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First report on two loggerhead turtle (*Caretta caretta*) nests in the Aeolian Archipelago (Southern Italy)

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Abstract. The Aeolian Archipelago (Southern Tyrrhenian Sea, Italy) hosts important foraging/overwintering habitats for Mediterranean loggerhead sea turtles (*Caretta caretta*), although nesting sites have never been documented. This study reports the data of two nesting events occurred in summer 2019 at Stromboli and Lipari islands. A hatchling success of 20.69 % (18 hatchlings from 87 eggs) was recorded at Stromboli, while a complete hatchling unsuccess characterised the Lipari nest, where 111 eggs were deposited. Data acquired during the monitoring of the nests suggest that combined factors, mainly temperature, beach morphology, and sand composition, could be the causes for the low success of these nesting events.

Keywords. Anoxic conditions, Lipari, Mediterranean Sea, Stromboli, temperature.

INTRODUCTION

The Aeolian Archipelago (Sicily, Italy), composed of 7 islands and located in the Southern Tyrrhenian Sea (Italy) (Fig. 1), is of volcanic origin with both extensive neritic and oceanic habitats within short distances (Favalli et al., 2005), which provide optimal foraging and overwintering grounds for both immature and adult loggerhead turtles (Blasi et al., 2016; Blasi and Mattei, 2017; Blasi et al., 2018) and fall within the historical nesting range of loggerhead turtle, although the 1960s quotations were not supported by documented data (Mingozzi et al., 2007).

Italy hosts regular nesting events along the Ionic coasts of the southern Calabria and in the Pelagian Islands (Linosa and Lampedusa; Mingozzi et al., 2008). Irregular nesting events are also reported on the coasts of Sicily, Sardinia, Apulia and the Ionic coasts of Basilicata and Calabria. However, in recent years, a significant increase in the numbers of nests along the Italian coasts has been reported, with 30-40 nests estimated per year up to 70 nests recorded in 2018, through a survey carried out on the Ionian coasts of Calabria, facing the Messina strait (Mingozzi et al., 2007) and in Sicily (Casale et al., 2012).

In Sicily there are numerous suitable coasts for loggerhead turtle nesting; nesting events are also occasionally reported by tourists or local people. For example, in 2011, seven nests were reported along the coasts close to Palermo and on the southern Sicily (Casale et al., 2012). Even though many potential nesting sites are not ade-

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guately monitored and consequently the actual nesting level and distribution in several areas remain partially unknown.

Here we report data on two nesting events by loggerhead turtles at Stromboli and Lipari islands (Aeolian Archipelago) in summer 2019. Our data represent the first official documentation showing that the Aeolian Archipelago could host irregular nesting events, and suggest a higher monitoring and conservation efforts to increase the chance of positive hatchings of these sites.

MATERIALS AND METHODS

Nesting sites

Two loggerhead turtle nests were surveyed and monitored during summer 2019 at Stromboli and Lipari islands, respectively. These two islands are stratovolcanoes, built by alternating hard lava flows and pyroclastic deposits of different sizes (ashes, pumices, scoriae, lithic fragments, and volcanic bombs). Stromboli, characterized by a continuous volcanic activity during the last 2,000 years, has a basaltic nature, with abundance of dark Fe-Mg minerals (Rosi et al., 2013). Its activity generated beaches composed of large (meters) basaltic rock blocks mixed to abrasive textures of sand and pebbles, with sizes up to few tens of centimetres. The dark colour of this substrate encourages the adsorption of the thermal infrared solar radiation, with surface daytime summer temperatures that can exceed 50 °C. The volcanic products of Lipari Island are more acidic, i.e., with major abundances of whitish silica. Solid wastes of pumice extraction from a close coastal quarry, presently inactive, are transported to the beach (Anzidei et al., 2017). Furthermore, during the last years, artificial replenishments of the beach were carried out, causing dramatic changes in its original morphology and lithological nature.

The first loggerhead turtle nested on the 21st of June at 7:35 AM (GMT+1) at Scari beach, in the north-east of Stromboli Island (15.2428°E, 38.8034°N WGS84), about 1 Km N of the main harbour and 14 m from the seashore (Fig.1). The site is characterized by a berm composed of large-sized pebbles, with a slope of 16.9°, located seaward of a dumping site. An anchor buoy field is present in its immediate neighbourhood and a sailing boat (about 50' long) was stranded in front of the nest few days after its emplacement, and stayed there for the whole incubation period. The nesting event was reported by two tourists and lasted about 2 hours.

The second loggerhead turtle nested on the 5th of July at 9:00 PM (GMT+1) in the heavily urbanised Canneto beach, in the north-east of Lipari Island (14.9617°E, 38.4937°N WGS84), at its inner end (Fig. 1). The turtle was disturbed by people with light and noise and consequently multiple nesting attempts were made before the final site was chosen. Facilities and roads run along the coast and, during the summer season, many tourists overcrowd the beaches all day long for the presence of bathhouses. A runoff channel is located in the proximity of the nesting site.

Nests monitoring and data collection

Standard fences were constructed to protect both sites immediately after the nesting events (Nooren and Claridge, 2002). A 24-hour monitoring was provided for each nest by Filicudi Wildlife Conservation volounteers during the whole incubation period, for checking sand temperatures and preventing predator/human intrusions. Two ONSET USB data loggers, equipped with 12-bit temperature smart sensors, were provided by the Istituto Nazionale di Geofisica e Vulcanologia (INGV); temperature sensors were buried at 10 and 40 cm depths in the proximity of the nests, and acquired data every 30 minutes in order to provide non-aliased hourly data. A via-radio remote Reolink IP RCL-410 W (4.0 MP) night camera was installed at Stromboli (courtesy of Attiva Stomboli Association). The duration of incubation period for both nests was predicted using the recorded mean temperature during the middle third of the incubation period as reported by Kaska et al. (1998) and other authors (Reid, 2005; Reid et al., 2009; Houghton and Hays, 2001; Godley et al., 2001).

The hatchling phase was continuously monitored with at least two operators for each nest, equipped with red filter headlights. During the hatchling phase at Stromboli, date and time of the emerging events were recorded and body size measurements (SCL, SCW, SPL, SPW, and weight) of hatchlings were collected, with a calibre and a scale, following standard protocols (Bolten et al., 1993; Nooren and Claridge, 2002). Dead hatchlings were stored in tubes provided with 70% ethanol solution, encoded with ID number, date, and time of collection. At the end of each emergence event, the hatchlings were left free inside the fenced area for a few minutes, to allow the imprinting process. Afterwards, considering that lights near to the beach and ostacles on the sand are a considerable risk to the hatchlings (Demetropoulos and Hadjighristophorous, 1995), they were placed in a basket filled with sand, which was transported offshore by boat, and then released directly into the sea. As a matter of fact the light might attract them in the wrong direction or slow down the race to the sea extanding the period hatchlings remain on land. Moreover, obsta-

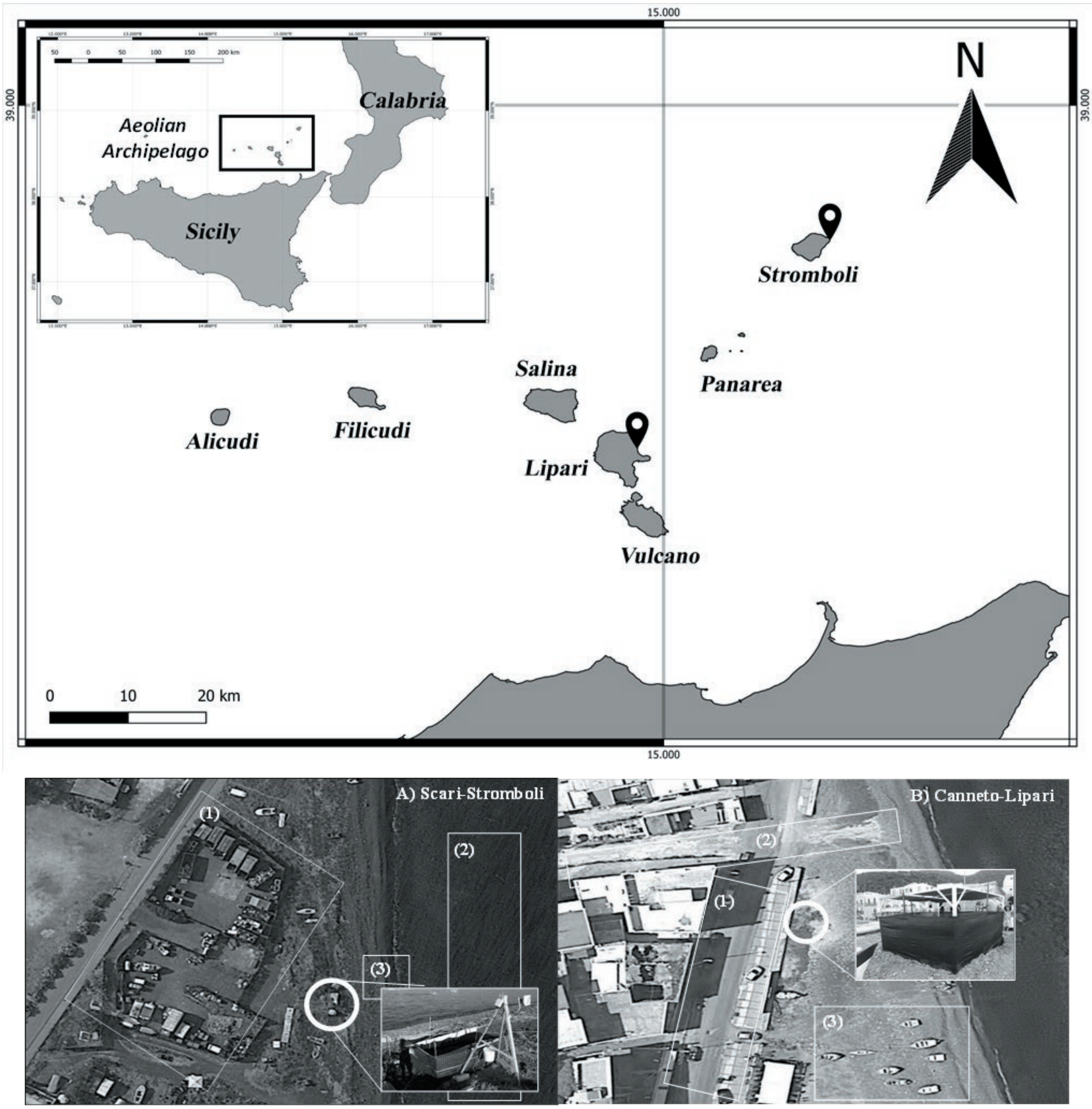

Fig. 1. On the top, location of study area and loggerhead turtle nests. On the lower left (A), particular of the Scari-Stromboli nest with in evidence (1) the dumping site, (2) the buoy field, and (3) the sailing boat stranded on the beach. On the lower right (B), particular of the Canneto-Lipari nest with in evidence (1) the cemented road (2) the runoff channel and (3) the boat storage. The nest removable protective coverages were indicated for both nests.

cles on the sand surface and in front of nest could also may extend the time to arrive at sea for hatchlings on the beaches. Finally, the longer hatchlings reaminding on land the higher is the risk of predation as well (Demetropoulos and Hadjighristophorous, 1995). The features of the beach and the set of circustances did not allow to let the hatchlings spontaneously reach the sea. The beach was characterized of large rocks, and pieces of bamboo cane. Furthermore, in front of the nest, there is an area where many sailing boats are in the harbour and during the night, a sailboat ran around on the beach. At the end of the last hatching phase, fixed at 72 hours

(Demetropoulos and Hadjighristophorous, 1995) from the last emergence event, the nest was excavated. After excavation, unhatched eggs were counted, weighed, and the developmental stage of embryos assessed according to standard classification (Miller, 1985), using the methodology stated by Kobayashi et al. (2017). Three embryogenetic classes were used in this study: a) ≤ 21st stages, b) between 22nd-29th stages, and c) ≥ 30th stages, which included pipping and not emerged hatchlings (for detailed embryonic stage description see Miller, 1985). Finally, each unhatched/hatched egg/embryo was stored in a plastic bag, encoded with an ID number, time, and date of collection, and immediately frozen at -20 °C. Core drill samples for sand analyses and nest measurements were taken, including nest minimum and maximum depths and distance from the sea.

RESULTS

Temperature monitoring

Temperature data acquired at 10 cm and 40 cm depths are reported for both nests (Fig. 2A). In the Stromboli nest the temperature at 10 cm depth was over the upper threshold for ideal egg maturation (32 °C) during the majority of the study period. In particular, higher values were reported on the 11th and 12th of July and since the 17th of July, every afternoon. On the other hand, temperatures < 26 °C were never recorded, with the exception of the 17th of July. At 40 cm the temperature regime was more stable, with a daily oscillation not higher than 1 °C, one order of magnitude less than that one observed at 10 cm. An approximately 0.5 °C temperature passing of the maximum threshold was observed in the period between the 29th of July and the 4th of August, after which temperature oscillations remained permanently below this limit. In addition, 2 peaks over the maximum threshold of temperature were recorded on the 15th and the 16th of July respectively, as a consequence of a rainfall event of 1 mm. The minimum temperatures recorded at 40 cm depth were over the lower threshold (26 °C) during the entire period, except for a few days in the middle of July.

Temperatures at Lipari showed lower variations (Fig. 2B). The maximum daily oscillation was < 5 °C, at the end of August and at 10 cm depth, and a few decimals of °C at 40 cm. Values over the upper threshold were recorded only after the 17th of August at 10 cm depth. The lower temperature values recorded were between 29 and 31.5 °C at 40 cm depth, and between 27 and 30 °C at 10 cm.

Hatchlings

At Stromboli 87 eggs were found in the nest (Table 1). The nest had a width of 15 cm (maximum distance between two eggs) and a depth of 18 cm and 33 cm to top and bottom of the eggs chamber, respectively. The incubation period ranged 46 days in Stromboli with a hatchling duration of 46-51 days. Particularly, 3 hatchling events were recorded and 2 excavations performed for a total of 18 emerged hatchlings (20.69%):

- on the 6th of August, between 9:00 PM and 11:46 PM, with 6 emerging hatchlings,
- on the 7th of August, at 2:30 PM, with a single emerging hatchling immediately dead, probably for the high surface temperature (about 39 °C):
- on the 8th of August, between 5:56 PM and 8:25 PM, with 8 emerging hatchlings, one of which died shortly after;
- on the 10th of August, at 11:00 PM, after two days since the last emersion, we cautiously excavated the most surficial portion of the nest, finding other two alive hatchlings stuck between basaltic stones;
- on the 11th of August, at 11:00 PM, after another day without any activity, we continued the excavation discovering the last alive hatchling blocked in the sand.

The remaining 69 eggs (79.31%) hosted unhatched embryos at ≤ 21st embryonic stages (Table 1).

The Lipari nest was excavated at the 54th day of incubation, on the 28th of August at 8:03 PM, since no emergences had occurred several days after the predicted incubation period (i.e., 45-50) (Kaska et al., 1998; Reid, 2005; Godley et al. 2001), finding 111 eggs with unhatched embryos. Twenty-one eggs (18.92%) contained embryos at ≤ 21st developmental stages, 70 eggs (63.06%) had embryos at 22nd-29th stages, and 16 eggs (14.41%) had embryos at ≥ 30th stages (Table 1), 11 of them (9.91%) had pipped (stage 31a) (Table 1). Additionally, 4 not-emerged hatchlings (stage 31b) were found dead at the upper part of the nest (3.60%). The nest had a width of 19 cm (maximum distance between two eggs) and a depth of 16 cm and 35 cm to top and bottom of the eggs chamber, respectively.

Average body size measurements of hatchlings for both nests are reported in Table 2.

DISCUSSION

This study is the first quantitative documentation of two nesting events of loggerhead turtle in the Aeolian Archipelago, with 18 hatchlings (20.69%) from 87

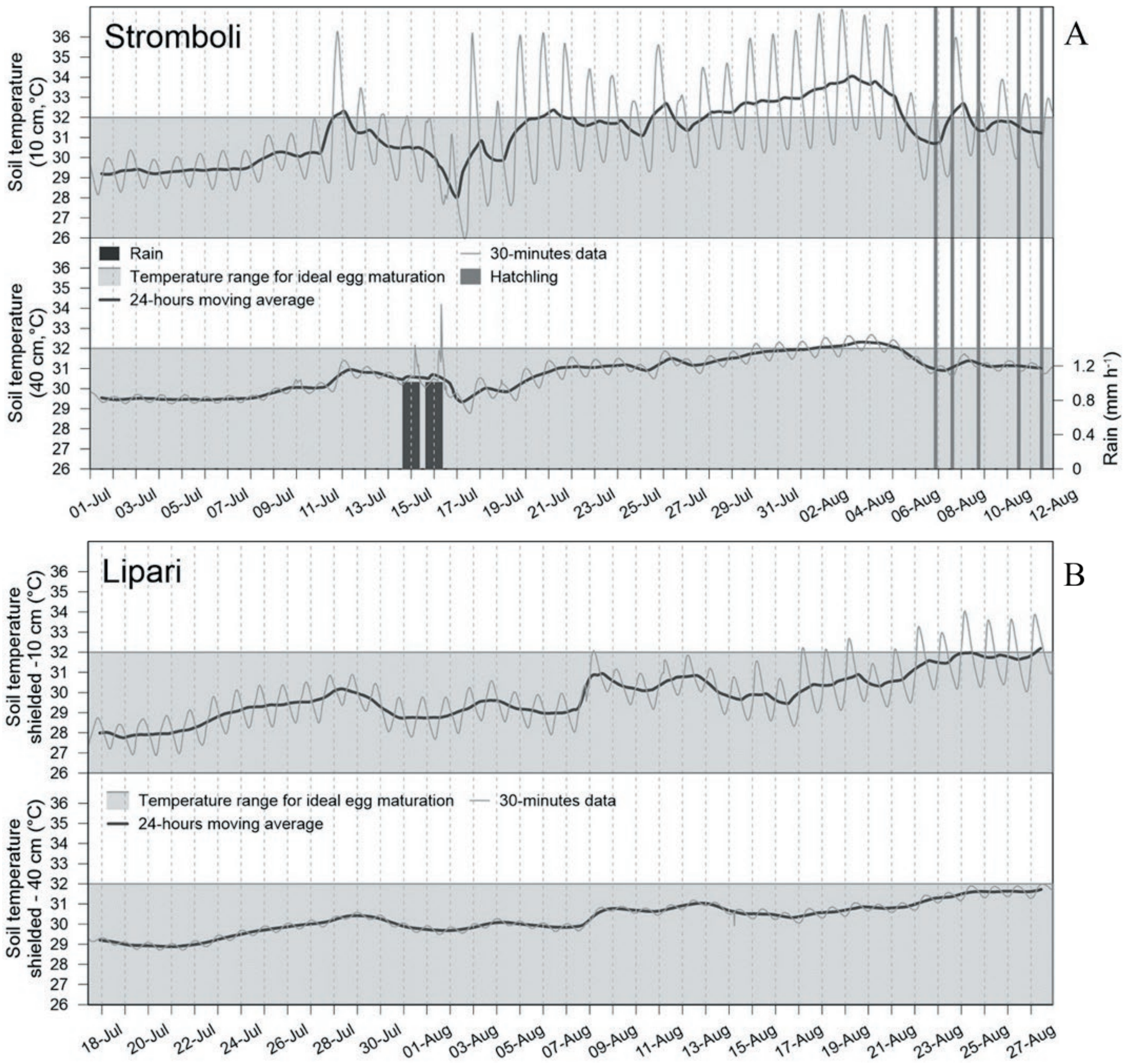

Fig. 2. Nest temperature at 10 cm and 40 cm depths recorded at Stromboli (A) and Lipari (B) during the nesting periods. Ideal temperature range for egg maturation, hatchlings and rainfall events are also reported for Stromboli.

eggs at Stromboli and no successfully released hatchlings at Lipari (111 eggs). Both nests were laid during the seasonal period of maximum frequency for the species in Italy and in the Mediterranean Sea (Giacoma et al., 2011). Similarly, the incubation period and the clutch size fall within the normal range for the species (Giacoma et al., 2011).

Different reasons could be at the base of the scarce hatchling success at Stromboli and its total unsuccess at Lipari.

In the case of Stromboli, the high temperatures recorded inside the nest, due to the color and composition of sand, could have been the main reason of the low percentage of hatchlings. The nest showed temperatures at 10 cm in depth over the upper threshold for ideal egg maturation (32 °C), with particular reference to the later incubation period. Conversely, temperatures were never below the lower threshold. Studies on nests with similar temperature ranges report on a low emergence success (Chu et al., 2008; Read et al., 2012), especially during the

Table 1. Percentage of hatchlings and embryos at different development stages (Miller, 1985) for Stromboli and Lipari nests.

	Stromboli (%) (N=87)	Lipari (%) (N=111)
Hatchlings		
Successfully released	18.40	0
Pre-emergence death	0	3.60
Post-emergence death	2.29	0
Embryos		
≤ 21	79.31	18.92
22-29	0	63.06
≥ 30	0	14.41

Table 2. Average morphometric data for Stromboli and Lipari hatchlings. SCL = straight carapace length; SCW = straight carapace width; SPL = straight plastron length; SPW = straight plastron width (Bolten et al., 1993).

Morphometrics data	Mean (±SD) Stromboli	Mean (±SD) Lipari
SCL (mm)	39.57 ± 3.73	37.26 ± 2.64
SCW (mm)	30.31 ± 4.35	27.48 ± 3.43
SPL (mm)	30.32 ± 5.19	26.96 ± 6.19
SPW (mm)	29.41 ± 4.11	23.36 ± 1.23
Weight (gr)	14.28 ± 1.27	11.6 ± 2.79

last days of incubation (Matsuzawa et al., 2002; Maulany et al., 2012). Finally, the presence of basaltic products mixed to sand in the nests could have influenced escape success (i.e., 3 hatchling events and 3 blocked hatchlings) and duration (from 46-51 days) of hatchling phase (Foley et al., 2006).

At Lipari nest temperature was always within the thresholds for ideal egg maturation, so different reasons should be invoked for explaining the complete hatchling unsuccess. Possible explanations could be found in the absorption of parassites/contaminants from the material constituting the partially artificial beach (Alava et al., 2006), fauvored by a rainfall event during the middle third of the incubation period (Foley et al., 2006), or in anoxic conditions (Margaritoulis, 2005; Lolavar and Wyneken, 2015) due to the presence of the very fine particulate created by the mechanical crushing of the pumice.

From this study, we have learned that the Aeolian Archipelago may ideally host irregular nesting sites for loggerhead turtles. A higher monitoring and conservation effort is recommended for these sites to increase the chance of positive hatchings.

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