológica, tipo de cuerpo de agua, formación vegetal y cobertura de vegetación acuática. Se censaron 93.944 babas con una densidad de 0,18 ind/ha de terreno. La superficie acuática (2688,85 ha) alcanzó 0,52 % de la superficie total. La abundancia poblacional mostró diferencias significativas entre las 6 regiones ecológicas. La máxima abundancia se observó en los ríos, mientras que lagunas y caños mostraron valores similares. Los préstamos mostraron valor mínimo y los módulos presentaron elevadas abundancias, siendo los ambientes secundarios más favorables. Las poblaciones más abundantes se encontraron asociadas a habitats primarios con vegetación marginal boscosa y vegetación acuática presente. Se debe promover su protección para favorecer a esta especie, actualmente sometida a manejo bajo control del Estado.

ABSTRACT

Primary and secondary habitats occupied by *Caiman crocodilus* are described in 514.096 ha of Venezuelan flooding llanos, divided in 6 ecological regions. Night-light counts were done and the surface of water bodies were estimated. Primary habitats were classified into channels, rivers and lagoons; secondary habitats in ponds and dykes, describing its dominant terrestrial vegetation and aquatic vegetation covering. Data were processed with ANOVA, with abundance of caimans as numerical variable and ecological regions, type of habitat, terrestrial vegetation and aquatic vegetation covering as classification variables. A total amount of 93.944 caimans were counted with a terrestrial density of 0,18 ind/ha. The aquatic surface was 2688,85 ha reached only 0,52 % total terrestrial surface. The abundance showed significant differences between the 6 ecological regions, with maximum in primary habitats. Among secondary habitats, dykes showed the highest abundance values. Most abundant populations were founded in primery habitats with forests and small amounts of aquatic vegetation. Special measures of protection of such habitats are strongly recommended for this species, currently under management by Venezuelan Government.

INTRODUCTION

The Baba (*Caiman crocodilus*) it is the most abundant crocodile in Venezuela, since the reduction of large caiman's populations American crocodile (*Crocodylus acutus*) and Orinoco crocodile (Crocodylus intermedius), caused by the indiscriminate hunt. Once initiated the industrial use of Baba skins, their commercial hunt began. In 1983 the Venezuelan Government implemented the Program of Commercial Use under control of the Ministry of the Environment and Natural Resources (MARN). In 1991-92 a first evaluation of the population status was made, in terms of abundance and size class structure, after 9 continuous years of controlled crops (Velasco and Ayarzaguena, 1995).

One of the most important results of that work was the description of 7 ecological regions in the area used for hunting in the Venezuelan southwestern Llanos: Alto Apure, Bajo Apure, Aguas Claras, Cajón de Arauca, Llanos Boscosos, Hoya de Arismendi and Guárico (Fig 1).

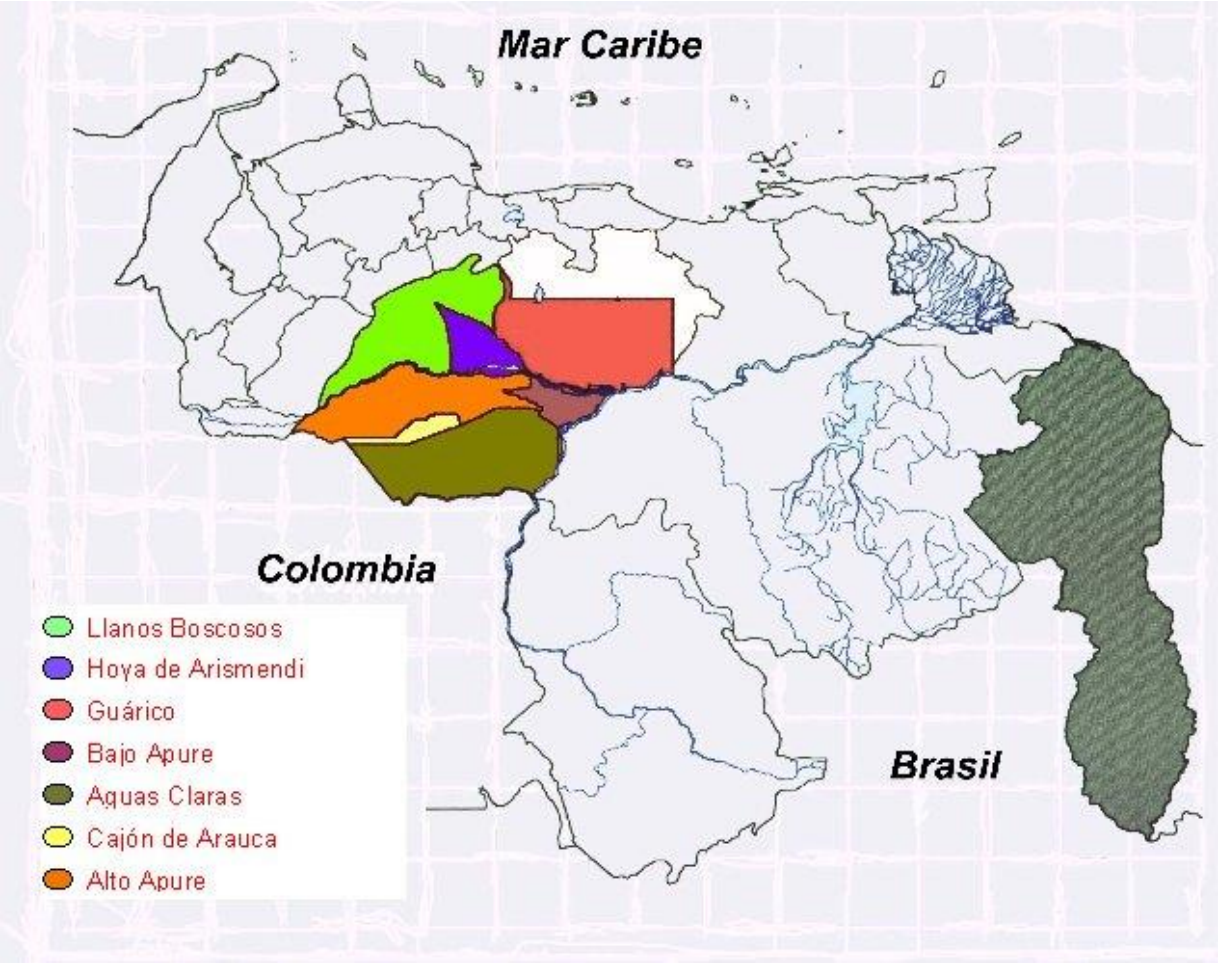

Figure 1. Ecological regions in Venezuelan Llanos.

Subsequently, during 1996 a detailed study was carried out under the Agreement between Universidad Central of Venezuela and MARN, during the Ecological Pause of the Program of Commercial Use (Quero & Velasco, 1995), covering 6 of the 7 ecological regions with the exception of the Guárico region. In each region, the population abundance and the primary and secondary habitats were characterized, in order to establish the most favorable habitats and to propose strategies for its preservation.

METHODS

1. FIELD WORK

The fieldwork was carried out during the dry season (February-April) of 1996, when the animals are concentrated in the habitats that keep water during the whole year and are easy to count. The fieldwork was made by six teams of technical personnel belonging to MARN and UCV. Observations were plotted in charts 1:25.000.

Night light censuses were performed (Chabreck, 1966, Woodward & Marion, 1977) in order to determine the population abundance. The aquatic habitats were classified accordingly to their type in primary habitats, integrated by "caños" (intermittent natural drainages of the flooded areas), lagoons, rivers and “esteros” (savanna depressions temporary flooded). As secondary or artificial habitats, "prestamos" (excavations for the construction of embankments), and "modulos" (cellular dykes to retain water on the savanna) were identified (Colomine, 1993). The predominant plant formation was evaluated in the surroundings (forest, bushes and grasslands or their combinations), as well as the covering of aquatic vegetation. All the accessible water bodies in the selected farms were monitored, using vehicles, boats, horses or on foot. Where it was possible, the water body was completely observed; when it was impossible to get a full observation of the waterbodies, no extrapolations of the number of individuals was made. An estimation of each observed aquatic surface was accomplished.

2. DATA ANALYSIS

An Excel database was built to practice analysis of variance (anova) using Statgraphics, with total amount of individuals counted by water body as numerical variable, verifiying its adjustment to normal distribution ($P<0.05$). As classification factors, the following categories were used:

- Ecological Regions: Alto Apure, Bajo Apure, Aguas Claras, Cajón de Arauca, Llanos Boscosos, Hoya de Arismendi.
- Covering of Aquatic Vegetation: completely absent, present (less than 30%), abundant (30-60%), very abundant (more than 60%) and total covering (100%)
- Associated Vegetation: forest, bushes, grasslands and its combinations
- Type of Water Body: rivers, "caños", lagoons, “esteros”, "prestamos" and dykes

The ANOVA provides the arithmetic average of individuals present in each classificatory category, as well as the significance level of its differences confirmed with *a posteriori* Duncan test ($P<0.05$). Variation coefficients were also calculated. Gross densities (individuals per hectare of land belonging to each property) and ecological or aquatic densities (individuals per hectare of observed water body) were estimated.

RESULTS

1. TOTAL DENSITIES AND SIZE CLASSES

The total number of water bodies surveyed was 693 (Table 1), with the lowest observations in "Hoya de Arismendi" (74) and "Cajón de Arauca" (28), due to difficulties to reach the waterbodies. The average number of individuals per water body for each region showed significant differences among the ecological regions, confirming the validity of the spatial subdivision of the whole study area proposed by Velasco & Ayarzaguena (1995). The levels of significance involved in the analysis, demonstrate variations in the spatial biotics and abiotic characteristics that could affect the quality of the habitats and its load capacities for the species.

Table 1: ANOVA results of the average number of individuals for in each region (ns = non significant, $P<0.05$).

REGION	CASES	MEAN	STD	Dif.
Alto Apure	140	199.3	33.97	* *
Hoya de Arismendi	74	187.4	26.94	***
Bajo Apure	163	147.1	31.58	***
Aguas Claras	115	106.1	13.65	***
Llanos Boscosos	173	86.5	24.68	**
Cajón de Arauca (ns)	28	37.0	14.75	*

The "Alto Apure" region reached the maximum average of individuals per water body. The intermediate values of "Aguas Claras", "Bajo Apure" and "Hoya de Arismendi" did not show significant differences. Llanos Boscosos showed a significantly low average, with the largest number of observed water bodies. The value registered for "Cajón de Arauca", with very low amount of individuals and observations, was not significant.

For the goals of the present study, the global analysis of the results in the 6 regions under study is comparable with the work made among 1991 - 1992 (Velasco & Ayarzaguena, 1995) using the gross density (individuals per hectare of surveyed properties).

Table 2: Comparison of number of individuals, surface surveyed and gross density (ind/ha) in 1992 and 1996, for 6 ecological regions.

REGION	NUMBER INDIVID.	SURFACE Ha	DENSITY '96	DENSITY '92
Alto Apure	27,903	109,127	0.26	0.22
Hoya de Arismendi	13,442	97,320	0.14	0.35

Bajo Apure	23,977	68,198	0.35	0.39
Aguas Claras	12,615	91,545	0.14	0.10
Llanos Boscosos	14,970	125,515	0.12	0.15
Cajón de Arauca	1,037	22,391	0.05	0.19
TOTAL	**93,944**	**514,096**	**0.18**	**-**

In total, 93.944 individuals were counted in 514.096 ha surveyed, with a terrestrial gross density of 0.18 ind/ha (Table 2). If the terrestrial or gross densities are compared between the ecological regions instead the average of individuals in waterbodies, a different result is obtained. In this case, "Alto Apure" and "Bajo Apure" presented the maximum densities and individuals counted. "Hoya de Arismendi", "Aguas Claras" and "Llanos Boscosos" showed very similar intermediate values, and "Cajón de Arauca" reached the lowest density and counts.

The total aquatic surface was estimated in 2.688,85 ha, which represents only 0,52% of the terrestrial surface, because the censuses were made during the period of extreme drought. The aquatic density was 34.94 ind/ha, which reflects a high concentration of animals in the water bodies that remains flooded.

2. HABITATS CHARACTERISTICS

Aquatic vegetation

The observed covering of aquatic vegetation in water bodies was classified in 5 categories: absent, present, abundant, very abundant and totally covered. The total amount of individuals associated to water bodies completely free of aquatic vegetation was 53.009 individuals (56,5%), compared with 40.837 individuals (43,51%) in areas with presence of aquatic vegetation.

Globally, there was significant differences between the categories of aquatic vegetation covering in regard to the observed average of individuals (Table 3).

Table 3: Average of individuals for each aquatic vegetation covering category (ns=no significant, P<0.05)

AQUATIC VEGETACION COVERING	CASES	MEAN	STD	Sig.
Absent	353	150.5	18.5	**
Present (0-25%)	132	179.9	39.5	***
Abundant (30-60%)	84	102.6	14.8	* *
Very abundant (60-90%)	80	52.2	8.7	*
Total covering (100%) (ns)	37	32.1	9.9	-

The maximum average of animals was registered in water bodies with aquatic vegetation present. This fact indicates the preference of the species toward habitats with certain covering of aquatic vegetation, taking into account that the efficiency of night light count method is maximum in waterbodies without aquatic vegetation. So, in spite of the

underestimation (not quantified) caused by this method's limitation, the amount of individuals was highest in habitats with floating plants. If the aquatic vegetation increases, the amount of surveyed crocs diminishes until a minimum in waterbodies totally covered, where the data obtained with the night light count is not reliable.

When crossing the aquatic vegetation with the surrouding vegetation, it is remarkable that the highest average of individuals (427,1) was found in waterbodies with forests and aquatic vegetation present, while without floating plants the average was 184,8 with significant difference. These results coincide with previous reports (Colomine, 1993). The waterbodies in savannas do not present significant difference in the average number of individuals regarding plant covering.

The comparison of average number of individuals against the aquatic vegetation covering in each ecological region offered significant differences. At "Alto Apure", "Bajo Apure", "Aguas Claras" and "Hoya de Arismendi", the largest amounts were registered in habitats with aquatic vegetation present, while in "Llanos Boscosos" and "Cajón de Arauca" more crocs were observed in habitats without aquatic vegetation.

Associated Vegetation

The following categories of surrounding vegetation were settled down: forests, bushes, grasslands and their combinations. More frequently, the waterbodies were associated to open grassland savannas (56.81%), while the forest habitat were less observed (17.25%). There was not significant difference in the average of animals censused with regard to the plant formation (Table 4).

Table 4: Average number of individuals in each plant formation type (P<0.05)

VEGETATION	CASES	MEAN	STD
Grassland	392	128.5	16.4
Bushes	39	81.5	22.3
Forest	119	185.6	42.8
Forest-Bush (ns)	2	23.0	4.0
Grassland-Bush	89	121.6	19.3
Grassland-Forest	23	117.3	55.5
All types (ns)	26	155.8	59.3

The water bodies associated with forests presented the highest average of sighted individuals, in spite of the difficulties of access to carry out the survey. In second place, the habitas with the three types of vegetation combined followed, but this numeric result is not reliable as the association forest-bush, due to low amount of surveyed locations.

This analysis of crocs abundance in relation to the plant formation associated to the water body was practiced for each ecological regions, repeating the situation evidenced in the global analysis: no significant differences between the different vegetation types was observed, with the maximum averages in forest habitats.

Type of Water Body

The considered water body types were primary habitats (rivers, "caños", lagoons, wetlands) and secondary ones (modular dykes and "préstamos"). Significant differences of the average number of individuals appeared between them. The most frequent waterbodies were lagoons, "caños" and "préstamos". The lagoons and "caños" showed highest averages of 133.6 and 197.6 individuals respectively, without significant difference among these primary habitats. On the other hand, the "préstamos" hardly reached average of 37.3 individuals, reflecting their condition of low-capacity habitats. The surveyed dykes (33 in total) contributed with a high average number of individuals (181.8), being the most favorable secondary habitats for the species. The largest average croc amount was observed in the 7 surveyed rivers, which indicates that these primary habitats tend to be occupied by numerous populations (Table 5). At wetlands, temporary flooded areas, the lowest amount of individuals were observed, also not significant.

Table 5: Average number of individuals for water body type (ns=no significant, P<0.05)

TYPE	CASES	MEAN	STD	Sig.
Rivers (ns)	7	228,4	148,5	-
"Caños"	224	197,6	30,0	***
Dykes	33	181,8	52,7	***
Lagoons	273	133,6	17,6	* *
"Préstamos"	148	37,3	6,6	*
Wetlands (ns)	8	13,5	4,1	-

The high crocs average presented in the rivers is the result of very few observations and is not significant (Table 6), and this can be related with the fact that it is completely forbidden the hunt in these habitats.

Table 6: average of individuals in rivers for ecological regions (not significant differences, P<0.05)

RIVERS	CASES	MEAN	STD
Alto Apure	2	47,0	10,0
Bajo Apure	-	-	-
Cajón de Arauca	-	-	-
Hoya de Arismendi	-	-	-
Llanos Boscosos	3	23,0	9,0
Aguas Claras	2	718,0	356,0

The "caños" are the habitats where more crocs were found, with significant results regarding the other water body types. The "caños" constitutes very frequent natural drainages of variable depth in all the southwestern "Llanos" with alluvial soils, with the exception of "Aguas Claras" region, where sandy dunes prevail on the soil. In the "caños" high concentrations of animals were observed, reaching an average of 303.3 individuals in the Alto Apure (Table 7), remarking that the courses of water surrounded by grasslands

reached 197.5 individuals on average, while the forest surrounded "caños" showed a higher value (250.4 individuals). In general, one "caño" can cross forest, bush and grassland formations along its itinerary that can be very long. The water in many "caños" are segmented during the dry season, forming small lagoons in their channel full of fishes that serves as food for the crocodilians.

Table 7: Comparison of average individuals in "caños" for each ecological region (not significant differences, P<0.05)

CAÑOS	CASOS	MEDIA	STD
Alto Apure	54	303,3	78,4
Bajo Apure	50	242,3	93,4
Cajón de Arauca	14	50,1	29,2
Hoya de Arismendi	46	203,2	31,9
Llanos Boscosos	58	89,6	24,0
Aguas Claras	2	262,0	-

The natural lagoons are shallow water bodies that keep water during all the year, very frequent in all these regions. It can present circular form occupying depressions on the savanna, or horseshoe form when they are derived from bends of rivers and "caños". It reach their maximum frequency in "Aguas Claras", region with a landscape characterized by the presence of dunes. The lagoons can be surrounded by grasslands, bushes or forests in their margins. In these primary habitats, large concentrations of crocs were recorded with significant difference between the ecological regions, with similar values to those of the "caños" although slightly inferior. The maximum was observed on the average in the "Llanos Boscosos" (Table 8).

Chart 8: average of individuals in lagoons on each ecological region (P <0.05)

LAGOONS	CASES	MEAN	STD
Alto Apure	31	214,7	41,4
Bajo Apure	50	242,3	93,4
Cajón de Arauca	13	25,6	5,4
Hoya de Arismendi	10	191,0	48,3
Llanos Boscosos	26	265,6	151,6
Aguas Claras	109	93,6	10,2

The "préstamos" are artificial excavations of small extension and depth, from which the land material is extracted for the construction of roads and dams. This secondary habitats presented very inferior values of average individuals in comparison with the primary habitats. This habitat type is very frequent at "Alto Apure", "Bajo Apure" and "Llanos Boscosos" (Table 9).

Table 9: average of individuals in "préstamos" in each ecological regions (not significant, P<0.05)

REGIONS	CASES	MEAN	STD
Alto Apure	44	53.6	18.7

Bajo Apure	24	32.3	6.2
Cajón de Arauca	1	3.0	-
Hoya de Arismendi	5	66.4	28.3
Llanos Boscosos	72	27.9	6.7
Aguas Claras	2	18.0	7.0

The best secondary habitats for the species resulted the modular dikes ("módulos"). These dams builted directly on the savanna cover large extents (3.000 to 10.000 ha) contained inside cellular dike-embankments, retaining water during the whole year. In these large dimensions, "caños", lagoons, "préstamos" can be embraced. Occasionally also forest areas are contained, transforming it into favorable habitats for the maintenance of numerous and stable populations. The regions of "Aguas Claras" and "Cajón de Arauca" does not has this type of dikes (Table 10).

Table 10: average of individuals in dikes in each ecological region (not significant P<0.05).

MODULOS	CASES	MEDIA	STD
Alto Apure	8	298.5	127.1
Bajo Apure	5	125.6	104.4
Cajón de Arauca	-	-	-
Hoya de Arismendi	13	175.5	98.2
Llanos Boscosos	7	100.1	57.2
Aguas Claras	-	-	-

Finally, the "esteros", wetlands located on depressions of open savanna, were relatively scarce in all the regions, due to the advanced dry season when the sampling was carried out. Only 8 cases were observed in "Alto Apure" with, with an average of 13.5 individuals.

DISCUSSION

The method used for obtaining the field information is advantageous to evaluate the population status of this species, in connection with the habitats occupied. The effort applied in the surveys is acceptable for the magnitude of the obtained data and its reliability. The observers needs to be trained to develop capacity to carry out the censuses and environmental evaluations in very wide territorial spaces.

The most important physical obstacle for the application of this method at this great scale is the accessibility to the water bodies. The source of more frequent error is the underestimation of abundance, caused by the presence of floating plants and the difficulty to observe the whole water body. However, the obtained volume of data allows the application of parametrical statistical methods of like the analysis of variance, with enough grades of freedom to validate the significance of the opposing differences. Even so, it is important to point out that this is only a punctual observation in time, and the obtained results are limited to the habitats condition for the moment of sampling.

In general, this species tend to occupy habitats with calm, shallow waterbodies, surrounded waters by forest, and physical-chemical relatively stable characteristics (Ayarzaguena, 1983; Gorzula *et al*, 1988; Colomine, 1993; Colomine *et al*, 1994). This preference is more conspicuous in the Venezuelan "Llanos", where the Babas has a behavior closely linked to the annual hydrological cycle (Muñoz, 1988), being dispersed during the rainy season with the maximum flood, and concentrated during drought on the habitats that remain with water, reaching large population densities in limited aquatic surfaces (Ojasti, 1989).

The reproductive stages are linked to the habitat cycling condition: mating and nesting during the rainy season, and hachtlings appearance at the beginning of the dry season. Migrations can be produced governed by the habitat selection, in search of more favorable conditions for the reproductive phases (Muñoz, 1988; Oubuter & Nanhoe, 1988).

These reproductive demands explain the fact that the most abundant populations are associated to the primary, isolated and forested habitats with floating vegetation present that can offer refuge, availability of food for all the size classes and nesting possibilities. Nevertheless, the secondary habitats also can advantageously occupied by the species to support extreme drought conditions (Ayarzaguena, 1983). The large extents of the modular dikes built on the plains to enhance cattle raise, include natural areas (flooded grasslands, "caños" and lagoons) that allow the presence of abundant populations (Colomine, 1993). Other populations have also been reported for reservoirs and in other places of the country (Arteaga, 1989).

Significant differences in abundance were found, and the regions with more abundance and density were "Alto Apure" and "Bajo Apure". This is a valuable information for the management plan for this species, which take into account the remarkable characteristics of the waterbodies in these regions. Equally, the relatively smaller levels observed in "Cajón de Arauca", "Aguas Claras" and "Llanos Boscosos", demands the application of controls for the use of the species.

CONCLUSIONS

The subdivision in ecological regions of the area for managing the commercial hunting program of the species on the basis of environmental and population differences, was supported by the results from the present work.

The most abundant populations were associated to primary habitats (rivers, "caños" and lagoons) surrounded by forests and with presence of aquatic vegetation. Among the secondary habitats, the "préstamos" serve as refuge during the dry season, but the modular dikes are favorable for the species, due to their great extension that generally embraces forest areas and primary habitats.

The presence of abundant and permanent populations of *C. crocodilus* can be considered as indicator of high-quality habitats for associated terrestrial and aquatic wild fauna. This fact

facilitates the adoption of management plans directed to achieve an effective protection of such habitats.

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