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## NOTE

### TOTAL LENGTH AND HEAD LENGTH RELATIONSHIP IN MUGGER CROCODILES *CROCODYLUS PALUSTRIS* (REPTILIA: CROCODILIA: CROCODYLIDAE) IN IRAN

Asghar Mobaraki, Elham Abtin, Malihe Erfani & Colin Stevenson

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## Total length and head length relationship in Mugger Crocodiles *Crocodylus palustris* (Reptilia: Crocodylia: Crocodylidae) in Iran

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A small population of around 500 Mugger crocodiles *Crocodylus palustris* in southeastern Iran occupies the western-most extreme of the species' global range (de Silva & Lenin 2010). This population is scattered across the region and individuals often come into close contact with local communities (Mobaraki 2015). The Mugger's habit of moving between different habitats depending on local climatic and seasonal conditions means that they often turn up in remote areas (Abtin & Mobaraki 2016). Because this population persists at the extreme edge of the species distribution, environmental limits or conditions are likely to affect its biology and population dynamics, as well as its susceptibility to potential threats (Mobaraki et al. 2019).

Like many other crocodylians around the world, monitoring of the *C. palustris* population in Iran has been based on day and night-time (spotlight) surveys. During surveys, crocodiles are usually partly submerged, with only the head exposed to observers. Where observers have considerable experience with carrying out surveys and capturing large numbers of different-sized crocodiles, estimating body length from size of

the head comes somewhat naturally (C. Manolis, pers. comm. 2021). However, this is not the case in many situations, including that in Iran.

Researchers working on morphometric relationships of different species of crocodylians have invariably noted that head length (HL) relative to total length (TL) tends to change little across size classes (e.g., Webb & Messel 1978; Magnusson 1983; Webb et al. 1983; Montague 1984; Hutton 1987; Verdade 2000; Wu et al. 2006; Platt et al. 2011; Fukuda et al. 2013; Edwards et al. 2017). Whitaker & Whitaker (2008) examined the HL/TL ratio for a number of crocodylian species, and confirmed the average ratio to be around 1:7, but this ratio was found to be closer to 1:8 for large (>4 m TL) species such as *Crocodylus porosus*, due to ontogenic changes associated with the head with increasing body size (Webb & Messel 1978; Whitaker & Whitaker 2008; Britton et al. 2012; Fukuda et al. 2013). In this study, we aim to quantify the relationship between TL and HL for Iranian Muggers, as well as examining the ratio between these two morphometric measures.

Material and Methods: Natural and artificial ponds are

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the main Mugger habitats along or near the Bahoukalat River, the main part of which runs within the Gandou Protected Area. This area comprises 3,825km<sup>2</sup> (61.462E and 25.755N at central part), and was established in 1970 for the conservation of the crocodile population. Fifty-three Mugger crocodiles of varying sizes and sex were captured using fishing nets or ropes, during surveys or the translocation of nuisance specimens, in 2018 and 2019. Head length (HL) was measured from the anterior tip of the snout to the rear edge of the cranial platform (parietal bone). Total length (TL) was measured from the anterior tip of the snout to posterior tip of the tail along the back of the animal. Both measurements were taken using fiberglass tape, and the results rounded to the nearest cm. We excluded any specimens that were missing the tip of their tail. Sex was determined for 30 individual by examination of the cliteropenis, but as this sample size was considered small, the effect of sex was not examined further.

**Statistical methods:** The measurements were first tested for normality using Shapiro-Wilk (SW) and Kolmogorov-Smirnov (KS) tests. Linear regression analysis was used to examine the relationship between TL and HL, and between the TL/HL ratio and body size (TL and HL).

**Results:** Total length of the 53 Mugger crocodiles varied from 43 to 280 cm (average  $\pm$  SD: 169 cm  $\pm$  63.7), and head length from 6 to 45 cm (average  $\pm$  SD: 24.4 cm  $\pm$  9.93). Shapiro-Wilk and Kolmogorov-Smirnov tests (SW= 0.973 and p-value= 0.271, KS= 0.0758 and p-value= 0.200 for total length; and SW= 0.978 and p-value= 0.426, KS= 0.066 and p-value= 0.200 for head length) confirmed data normality, allowing parametric tests like linear regression. The linear regression relationship between TL and HL was highly significant, and is described as:

$TL (cm) = 15.52 + 6.283HL (cm)$  (N= 53; SEE= 13.08;  $p = 0.00$ ;  $r^2 = 0.96$ ) (Figure 1)

The mean TL/HL ratio was 7.03 (N=53; range 5.8 to 8.5; SD= 0.57). The linear regression relationships between TL/HL, and TL and HL, were significant, albeit highly variable and relatively low proportions of the variation explained by the regressions.

$TL/HL = 7.55 - 0.003TL (cm)$  (N= 53; SEE= 0.54;  $p = 0.01$ ;  $r^2 = 0.12$ ) (Figure 2)

$TL/HL = 7.75 - 0.03HL (cm)$  (N= 53; SEE= 0.49;  $p = 0.00$ ;  $r^2 = 0.26$ ) (Figure 3).

**Discussion and Conclusion:** As with other crocodilians, the relationship between HL and TL in Iranian Muggers was linear and thus provides a means to estimate size from heads/skulls found in the field or as museum specimens. The mean TL/HL ratio in this study (7.03) was

similar to that obtained by Whitaker & Whitaker (2008) in their review of other crocodilian species. For all but perhaps the most longirostrine species, there appears a similarity in TL/HL ratio for crocodilians of moderate size.

The increasing TL/HL ratio with increasing size in our sample of Muggers merits further investigation, particularly with inclusion of data from larger Muggers (>3 m TL), since in some other species there is an increase in the TL/HL ratio in the largest crocodiles (Whitaker & Whitaker 2008; Fukuda et al. 2013). More

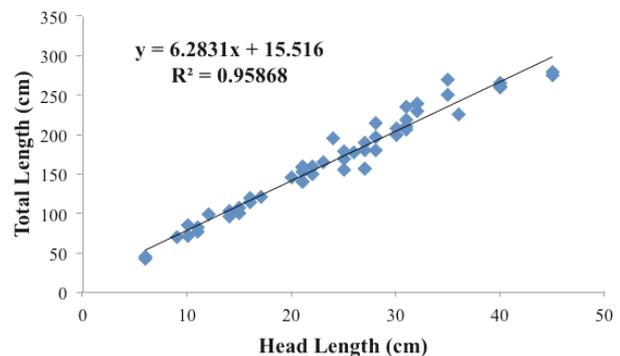


Figure 1. Linear regression between total length and head length for Mugger crocodiles.

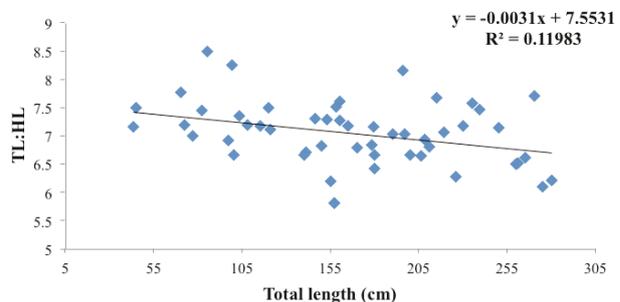


Figure 2. Linear regression relationship between TL/HL ratio and total length for Mugger crocodiles.

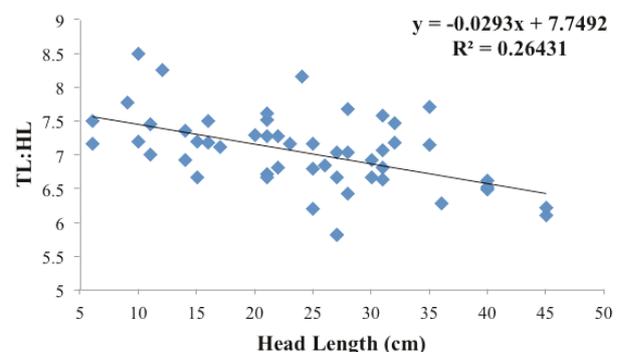


Figure 3. Linear regression relationship between TL/HL ratio and head length for Mugger crocodiles.

accurate data on additional head measurements (e.g., see Webb & Messel 1978) is likely to have provided more insights into how head shape changes with size in our sample of Muggers, and future work will take this into consideration.

In view of the relatively harsh environment in which Iranian Muggers occur, similar studies in other range states, namely Pakistan, Nepal, India, and Sri Lanka, may provide a clearer picture of potential morphometric differences across localities or populations for Muggers.

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