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Growth patterns of critically endangered, head-started three-striped roofed turtle, *Batagur dhongoka* (Gray, 1834)

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Abstract
Limited information is available on the growth rates of turtles in head-starting programs. The current study provides vital information on the growth patterns of *Batagur dhongoka*, a critically endangered turtle inhabiting the Ganga River basin that were part of a head-starting program at Turtle Breeding and Rehabilitation Centre, Sarnath, India. Our results indicate that the post-hatchling stage shows the maximal growth with a reduced increment in the second year as compared to the first year. The study revealed a strong relationship between the weight and increments in carapace length, width and plastron length.

Keywords Critically endangered · Hatchling · Morphometric measurements · Relative growth rate · Absolute growth rate

Introduction

Three-striped roofed turtle, *Batagur dhongoka* (Gray, 1834), listed as critically endangered in the IUCN Red list of threatened species (Das et al. 2019) belong to the order Testudines, family Geoemydidae (Das 1995; Das et al. 2019). Large, deep and flowing rivers are the habitat for *B. dhongoka*, which are omnivore in nature (Das 1995). Various anthropogenic stressors result in habitat degradation and loss for the species. Environmental pollution due to agricultural runoff, discharge of treated and untreated industrial and domestic effluents and large scale extraction of water for agriculture are causes for decline of chelonians along Ganga basin (Das 1995; Das et al. 2019). Additionally, illegal consumptive exploitation for food and pet animal trade, dams and fishing nets undermine populations of chelonians including *B. dhongoka* (Das 1995; Das et al. 2019). The few studies carried out on the species are restricted to natural history (Das 1995), status and distribution (Bhupathy 1995), phylogeny and taxonomy (Praschag et al. 2007), reproductive output (Sirsi et al. 2017), and blood profiling (Bardi et al. 2018). Amongst others, the growth rate of juveniles of the species remains poorly studied. We studied the growth rate of head started *B. dhongoka* from hatchlings upto two years of age prior to their release in natural habitat.

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Material and Methods

Study area The study was conducted in Turtle Breeding and Rehabilitation Centre (TBRC), situated at 25°22’54.90” N and 83° 1’47.83” E in Varanasi, India covering an area of 3.75 hectares.

Methods The juvenile turtles hatched from rescued eggs in 2018 are included in the study. The animals were maintained in captivity for two years with a natural hibernating experience of two winters. Identification of sex of the animals was not carried out due to limitations in identification sex of juveniles (Baruah et al. 2016). The study was carried out from June 2018 to May 2020. We selected 28 healthy hatchlings of *B. dhongoka* maintained in outdoor ponds with a water depth of 0.46 m and with a dimension of 15.24 m in width and 22.86 m in length with land and water pool comprising 70 and 30 % water respectively.

Air temperature data from a nearby weather station at Varanasi, India was recorded during first week of each month throughout the study period (Online resource 1). The lowest temperature recorded was 7 °C with maximum temperature as 44 °C during the study period.

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Table. 1 Morphometric measurements of *B. dhongoka* at hatch, after one and two years at Turtle Rehabilitation Centre, Varanasi, Uttar Pradesh, India

Morphometry (unit)	At the time of hatch (n=28)	After one-year in captivity(n=28)	After two-years in captivity(n=28)
SCL (mm)	54.07±2.84	76.34±9.06	102.14±2.68
SPL (mm)	47.23±3.32	68.68±8.82	95.88±3.34
SCW (mm)	45.17±3.01	63.44±7.59	81.35±3.24
WT (gm)	25.43±4.67	76.17±26.15	162.93±6.42

The turtles were fed once a day at the same time before sunset at 4–12 % of their total body weight (Rawski et al. 2018). During winters months (October to February for both years), the animals were less active and the food intake was lower (4 % of the body weight) whereas they were more active and had higher food intake (12 % of the body weight) during summer months (June and July for both years). Commercial turtle food (Taiyo Turtle Food, Taiyo Group, Tamil Nadu, India) was provided for the initial three months, followed by a fish and vegetable-fruit mix on alternate days based on total calorific requirement of 35–128 kcal/day per kg body weight with a crude protein requirement of 39-46.5 %, fat of 8.80 %, calcium of 5.70 %, phosphorus of 4 %, methionine of 1.03 % and cysteine of 0.25 % based on Handling (2018). Food were given based on their feeding habit (natural condition) along with various seasonal vegetables (50 %) based on availability. These included *Daucus carota sativus*, *Spinacia oleracea* (once a week), *Carica papaya*, *Malusdo mestica*, *Citrullus lanatus, Cucumis sativus, Ficus racemosa* and *Cucurbita maxima* and fish (50 %) like *Labio rohita*, *Catla catla* and *Tilapia* sp. We enriched the environment for the turtles by providing basking sites in the form of logs and shade using shrubs, for thermoregulation. Additionally, duckweed (*Lemna* sp.) was provided in the ponds as it served a dual function of providing cover for ensuring safety from dominant conspecifics, besides being consumed as food by the turtles. We maintained hygienic conditions by replacing 20 % of the total water volume of the pool daily; scrubbing of all hard substrates on monthly basis and by replacing the sand substrate on a quarterly basis (Talukdar et al. 2019).

We recorded morphometric measurements including body-weight (WT) (using a KERN EMB 2200-0 Compact Digital Weighing Balance with an accuracy of ± 1.0 g), straight carapace length (SCL) measured at the maximum length of the carapace, straight carapace width (SCW) measured at the maximum width of the carapace, straight plastron length (SPL) measured at the maximum length of the plastron (using a Scienceware® Digi-Max™ slide calliper with an accuracy of ± 0.1 mm) in the first week on a monthly basis. We calculated the relative and absolute growth rates following Huang (2012) as relative growth rate,$v = 100\% \times (W2 - W1)/W1$ (where W2 and W1 are the end and initial weights); the absolute growth rate as$\overline{\eta} = (W2 - W1)/T2 - T1($ where W2 and W1 are the end and initial weights and T2 and T1 are the end and initial times). We also considered a correlation of more than 60 % (R > 0.6) as minimum for the morphometric measures for WT, SCL, SPL and SCW separately for both years followed by regression for each variable with the highest correlated morphometric measures were considered for

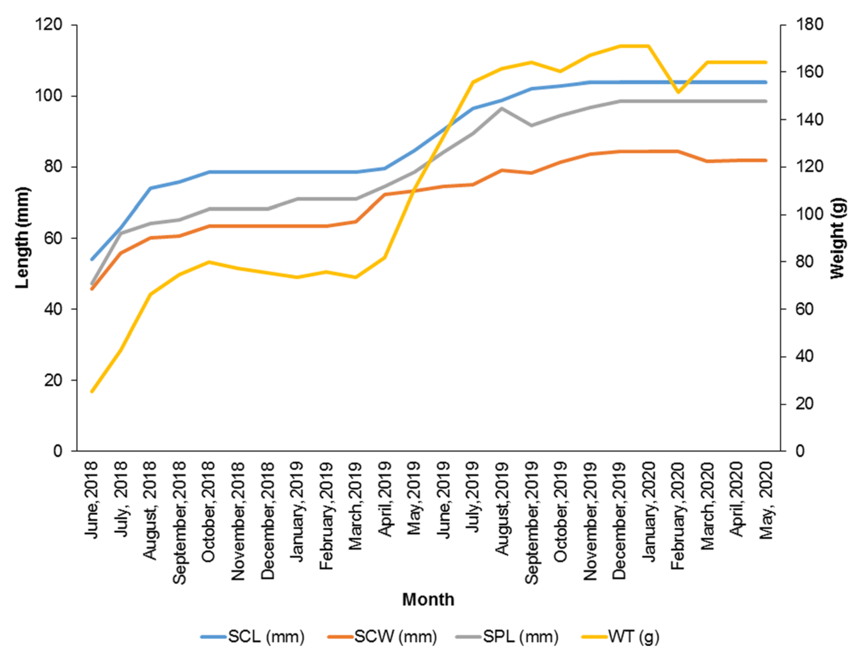

Fig. 1 Monthly changes in SCL (mm), CW (mm), PL (mm) and body-weight (gm) during the study period for *B. dhongoka* at Turtle Rehabilitation Centre, Varanasi, Uttar Pradesh, India

Table. 2 Growth rates of *B. dhongoka* after one and two years at Turtle Rehabilitation Centre, Varanasi, Uttar Pradesh, India

Parameters	Increment at one-year (mm)(Mean± SD)	Increment attwo-year (mm)(Mean± SD)	Relative growth rate 1st year, v (%)	Relative growth rate 2nd year, v (%)	Absolute growth rate 1st year, ή	Absolute growth rate 2nd year, ή
SCL/mm	32.53±37.63	9.25±12.90	56.38	20.1	0.058	0.058
SPL/mm	32.53±38.74	23.37±24.9	66.31	25.61	0.093	0.06
SCW/mm	22.61±32.27	17±15.21	60.39	42.23	0.082	0.058
WT/gm	11.31±10.11	6.81±6.14	334.60	125.68	0.25	0.25

development of regression equation formula. Multiple regressions were also performed considering the morphometric measures together for each year. The data was analysed using SPSS 10.0 package (IBM Corporation, USA). $P < 0.05$ was considered for significant differences.

Results

The turtles were maintained for 335 days during the first year (June 2018 to May 2019) completing 700 days by the end of the second year (June 2019 – May 2020). During the first year

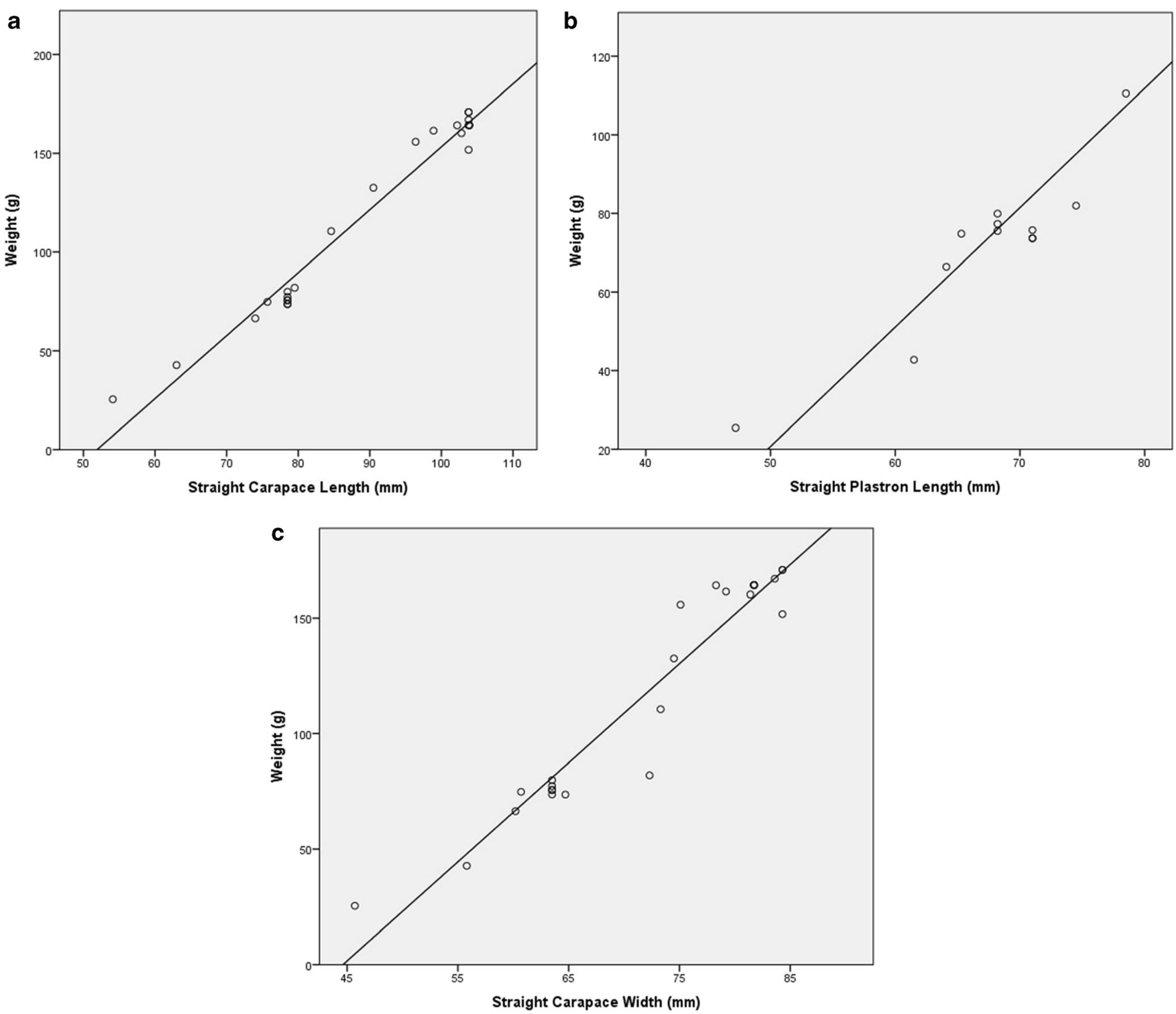

Fig. 2 **a** the relationship of weight and straight carapace length, **b** the relationship of weight and straight plastron length, **c** the relationship of weight and straight carapace width in 1-year-old *Batagur dhongoka* at Turtle Rehabilitation Centre, Varanasi, Uttar Pradesh, India

the mean body-weight increased from 25.43 to 76.17 g and the overall relative growth rate was 334.60 %, while the absolute growth rate was 0.25. For second year, the mean body-weight increased from 76.17 to 162.93 g and relative growth rate was 125.68 % and the absolute growth rate was 0.25. It was found that the growth rate in the second year was slower as compared to the first year. The average, mean and standard deviation of SCL, SCW, SPL and WT from the day of hatch to date on completion of first year and second year is provided in Table 1. The monthly morphometric average for SCL (mm), SCW (mm), SPL (mm) and WT (gm) during the study period for *B. dhongoka* is provided in Fig. 1. The average relative and absolute growth rates at the end of first and second year are provided in Table 2. The rate of increase in weight was found to be faster than the SCL and SPL of the juveniles followed by the SCW (Fig. 1).

We also observed that SCL, SCW, SPL were strongly correlated to WT for yearling *B. dhongoka*. The regression equations for SCL, SPL and SCW is WT = 2.384 SCL − 107.71, $r = 0.957$, $p < 0.001$ (Fig. 2a); WT = 2.472 SPL − 95.12, $r = 0.929$, $p < 0.001$ (Fig. 2b) and WT = 2.73 SCW − 99.38, $r = 0.935$, $p < 0.001$ (Fig. 2c) respectively with significant relevance. For two-year-old turtles the regression equation for SCL, SPL and SCW when correlated with weight as the dependent variable was WT = 2.11 SCL-53, $r = 0.832$, $p < 0.001$ (Fig. 3a); WT = 1.79 SPL − 10.12, $r = 0.770$, $p < 0.005$ (Fig. 3b) and WT = 2.01 SCW − 2.24, $r = 0.67$, $p < 0.05$ (Fig. 3c) respectively with significant relevance.

For one-year-old turtles, the multiple regression equation was WT = -112.29 + 1.81 SCL − 1.62 SCW − 0.80 SPL, $r = 0.97$, $p < 0.001$ and for the two-year-old the multiple regression equation was WT = -33.41 + 2.24 SCL − 1.29 SCW + 0.75 SPL, $r = 0.85$, $p < 0.05$. It indicates that the weight gain observed in the first-two years of the turtles was mainly due to

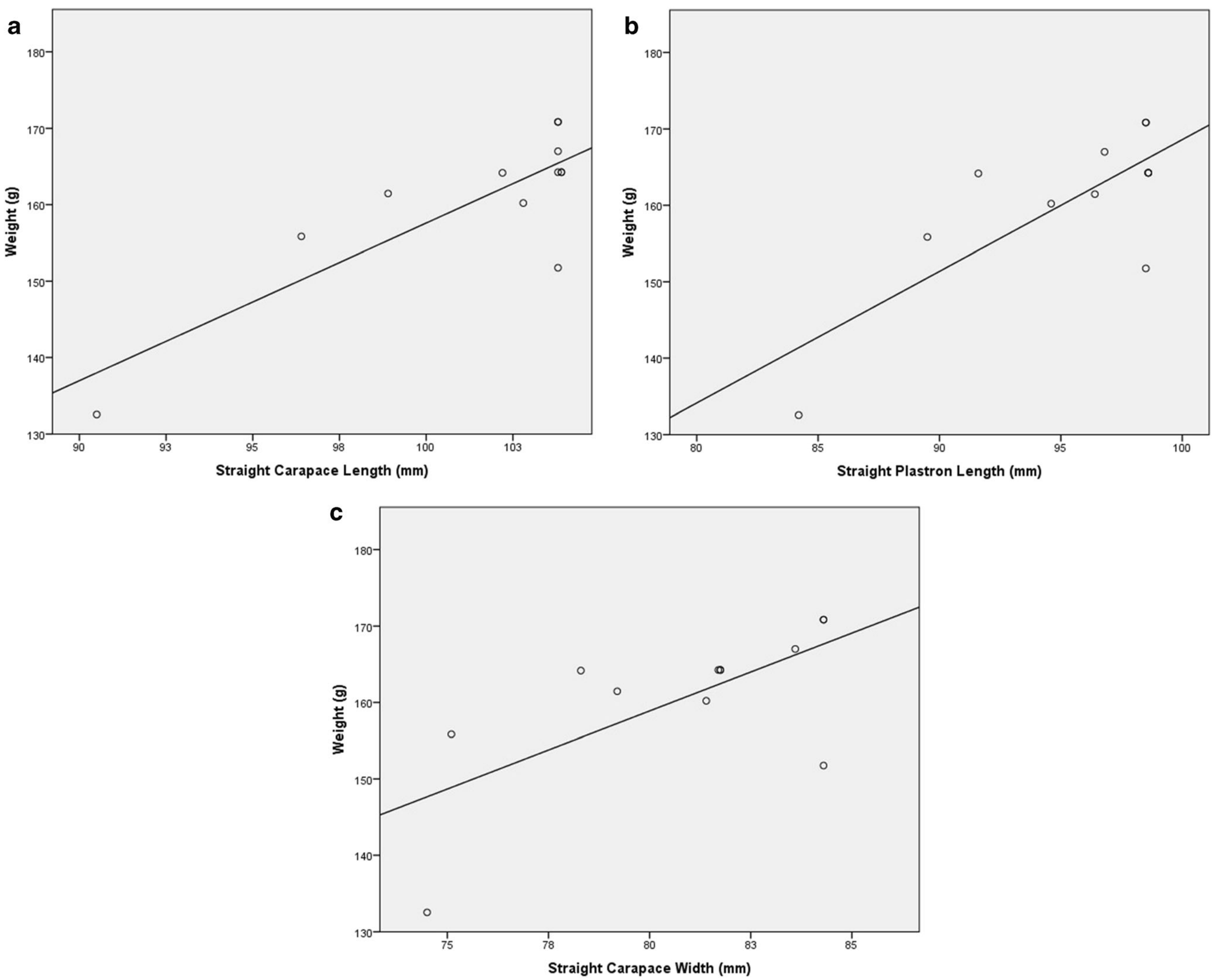

Fig. 3 **a** the relationship of weight and straight carapace length, **b** the relationship of weight and straight Plastron length, **c** the relationship of weight and straight carapace width in 2-year-old *Batagur dhongoka* at Turtle Rehabilitation Centre, Varanasi, Uttar Pradesh, India

increase in size of its integument (SCL, SCW and SPL). Our study also indicates a concomitant increase in body-weight, carapace length, carapace width and plastron length in the head-started *B. dhongoka* population.

Discussion

Head-started *B. dhongoka* have been maintained in a few rehabilitation facilities in India however, the information on their growth patterns is lacking. This is the first report documenting the growth rate pattern of *B. dhongoka* from India. The values obtained in the present study for *B. dhongoka* were compared with available published information for other turtle species namely *Cuora flavomarginata* (Gray, 1863) and *Batagur affinis* (Cantor, 1847). The relative growthrate in the current study was found to be higher than *C. flavomarginata* and lower than that reported for *B. affinis* (Huang 2012; Chen 2008, 2017). The absolute growth rate was found to be higher for *B. dhongoka* than *C. flavomarginata* (Huang 2012) and lower on comparison with *B. affinis* (Chen 2008, 2017) during both the years the animals were maintained in captivity. The increase in WT was faster than that observed for SCL, SCW and SPL and the findings were in tandem with those reported for *C. flavomarginata* and *B. affinis* (Huang 2012; Chen 2008; Chen 2017). A negative growth rate as indicated by reduction in weight was recorded from early September to March for both the years and the findings were similar to those reported for *C. flavomarginata* by Huang (2012). Positive correlation was observed in current study for SCL, SCW, SPL when correlated to WT for one year and two years old *B. dhongoka* and is consistent with the findings of Huang (2012).

The observed differences in growth rate may be attributed to a range of reasons that include the distribution range of the species with growth rates declining as turtle species move away from the equator due to reduced ambient temperatures. *B. affinis* are equatorial inhabiting the Malayan archipelago (Horne et al. 2019) with associated higher ambient temperatures. *B. dhongoka* on the other-hand inhabit the Indo-Gangetic plains along the Tropic of Cancer (Das et al. 2019) while *C. flavomarginata* are the northernmost in distribution inhabiting China, Japan and Taiwan (Asian Turtle Trade Working Group 2000). This is supported by Angielczyk et al. (2015) who observed carapace length of turtles to be inversely related to latitude. Further, Rodrigues et al. (2018) observed a positive relationship between temperature and body size and provides support to the observed differences in growth rates with *B. affinis* being the southernmost species exhibiting the fastest growth while *C. flavomarginata* being the northern most showing the slowest growth.

The results presented here are based on limited population testing and do not account for variations within sub-populations defined by age, sex, subspecies, or extrinsic factors such as instruments and human error. Further studies with larger sample sizes and from free-living population would be able to provide detailed and accurate information on the growth patterns of a healthy population.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11756-021-00858-y.

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Data availability All data generated or analysed during this study are included in this published article.

Code availability Not applicable.

Declarations

Conflicts of interest/Competing interests The authors declare that they have no conflict of interest.

Ethics approval The study was conducted with necessary approvals and permissions from Wildlife institute of India and Forest department, Uttar Pradesh. It is also accepted that all authors have abided by ethical standards while conducting the study and in writing the manuscript. The work is presented for publication in Biologia Journal.

Consent to participate Not applicable.

Consent for publication Not applicable.

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