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Artículo

Dispersal of Orinoco crocodiles (*Crocodylus intermedius*) after their release into the Capanaparo River, Santos Luzardo (Cinaruco-Capanaparo) National Park, Apure State, Venezuela

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Abstract. In the Santos Luzardo (Cinaruco-Capanaparo) National Park, Apure State, Venezuela, 3,136 Orinoco crocodiles raised in captivity until one year of age have been released into the Capanaparo River over the past 18 years. During the population surveys, specimens were captured to evaluate their adaptation to the natural habitat. Thirty six Orinoco crocodiles were captured, of which 19 were released by breeding farms and recaptured at different times. The distance between the release and recapture sites was determined. The remaining 17 correspond to individuals born in the Capanaparo River. Dispersal distances ranged from 0.24 to 9.76 km from the release site. Only four Orinoco crocodiles dispersed upstream, whereas the remaining individuals dispersed downstream. The period between release and capture ranged from one month to 130 months.

Keywords: Orinoco crocodile; *Crocodylus intermedius*; mark-recapture; dispersal.

Dispersión de caimanes del Orinoco (*Crocodylus intermedius*) luego de su liberación en el río Capanaparo, Parque Nacional Santos Luzardo (Cinaruco-Capanaparo), estado Apure, Venezuela

Resumen. En el Parque Nacional Santos Luzardo (Cinaruco-Capanaparo), estado Apure, Venezuela, 3.136 caimanes del Orinoco criados en cautiverio hasta el año de edad, fueron liberados en el río Capanaparo durante los últimos 18 años. Durante los censos poblacionales, se capturaron ejemplares para evaluar su adaptación al hábitat natural. Se capturaron 36 caimanes del Orinoco, de los cuales 19 fueron liberados por granjas de cría y recapturados en diferentes momentos. Se determinó la distancia entre los sitios de liberación y recaptura. Los 17 restantes corresponden a individuos nacidos en el río Capanaparo. Las distancias de dispersión variaron de 0,24 a 9,76 km desde el sitio de liberación. Solo cuatro cocodrilos del Orinoco se dispersaron río arriba, mientras que los demás individuos se dispersaron río abajo. El período entre la liberación y la captura varió de un mes a 130 meses.

Palabras clave: Caimán del Orinoco; *Crocodylus intermedius*; marcaje-recaptura; dispersión.

Introduction

The release of Orinoco crocodile (*Crocodylus intermedius*) bred in captivity in Venezuela began in 1990 (Velasco 1999) with the main objective of recovering, increasing, and creating new populations of the species.

The first Action Plan for the Orinoco crocodile conservation was the result of a workshop coordinated by Fudena (1993) in conjunction with the Venezuelan Crocodile Specialist Group (GECV), which stipulated release, reintroduction, and monitoring as among the actions to be implemented. Subsequently, the Autonomous Wildlife Service PROFAUNA (1994) published the Strategic Plan compiled and edited by Fudena, which ratified reintroduction and monitoring as among the lines of action.

In 2003, an updated Action Plan for the Conservation of the Orinoco Crocodile was published by the National Office of Biological Diversity of the Ministry of Environment and Natural Resources of Venezuela (Velasco 2003), maintaining the release of captive-bred individuals as one of its specific objectives.

Individuals released into their natural habitat are given a Monel-type metal tag on their hind legs, all morphometric measurements are taken, and the location where the release took place is georeferenced. This allows on recapture to determine whether the animal is wild or captive-bred, as well as its growth rate and dispersal.

One of the methodologies used to determine the adaptability, survival and dispersion of Orinoco crocodiles released into the wild is through recapture methodology, also used to estimate the population size, mortality, and growth rates (Davis and Winstead 1980).

In Venezuela, only two studies have been conducted using the mark-recapture methodology with the Orinoco crocodile. The first study was conducted by Lugo (1998) in the Caño Guaritico Wildlife Refuge, Apure State. The second study was conducted by Llobet (2002) in the Santos Luzardo National Park, Capanaparo River. Both studies report dispersal distances of recaptured individuals higher than those reported in this study.

The other methodology used to evaluate the dispersion of released crocodiles is through VHF, UHF radiotelemetry and more recently through satellite GPS systems. In Venezuela, two studies have been carried out with VHF in the Capanaparo River on eight Orinoco crocodile specimens (Muñoz and Thorbjarnarson 2000) and Antelo (2008) who place twenty seven radio transmitters on three males and twenty four females, that were released and monitoring at the Caño Guaritico Wildlife Refuge, Apure State. Moreno and Ardila (2020) studied the dispersal of the Orinoco crocodile in Colombia, using satellite radio telemetry, evaluating movement patterns between females and males.

In the present study, tagging individuals allows us to identify them upon recapture after their release into the wild. This pre-tagging also allows us to determine the dispersion of individuals from the release site until their subsequent recapture in the Capanaparo River.

Methodology

Fieldwork was carried out in the Las Campanas, Basiliero, Santa Josefina, and Piedra Azul sectors of the Capanaparo River in the Santos Luzardo National Park (Figure 1). The released *Crocodylus intermedius* were identified with numbered metal tags of National Wing Bands model 893 JIFEY size 3 on both hind legs. Previously, morphological data such as total length (TL), body length (TC), weight, and sex were taken.

Night surveys were conducted using a 16-foot boat with a 40-HP outboard engine. The search for specimens was carried out using 200,000 lumen LED headlights. Metal snares were used to capture them, and small specimens were captured by hand. Once captured, the presence of metal tags was verified to determine whether it was a recapture or a new individual, indicating that it had been born in the wild. Morphometric

measurements, weight, and sex were taken for each specimen. The recapture location was georeferenced using a Garmin GPSMAP 78s GPS.

Two chi-square tests were performed: one to evaluate the relationship between dispersal distance from the release site and river flow direction, and a second to assess the relationship between dispersal distance from the release site and time since release. Fisher's exact test and Monte Carlo simulations were used when appropriate due to small sample sizes and low expected frequencies in contingency table cells.

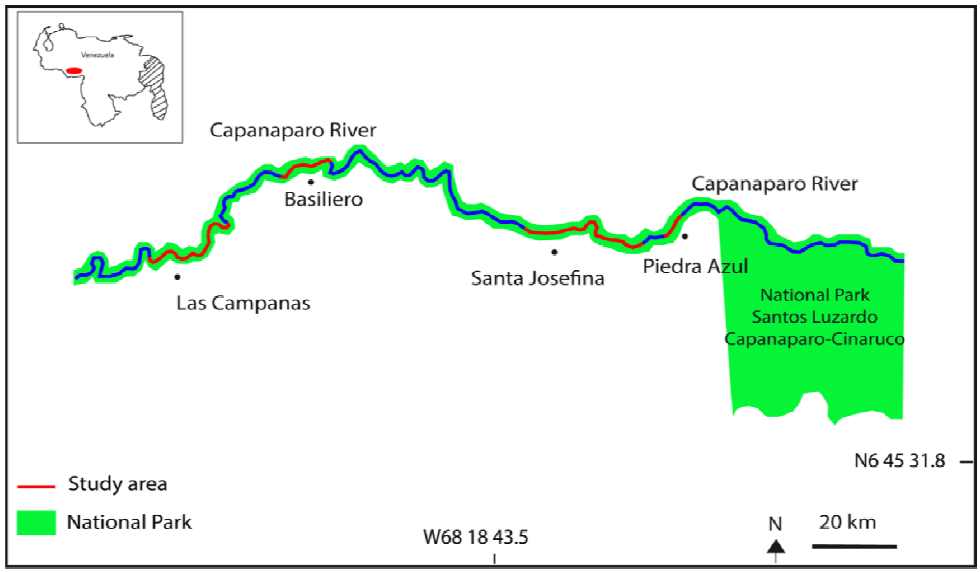

Figure 1. Study area. The areas of the Capanaparo River where the tours were conducted are shown in red.

Results

Thirty-six Orinoco crocodiles were captured, 19 of which had been reintroduced in previous years (Table 1). One of them was recorded in the Las Campanas sector, and 18 were recorded in the Santa Josefina sector. Of these, 18 were bred at Masaguaral Ranch, and one was born at the Dallas World Aquarium (Texas, USA). The remaining 17 were born in the Capanaparo River.

The distances from the release sites to those where the Orinoco crocodiles were captured, ranged from 0 to 9.76 km. Only four individuals dispersed upstream of their reintroduction site in the Santa Josefina sector. The rest of the recaptured Orinoco crocodiles (15 individuals) were found downstream from the reintroduction site.

The oldest individuals captured was a 13-year-old female born at the Dallas World Aquarium in Texas, USA, with a dispersion range of 4.17 km, and a 5.7-year-old male born at Masaguaral Ranch with a dispersion range of 1.93 km. Twelve Orinoco crocodiles had been reintroduced less than a year before their recapture and their dispersion range was less than 2 km, but four others showed a larger dispersal range (3.39 – 9.76 km). A 2.5-year-old individual, released 18 month earlier, presented the lowest dispersion 0.42 km.

Table 1. Orinoco crocodiles recaptured that born in captivity, origin of the specimens, release and capture coordinates, the time elapsed between both events, and the distances from the released sites.

Tag ID	Origin	Reintroduction coordinates		Recapture coordinates		Direction	Time between reintroduction and capture (months)	Distance between release and recapture (km)
1303	Masaguaral	N6 57.610'	W68 13.040'	N6 57.841'	W68 11.639'	downstream	7	3.39
M1615	Masaguaral	N6 57.610'	W68 13.040'	N6 57.699'	W68 12.600'	downstream	7	0.90
M1660	Masaguaral	N6 57.610'	W68 13.040'	N6 57.762'	W68 13.164'	upstream	9	0.30
1461	Masaguaral	N6 57.610'	W68 13.040'	N6 57.312'	W68 11.509'	downstream	6	4.74
1372	Masaguaral	N6 57.610'	W68 13.040'	N6 57.747'	W68 12.515'	downstream	7	1.80
M1659	Masaguaral	N6 57.610'	W68 13.040'	N6 57.950'	W68 12.251'	downstream	9	1.70
M1509	Masaguaral	N6 57.610'	W68 13.040'	N6 57.290'	W68 13.620'	upstream	9	1.19
1338	Masaguaral	N6 57.610'	W68 13.040'	N6 57.649'	W68 12.925'	downstream	9	0.24
M1694	Masaguaral	N6 57.610'	W68 13.040'	N6 57.969'	W68 12.320'	downstream	9	1.61
290684	Masaguaral	N6 57.610'	W68 13.040'	N6 57.759'	W68 13.046'	downstream	1	0
VE0365	DWA-EBRG	N6 57.553'	W68 13.431'	N6 57.871'	W68 11.612'	downstream	130	4.17
290182	Masaguaral	N6 57.610'	W68 13.040'	N6 57.668'	W68 12.808'	downstream	7	0.50
M1637	Masaguaral	N6 57.610'	W68 13.040'	N6 58.026'	W68 11.704'	downstream	7	3.78
306523	Masaguaral	N6 55.778'	W68 39.087'	N6 56.289'	W68 38.190'	downstream	68	1.93
M1563	Masaguaral	N6 57.610'	W68 13.040'	N6 57.668'	W68 12.808'	downstream	9	0.48
290167	Masaguaral	N6 57.610'	W68 13.040'	N6 57.786'	W68 12.427'	downstream	9	1.24
290134	Masaguaral	N6 57.610'	W68 13.040'	N6 57.719'	W68 13.289'	upstream	18	0.42
1402	Masaguaral	N6 57.610'	W68 13.040'	N6 56.715'	W68 09.054'	downstream	7	9.76
M1687	Masaguaral	N6 57.610'	W68 13.040'	N6 57.546'	W68 13.473'	upstream	6.5	0.87

Although the chi-square test suggested an association between dispersal distance and direction ($\chi^2 = 8.2308$, df = 1, p = 0.0041), this result was not supported by Monte Carlo simulations (p > 0.05), likely due to small sample size.

Most individuals (17) were recaptured within 4.5 km of the release site. Only two individuals were recorded at 4.6–9 km, both within the first year after release, whereas none of the individuals recaptured after > 1 year (n = 3) were observed in this distance class. No significant association was found between dispersal distance and time since release ($\chi^2 = 0.42$, df = 1, p = 0.52). This result was confirmed by Fisher's exact test (p = 1.00).

Of the captured specimens born in the Capanaparo River (Table 2), 11 were less than 1 meter in length, two were juveniles, and four were adults over 2 m in length. Among these, there is a female over 3 m in length and a male over 4 m in length.

In the Santos Luzardo National Park, 3,136 captive-bred specimens have been reintroduced in 1991–1993, 2001, 2009, 2019, 2021, and 2023. This means that the capture of reintroduced specimens represents 0.61% of the reintroduced Orinoco crocodiles.

Table 2. Orinoco crocodiles captured that born in Capanaparo River, the morphological data and capture coordinates of the captured specimens born in the Capanaparo River.

Tag ID	Total length (mm)	Body length (mm)	Sex	Coordinates	Coordinates	Sector
	704	369				
1402	645	350		N6 56.715	W68 09.054	Santa Josefina
1488	1,971	1,092	M	N6 57.002	W68 10.626	Santa Josefina
1492	596	315		N6 57.600	W68 12.674	Santa Josefina
1483	2,123	1,170	M	N6 58.171	W68 12.093	Santa Josefina
290600	700	365		N6 57.857	W68 12.388	Santa Josefina
	4,005		M	N6 58.031	W68 11.697	Santa Josefina
VE1122	1,675	914	M	N 6 57.682	W 68 11.733	Santa Josefina
VE1124	850	477		N 6 57.769	W 68 13.046	Santa Josefina
VE1177	637	335		N6 58 10.4	W68 11 44	Santa Josefina
	3,950		M	N6 58 38.8	W68 18 32.3	Santa Josefina
	578	300		N7 00 24.3	W67 47 26	Piedra Azul
	489	290		N7 00 32.9	W67 47 18.6	Piedra Azul
	520	283		N7 00 46.5	W67 47 20.2	Piedra Azul
1485	547	334		N6 58.920	W68 35.161	Basiliero
1487	704	367		N6 56.631	W68 39.804	Las Campanas
	3,155	1,640	F	N6 56.458	W68 39.649	Las Campanas

Discussion

With the data obtained in this study and the methodology used, we can only show how far the recaptured specimens dispersed and where they moved, with a wide dispersal distance, the longest of which was 9.76 km for a specimen seven months after reintroduction. Almost of these specimens were recaptured downstream of their reintroduction site. This pattern is primarily due to the direction of the river current. Only four specimens were captured upstream of their reintroduction site, with a distance close to 1 km. This downstream-biased dispersal pattern is consistent with the influence of river current on juvenile movements following release.

The occurrence of longer dispersal distances within the first year after release may reflect an initial exploratory phase, during which juveniles search for suitable habitat and resources before establishing more stable activity areas. As individuals settle, movements may become more restricted, resulting in shorter dispersal distances over time.

In the Capanaparo River, two previous studies were carried out, one with the same methodology used in the present work (Llobet 2002) and another by Muñoz and Thorbjarnarson (2000) using UHF radio transmitters. The individuals captured by Llobet (2002) were downstream of the release sites with distances greater than those reported in the present study (Table 3). Muñoz and Thorbajarnarson (2000) reported that the individual that presented the greatest dispersal distance (11.60 km; Table 3) was upstream, and the rest of the specimens with shorter distances were downstream from the release site, like this report.

Other studies with the Orinoco crocodile have been carried out using satellite radio telemetry, both in Venezuela by Lugo (1998) and Antelo (2008), reporting higher dispersal distances (Table 3) in the Caño Guaritico Wildlife Refuge, Lugo (1998) reported greater distances downstream from where the samples were released (table 3), only three Orinoco crocodiles dispersed upstream with distances that did not exceed 5 km. Antelo (2008) used satellite tracking to determine the type of habitat used by Orinoco crocodiles. Much higher distances have been reported in Colombia (Moreno and Ardila, 2020) through satellite telemetry (Table 3).

Table 3. Maximum and minimum dispersion reported for Orinoco crocodile in other studies.

Species	Minimum dispersion (km)	Maximum dispersion (km)	Reference
Crocodilus intermedius	1.50	70.00	Lugo (1998)
Crocodilus intermedius	0.30	11.60	Muñoz and Thorbjarnarson (2000)
Crocodilus intermedius	10.36	21.86	Llobet (2002)
Crocodilus intermedius	Not reported	Not reported	Antelo (2008)
Crocodilus intermedius	Not reported	177.00	Moreno and Ardila (2020)
Crocodilus intermedius	0.00	9.76	This study

Studies with other crocodile species (Table 4) used satellite radio telemetry, which reports dispersal distances and directionality. Griffith *et al*. (2020) and the Gharial Ecology Project (2021) reported a wide dispersal range and that specimens moved in either direction along the riverbed depending on the season.

Table 4. Maximum and minimum dispersion reported for *Gavialis gangeticus*.

Species	Minimum dispersion (km)	Maximum dispersion (km)	Reference
Gavialis gangeticus	7.00	50.00	Griffith *et al.* (2020)
Gavialis gangeticus	6.00	62.00	Gharial Ecology Project (2021)

Our study in the Capanaparo River, reveals several interesting points: First, the reintroduced specimens appear to adapt well to the habitat; the relatively short dispersal distances suggest that some juveniles remain near the reintroduction site due to the availability of food and shelter.

Notably, a female was captured with a dispersion of 4.17 km, and at this same location, we observed the presence of at least four nests and equal number of adult individuals during the breeding season. This female was part of a group of females that were reintroduced 10 years ago. Months after this recapture, a male, which we believe is responsible for the increase in nest numbers in this area, was captured, measuring 4,005 mm, and included in the present study.

Regarding the specimens born in the Capanaparo River, the interesting thing is that specimens of different sizes were captured (Table 4) in areas where reintroductions have been carried out in previous years.

Our results on the directionality of dispersion and distances between release and capture do not define a trend in the behavior of the species and when reviewing what has been published in the literature, we observed that in each location the dispersion and distances could be related to the particular habitat.

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