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Habitat suitability for loggerhead turtle nesting sites along the Southern Adriatic and Northern Ionian (Central Mediterranean Sea)

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***Abstract* – We present a model of habitat suitability for the loggerhead turtle nesting sites along the Apulian and Lucanian Coasts. The model is based on nesting records and seven environmental variables, i.e. distances from isobaths of 1500 m and 3200 m, absolute depth, mean monthly surface temperature of sea, mean monthly concentration of chlorophyll, mean monthly solar radiation and mean VIIRS Day/Night Band Nighttime Lights. Maps were computed for each variable and processed to obtain a MaxEnt distribution model of nesting sites suitability. The nesting suitability model shows that AUC estimate from iterative ROC analysis is high (0.981, s.d.= 0.009). Jackknife estimations for variable contribution to model indicated that the most important contributors were absolute depth, Day/Night Band Nighttime Lights and coastline distance from the bathymetric lines of 3200 m. Areas of maximum suitability for nesting are around Salento, and great part of Ionian coast of Lucania. Although preliminary, the present model represents a useful tool for the prediction of the habitat suitability of *C. caretta* and the implementation of conservation measures according indications from the SPA/BD Protocol.**

I. INTRODUCTION

The loggerhead turtle *Caretta caretta* is worldwide classified as Vulnerable (VU) while the Italian population is considered as endangered (EN) by the IUCN Italian Red List [1]. In the Mediterranean Sea the species presents a wide nesting area along the Levantine coasts of Greece, Turkey, Cyprus, and Libya [2,3]. Moreover, due to the growing interest in defining its conservation status, there are several reports of new nesting areas with a number that in 2010 stood at around 7200 across the Mediterranean [3]. As far as the Italian seas, the reports are increasing, including the Apulian and Lucanian coasts (Southern Italy) [4,5]. The importance of these coasts is confirmed by the constant presence of nesting and foraging areas [6,7,8].

This area is subjected to significant anthropogenic pressure due to maritime traffic, coastal fishing practices and the intense use of the coast that leads among other things to light pollution that can interfere with the choice of the nesting site and the achievement of the sea by the hatchling marine turtles on nesting beaches [3,9].

Locally the availability of food, the bathymetric profile and a series of other environmental factors, can indeed determine the choice of a nesting site compared to another.

The possibility of early detect areas with greater environmental suitability for the nesting of sea turtles represents a useful tool to develop monitoring and managing strategies. In fact, the identification and characterization of the most suitable habitats for endangered species is a general and fundamental step for the design of suitable protection measures that must start from the maintenance of habitat sustainability. The protection of reproduction habitats is essential for species that show high loyalty to the site and poor reproductive success, such as sea turtles. The protection of nesting beaches is therefore a priority because the protection of the nest from disturbs affecting the reproductive success, increases the possibility that populations may survive. In the same way, it is also important to locally identify the type and conservation status of feeding, mating and wintering habitats [10].

Table 1. Nineteen environmental variables used in the MaxEnt models.

n°	Variable	Source
1	Distance from isobath of 1500 m	[13]
2	Distance from isobath of 3200 m	[13]
3	Absolute Depth	[13]
4-8	Mean surface temperature of sea in May, June, July, August, and September in the time lapse 2005-2010 (5 variables)	[14]
9-13	Mean monthly concentration of chlorophyll in May, June, July, August, and September in the time lapse 2005-2010 (5 variables)	[14]
14-18	Mean monthly solar radiation in May, June, July, August, and September in the time lapse 1981-1990 (5 variables)	[15]
19	Mean VIIRS Day/Night Band Nighttime Lights in August in the time lapse 2012-2017	[16]

An attempt to use a data series of nesting records to test a preliminary model of beach nesting suitability was applied recently [5]. Thereafter, the model was implemented by adding more nesting records and additional environmental data from a wider area including the Southern Adriatic Sea and the Northern Ionian Sea (Apulia and Lucania Regions), as well as data about the artificial night light impact.

II. MATERIAL AND METHODS

Nesting sites data were collected from many different sources. Literature data were used to assess nesting sites along Mediterranean [11,12] and Apulian coasts [6]. Lucanian nesting sites were assesses through the data bank of the CRTM WWF Policoro/Progetto Tartarughe WWF. All the data referred to the period from 2014 to 2018 and led to a total of 43 nesting sites. Related to the reference grids available for the environmental variables used, all the nesting points were translated off shore of coast for 2 km, to fit then with each environmental layer. Nineteen environmental variables thought to influence the reproductive activities of the loggerhead turtle were chosen [11,12] as indicated in Table 1.

The maps of environmental variables were processed with software ESRI® ArcGis™ 9.3 to obtain a perfect overlap among them. Original data, some of which in NetCDF format, were converted into digital raster, therefore maps were resampled at a resolution of 1' (due to resolution of the available environmental data) and clipped to collect the entire geographic area of nesting sites selected in this study. Maps for mean monthly concentration of chlorophyll, sea surface temperature, solar radiation and Day/Night Band Nighttime Lights were obtained from the monthly averages of each years. Each monthly map was resampled, cropped and elaborated to create an average map for each parameter per month, i.e. May to September (from 2005 to 2011 for SST, from 2005 to 2010 for chlorophyll, from 1981-1990 for solar radiation and from 2012 to 2017 for Day/Night Band Nighttime Lights, in this last case only for the month of August).

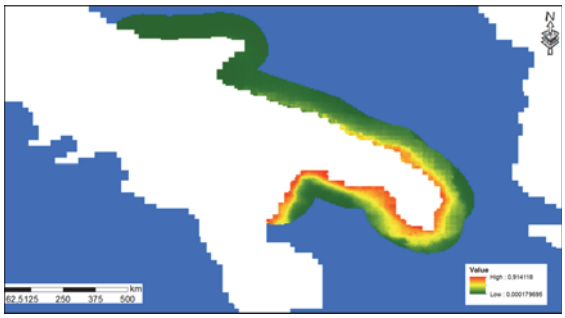

Fig. 1. MaxEnt model: areas potentially suitable for nesting of *C. caretta* along the Apulian and Lucanian coasts. The level of suitability is indicated by a scale varying from green to red corresponding to a value between 0 and 1.

All raster data were georeferenced according to the geographic coordinate system, World Geodetic System 1984. Each dataset was then used to build layers that were subsequently mapped.

All data were elaborated by means of software MaxEnt [17] version 3.4.1 to realize a distribution model of nesting sites suitability. The weight of each variable to build the model was estimated, directly by MaxEnt [17] version 3.4.1 by means of a jackknife analysis. The predictive performance of the model was estimated by ROC (Receiver Operating Characteristic) with plotting the curve and calculating the AUC (Area Under Curve) in an iterative approach with 15 replicates selected via a subsample resampling from 25% of records [18].

Finally, from result map was clipped area of our interest, just along the coast of Apulia and Ionian coast of Lucania, until a distance from coastline of 30 km about.

III. RESULTS

The nesting suitability model shows that AUC estimates from iterative ROC analysis is high (0.981, s.d.= 0.009). Jackknife estimations for variable contribution to model indicated that the most important contributors were absolute depth (contribution 33.6%, permutation importance = 79.4), Day/Night Band Nighttime Lights (contribution 22.2%, permutation importance = 0.2) coastline distance from the bathymetric lines of -3200 m (contribution 15.2%, permutation importance = 5.3), mean surface temperature of sea in September (contribution 8.2%, permutation importance = 0.2) and mean surface temperature of sea in August (contribution %, permutation importance = 0.2).

The resulting map obtained from the elaboration of nesting data (Fig. 1) shows how areas of maximum suitability for nesting are around Salento, and great part of Ionian coast of Lucania. The min value of suitability estimate by MaxEnt for clipped area is equal to 0.91

IV. DISCUSSION

Results indicate the coasts of Salento and Lucania as suitable nesting areas for the loggerhead sea turtles in the Central Mediterranean Sea. In particular, results from iterative ROC analysis carried out in this study provided better AUC estimates indicating consistency improvement when additional nesting records and artificial light impact were added for modeling habitat suitability [5] (0.981 vs 0.965). In fact, it was confirmed that light pollution can negatively affect nest site selection for *C. caretta* in the study area [19]. To that regard, it is very important to underline that some sites were discovered after the finding of hatchlings crushed and killed by road traffic, probably because of their disorientation induced the high light pollution near the beach.

Although further research should be focused on the factors that locally influence the choice of the nesting site and the reproductive success, the present model represents a useful tool for the prediction the habitat suitability of *C. caretta* along the Lucania and Apulia coasts allowing the implementation of conservation measures according indications from the SPA/BD Protocol.

The collection for new data from the already investigated areas and from other important areas in southern Italy represents the new challenge to be faced. Since other nesting sites along the Italian Ionic coasts are well known, they represent important area whose contribution could be fundamental for the development of useful tools for the development of protection strategies on a wider geographical scale.

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