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Are the characteristic of nesting beaches influencing emergence rate and hatching success of loggerhead turtle *Caretta caretta* along the Ionian coast of Calabria (Italy)?

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INTRODUCTION:

The southern coast of Ionian Calabria (the southern most part of the Italian peninsula, **Fig. 1**) was recently recognized as the most important nesting ground of the loggerhead turtle in Italy. Despite a regular nesting activity, the distribution of loggerhead turtle nests along the 35 km of sandy beaches of this coastline shows a quite uneven pattern. As the nesting activity and hatchlings movements are critical for species reproductive success and they are the only terrestrial phases of these marine reptiles, we decided to investigate the supralittoral characteristics of nine representative beaches of this area and relate them to nesting activity and hatching success.

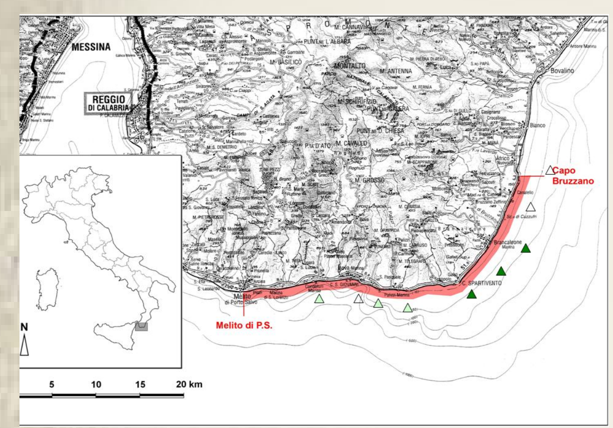

FIGURE 1: Study area. The study area extends from Capo Bruzzano (33S 0600340 4210956) to Capo dell'Armi (33S 0660207 4200962) along the Southern coast of Ionic Calabria (Southern Itlay). Triangles indicate the sites; colours indicate the nesting classes: ▲high, △medium, △none

STUDY AREA AND METHODS

The study area (**Fig. 1**) was represented by three coastal sectors differing for geomorphology and coastline orientation: North-South; East-West; Central. Within these sectors, on the basis of a ten-years dataset, nine sites have been selected and divided in three nesting classes (high, medium and none).

Ecological parameters of the supralittoral zone have been measured (**Figs. 2-6**) during the beginning of nesting time of *Caretta caretta* (June), the beginning of hatching time (July) and the end of hatching time (September). Also, mean grain size (Mz), sea water salinity (gNa/l), presence and number of discharges into the sea (active within 500 m of each study site) have been estimated for each site. On the basis of these parameters the beaches have been ordered according to similarity through non-metric multidimensional scaling (nMDS) considering the parameters contributing for at least 4% to the definition of the groups (**Tab. 1; Fig. 7**).

From the data regarding nesting females and nests found at the study sites, we estimated:

a) the straightness of the tracks left by the emerging females (as a proxy of the research effort towards the nesting site). This was estimated as D/L ratio, with D = track length and L = rectilinear length (Batschelet, 1981). To this aim, we used pictures corrected for the slope (**Fig.8**). Then we compared straightness from the sea to the nest and straightness from the nest to the sea were compared (t-test; **Tab. 2**);

b) the hatching success (number of hatched turtles/number of laid eggs) and the probability for a hatchling to reach the sea, estimated as odds ratio [(hatchlings at sea/laid eggs)/(hatchlings not at sea/laid eggs)] were estimated for each site and compared between sites with different nesting activity (Mann-Withney test for independent samples, using a permutation approach to estimate error probabilities) (Siegel and Castellan, 1988; Good, 2000) (**Tab.3**).

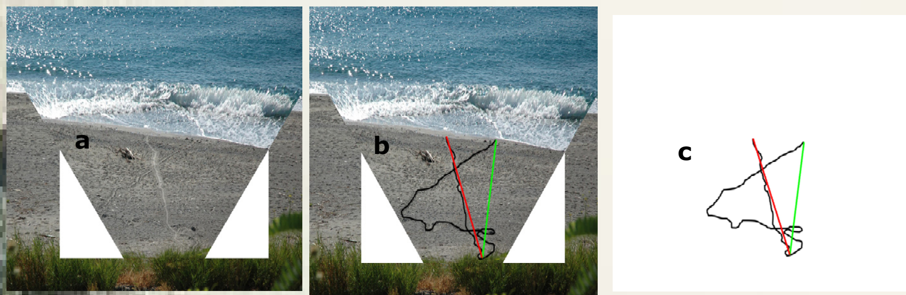

FIGURE 8: Graphic methods to estimate the track straightness

a: picture of the track with correction for perspective ***b:*** paths layout on the image with correct perspective, green: rectilinear sea-nest distance, red: rectilinear nest-sea distance, ***C:*** track

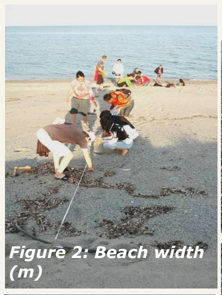

Figure 2: Beach width (m)

Figure 3: Beach slope (degrees)

Figure 4: Local shoreline orientation (degrees from North)

Figure 6: Sand penetrability (cm)

Figure 5: Swash width (m)

RESULTS AND DISCUSSION

On the basis of the ecological parameters recorded, the beaches under analysis clustered into two main groups, partly independent from both coastal sector and nesting classes (**Fig. 7**). Parameters such as grain size, swash width, seawater salinity and number of discharges into the sea discriminated the high nesting from the no nesting group of beaches (**Tab.1**). A direct human impact such as the water discharge to the sea resulted to be the main factor contributing to the similarity among high nesting beaches (**Tab.1**).

The analysis of the tracks left by emerging females pointed out a higher research (lower track straightness) in the path from the sea to the nest with respect to the opposite path (**Tab. 2**). By comparison with typical research patterns (e.g. loops or multi-cue navigation), the choice of the nesting site seems to be driven by a single cue, probably the slope (negative geotaxis).

Despite the apparently consistent differences, our data cannot support the hypotheses that there are differences in the two nesting classes beaches with respect to hatching succes nor probability for a hatchling to reach the sea (**Tab.3**).

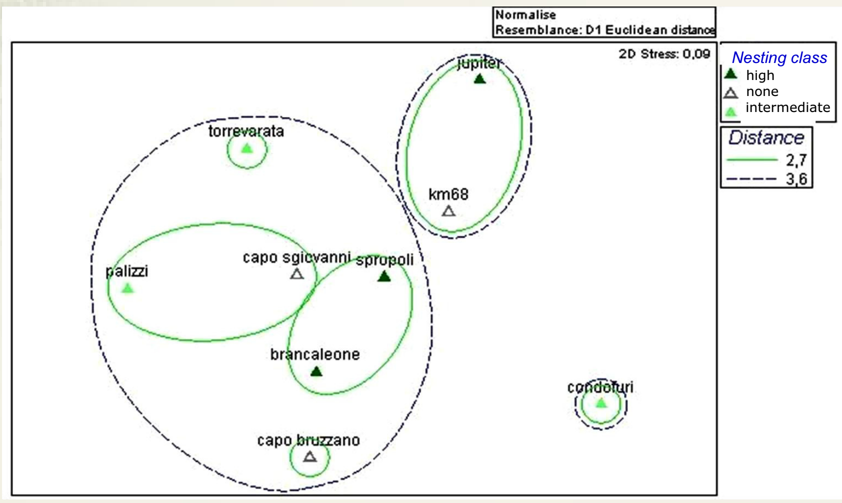

FIGURE 7: nMDS results.

Table 1: Contribution percentages of the environmental variables to the similarity among the three beach classes.

Only contributions > 4% are reported

High nesting beaches	
Variable	**%**
Water discharges	60.09
Mean grain size	18.91
Swash width	9.35
Seawater salinity	5.43
Intermediate nesting beaches	
Variable	**%**
Beach width	30.06
Beach slope	24.09
Swash width	20.07
Seawater salinity	18.58
No nesting beaches	
Variable	**%**
Mean grain size	45.80
Swash width	14.64
Seawater salinity	19.07
Water discharges	9.07

	Hatching success ± SEM (%)	Probability to reach the sea ± SEM (odds ratio)
High nesting beaches (N = 19)	75.1 ± 5.34	5.84 ± 1.14
Intermediate nesting beaches (N = 4)	56.7 ± 12.53	2.24 ± 1.31

Table 3: summaries of hatching success and probability to reach the sea. Mann-Withney test n.s.

Straightness (D/L)	range	mean ± SD
path from the sea to the nest	0.24 – 0.84	0.62 ± 0.18
path from the nest to the sea	0.52 – 0.96	0.78 ± 0.12

Table 2: summaries of track straightness. N = 20

* $p < 0.05$; df = 38

CONCLUSIONS

The beaches under analysis resulted similar with respect to the supralittoral zone characteristics, independently on their coastline orientation and geomorphology. This may be rather related to the longshore sea currents, which have an effect on most of the variables found relevant to similarity among beaches.

The track straightness indicated a research of the nesting site on the supralittoral zone, however no typical research patterns (e.g. loops, see Schöne, 1984) was found at overall level. This seems to confirm that the principal choice of the nesting site is taken by the female in water before the emersion, and the choice of the nesting beach is thus likely to depend upon features (e.g., imprinting, sea currents, etc) other than the supralittoral characteristics. Hatching success did not vary significantly among the different sites, and this could indicate that after the selection of a nesting site, the same hatching success is ensured. However, the relatively low power of the test due to low numbers claims for further studies.

From these data, it is highlighted the importance of the consideration of littoral zone and longshore sea currents as a whole, to understand the critical phase of nesting of *C. caretta* and protect the species and the nesting beaches at the time.

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