IUCN SSC Crocodile Specialist Group
SRAS Grant Report

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Introduction

The Philippine crocodile (*Crocodylus mindorensis*) is classified as Critically Endangered on the IUCN Red List (van Weerd et al., 2016), Appendix I of CITES, and is protected by Philippine law under the Wildlife Resources Conservation and Protection Act (Republic Act 9147; van Weerd, 2010). In 2005, the Mabuwaya Foundation spearheaded a nest protection and headstart program in an effort to increase hatchling survival rates and to reinforce the wild population of northern Luzon Island (van Weerd and van der Ploeg, 2008). Although rigorous monitoring efforts are still on-going, limited studies exist on the progress and post-release performance of headstarted individuals. Further, there is a notable absence of any studies on the diet of headstarted crocodiles. And although there have been a handful of recent studies on the basic ecology of *C. mindorensis* (Manolo, 2008; Oliveros et al., 2005; Manolo et al., 2013; van de Ven et al., 2009; van Weerd et al., 2006), this conservation flagship species still remains one of the least studied crocodylians in the world with little information about key natural history traits, such as diet, critical for effective conservation action plans (van Weerd and van der Ploeg, 2012; Bohm et al., 2013).

In this study, we conduct the first analysis of stomach contents for *C. mindorensis*, characterizing the diet of wild Philippine crocodiles in Isabela Province of northern Luzon. In addition, we address concerns regarding captive-release programs by analyzing stomach contents and characterizing the diet of headstarted crocodiles released into the wild over the last decade. We quantify dietary niche breadth and examine dietary differences of headstarted and wild individuals. Our study of diet from a resident wild population acts as a robust, baseline comparison for evaluating the dietary habits of headstarted crocodiles and assessing their ability to forage efficiently and adjust to wild conditions. Finally, we provide the first calculation of a body condition index for *C. mindorensis* to provide baseline data for population monitoring and to examine any potential variability in condition between headstarted and wild crocodiles.

Methods

Field studies were conducted during February–October 2018, starting at the end of the 2018 northeast monsoon season (21 February 2018), through the dry season, and concluding at the end of the southwest monsoon season (16 October 2018). Surveys were conducted at six sites, five in San Mariano Municipality (Dunoy Lake and Catalangan River, Narra, Diwagden, Dinang, and Baliao) and one in Divilacan Municipality (Dicatian Lake), Isabela Province. Both municipalities are located in northeast Luzon Island along the northern Sierra Madre mountain range.

The presence/absence of crocodiles was determined using standard Mabuwaya Foundation nighttime spotlight surveys (van de Ven et al., 2009) and daytime snorkel surveys to search underwater caverns. Detected crocodiles were captured using baited snare traps deployed overnight (Woodward & David, 1994), manual snaring during snorkel surveys, or by hand. All crocodiles were measured for total length (TL), snout–vent length (SVL), tail girth (TG), neck girth (NG), head length (HL), tail length (Tail), mass, and sex following Zweig et al. (2014).

Crocodiles were identified as wild or headstarted by the presence or absence of caudal scute notching (van Weerd & van der Ploeg, 2012). Newly captured wild crocodiles were caudal scute notched and passive integrated transponder (PIT) tags were implanted under the nuchal rosette of all captured individuals. Each individual was classified as juvenile (< 1.5 m TL) or adult (≥ 1.5 m TL) (van Weerd & van der Ploeg, 2012).

Stomach contents were extracted using the modified hose-Heimlich technique (Fitzgerald, 1989; Shirley et al., 2016). Contents were sorted, counted, digitally photographed, and identified to the lowest possible taxonomic classification. Contents were then assigned to one of eleven categories: fish, birds, crabs, snails, insects, mammals, reptiles, amphibians, gastroliths, vegetation, and 'other' which were excluded from subsequent analyses. Differences between groups (wild vs. headstarted; juvenile vs. adult) was tested for percent occurrence (using chi-squared tests; Saalfeld, Conway & Calkins, 2011), percent composition (using Wilcoxon rank sum tests), and dietary niche breadth and degree of specialization (using the Shannon-Weiner diversity index *H'*; Schoener, 1968; Platt et al., 2013).

Body condition indices, such as Fulton's condition factor (*K*) and the relative condition factor (K_n) (Le Cren, 1951), are regularly used as indicators of crocodylian health and well-being (Elsey et al., 1992; Rice, 2004; Fujisaki et al., 2009; Mazzotti et al., 2012; Shirley et al., 2016). *Crocodylus mindorensis* body condition was evaluated following Zweig et al. (2014). Philippine crocodiles did not exhibit isometric relationships between different lengths (e.g., SVL, HL) and masses, indicating Fulton's *K* would not be an appropriate body condition index. The relative body condition index K_n does not assume isometric relationships and was, therefore, used to evaluate body condition of *C. mindorensis* (Le Cren, 1951). The mass-length relationship (*b*) was determined via linear regression using empirical data (Le Cren, 1951). To obtain K_n for each individual, the mass-SVL relationship was modelled over all individuals combined (i.e., both wild and headstarted) and also by treating the wild and headstarted groups as two separate populations. Relative K_n was calculated for each individual as the ratio of observed mass to theoretically expected mass ($K_n = W/W_e$), and a Student's t-test was used to test the difference between crocodile groups, and to test the mean values of estimated K_n for each group against the standard expected value $K_n = 1$.

Results

Stomach contents were collected from 30 Philippine crocodiles (22 females, eight males) ranging in size from 71.0–264.5 cm TL (SVL = 14.1–143.0 cm, 1.01–106.4 kg), including 28 from San Mariano and two from Divilican. Of these, 20 were wild (13 females, seven males), including 14 adults and six juveniles ranging in length from 71.0–264.5 cm TL (SVL: 35.0–143.0 cm; $\overline{X}$ = 68.2 ± 5.65 cm). Ten were headstarted (nine females, one male), released an average of 5.65 years before capture, including six juveniles and four adults ranging in length from 72.3–169.9 cm TL (SVL: 36.6–90.4 cm; $\overline{X}$ = 82.9 ± 5.74 cm). Both groups were of similar length (SVL: t = -1.62, $p = 0.116$).

No empty stomachs were observed in this study. For all crocodiles combined, snails were the most prominent prey group (70% occurrence), followed by fish (36.7% occurrence), birds and reptiles (33.3% occurrence each), while the remaining prey groups were all represented in 16–27% occurrence. There was no significant difference in percent occurrence or percent composition of any of prey category between wild and headstarted crocodiles. Dietary diversity (*H'*) (wild =0.89, headstart = 0.70) was not significantly different (W = 73, $p = 0.228$) and wild and headstarted crocodiles exhibited comparable specialization (*J'*) (wild = 0.43, headstart =

0.34) (Table S2). Gastroliths were recovered in almost equal proportions for both groups (65% wild, 60% headstarted) (Table 1). Diet did not vary significantly between juvenile and adult percent occurrence (Table 2) or percent composition (Table S3; Supplementary Data).

Three individuals were excluded from the body condition analysis, including the two Divilacan individuals to avoid any bias in relative K_n resulting from comparing individuals from isolated populations—leaving 17 wild and 10 headstarted. When modeling the mass-SVL relationship using all individuals combined, body condition (K_n) was significantly higher in wild than headstarted crocodiles (t = -2.88, p = 0.008; Figure 2). Mean condition of wild crocodiles (K_n = 1.060) was significantly higher than the standard condition value of K_n = 1 (t = 2.38, p = 0.030; Figure 2; Table S4); while mean condition of headstarted crocodiles (K_n = 0.925) was not significantly different (t = -1.71, p = 0.121). However, when modeling the mass-SVL relationship as two separate populations (K_n wild = 1.003, K_n headstarted = 1.010) to obtain K_n, no differences in body condition were observed (t = 0.13, p = 0.895). No physical abnormalities or deficiencies were observed in headstarted crocodiles during the study.

Conclusions

Headstarted Philippine crocodiles exhibited no dietary differences compared to their wild counterparts, strongly supporting their ability to forage on the expected natural prey base after release. The results of this study show that both juvenile and adult Philippine crocodiles consume a wide diversity of 17 different aquatic and terrestrial invertebrate and vertebrate prey species. Snails, in particular, were the most frequently recovered prey type regardless of crocodile history (wild vs. headstart) or size class.

To date, only one previous study compared dietary habits between captive-released and wild crocodylians (Elsey, 1992), which found that farm-released *Alligator mississippiensis* (after being raised in captivity for two years) had similar diet and foraging habits to wild alligators (Elsey, 1992). The present study found similar results, but also illustrated that both juvenile and adult Philippine crocodiles consume a comparably broad spectrum of prey inhabiting a variety of habitats and trophic classes. Additionally, the abundance and diversity of prey species from both agricultural habitats (e.g. invasive Golden apple snail, snakehead, walking catfish, oriental house rat) and less disturbed habitats (e.g., Philippine bush hen, smooth-scaled mountain rat snake, Philippine rat snake) suggests that headstarted *C. mindorensis* are exploiting a similar breadth of habitat and, thus, have foraging behaviors comparable to their wild counterparts.

Although body condition values for the wild and headstarted Philippine crocodile groups showed a degree of overlap, wild *C. mindorensis* individuals were found to have significantly higher body condition compared to headstarted individuals when both groups were treated as the same population. However, the mean body condition for both groups either met or exceeded the mean population expectation (i.e., $K_n \geqq 1.0$), suggesting that headstarted crocodiles still met the normal expectations for body condition in this population. Further, when these two groups were treated as separate populations as a means to achieve a "true" baseline K_n (e.g., K_n for wild *C. mindorensis*) for comparison, no differences in body condition were observed.

Beyond its use as a metric of translocation success, studies of diet are essential to understanding species ecology (Rosenberg & Cooper, 1990). This study found that *C. mindorensis* consumed a generalist diet reflective of the available prey items and habitat variability at the study sites. However, despite general expectations for crocodylian ontogenetic dietary trends, snails were still prominent in the diet of adult *C. mindorensis*. It is both

astonishing and encouraging that one of the world's rarest vertebrate species survives in a human-dominated landscape consuming mostly introduced species. However, this study highlights the incredible adaptive capacities of crocodylians and suggests that, if protected from hunting and with sufficient prey availability, *C. mindorensis* and other heavily threatened crocodylians are able to survive in heavily degraded habitats.

Translocation success can be challenged when there is potential for the translocated species to cause human-wildlife conflict (Ewen, Soorae & Canessa, 2014), a global crocodylian conservation issue. *Crocodylus mindorensis* today inhabits waterways within rural, impoverished communities, where the fate of the species is ultimately dependent on acceptance and support by local residents – in particular rural farmers. The invasive golden apple snail is considered an agricultural pest because it feeds on young rice seedlings and, in the Philippines alone, *P. canaliculata* invasions result in $28–45M USD losses annually (Naylor, 1996). Most (93.3%) of the crocodiles captured in this study were within or near adjacent rice paddies, and 50% of individuals had *P. canaliculata* remains in their stomachs. This information could be capitalized upon in environmental outreach campaigns, convincing local communities about the conservation value of this critically endangered species controlling agricultural pests. Future community outreach efforts by the Mabuwaya Foundation could consider incorporating such information.

Continued post-release monitoring remains critical for identifying emerging threats that may jeopardize long-term success of translocations, and future efforts should work to better understand factors that result in reintroduction failures. For example, despite over a decade of intensive community-based conservation efforts by the Mabuwaya Foundation that have been shown to have resulted in transformative community-wide support for crocodile conservation, both wild adult and headstarted juvenile individuals were intentionally killed by community members during this study period. Although headstarted crocodiles are shown to be capable of successfully integrating into wild environments, only 11 headstarted individuals were recaptured out of 150 crocodiles that have been reintroduced to date. Future efforts should be devoted to understanding the factors that lead to individual reintroduction failures and improving survival of released individuals.