

# NESTING RANGE EXPANSION OF LOGGERHEAD TURTLES IN THE MEDITERRANEAN: PHENOLOGY, SPATIAL DISTRIBUTION AND CONSERVATION IMPLICATIONS

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## Introduction

Marine turtles have expanded their ranges several times throughout their >100 million years of evolutionary history and they colonized tropical and subtropical nesting habitats around the world notwithstanding their natal philopatry. However, current nesting ranges are not in a final fixed state but are predicted to change still due to climate change and possibly, "spillover effects" where rapidly growing populations lead to increased frequencies of exploratory animals. It seems that in the Mediterranean, loggerhead turtles have already started to expand their nesting range. In particular, in the Western Mediterranean basin, which has only been known to host sporadic nests, nesting activity has been increasing since the 2010's. Here we compile information on nesting activity from four countries surrounding the Western Mediterranean and collected data on loggerhead turtle nests between 2010 and 2020 to provide an exhaustive overview on the phenomenon of emerging new nest sites for loggerhead turtles.

## Results

Loggerhead turtle nests in the Western Mediterranean were absent in the last century, except for one nest reported in Spain, and were sporadically reported (on average 1 nest per year) during the first decade of this century (Fig. 1). The number of nests increased steadily since 2013, reaching a record number of 79 in 2020 with more than three times as many nests as registered in the years before.

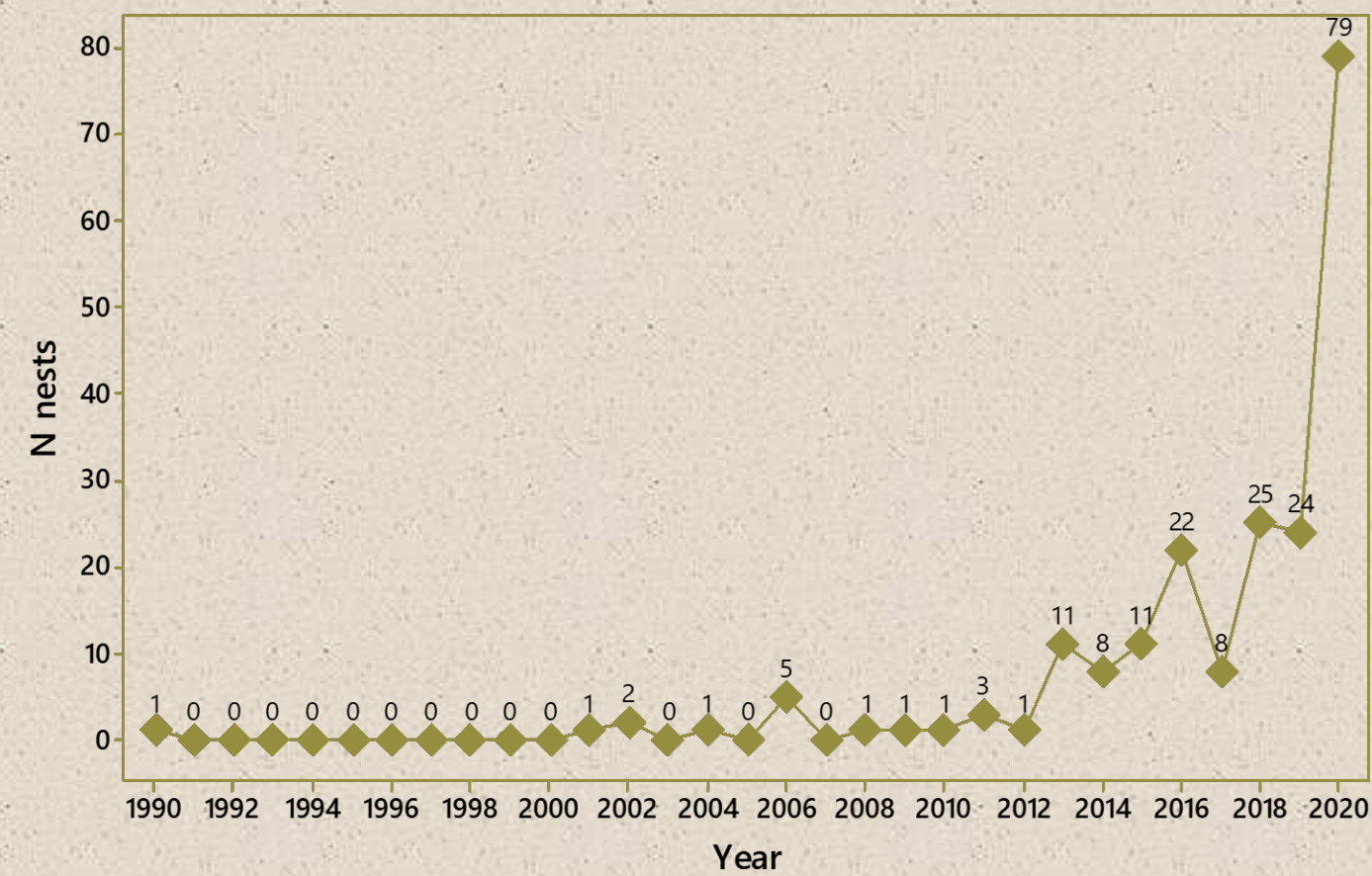


Fig. 1 - Number of loggerhead turtle nests recorded per year in the Western Mediterranean in the years 2010-2020 (N=193)

The nests are unevenly distributed over the coasts of Spain, France, Italy and Tunisia with most nests occurring on the coasts of the Tyrrhenian Sea (Fig. 2).

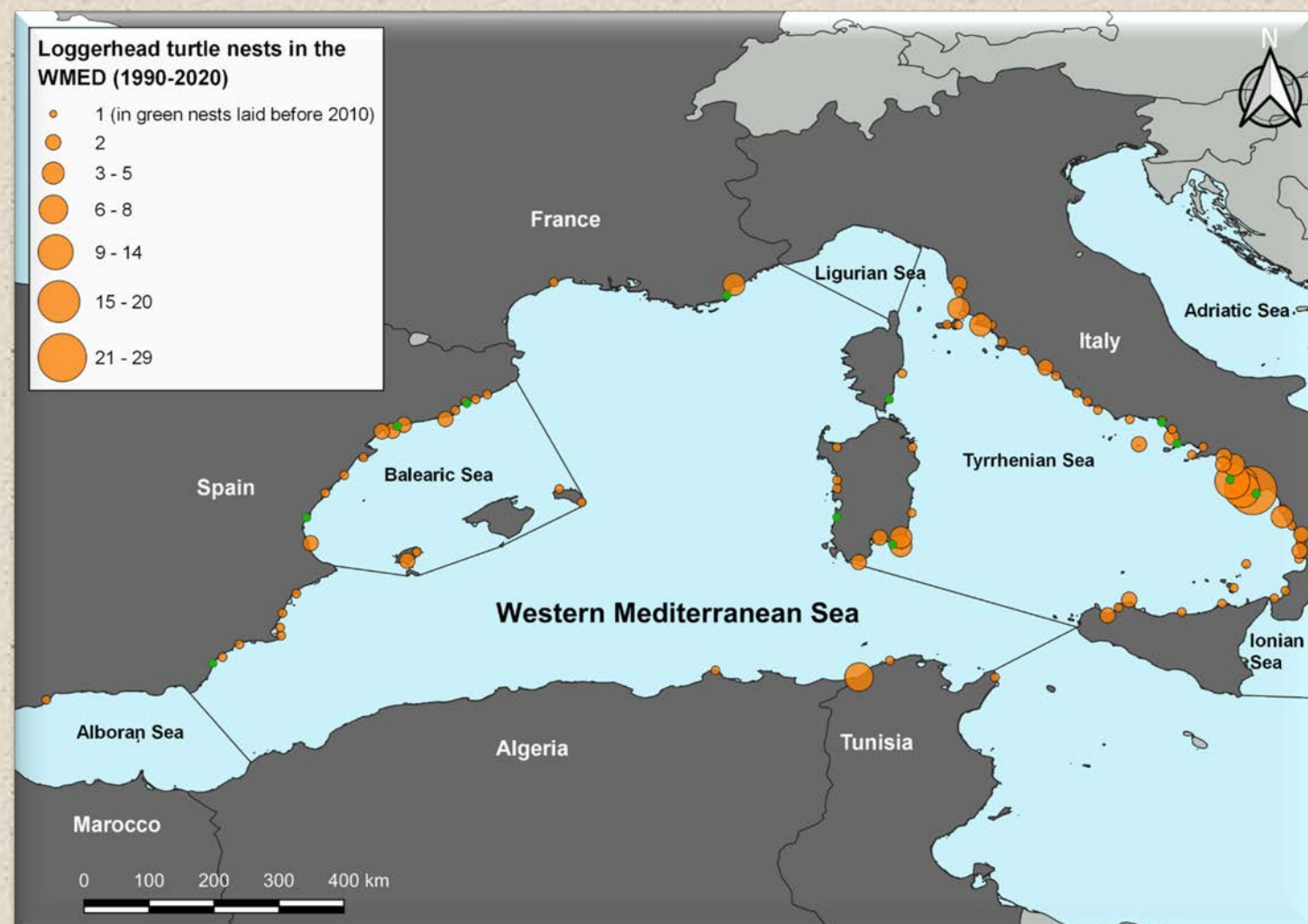


Fig. 2 - Distribution of loggerhead turtle nests in the Western Mediterranean: number of nests per 15 km, symbol size increases in proportion with number, green dots indicate single nests registered before 2010.



Photograph 2 - Example of light pollution on Western Mediterranean beaches

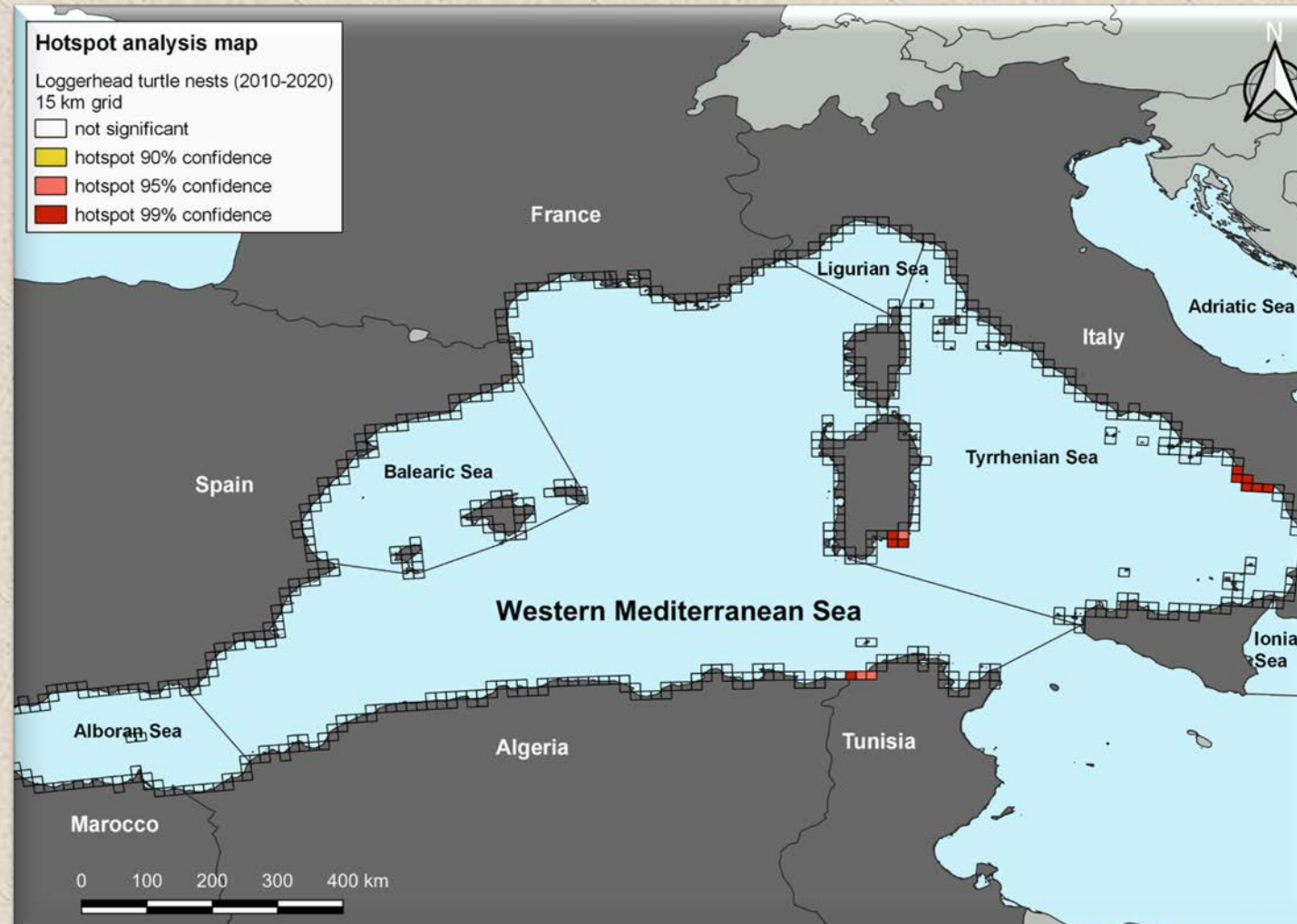
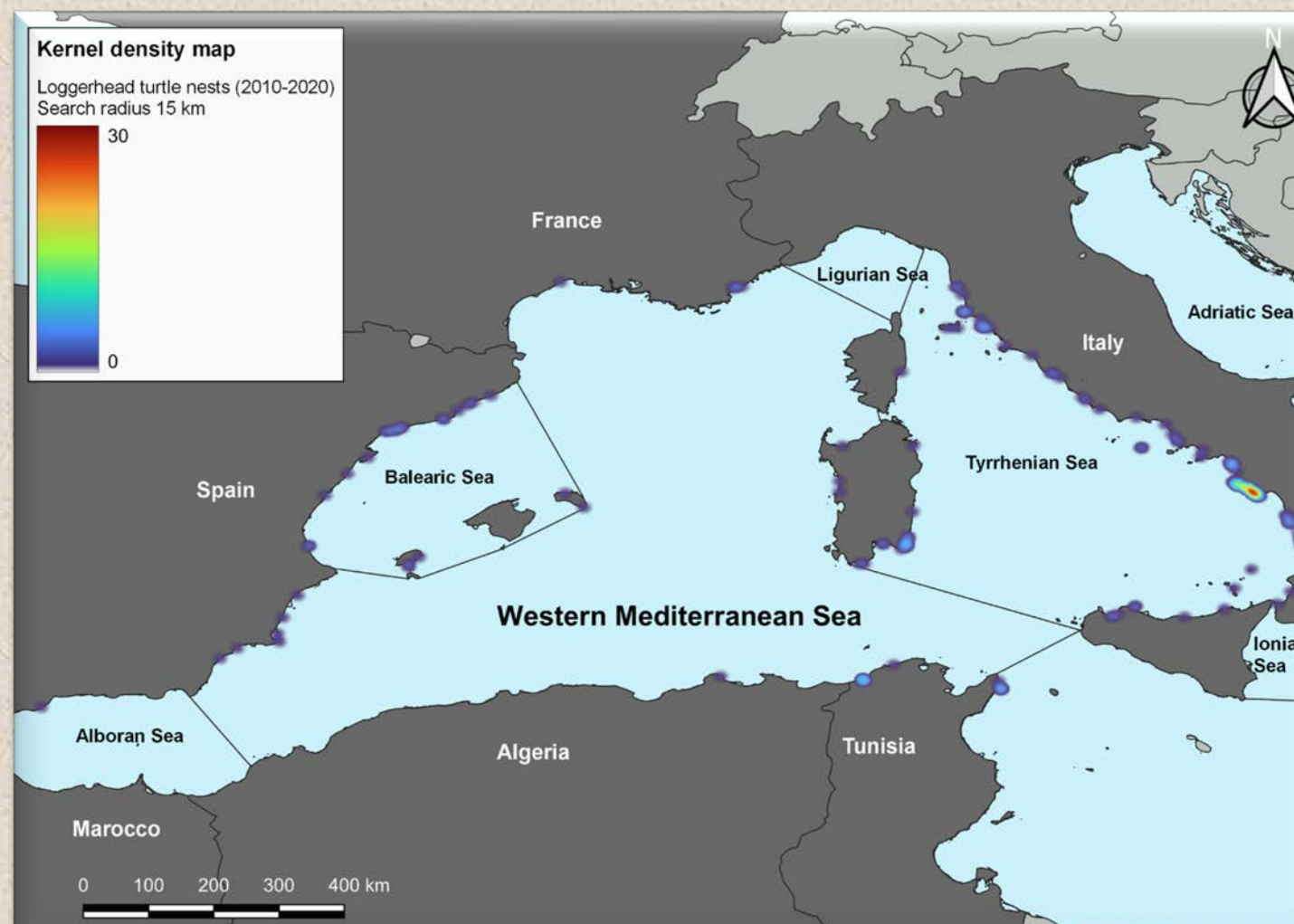


Fig. 3 - Distribution of loggerhead turtle nests in the Western Mediterranean: upper panel: Kernel density map created using a bandwidth of 15 km; lower panel: hotspots for nesting in the Western Mediterranean, see details in methods for how the hotspot analysis was performed. Solid lines indicate borders of sea regions.

A hotspot analysis identified beaches in SW Italy, SE Sardinia and NW Tunisia with statistically significant clustering of nests (Fig. 3). Within these hotspots four beaches had nests regularly identified at least four out of the five last years, three in the Cilento Park (SW Italy) and one in Tunisia. Despite not showing hotspots yet, nesting events are increasing rapidly also in Spain since 2014. Analysis of the metadata showed mostly a good correspondence to nesting phenology of Eastern Mediterranean rookeries. However, sex ratios, inferred from incubation durations, were balanced as opposed to the prospected feminisation of sea turtle nesting populations under climate change. Median hatching success of naturally incubating, non-manipulated nests was 78.1%, highlighting the suitability of the emerging nesting beaches.

	FRANCE	ITALY	SPAIN
2020	2	50, 36	11, 17
2019	1	14, 6	5, 3
2018	1	16, 1	4, 6
2017	1	16, 6	1, 9
2016	1, 5	17, 3	2, 3
2015		9, 1	2, 5
2014	2	5	3, 3
2013		7	
2012		1	
2011		1	1
2010		2	

Fig. 4 - Proportion of the number of registered nesting attempts (light grey bars) to numbers of successful nests (dark grey bars) for the period 2010-20 in France, Italy and Spain.

Unfortunately for the nesting turtles, the Mediterranean is one of the major tourist destinations in the world, and Spain, France and Italy are among the top seven countries with the highest tourist pressure on Mediterranean coasts. Exploitation and intense coastal development give females a hard time to select a suitable site to lay their eggs, while some nests are destroyed by mechanical beach levelling and emerging hatchlings are disoriented by artificial lights.



Photograph 3 - tracks from emerged hatchlings leading away from the sea, distracted by artificial lighting on the back of the beach

Photographs 4-5 - Examples for anthropogenic impact on nesting beaches: upper left) turtle ascending the beach encounters sunbeds; upper right) female trying to crawl on the beach between a crowd of tourists; lower left and right: nests that were laid after the beach levelling operations by a tractor - many nests are not detected because the tracks have been cancelled by beach levelling or the nest itself destroyed.



Photograph 2 - Spain: Turtle nesting in front of a beach bar, illuminated by artificial light.

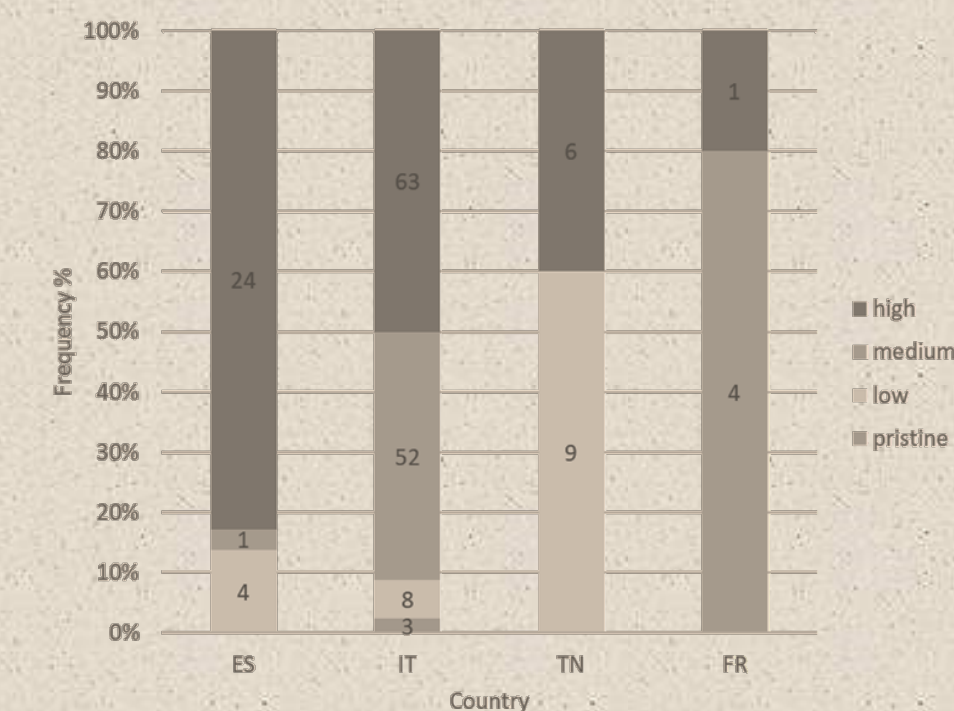


Fig. 5 - Level of anthropogenic impact on the beaches where loggerhead turtle nests occurred in the Western Mediterranean, shown for each country separately. Numbers are total counts for each category, zero values are not shown. For description of levels see Materials & Methods

## Conclusion

This study reveals a unique opportunity to witness and study an ongoing new colonisation process in loggerhead turtles, in the light of current climate change and population dynamics. With the results of this study at hand, including the knowledge on the most likely hotspots for future turtle nesting in the Western Mediterranean and on the threats present on these beaches, we call for vigilance of these new precarious habitats and for immediate and continued conservation actions.

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