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Criados en cautividad.

ABSTRACT.—To test the feasibility of using captive-reared Orinoco crocodiles to restock depleted wild populations we used radio-telemetry to monitor eight crocodiles (103.3–139.3 cm total length) released in the Capanaparo River in southwestern Venezuela. Crocodiles were located every 1–2 d from April 1991 to March 1992 to determine movement patterns, survivorship, and growth rates. The crocodiles moved considerably during the first month following release, and the maximum distance moved was 11.6 km upstream by one crocodile four months after release. However, following an initial period of movement, crocodiles became more sedentary and by the end of the study the maximum distance from the point of release was less than 8 km. Six of the eight crocodiles moved upstream while two moved up to 3.3 km downstream. Crocodiles remained principally along the main course of the river in areas with mixed shallow and deep water habitats and abundant sand beaches. As the river rose during the wet season, crocodiles remained in the same areas, but moved into shallow-water areas among flooded riparian vegetation. The mean growth rate of released crocodiles (0.079 cm TL/day) was similar to that of smaller wild-born juvenile crocodiles. One animal was accidentally killed by a local resident who was hunting spectacled caiman. Based on the results of this study, we feel that a carefully designed program of releases of captive-reared crocodiles can be an effective conservation tool to speed the recovery of depleted populations of Orinoco crocodiles. However, care must be taken to insure that the release program is designed as one component of an overall crocodile strategy and not an excuse to avoid the onerous issues of the protection of wild crocodile populations and their habitat.

The Orinoco crocodile (*Crocodylus intermedius*) is one of the most world's most endangered crocodilians (Thorbjarnarson, 1992; Ross, 1998). At one time commonly found throughout the Orinoco and its major fluvial tributaries, Orinoco crocodiles were brought to near-extinction levels by commercial skin hunting between 1930 and the 1960s (Medem, 1981, 1983). Since that time little evidence of natural population recovery has been noted in Venezuela (Thorbjarnarson and Hernández, 1992; Arteaga et al., 1994). Following the success of the crocodile release program in India with three species of crocodilians (Choudhury and Chowdhury, 1986; Choudhury, 1990), a captive-rearing and release program was initiated as a conservation strategy in certain protected areas in the Venezuelan Llanos (Seijas, 1995; Thorbjarnarson and Arteaga, 1995). Since 1990, over 1500 animals have been released into the Cinaruco-Capanaparo National Park, the Aguaro-Guariquito National Park, and the Caño Guaritico National Wildlife Refuge)(Arteaga and Hernandez, 1996). In Venezuela, there are currently four captive-breeding and rearing stations for Orinoco crocodiles. Most operations are small and are funded by private individuals or institutions interested in assisting the recovery of this threatened species (Arteaga et al., 1994).

Two types of crocodile release programs have been conducted in Venezuela. Most animals that have been released, including the vast majority of those in the Aguaro-Guariquito National Park and the Caño Guaritico National Wildlife Refuge, have been offspring of captive breeding stock maintained at the breeding centers. These animals have been reintroduced into areas where crocodiles have been extirpated or where they exist at critically low levels. However, the Capanaparo River, which forms the northern boundary of the Cinaruco-Capanaparo National Park, is one of the largest known remaining populations of Orinoco crocodiles with >100 adults (Thorbjarnarson and Hernandez, 1992). Principal threats to this population have been the collection of eggs for food, as well as the capture of neonates for sale as pets (Thorbjarnarson and Arteaga, 1995). As a result, recruitment was extremely low and it was felt that a restocking program based on headstarting ani-

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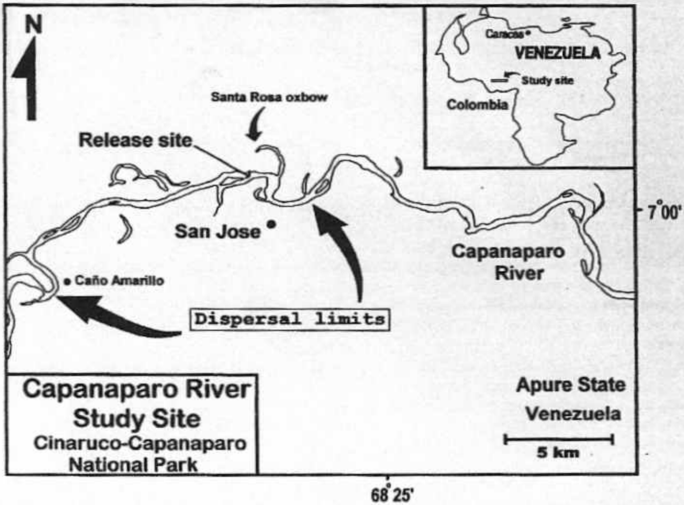


FIG. 1. Map of Capanaparo River study site showing release site, and points of maximum dispersal upstream and downstream (marked with arrows).

mals from nests collected along the Capanaparo could be an effective conservation strategy (Thorbjarnarson, 1993). To evaluate the ability of captive-reared crocodiles to adapt to a natural environment, we conducted a radio-telemetry study of captive juvenile crocodiles released into the Capanaparo River.

## Materials and Methods

*Study Area.*—The study was conducted in the Capanaparo River, a tributary of the Orinoco River in Apure state (Fig. 1). The release site was within the Cinaruco-Capanaparo National Park, between the communities of San Jose and Caño Amarillo (6°54′41″ N to 7°03′23″ N, 68°36′06″ W to 68°23′04″ W). The region is characterized by a treeless aeolian savanna with thin strips of gallery forests along river and stream courses. Annual precipitation averages 1915 mm and the climate is highly seasonal with a well defined wet (May–November) and dry (December–April) season (Fig. 2). During the dry sea-

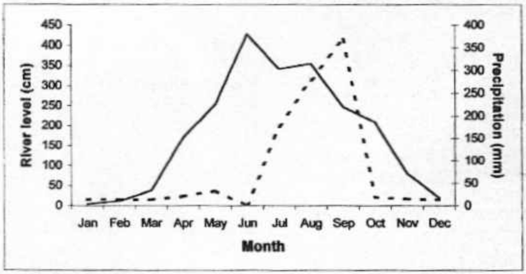


FIG. 2. Mean precipitation (solid line; 19 year average) in Capanaparo region and mean river level (dashed line) during the 1991–1992 study period. Precipitation data from the Ministerio of the Environment (MARNR).

TABLE 1. Length, mass, and study interval of crocodiles used in the radio-telemetry study.

| Crocodile | Date released | Snout-vent length (cm) | Total length (cm) | Mass (kg) | Last radio location | No. radio locations | Days radio-tracked | Mean interval (days) |
|---|---|---|---|---|---|---|---|---|
| [illegible] | 28/03/91 | 71.0 | 130.8 | 9.0 | 11/04/91 | 5 | 14 | 2.80 |
| [illegible] | 28/03/91 | 74.9 | 138.8 | 11.5 | 6/02/92 | 187 | 313 | 1.67 |
| [illegible] | 04/04/91 | 62.5 | 115.2 | 5.5 | 17/03/92 | 195 | 347 | 1.78 |
| [illegible] | 04/04/91 | 65.4 | 120.8 | 6.5 | 22/03/92 | 185 | 352 | 1.90 |
| [illegible] | 04/04/91 | 68.9 | 127.0 | 8.5 | 17/03/92 | 191 | 347 | 1.82 |
| [illegible] | 04/04/91 | 70.5 | 103.3 | 8.5 | 25/11/92 | 134 | 235 | 1.75 |
| [illegible] | 04/04/91 | 71.5 | 131.9 | 9.0 | 22/03/92 | 191 | 352 | 1.84 |
| [illegible] | 04/04/91 | 75.3 | 139.3 | 11.5 | 17/02/92 | 190 | 319 | 1.68 |
| Mean | | 70.0 | 125.9 | 8.7 | | | 284.9 | 1.78 |

son extensive sandy beaches and shallow water stretches (mean depth 1.3 m, N = 61) alternate with deeper pools (>2.5 m deep). Water conductivity ranged from 27.1–45.3 μS with a mean value of 34.5 μS. Mean diurnal air and water temperatures were 29.0 C and 29.2 C, respectively. The activity of most adult crocodiles, including nesting, centers on the areas around the deeper pools during the dry season (Thorbjarnarson and Hernández, 1993). The river meanders and has numerous oxbows or isolated floodplain lakes (Fig. 1). During the rainy season the river rises approximately 4 m above its lowest level, covering most beaches and in some areas flooding sections of gallery forest. Riverside vegetation is dominated by riparian trees and shrubs (*Campsiandra comosa, Psidium maribense, Coccoloba obtusifolia*), or xeric-adapted species (*Byrsonima crassifolia, Couepia ovatifolia, Erisma uncinatum*) where the river course has recently eroded into the surrounding savannas. Human population pressure in the region is low, with scattered small communities of Yaruro Indians and cattle ranches. The Cinaruco-Capanaparo National Park was established in 1989, and the Capanaparo river supports good populations of spectacled caiman (*Caiman crocodilus*), river dolphins (*Inia geoffrensis*), yellow-spotted river turtles (*Podocnemis unifilis*), and giant river otters (*Pteronura brasiliensis*), as well as small numbers of giant river turtles (*P. expansa*), and manatees (*Trichechus manatus*).

*Radio-telemetry Study.*—Eight juvenile crocodiles were released with radio transmitters in late March and early April 1991. The crocodiles hatched from eggs collected along the Capanaparo River on 25 February 1987, and were subsequently reared at the crocodile facility at Fundo Pecuario Masaguaral (Guárico state), approximately 200 km northeast of the site of collection. All eight crocodiles were males, and radio transmitters were attached to the dorsal caudal scutes immediately anterior of the junction of the single and double caudal crests using nylon monofilament fishing line. Radio-transmitters were 3.0 v Lonner modules (AVM Instrument Co., Ltd) that produced signals in the 164–165 MHz frequency range. Radios measured 8.7 cm by 2.3 cm, weighed 62 g and had a 30 cm long whip antenna. We located crocodiles every 1–2 d using a Telonics® TR-2 receiver and an RA-2A antenna from an aluminum boat with an outboard motor, and locations were plotted on 1:100,000 topographic maps. Crocodiles were approached cautiously and initially spotted with binoculars to minimize potential disturbance. Dispersal distance was considered to be the distance (following the main river course) between the crocodile's location and its initial point of release. A daily movement index (DMI) was calculated by dividing the distance between two successive locations by the interval (in days) between the radio-fixes. At the end of the study we attempted to recapture all radio-tagged crocodiles to measure growth rates and compare these with the growth of wild juvenile crocodiles from the same area. Growth rate was calculated by dividing the difference in total length (TL at recapture–TL at release) by the number of days between release and recapture, and expressed as cm of growth per day.

## RESULTS

Eight male crocodiles with radio transmitters were released on 28 March or 4 April 1991 at the height of the dry season. Crocodiles ranged from 115.2 to 139.3 cm total length (Table 1). Between 5 April 1991 and 22 March 1992 we radio-located the crocodiles a total of 1278 times. The mean interval between radio-locations for all animals was 1.78 d (Table 1), and seven crocodiles were followed for intervals of 235–352 d. Two weeks after being released, one crocodile was killed by a Yaruro Indian who mistook it for a spectacled caiman. Caiman are regularly hunted for food by the Yaruro using bow and arrow; crocodiles are not hunted or eaten as the Yaruro claim their flesh has an oily

TABLE 2. Maximum dispersal distance (in km) of crocodiles from the release site, by month.

| Crocodile | Apr 1991 | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan 1992 | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C32 | 3.3 | — | — | — | — | — | — | — | — | — | — | — |
| C44 | 1.0 | 0.7 | 0.7 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | — |
| C26 | 5.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.5 | 5.5 | 5.5 |
| C34 | 2.7 | 5.1 | 5.1 | 5.1 | 4.8 | 4.8 | 4.8 | 5.6 | 5.6 | 2.1 | 5.4 | 5.4 |
| C38 | 5.8 | 6.0 | 5.2 | 5.1 | 5.3 | 5.8 | 5.8 | 4.8 | — | — | — | — |
| C33 | 1.7 | 1.7 | 1.7 | 1.3 | 0.6 | 0.5 | 0.6 | 1.0 | 1.8 | 1.7 | 1.8 | 1.8 |
| C37 | 8.0 | 8.0 | 8.0 | 8.0 | 7.4 | 7.4 | 7.7 | 7.7 | 7.7 | 7.8 | 7.4 | 7.7 |
| C40 | 7.5 | 9.9 | 10.1 | 11.6 | 7.5 | 7.3 | 7.3 | 7.9 | 7.6 | 7.5 | 7.5 | — |
| Mean | 4.5 | 5.3 | 5.2 | 5.3 | 4.5 | 4.5 | 4.6 | 4.7 | 4.8 | 4.1 | 4.6 | 5.1 |

and bitter taste. The crocodile followed for 235 d was lost when its transmitter failed.

Crocodiles began moving immediately following release, and three of the crocodiles reached their maximum dispersal distance within two months (Table 2). Maximum dispersal distance was 11.6 km upstream by a crocodile four months following release. In general, crocodiles made moderate upstream movements (3–8 km upstream), or short downstream movements (1–2 km) (Fig. 3). During the low-water, dry-season period, dispersal distance reflected movements to open sections of the river with extensive sand beaches and a mixture of shallow water and deeper pools. Daily movement was highest during the first month (Fig. 4).

When the rains began and the river started to rise in June-July, crocodiles remained in the same areas, but moved into shallow water areas in flooded riparian vegetation. Maximum river levels occurred in August–September and crocodiles were mostly sedentary during this period (Fig. 4). Crocodiles began moving again in the early dry season (December–February) presumably in response to dropping river level (Fig. 4)

Crocodiles were usually found in the main river course (82% of radio-locations), but on occasion entered an oxbow lake (12%) or secondary (overflow) river course (6%). The use of the one oxbow (Santa Rosa; Fig. 1), an abandoned meander still connected to the main river, was observed principally during the early part of the study. This oxbow was recently formed (ca. 20 yr old, based on examination of maps) and still retained open, sandy beaches. Older, more heavily vegetated oxbows were not used by crocodiles but contained large numbers of spectacled caiman.

Released crocodiles were observed mostly in shallow-water near the shoreline (66% of locations). In the dry season, crocodiles were found near seasonally exposed, low-gradient, open beaches without any vegetation (93.2% of dry-season locations). During the wet season there was a greater tendency to encounter the croco-

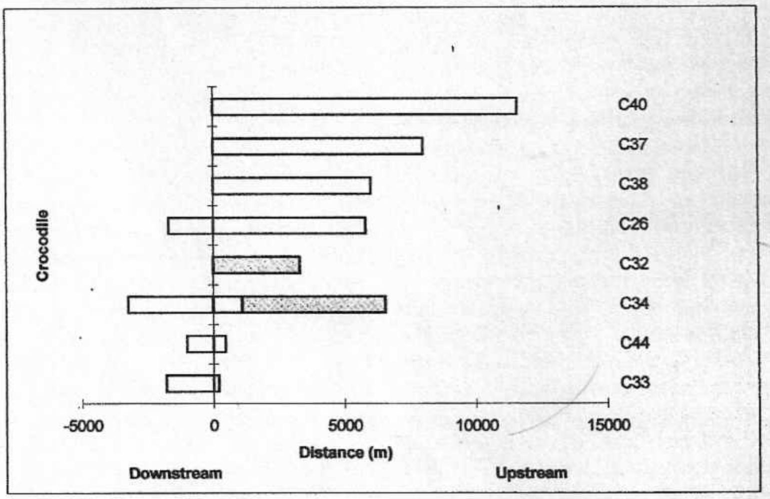


FIG. 3. Maximum dispersal distance for radio-tracked crocodiles. Shaded bars represent movements into oxbow lakes.

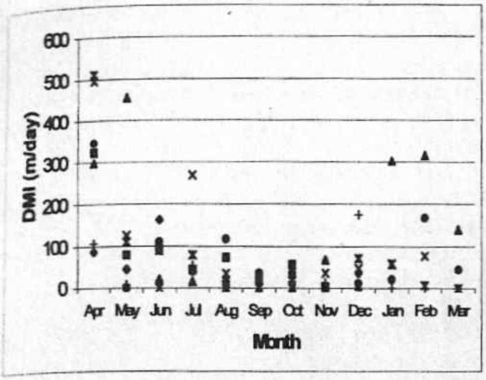


FIG. 4. Daily movement index (DMI) for crocodiles in the study. Values for individual animals are represented with different symbols.

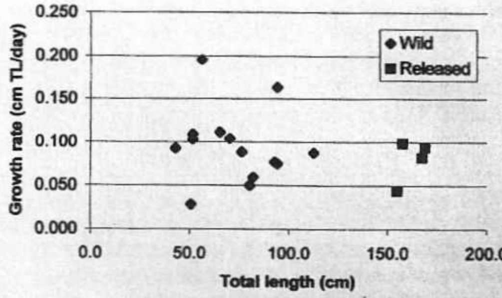


FIG. 5. Comparison of growth rates of 13 wild juveniles with 4 released subadult crocodiles that were recaptured.

diles among partially submerged live or dead vegetation (44.3% of wet-season locations).

At the end of the study we were only able to recapture four of the six crocodiles that still had functioning radios. Mean growth for these individuals was 0.079 cm total length/day (SD = 0.048 cm TL/day), equivalent to an annual growth rate of approximately 29 cm. We were unable to mark and recapture similarly sized wild crocodiles, so a direct comparison of growth rates among similarly-sized animals is not feasible. However, when plotted against size at recapture (Fig. 5), the growth rates of the released crocodiles is comparable to that of the smaller, wild individuals (mean = 0.096 cm TL/day; J. Thorbjarnarson unpubl. data), particularly as there is an expected trend of decreasing rate of growth with increasing size (Webb et al., 1983).

## DISCUSSION

For restocking to be a successful strategy for speeding population recovery requires that released crocodiles should not disperse long distances from the point of release (and potentially move outside of protected areas), and should adapt well to their new environment, which can be measured most effectively by their survivorship and growth rates. However, as the ultimate goal of restocking programs is to establish, or enhance, the breeding population of the species in question, long-term monitoring is required for long-lived species before success can be gauged (Dodd and Seigel, 1991). While the past track record of success of programs based on the release of reptiles and amphibians has been debated (Burke, 1991; Dodd and Seigel, 1991), it is clear that the one group for which this type of management has been most successful is the Crocodylia (Dodd and Seigel, 1991). While it should be emphasized that this study was a short-term follow up of a small group of animal, and it is difficult to generalize from this data, our initial results suggest that the use of captive-reared Orinoco crocodiles for restocking purposes appears to be a viable strategy.

Although crocodiles tended to move away from the release site, the maximum distance dispersed was less than 12 km. Aside from the one crocodile mistakenly killed by a local resident, the known survivorship of the released crocodiles was high, and our study animals grew at rates similar to those of wild crocodiles. Captive-reared crocodiles were seen in areas similar to those used by wild crocodiles (Thorbjarnarson and Hernández, 1992) and were occasionally seen together in the same areas along the river. However, the paucity of wild-born crocodiles made quantitative studies of habitat use and movements of these animals difficult. The lack of wild juveniles was, in fact, the reason for initiating the restocking program.

Unlike wild crocodiles, the released animals were easy to approach at night from a boat early in our study. This behavior is more like that of the sympatric spectacled caiman, and is probably why the one crocodile was mistaken for a caiman and killed. However, by the end of the study, the captive-reared crocodiles had become wary and were difficult to approach. This behavior may be a result of our presence over the course of the study, but in other areas where intensive follow-up studies have been not been conducted (e.g., Caño Guaritico National Wildlife Refuge) we have also observed that captive-reared crocodiles are easily approached shortly following release but become wary with time. The natural shyness of these animals is one of the most important factors to ensure the survival of crocodiles in rivers that serve as the principal means of transportation by local residents.

While our study group of crocodiles adapted well following release, care must be taken when extrapolating the results of this study to other areas. The Capanaparo River contains large expanses of good habitat for Orinoco crocodiles (Thorbjarnarson and Hernández, 1992), and may be one of the reasons why the animals in this study moved relatively little after being released. Under other circumstances, crocodiles may be more likely to move longer distances, and may even disperse outside of the boundaries of the protected area. Evidence from the Caño Guaritico suggests that at least some of the released crocodiles have moved 70–80 km downstream within six months of release (J. Thorbjarnarson, unpubl. data).

Crocodile size (and age) is another factor that needs to be taken into consideration when planning the release of captive reared crocodiles. Our study was conducted using the first animals released in the Capanaparo, animals that had been maintained in captivity for nearly four years and measured over 1.2 m long. Due to limitations of funding and space in the rearing centers, in subsequent years most crocodiles were released when they were one year old and measured 70–100 cm TL, and this size will likely influence crocodile movement patterns, survivorship and growth. One possibility is that the longer the animals are kept in captivity, the less likely they are to adapt to wild conditions after release. However, our study does not support this conclusion. Releasing animals at a smaller size may affect their survival, growth or movements, and in fact preliminary analyses of the releases at the Caño Guaritico National Wildlife Refuge and the Aguaro-Guariquito National Park (Arteaga, and Hernández, 1996; C. Chávez, pers. comm., G. Hernández, pers. comm.) in fact suggests that crocodiles in these areas are less sedentary, but grow faster, than those released in the Capanaparo.

We feel that if designed properly (including the following of IUCN guidelines for reintroductions), a headstarting program can have positive conservation benefits in Venezuela. This is particularly true in areas where the collection of eggs and neonates represents on of the population's major threats. In areas with remnant crocodile populations, programs can be readily designed to protect nesting beaches and monitor annual nesting levels as part of egg-collecting efforts. Follow-up studies, based on nocturnal spotlight counts and the recapture of animals can provide much needed information for program evaluation.

Also, reintroduction programs that rely on the release of captive-bred animals, which has been the case in the two other areas in Venezuela where crocodiles have been released, can also produce positive conservation results. Extirpated populations can be reestablished, and this may be particularly important in areas where protected habitat and existing crocodile populations do not coincide. However, in these cases there is no "built-in" monitoring component, an essential part of the management program, and special effort must be made to conduct follow-up surveys to monitor the progress of the program.

One drawback to captive-rearing and release programs is that these efforts can easily become the sole focus of conservation efforts, at the expense of adequate protection of wild crocodile populations and their habitat (Dodd and Seigel, 1991). In India, Choudhury and Chowdhury (1986) noted that following the initiation of a crocodile release program there was a general feeling that the species' involved were now safe from extinction. Yet, this is rarely the case unless restocking and reintroduction programs are undertaken as part of larger effort that addresses the root causes of the species decline. In the particular case of the Orinoco crocodile, this is habitat degradation, the killing of adult crocodiles and the capture and sale of juveniles as pets. Captive breeding and releasing of animals back into the wild must not be used as an excuse for not addressing the onerous issues of habitat protection and enforcement of national wildlife legislation.

In this sense, ideally the conservation of Orinoco crocodiles would be part of a larger effort that addressed the need to conserve riverine and riparian habitat and the wildlife community therein. Unfortunately, the development of programs to protect habitats and their natural wildlife assemblages is a difficult issue to tackle, can involve a wide variety of non-biological issues and require major sources of funding (which, however, is no guarantee that these projects will contribute to wildlife conservation, Kremen et al., 1994). In contrast, the implementation of reintroduction or restocking efforts can be initiated quickly and at relatively low cost, but this can lead to these efforts being done in a conservation vacuum. In Venezuela, the program was almost entirely the initiative of private individuals and conservation organizations (Thorbjarnarson and Arteaga, 1995), and there has been relatively little coordination with and assistance from the responsible government wildlife agencies. While two protected areas (the Cinaruco-Capanaparo National Park and the Caño Guaritico National Wildlife Refuge) were declared in 1989, in large part out of concerns for the survival of the crocodile, effective management plans and wildlife protection measures were not initiated. Unfortunately, in subsequent years the situation in the Capanaparo region has been less than ideal. Civil unrest, largely from politically-motivated objections to the establishment of the park, has prevented crocodile conservation work in the Capanaparo region since 1993.

Nevertheless, the captive breeding centers continue to produce an annual crop of young, and each year 100–200 one-year old crocodiles need to be released despite a shortage of protected sites where this can be done. The result is a management program being driven more by the production capacity of the breeding centers than by any organized plan to restore populations of Orinoco crocodile.

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