A Newly Identified Nesting Beach in Greece Producing Male Loggerheads

Anna Lamaj, Galini Samlidou, ALan F. Rees, Dimitris Margaritoulis[#]

ARCHELON, the Sea Turtle Protection Society of Greece, Athens, Greece (#margaritoulis@archelon.gr)

Sea turtles, like many reptiles, exhibit temperature-dependent sex determination (TSD). This means that the temperature at which their eggs incubate within the nest plays a pivotal role in determining the sex of the hatchlings (Yntema & Mrosovsky 1982). The phenomenon is critical to the survival and population dynamics of these threatened species. Given that most nesting beaches in the basin predominantly produce female hatchlings (e.g., Zbinden et al. 2007), particularly considering the impacts of climate change, beaches yielding a higher proportion of male hatchlings hold significant regional importance. In this context, understanding the male-to-female ratio, both for modelling purposes and to assess the future success and survival of sea turtle sub-populations, is crucial.

This work presents findings from the nesting site of Preveza beach, initiated by ARCHELON in 2017, as part of a five-year study (2017-2021) of the LIFE EUROTURTLES project, co- funded by the European Commission. The beach, which is located on the northern side of the mouth of Amvrakikos Gulf (38.9561°N, 21.0222°E), stretches approximately 13 km from Kastrosykia in the north to Mytikas Cape in the south with a south-western orientation (Fig. 1).

From 2017 to 2019, ARCHELON undertook mostly daily surveys to document sea turtle nesting activities on Preveza beach. Fieldwork encompassed beach monitoring, nest protection against predation, and post-hatch excavations. Due to the impact of the COVID-19 pandemic, systematic beach surveys were greatly restricted in 2020 and were not undertaken in 2021.

Nesting activity at Preveza beach was regular but low-level. In 2017, three nests were recorded, followed by eight in 2018, and 13 in 2019. In 2020, a total of 16 tracks, including at least one nest, were identified during sporadic surveys, nonetheless the exact count of nests or nesting attempts remains undetermined due to infrequent surveying. Nests were distributed across the entire length of the beach, but they were predominantly, concentrated on both the northern and southern parts of the beach and less in its centre (Fig. 1). The average distance of these nests to the sea was 20.6 m.

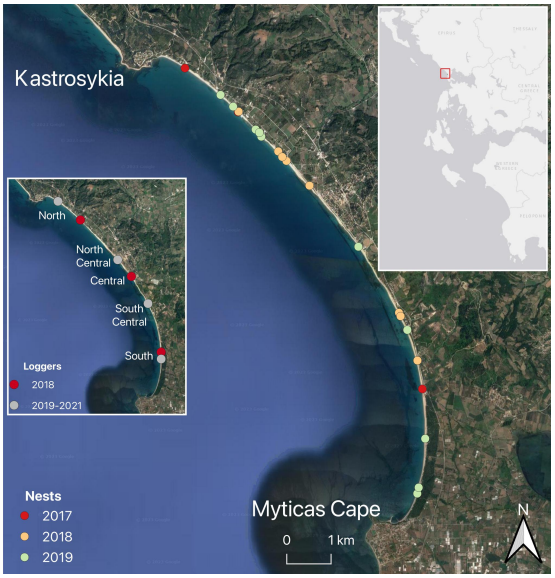

Figure 1. The 13 km beach near the town of Preveza showing locations of nests. Insets show the beach location in the context of the Ionian region of Greece and the placement of temperature loggers. Locations for three nests from 2019 were not recorded accurately and are not shown.

From 2018 until 2021, we deployed in total 15 temperature loggers (Mindset; mindsetsonline.co.uk) to record beach temperature to indicate primary sex ratio of hatchlings produced at this beach. In 2018 we deployed three loggers and from 2019 to 2021 we deployed four loggers per year. Deployment locations were

maintained over the years using GPS coordinates to ensure data consistency (Fig. 1). Loggers were set to record temperature at 30 min intervals and were placed 30 m from the sea and at a depth of 40 cm within the sand. To aid logger retrieval, a triangulation method was also employed with measurements taken from stable reference points. The temperature data was processed to determine an average weekly temperature per logger (Table 1). This was simply achieved by calculating the arithmetic mean of all recorded temperatures during each week-long period.

Beach temperatures were almost exclusively below the pivotal temperature of 29.7 °C (Mrosovsky et al. 2002) for sex determination. In 2018, temperatures ranged from 25.1°C to 29.7°C; in 2019, from 25.5°C to 29.9°C; in 2020, from 25.1°C to 30.3°C; and in 2021, from 25.4°C and 29.5°C (Table 1). Temperatures only exceeded the pivotal threshold by one logger for three weeks in 2019 (max. 0.2°C above pivotal) and one logger for four weeks in 2020 (max. 0.6°C above pivotal).

Several challenges were encountered during the study. Some of the retrieved temperature loggers were found to be in poor condition or not functioning likely resulting from exposure to sea water and high humidity conditions.

Upon analysing the data collected from the temperature loggers, we observed that 85% of the sand loggers measured temperatures below the pivotal temperature threshold (29.7°C, where a balanced sex ratio of hatchlings is typically produced (Mrosovsky et al. 2002)). This pattern suggests the likelihood of a predominant production of male hatchlings. Peak sand temperatures in the Mediterranean are expected in July and August, thus we can assume that temperatures before logger deployment each season were equal to or lower than the first readings. This indicates that temperatures during June and early July were constantly below pivotal temperature

Table 1. Average weekly temperatures between 2018 and 2021. Each column represents data from an individual logger. Logger locations are depicted in Figure 1. One of the loggers deployed in 2019 and 2020 failed. Temperatures below the pivotal temperature are shown in the blue colour range, while temperatures above the pivotal in the red colour range.

Logger location			South	Central South	Central North	North
2018	June	Week 3		NO DATA		
		Week 4	26.0	25.1		25.2
	July	Week 1	28.1	27.2		26.8
		Week 2	29.0	28.1		27.7
		Week 3	29.2	28.4		28.0
		Week 4	28.8	28.3		27.9
	August	Week 1	29.1	28.7		27.8
		Week 2	29.7	29.6		28.2
		Week 3	29.1	29.0		27.9
		Week 4	28.8	29.1		28.0
		Week 5	28.1	28.4		27.7
	Septermber	Week 1	28.3	28.2		27.8
		Week 2	27.4	27.4		27.0
		Week 3	27.0	27.0		26.4
		Week 4	25.5	25.4		25.2
2019	June	Week 3		NO DATA		
		Week 4	28.1	27.8		28.7
	July	Week 1	28.8	28.5		29.2
		Week 2	29.0	28.9		29.5
		Week 3	26.9	27.4		27.9
		Week 4	27.9	28.4		28.6
	August	Week 1	29.2	29.3		29.8
		Week 2	29.1	29.4		29.8
		Week 3	29.2	29.5	NO DATA	29.9
		Week 4	28.5	29.2		29.3
		Week 5	28.8	29.4		29.6
	Septermber	Week 1	28.4	28.9		28.9
		Week 2	28.0	28.4		28.2
		Week 3	26.9	27.7		27.2
		Week 4	25.5	26.9		26.0
2020	June	Week 3	NO DATA			
		Week 4				
	July	Week 1		NO DATA		
		Week 2				
		Week 3				
		Week 4		27.4	29.3	28.4
	August	Week 1		28.1	29.9	28.8
		Week 2		28.3	29.6	28.9
		Week 3		28.56	30.2	29.1
		Week 4		28.6	30.3	29.2
		Week 5		28.6	30.1	29.0
	Septermber	Week 1		27.9	29.0	28.3
		Week 2		27.6	28.7	27.7
		Week 3		26.4	27.4	26.3
		Week 4		25.3	25.7	25.1
2021	June	Week 3		NO DATA		
		Week 4				
	July	Week 1				
		Week 2	28.2	27.7	28.4	28.3
		Week 3	28.9	28.3	29.0	28.7
		Week 4	28.5	28.1	28.7	28.5
	August	Week 1	28.9	28.6	29.1	28.8
		Week 2	29.3	28.9	29.5	29.0
		Week 3	29.1	28.8	29.4	28.9
		Week 4	29.1	28.9	29.4	28.9
		Week 5	27.9	28.5	28.9	28.2
	Septermber	Week 1	27.3	28.0	28.0	27.4
		Week 2	26.5	27.2	27.1	26.5
		Week 3	25.4	26.4	26.3	25.6
		Week 4	25.5	26.3	26.3	25.5

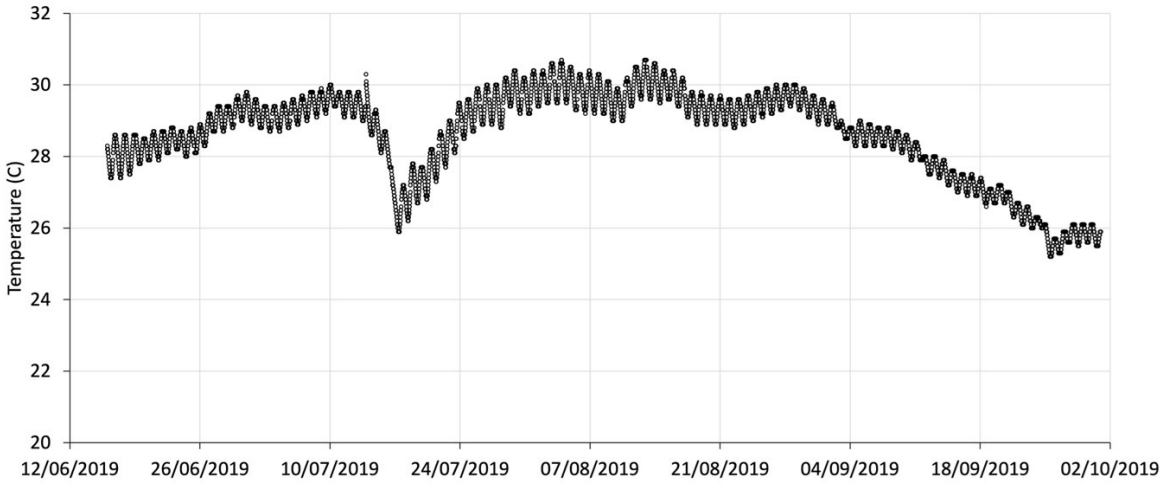

Figure 2. Example dataset from a temperature logger deployed in 2019, showing diel temperature variation and thermal effects of weather events (between 10 and 24 July).

Table 2. Average temperature ranges recorded in sand temperature loggers by month from 2018 to 2021. Range based on weekly averages. * denotes data from only the last week of the month.

Temperature range by month	Year							
	2018		2019		2020		2021	
	Min	Max	Min	Max	Min	Max	Min	Max
June	25.1*	26.0*	27.8*	28.7*	N/A	N/A	N/A	N/A
July	26.8	29.2	26.9	29.8	27.4	29.9	27.7	29.0
August	27.7	29.7	28.5	29.9	28.3	30.3	27.9	29.5
September	25.2	28.3	25.5	28.9	25.1	29.0	25.4	28.0

and contributed to a heavily male-skewed hatchling sex ratio. In our research, the laying dates of nests were documented, ranging from mid-June to the latest recorded date at the end of July with temperature ranges shown in Table 2. Hence, Preveza beach stands out as a site that consistently produces male hatchlings due to its cooler sand conditions. This characteristic holds promise for the area's significance in sea turtle conservation efforts in the coming years.

Considering that Greece hosts the largest reproductive aggregations of loggerhead sea turtles (*Caretta caretta*) in the Mediterranean Sea (Casale et al. 2018), the apparent increasing nesting activity on Preveza beach, the length of the beach and its relatively undeveloped state suggests the potential for this location to become a significant nesting site in the future. This observation is especially noteworthy in the context of the ongoing warming trends affecting other nesting beaches. As these trends continue, they are expected to produce a progressively increasing female-biased hatchling output on those beaches. Range expansion for loggerhead nesting in the Mediterranean is well documented northwards, into Albania in the eastern Mediterranean (Piroli & Haxhiu 2020), western Mediterranean (Hochscheid et al. 2022) and in the northern part of the Aegean (Özdilek et al. 2020) because of global warming. Thus, over time Preveza beach will be less of a peripheral nesting area and likely part of the core nesting zone.

Acknowledgments

We thank all ARCHELON volunteers who worked at this project. We also thank the reviewers whose comments improved the earlier draft of this manuscript.

Literature cited

Casale P, Broderick AC, Camiñas JA, Cardona L, Carreras C, Demetropoulos A, Fuller WJ et al. (2018) Mediterranean sea turtles: current knowledge and priorities for conservation and research. Endangered Species Research 36: 229-267

Hochscheid S, Maffucci F, Abella E, Bradai MN, Camedda A, Carreras C, Claro F et al. (2022) Nesting range expansion of loggerhead turtles in the Mediterranean: phenology, spatial distribution, and conservation implications. Global Ecology and Conservation 38: e02194

Mrosovsky N, Camel S, Rees AF, Margaritoulis D (2002) Pivotal temperature for loggerhead turtles (*Caretta caretta*) from Kyparissia Bay, Greece. Canadian Journal of Zoology 80: 2118-2124

Özdilek SY, Kirbeci S, Yalcin S, Altin A, Uzatici A, Tosunoglu M, Ayaz A et al. (2020) The first record of loggerhead turtle (*Caretta caretta*) nesting on the northernmost Aegean coast, Turkey. Natural and Engineering Sciences 5(3): 198-203

Piroli V, Haxhiu I (2020) Nesting of the loggerhead turtle (*Caretta Caretta*) in the southeast Adriatic confirmed. Natura Croatica 29: 23-30

Yntema CL, Mrosovsky N (1982) Critical periods and pivotal temperatures for sexual differentiation in loggerhead sea turtles. Canadian Journal of Zoology 60: 1012-1016

Zbinden JA, Davy C, Margaritoulis D, Arlettaz R (2007) Large spatial variation and female bias in the estimated sex ratio of loggerhead sea turtle hatchlings of a Mediterranean rookery. Endangered Species Research 3: 305-312