

## Identification via suitability model of potential nesting areas for the loggerhead turtle *Caretta caretta* along the Adriatic coast of Molise

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**Abstract.** The loggerhead turtle *Caretta caretta* is an endangered cosmopolite pelagic species occurring in temperate, tropical and subtropical seas. The species is known to nest along the eastern Mediterranean coasts, including Italy, where nesting sites are reported for some localities of Calabria and Puglia, for Sicily and for Linosa and Lampedusa islands. Focusing on the need of identifying new nesting sites of *Caretta caretta* along the Italian coasts, we produced a suitability model for potential nesting areas of the species along 38 km of the Adriatic coast of Molise. A GIS expert based model was developed on the basis of five environmental variables concerning geomorphology, vegetation cover, and habitat disturbance factors. The results of the analysis indicate the persistence of a continuous suitable stretch 2850 m long in the southern portion of the coast of Molise, while in the northern portion only fragmented tracts of potential nesting areas were found. All the identified stretches suitable for nesting occur within two Sites of Community Importance. Field investigations are strongly recommended in the areas identified in this paper in order to ascertain actual nesting of *Caretta caretta*, to validate the GIS expert based model, and to improve the model itself for further investigations concerning potential/actual nesting sites of *Caretta caretta* in other Mediterranean sandy shores.

**Keywords:** Reptiles, *Caretta caretta*, nesting areas, habitat suitability model, Molise.

### INTRODUCTION

The loggerhead turtle, *Caretta caretta* (Linnaeus, 1758), is a cosmopolitan pelagic species occurring in temperate, tropical and sub-tropical marine areas (Pritchard & Mortimer, 1999). *Caretta caretta* is worldwide threatened and is listed as Endangered (EN, A1abd) by IUCN (2012). It is one of the most endangered vertebrate species in Italy, where it is considered as Critically Endangered (Capula, 1998; Giacoma et al., 2011). Being a species of high conservation interest, it is listed in the annexes II and IV of the Habitat Directive 92/43/CEE, in the Appendix I of the Convention on International Trade of Endangered Species (CITES), in the Appendix I of the Bonn Convention (1979), and in the Annex II of the Bern Convention (1979). Like other sea turtle species, *Caretta caretta* is particularly susceptible to population declines because of its vulnerability to anthropogenic impacts during all life-stages. The main threats to the species include incidental bycatch in marine fisheries, habitat degradation and habitat disturbance by humans at nesting beaches and feeding areas, intentional killing and exploitation, and marine pollution (Gerosa & Casale, 1999; Panou et al., 1992; Balletto et al., 2003; Giacoma et al., 2011).

Based on mtDNA analyses several authors have shown that the Mediterranean Sea hosts loggerhead turtle populations which are genetically differentiated from the Atlantic ones, and the Mediterranean haplotypes are limited to a low number of interbreeding colonies (see e.g. Bowen & Karl, 2007). This evidence clearly indicates that the Mediterranean populations are of particular conservation relevance (Bowen et al., 1993; Laurent et al., 1993; Schroth et al., 1996; Giacoma et al., 2011).

In the Mediterranean basin nesting areas of the species are known especially along the eastern coasts (Greece, Turkey, Cipro, Syria, Israel, Egypt, Italy). In Italy the loggerhead turtle is known to nest on Linosa and Lampedusa islands (Pelagic Archipelago), and in some localities along the coasts of Calabria, Apulia (southern Italian Peninsula) and Sicily (see Balletto et al., 2003; Scaravelli & Tripepi, 2006; Marzano et al., 2010; Mingozzi, 2010; Giacoma et al., 2011; Casale et al., 2012). According to Piovano et al. (2004), Mingozzi et al. (2007) and Casale et al. (2012) the number of nesting areas of *Caretta caretta* in Italy is probably underestimated, and thus it would be necessary to carry out ad hoc investigations in suitable areas to get data on new potential/actual nesting sites, especially along the Adriatic coast of the Italian Peninsula. Following this suggestion and based on some field observations indicating the recent finding of many stranded adults of loggerhead turtle in some sites of the coastline of Molise (Capula et al., 2010; Affronte M., pers. comm.; Lucchese L., pers. comm.), we investigated the potential occurrence of nesting areas for *Caretta caretta* by analysing 38 km of sandy beaches along the Adriatic coast of Molise and by developing a suitability GIS model for *Caretta caretta* nesting sites. Suitability models or Species Distribution Models can be either deterministic, i.e. expert based, when a sufficient knowledge on the ecological requirements of a species in a given area are available, or inferential, when a sufficient number of occurrence data is available (Corsi et al., 2000; Boitani et al., 2002; Catullo et al., 2008; Rondinini & Chiozza, 2010). As the number of nesting sites in Italy would not offer a significant sample size to produce an inferential model (Boitani et al., 2002; 2008; Catullo et al., 2008; Rondinini & Chiozza, 2010), we produced an expert based distribution model on the basis of the available information regarding nesting areas of the loggerhead turtle in Italy.

## MATERIALS AND METHODS

### Study area

The present investigation was carried out along the Adriatic coast of Molise, taking into account all available data on landscape, vegetation and soil structure. Molise coastal line is 38 km long, ranging from the mouth of the river Trigno to the mouth of the river Saccione, and 90% of it is represented by sandy beaches and coastal dunes. Most of the Molise coastal dunes of high conservation interest are currently included in the following Sites of Community Importance (SIC): (1) Foce Trigno-Marina di Petacciato (SIC IT7228221); (2) Foce Biferro-Litorale di Campomarino (SIC IT7222216); (3) Foce Saccione-Bonifica Ramitelli (SIC IT7222217).

### Experimental protocol

The distribution model for the suitability of nesting areas of *Caretta caretta* along the Adriatic coast of Molise was produced within a GIS environment, by combining a series of fine scale thematic layers (1:5000) produced ex-novo to describe the distribution of environ-

mental factors which are known to affect positively or negatively nesting of the loggerheads. Layers were produced through visual interpretation of recent digital high resolution (0,5 m) color orthophotos (2007 flight), which were kindly provided by the Italian Dipartimento della Protezione Civile, using ESRI.ArcGis10. Each cartographic element (point, line or polygon) which was considered to have either a negative or positive effect on loggerheads nesting sites was buffered based on the radius of its influence on the surrounding landscape (Witherington & Martin, 2000; Scaravelli & Tripepi, 2006). Then, a suitability value ranging from 0 (not suitable) to 1 (suitable) was assigned to each buffer area. Each layer was then filtered following a dichotomic process as shown in Fig. 1. According to Scaravelli & Tripepi (2006) fine-grained sand substrates located ~10-15 m from the shoreline are usually experienced by loggerheads as preferential nesting areas. Based on this evidence, a 30 m buffer was first drawn along the coastline, considering ~10 m of tide oscillation. The area inside the buffer was considered as suitable (value 1), while the territory outside the buffer was considered unsuitable (value 0) (see Fig. 1). In a second step, the non-sandy areas within the buffer (i.e. estuary, eroded coast, gravels, rocks) were considered unsuitable and excluded from further analysis. Anthropogenic disturbance was evaluated by considering two factors:

- 1) light pollution, which is known to interfere with visual orientation during the seafinding of hatchlings (Salmon et al., 1995; Witherington & Martin, 2000);
- 2) noise disturbance.

To introduce the above mentioned disturbance factors in the distribution model, a 100 m buffer of unsuitable areas was drawn around the urban areas because of their intense light pollution. Moreover, in order to include the effects of noise on the distribution of potential loggerhead nesting sites, a non suitable buffer of 50 m was drawn around human buildings and parking areas; in addition, a non suitable buffer of 30 m was drawn also around the suburban roads.

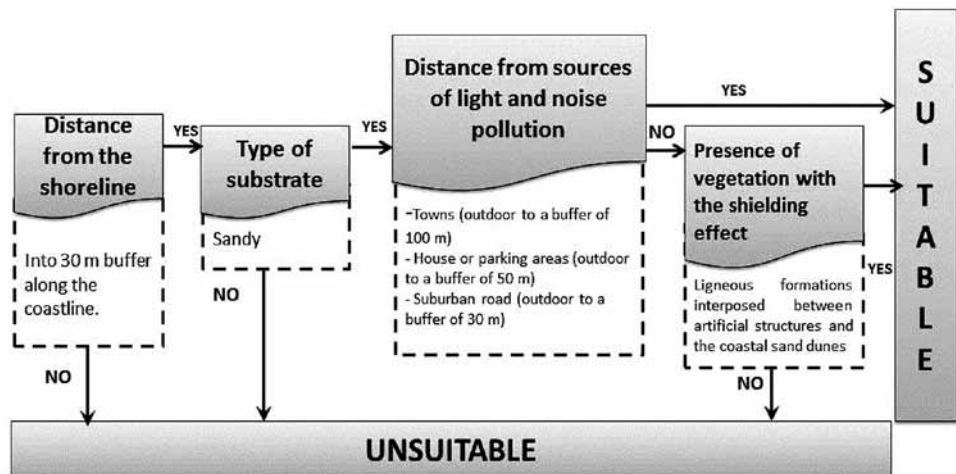


Fig. 1 – Schematic representation of the procedure for modeling the potential nesting areas of *Caretta caretta* along the Adriatic coast of Molise (see Materials and Methods for detailed explanation).

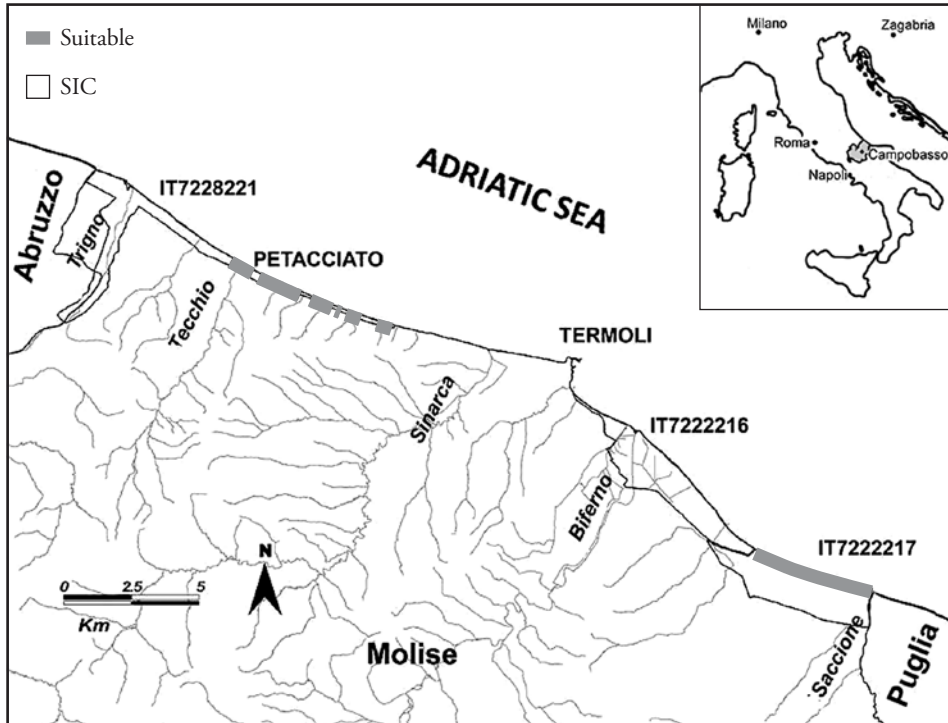


Fig. 2 – Suitable nesting areas for *Caretta caretta* along the Adriatic coast of Molise. The perimeters of the Sites of Community Importance (Foce Trigno-Marina di Petacciato; SIC IT7228221; Foce Biferno-Litorale di Campomarino, SIC IT7222216; Foce Saccione-Bonifica Ramitelli, SIC IT7222217) are also indicated. The thickness of the suitable areas is shown out of scale to allow better viewing.

## RESULTS

Figure 2 shows the distribution of potential nesting areas for *Caretta caretta* along the Adriatic coast of Molise resulting from the GIS expert based model analysis. The highly suitable areas - which can be defined as optimal habitats - occur on six kilometers of the coastline only, while the rest of the regional coastal territory resulted to be not suitable. The suitable areas are divided into seven sectors, which are included in two Sites of Community Importance: Foce Trigno-Marina di Petacciato (SIC IT7228221), and Foce Saccione-Bonifica Ramitelli (SIC IT7222217).

The length of each suitable sector varies from a minimum of 300 m to a maximum of 2850 m. In the northern portion of the coast (SIC Foce Trigno-Marina di Petacciato) only fragmented tracts of suitable nesting areas were found. The total length of these areas is 3232 m. At the SIC Foce Saccione-Bonifica Ramitelli (southern coast of Molise) the distribution of potential nesting areas is concentrated in a single, very interesting site 2850 m long, which is close to the mouth of the river Saccione (see Fig. 2). However, it must be noted that at this SIC a recent process of marine erosion is damaging the whole coastal line (see Iannantuono, 2002; Aucelli et al., 2003).

## DISCUSSION

Our data clearly indicate that some potential nesting areas for *Caretta caretta* still persist along the Adriatic coast of Molise, fulfilling the need to correctly orient the monitoring efforts on *Caretta caretta* in Italy (see Piovano et al., 2004; Mingozzi et al., 2007) and providing a better estimate method to recognize potential/actual nesting sites of the species. The sites identified via GIS expert based model analysis are characterized by a very reduced surface (no more than 6 km out of 38 km of the Molise Adriatic coastline) and, in addition, are threatened by human activities and by marine erosion processes in action. These evidences indicate that the coastal areas of conservation interest identified in this paper are in need of urgent protection measures primarily aimed to reduce the process of marine erosion and human disturbance (light and noise pollution). In this respect it must be noted that the potential nesting sites for *Caretta caretta* are located in two Sites of Community Importance and are the last stretches of natural pristine landscape occurring along the Adriatic coast of Molise (see e.g. Carranza et al., 2004; Di Iorio et al., 2005; Izzi et al., 2007; Stanisci et al., 2007). Although the presence of physically suitable beaches for nesting detected by beach surveys does not always indicate the effective occurrence of nesting (see e.g. the suitable beaches found in Albania and in the southern coast of Croatia, where no sea turtle tracks or nesting activity were recorded to date; Casale & Margaritoulis, 2010), based on the results provided in this paper field investigations in the areas identified as potential nesting sites are needed and strongly recommended in order (i) to ascertain actual nesting of *Caretta caretta* in Molise, (ii) to validate the GIS expert based model and the robustness of our hypothesis, and (iii) to improve the model itself for further investigations concerning potential/actual nesting sites of *Caretta caretta* in other Mediterranean sandy shores.

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## RIASSUNTO

### **Identificazione di aree potenziali di ovodeposizione di *Caretta caretta* lungo la costa del Molise mediante modelli di idoneità ambientale**

La Tartaruga comune *Caretta caretta* è una specie pelagica a distribuzione cosmopolita attualmente in pericolo di estinzione. Nel bacino del Mediterraneo le aree note di nidificazione della specie sono distribuite prevalentemente lungo le coste orientali, inclusa l'Italia. Nel nostro Paese i siti di ovodeposizione sono attualmente noti in alcune aree della Calabria, della Puglia e della Sicilia e per le isole di Lampedusa e Linosa. Al fine di individuare nuovi siti di nidificazione di *Caretta caretta* lungo le coste italiane, nel presente lavoro è stato prodotto un modello di idoneità ambientale analizzando le caratteristiche dell'intera costa adriatica del Molise (38 km). Il modello è stato sviluppato in ambiente GIS, utilizzando un approccio deterministico (expert based) e prendendo in considerazione cinque variabili ambientali: la geomorfologia (tipologia di substrato e distanza dalla linea di costa), la vegetazione presente e i fattori di disturbo antropico (inquinamento luminoso e tipologia delle infrastrutture presenti sulle spiagge). Sulla base di questa analisi è stato possibile identificare due aree potenziali di

nidificazione di *Caretta caretta*: la prima, sita nella parte meridionale del Molise, è costituita da un tratto continuo di costa lungo 2850 m, mentre la seconda, posta nella parte settentrionale della regione, consta di 6 aree frammentate e contigue, lunghe complessivamente 3232 m. Tutte le aree risultate idonee si trovano all'interno di due Siti di Importanza Comunitaria (Foce Trigno - Marina di Petacciato, SIC IT7228221, Foce Saccione-Bonifica Ramitelli, SIC IT7222217). Al fine di (i) accertare se nei tratti di costa del Molise individuati nel presente lavoro avvenga o meno la nidificazione di *Caretta caretta* e (ii) validare il modello di idoneità utilizzato per le analisi (GIS expert based) sarà necessario compiere al più presto delle ricerche mirate ed approfondite nel corso del periodo riproduttivo della specie.

## REFERENCES

- Aucelli, P.P.C., Iannantuono, E. & Roskopf, C.M., (2003). Evolutive trends and present morphodynamics along the Molise coast and their relationship to shore protection structures (Southern Italy). 4<sup>th</sup> European Congress on Regional Geoscientific Cartography and Information Systems, Bologna, Giugno 2003: 157-159.
- Balletto, E., Giacoma, C., Piovano, S., Mari, F. & Dell'Anna, L. (2003). Piano d'Azione per la conservazione della tartaruga marina *Caretta caretta* nelle isole Pelagie. Edi.tur srl, 60 pp.
- Boitani, L., Falcucci, A., Maiorano, L. & Montemaggiori, A. (2002). Rete Ecologica Nazionale: il ruolo delle aree protette nella conservazione dei vertebrati. Dip. B.A.U. Università di Roma "La Sapienza", Dir. conservazione della Natura, Ministero dell'Ambiente e della Tutela del Territorio, Istituto di Ecologia Applicata. Roma.
- Boitani, L., Sinibaldi, I., Corsi, F., De Biase, A., d'Inzillo Carranza, I., Ravagli, M., Reggiani, G., Rondinini, C. & Trapanese, P. (2008). Distribution of medium- to large-sized African mammals based on habitat suitability models. *Biodiversity and Conservation* **17**: 605–621.
- Bowen, B.W., Avise, J.C., Richardson, J.I., Meylan, A.B., Margaritoulis, D. & Hopkins-Murphy, S.R. (1993). Population structure of loggerhead turtles (*Caretta caretta*) in the northwestern Atlantic ocean and Mediterranean Sea. *Conservation Biology* **7**: 834–844.
- Bowen, B.W. & Karl, S.A. (2007). Population genetics and phylogeography of sea turtles. *Molecular Ecology* **16**: 4886-4907.
- Capula, M. (1998). Tartaruga marina comune - *Caretta caretta*. In: Bulgarini F., Calvario E., Fraticelli F., Petretti F., Sarrocco S. (eds), Libro Rosso degli Animali d'Italia - Vertebrati. Roma, WWF Italia: 49.
- Capula, M., Carafa M., De Liso L. & Loy, A. (2010). Il Progetto Atlante degli Anfibi e Rettili del Molise. In: Di Tizio L., Di Cerbo A.R., Di Francesco N., Cameli A. (eds), Atti VIII Congresso Nazionale Societas Herpetologica Italica, Chieti, 22-26 Settembre 2010, Pescara, Ianieri Edizioni: 37-49.
- Carranza, M.L., Acosta, A. & Giancola, M. (2004). Analisi del paesaggio costiero del Molise. *Estimo e Territorio* **12**: 39-43.
- Casale, P. & Margaritoulis, D. (Eds)(2010). Sea turtles in the Mediterranean: Distribution, threats and conservation priorities. Gland, Switzerland, IUCN, 294 pp.
- Casale, P., Palilla, G., Salemi, A., Napoli, A., Prinzi, M., Genco, L., Bonaviri, D., Mastrogiacomo, A., Oliverio, M. & Lo Valvo M. (2012). Exceptional sea turtle nest records in 2011 suggest an underestimated nesting potential in Sicily (Italy). *Acta Herpetologica* **7**: 181-188.
- Catullo, G., Masi, M., Falcucci, A., Maiorano, L., Rondinini, C. & Boitani, L. (2008). A gap analysis of Southeast Asian mammals based on habitat suitability models. *Biological Conservation* **141**: 2730-2744.
- Corsi, F., De Leeuw, J. & Skidmore, A. (2000). Modeling species distribution with GIS. In: Boitani L. & Fuller T. (eds), *Research Techniques in Animal Ecology. Controversies and Consequences*, **11**: 389-434.
- Di Iorio, A., Stanisci, A., Acosta, A., Vergalito, M. & Lucarelli M. (2005). Caratteri ecologico-funzionali di alcune specie del litorale sabbioso molisano. *Informatore Botanico Italiano* **37**: 204-205
- Gerosa, G. & Casale, P. (1999). Interaction of marine turtles with fisheries in the Mediterranean. *Mediterranean Action Plan - UNEP Regional Activity Centre For Specially Protected Areas* 12-17.
- Giacoma, C., Balletto, E., Bentivegna F., Guarino, F.M., Hochscheid, S., Maio, N., Mingozzi, A.T., Piovano, S.

- & Scaravelli, D. (2011). *Caretta caretta* (Linnaeus, 1758). In: Corti C., Capula M., Luiselli L., Razzetti E., Sindaco R. (eds), Fauna d'Italia. Vol. XLV, Reptilia. Bologna, Calderini - Edizioni Calderini de Il Sole 24 ORE S.p.A.: 210-219.
- Iannantuono, E. (2002). Studio della dinamica della costa molisana dal 1954 ad oggi attraverso l'analisi geomorfologica e climatica. Tesi di laurea inedita, Università degli studi del Molise.
- IUCN (2012). IUCN Red List of Threatened Species. Version 2012.1: [www.iucnredlist.org](http://www.iucnredlist.org) (accessed July 26<sup>th</sup>, 2012).
- Izzi, C.F., Acosta, A., Carranza, M.L., Carboni, M., Ciaschetti, G., Conti, F., Del Vecchio, S., Di Martino, L., Frattaroli, A., Pirone, G. & Stanisci A. (2007). Entità a rischio negli ambienti dunali costieri di alcune regioni dell'Italia centrale. *Fitosociologia* **44**, suppl. 1: 251-254.
- Laurent, L., Lescure, J., Excoffier, L., Bowen, B, Domingó, M., Hadjichristophorou, M., Kornaraky, L. & Trabuchet, G. (1993). Genetic studies of relationships between Mediterranean and Atlantic populations of loggerhead turtles *Caretta caretta* with a mitochondrial marker. *C. R. Académie des Sciences Paris* **316**: 1233-1239.
- Marzano, G., Nannarelli, S. & Scarafino, C. (2010). Documentata nidificazione di *Caretta caretta* lungo il litorale leccese (Puglia). In: Di Tizio L., Di Cerbo A.R., Di Francesco N., Cameli A. (eds), Atti VIII Congresso Nazionale Societas Herpetologica Italica, Chieti, 22-26 Settembre 2010, Pescara, Ianieri Edizioni: 559-562.
- Mingozzi, T. (2010). Nidificazione della Tartaruga marina *Caretta caretta* in Italia: Sintesi dei dati 2005-2009. In: Di Tizio L., Di Cerbo A.R., Di Francesco N., Cameli A. (eds), Atti VIII Congresso Nazionale Societas Herpetologica Italica, Chieti, 22-26 Settembre 2010, Pescara, Ianieri Edizioni: 525-530.
- Mingozzi, T., Masciari, G., Paolillo, G., Pisani, B., Russo, M. & Massolo, A. (2007). Discovery of a regular nesting area of loggerhead turtle *Caretta caretta* in southern Italy: a new perspective for national conservation. *Biodiversity and Conservation* **16**: 3519–3541.
- Panou, A., Antypas, G., Giannopoulos, Y., Moschonas, D., Mourelatos, G., Mourelatos, C., Toumazatos, P., Tselentis, L., Voutsinas, N. & Voutsinas, V. (1992). Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. *Testudo* **3**: 1-6.
- Piovano, S. , Nicolini, G. , Nannarelli, S., Dominici, A, Lo Valvo, M. & Di Marco, S. (2004). Analisi delle deposizioni di *Caretta caretta* sui litorali italiani. In: Zuffi M. (Ed.), Societas Herpetologica Italica, Atti del V Congresso Nazionale, Calci (Pisa), 29 settembre - 3 ottobre 2004: 199-205.
- Pritchard, P.C.H. & Mortimer, J.A. (1999). Taxonomy, external morphology, and species identification. In: Eckert K.L., Bjorndal K.A., Abreu-Grobois F.A. & Donnelly M. (eds.), *Research and Management Techniques for the Conservation of Sea Turtles*, IUCN/SSC Marine Turtle Specialist Group Publication No. 4: 21-38.
- Rondinini, C. & Chiozza, F. (2010). Quantitative methods for defining percentage area targets for habitat types in conservation planning. *Biological Conservation* **143**: 1646–1653.
- Salmon, M. & Witherington, B.E. (1995). Artificial lighting and seafinding by loggerhead hatchlings: evidence for lunar modulation. *Copeia* **1995** (4): 931-938.
- Scaravelli, D. & Tripepi, S. (2006). *Caretta caretta*. In: Sindaco R., Doria G., Razzetti E., Bernini F. (eds), *Atlante degli Anfibi e dei Rettili d'Italia / Atlas of Italian Amphibians and Reptiles*. Firenze, Societas Herpetologica Italica, Edizioni Polistampa: 400-403.
- Schroth, W., Street, B. & Schierwater, B. (1996). Evolutionary handicap for turtles. *Nature* **384**: 521- 522.
- Stanisci, A., Acosta, A., Carranza, M.L., Feola, S. & Giuliano, M. (2007). Gli habitat di interesse comunitario sul litorale molisano e il loro valore naturalistico su base floristica. *Fitosociologia* **44**: 171-176.
- Witherington, B. E. & Martin, R. E.. (2000). Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. Second edition. Florida Marine Research Institute Technical Report TR-2, 73 pp.