

## ARTICLES

## Growth Through Puberty in Male Mediterranean Loggerhead Sea Turtles

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This article is another in a series of publications on the loggerhead turtles found in Amvrakikos Gulf, a well-established foraging area for this species in the Mediterranean (Rees et al. 2013). We have previously published observations on a turtle that spent extended periods in a river (Rees et al. 2023), another turtle that has resided in the area for 18 years (Rees & Margaritoulis 2024) and a third turtle that has survived in the wild without a lower jaw for at least 6 years (Rees & Margaritoulis 2025).

Due to their relative difficulty in access, the biology and ecology of male sea turtles is understudied compared to females, especially for adults. This is where in-water capture-mark-recapture (CMR) programmes and projects, such as the one ARCHELON has been running in Amvrakikos Gulf since 2002, are invaluable as they facilitate encounters with the elusive adult males and non-adult turtles of both sexes.

Here we present data on a selection of male loggerhead turtles, captured multiple times spanning several years. Each was observed going through sexual maturation (puberty), as indicated by their disproportionately elongating tails.

Attainment of sexual maturity was not confirmed, though inferences towards that assignment are made.

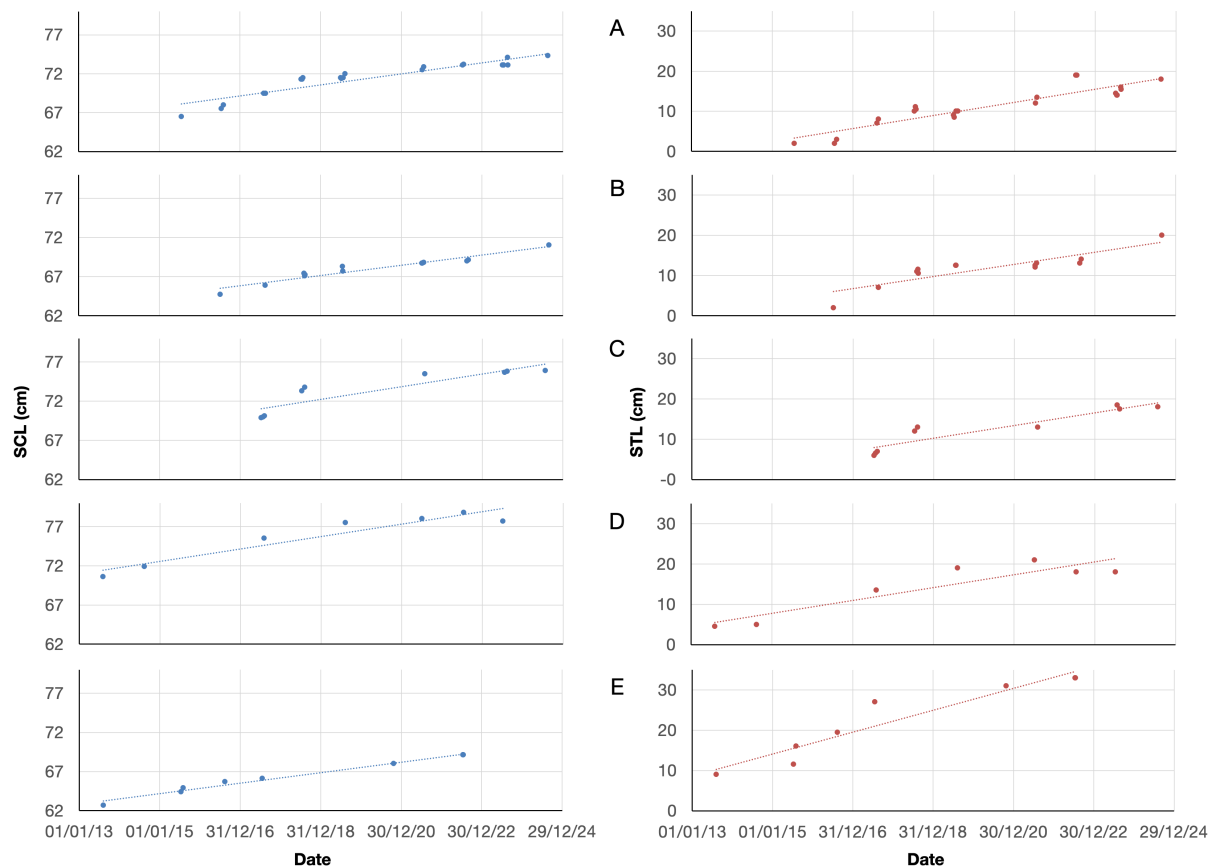
As part of the monitoring and research programme, carapace (Straight Carapace Length, notch to tip (SCL), Bolten 1999) and tail (supracaudal notch to tip of tail (STL), Limpus & Limpus 2003) lengths are measured for each turtle captured, along with flipper tagging and a diagnostic photographic record (see Rees et al. 2013 for further details).

The turtles presented in this paper were selected based on STL growth of over 10 cm from the dataset ranging from 2005 to 2024. This filtering identified 5 turtles (A to E; Table 1) with a minimum tagging history spanning 8 years. In Greece, adult female tail lengths are rarely over 5 cm (Rees et al. 2013), hence any turtles with tail lengths exceeding this are assumed to be males. Three of the turtles (A, B, D) were followed from a time when their sex could not be determined from external characteristics (i.e. STL  $\leq$  5 cm), whilst the remaining turtles (C, E) could be classified as males at first capture (STL  $>$  5 cm) (Table 1, Fig. 1).

**Table 1.** Carapace (SCL) and tail (STL) size and growth rates, determined by linear regression, of male loggerhead turtles captured in Amvrakikos Gulf passing through puberty.

Turtle ID	Initial SCL (cm)	Final SCL (cm)	SCL growth rate (cm yr <sup>-1</sup> )	Initial STL (cm)	Final STL (cm)	STL growth rate (cm yr <sup>-1</sup> )
A	66.5	74.3	0.71	2.0	18	1.64
B	64.7	71.0	0.65	2.0	20	1.51
C	69.9	75.9	0.80	6.0	18	1.57
D	70.6	77.7	0.79	4.5	18	1.60
E	62.7	69.1	0.67	9.0	33	2.71





**Figure 1.** Carapace lengths (SCL) and tail lengths (STL) of male loggerhead turtles (A to E) captured in Amvrakikos Gulf passing through puberty. Line of linear regression is presented on each chart as a basic indicator of relative growth rates. All records are presented, thus giving a visual indication of interannual variation in measurements.

Intra-annual and interannual variation in STL measurements were relatively high, due to the difficulty in ensuring the tail is relaxed and fully extended at the time of measuring, and from the use of multiple observers recording the data over the duration of the programme. Despite this, growth trends in STL and SCL were clearly observable (Fig. 1).

**Growth rates:** Average carapace growth rate, determined from linear regression, was relatively uniform at  $0.7 \pm 0.1(\text{SD}) \text{ cm yr}^{-1}$  (Table 1) and is likely a conservative trait. Average tail length growth rate, determined from linear regression, was less uniform at  $1.8 \pm 0.5(\text{SD}) \text{ cm yr}^{-1}$ , elevated from an average of  $1.6 \text{ cm yr}^{-1}$  by individual E with growth rate of  $2.7 \text{ cm yr}^{-1}$  (Table 1). This individual with the fast-growing tail also has the longest tail and shortest carapace in the sample (Figs. 1 & 2). A genetic study (Rees

et al. 2017) showed that turtles in Amvrakikos Gulf likely come from multiple breeding sites from Greece and further east, including Cyprus, and Cyprus has been shown to have the smallest loggerhead turtles, globally (Margaritoulis et al. 2003). Other studies have shown that foraging area affects body size (see below). Therefore, in combination these factors *may* indicate he is from a different part of the Mediterranean metapopulation. Tracking this individual to a breeding site or characterising his genetic signature would be needed to conclude his origin.

We believe that the data presented here are the first individual-based data published on male loggerheads passing through puberty. Their persistent tail growth suggests that male turtles may take a decade to pass through puberty, a duration similar to that determined for female Australian loggerheads (Limpus 1990).



**Tail length at maturity:** Rees et al. (2013) show that for the largest male turtles (>80 cm SCL) in Amvrakikos Gulf tail length averages around 25 cm and its minimum is 20 cm. Maturity status of these individuals is unknown, but they are assumed adults. Tail lengths of three adult male turtles captured during mating in Kyparissia Bay (Rees et al. 2025) ranged from 19.5 to 25.0 cm, again suggesting that tail length for an adult must be at least 19.5 cm. Furthermore, Limpus & Limpus (2003) assigned loggerhead turtles with tail lengths >19.0 cm as mature, which aligns with our findings, thus it is highly probable that male loggerhead turtles mature with a minimum tail length of ~20 cm.



**Figure 2.** Turtle E photographed on his release in 2020, when he was equipped with a satellite tag to track his movements. Photo: Anna Lamaj / ARCHELON.

Consequently, one of the five male turtles presented herein (individual E) is highly likely to have reached sexual maturity and the other four may have reached or are at least approaching that life-stage (see Fig. 1). However, to confirm maturity status of any males we would need to 1) see the turtle mounted on a female, or 2) observe a soft flexible plastron (indicative of breeding condition) or 3) use laparoscopy to visually examine the testes.

Although we may assume male loggerhead turtles could be mature when their tail lengths reach 20 cm, a large dataset would be needed to determine any statistical confidence in maturation status at smaller tail lengths.

The results we present here offer novel insights into the biology of male loggerhead turtles which will be enhanced as the CMR programme continues to record additional data on these and other individuals. Further questions on male turtle biology and ecology that we hope to answer are: 1) Is there sexual dimorphism in adult carapace length and 2) Do the tails of adult turtles continue to grow post sexual maturation, and if so, at what rate?

**Sexual dimorphism:** Body size of adult female loggerhead turtles nesting in Greece is highly dependent on foraging region (Zbinden et al. 2011, Patel et al. 2015, Rees et al. 2025, Margaritoulis & Rees 2026) but size is likely also influenced by genetic components leading to observed size differences of breeding females across the region (Margaritoulis et al. 2003), hence for accurate characterisation of dimorphism both the foraging locations and breeding sites of adult male loggerheads need to be determined and compared to conspecifics from the same combination of locations and not from a pooled dataset. A first step towards this determination has been carried out. The three adult male loggerheads tracked from breeding in Kyparissia Bay (Rees et al. 2025) were on average larger than the female conspecifics breeding in the same location, but the spread of foraging sites used by the turtles and the low sample size does not allow categorical determination of body length sexual dimorphism.

**Sexual selection:** Breeding adult female turtles at nesting areas may be approached by multiple males simultaneously (e.g. Schofield et al. 2006) or over their receptive period (e.g. Papafitsoros et al. 2022). Hence there is potential for sexual selection based on some aspect of male turtle morphology



and/or behaviour, as suggested for some freshwater turtles (Berry & Shine 1980). Knowledge on the persistence of tail growth, where a long tail would indicate health and longevity, might illuminate the reproductive ecology of the species, where tail length may be a factor in potential mate selection by breeding female turtles.

In conclusion, we present length measurements and growth rates of male loggerhead turtles going through puberty in a foraging ground in Greece, and raise the potential to use tail length in determining maturity status. We also propose the potential ecological importance of tail length in mate selection, for which data are lacking. Acquiring the temporally extensive data presented here is only possible through ARCHELON's commitment to the on-going, long-term monitoring of the turtles inhabiting Amvrakikos Gulf.

### Acknowledgements

We thank the project coordinators, field leaders and volunteers, that have overseen and undertaken the fieldwork over the history of ARCHELON's Amvrakikos Project. ARCHELON's activities in the gulf are supported by the Management Agency of the Amvrakikos Wetlands National Park and the local Coast Guard stations at Menidi and Preveza. Field work in Amvrakikos Gulf is conducted under research permits issued bi-annually by the Greek Ministry of the Environment. Thanks to the two reviewers whose comments improved the clarity of this manuscript.

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