Dottorato di Ricerca in Biologia Ambientale ed Evoluzionistica
Curriculum Biologia Animale
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# SOME LIKE IT HOT (OR NOT?): GLOBAL CHANGES AND CONSERVATION OF CHELONIIDAE IN THE MEDITERRANEAN SEA

## STATE OF THE ART

A major research program in ecology and conservation is to understand the consequences of global changes for population and communities (Gotelli & Stanton-Geddes, 2015; Sage, 2020). Climate and land use changes represent the most imminent threats to biological communities and to the functions they perform within ecosystems (Sala et al., 2000; Pereira et al., 2010).

Marine ecosystems are being extremely impacted by increasing concentrations of carbon dioxide ($CO_2$) in atmosphere and other greenhouse gases of human origin. This causes an increase in the greenhouse effect, which leads to an increase in temperature. The latter leads to a series of consequences such as ocean acidification, changes in oceanic circulation and chemistry, the melting of polar ice, leading to the rising sea level, increased storm intensity, as well as changes in the diversity and abundance of marine species (Bischof, 2000; Boyd & Doney, 2003).

The Mediterranean Sea is one of the most vulnerable regions in the world to the impacts of global warming, given that all sub-regions of the Mediterranean Basin, on land and in the sea, have already been heavily impacted by historical and recent anthropogenic changes. Annual mean temperatures on land and sea in the Mediterranean Basin are 1.5°C higher than in pre-industrial times (Cramer et al., 2018; MedECC, 2020). Furthermore, the coasts of Mediterranean are for the most part inhabited, with about 450 million people (UNEP-RAC, 1995).

Exploring and understanding the effects of climate changes on ecological processes is essential for the development of a better understanding of the dynamics of the wild population (Hallett et al., 2004). However, the task is particularly difficult when dealing with species like the sea turtles, which depends on both terrestrial and marine habitats, have a migratory life stage, complex life cycles, and a sex determination that is based on incubation temperature (Pritchard, 1997). I will focus my research project on the understanding of global change impacts on sea turtles in the Mediterranean basin.

Globally, all sea turtles are classified as “Vulnerable”, “Endangered”, or “Critically Endangered” by the international IUCN Red List, with the only exception of the flatback sea turtle (*Natator depressus*) which is listed as "Data Deficient". All species are listed in CITES Appendix I, restricting international trade of sea turtles and sea turtle products. Three species are commonly present in the Mediterranean basin (Casale & Margaritoulis, 2010): the leatherback turtle (*Dermochelys coriacea*), the green turtle (*Chelonia mydas*), and the loggerhead turtle (*Caretta caretta*). Only the last two of them breed in the Mediterranean and their populations have only a limited gene flow with those breeding along the Atlantic coasts (Encalada et al., 1996; Laurent et al., 1998). The leatherback turtle is only present in the Mediterranean with vagrant individuals, probably of Atlantic origin (Laurent, 1998; Casale et al., 2003).

I will use the two species of Cheloniidae, *Caretta caretta* and *Chelonia mydas*, regularly nesting along the Mediterranean shores, as model species to explore the potential impacts of global changes in the basin, including both marine and terrestrial elements. All Cheloniidae are considered keystone species, playing important ecological roles and influencing several species (Butler et al., 2012). Cheloniidae can control their prey*, C. caretta* helps manage the jellyfish blooms, *C. mydas*, grazing on seagrass, keeps seagrass beds healthy. They provide habitat for an array of species, like barnacles and other small crustaceans, remoras, algae, and diatoms, helping to transport them during their migrations. Moreover, they have a life cycle with both terrestrial and aquatic phases (Barnosky et al., 2011), and therefore I will be able to provide a comprehensive and coordinated picture which is rarely available in the literature.

The effects of global change are potentially enormous for sea turtles. Sea level rise from the melting of polar ice is already contributing to the loss of beach and sea turtle nesting habitat (Fuentes et al., 2011), and extreme weather events contribute even further to beach erosion (Pike, 2007). Hotter sand (linked to increasing temperatures) can completely alter population biology for the species which have a temperature-based sex determination. In fact, extreme hot summers can drive to complete nest failure or at least to decreased hatching rates (Pike, 2014). Increased sand temperatures also affect hatchlings by altering natural sex ratios, with hotter temperatures producing more female hatchlings (Laloë et al., 2016). Altered ocean currents (Rahmstorf, 1997), which play an important role in animal dispersal (Lohmann & Lohmann, 2008; Witt et al., 2010), can influence the future of young hatchlings during the development phase (Hamann et al., 2013), how to alter the current foraging habitat (Bjorndal, 1985; Meylan, 1988; Davenport, 1998; Polovina et al., 2004). Although our understanding of the potential impacts of climate change on sea turtles has increased in the last decades, several knowledge gaps still exist, especially in the Mediterranean Sea, and I will focus my research on these gaps.

**OBJECTIVES**

The main aim of my project is to study and predict how global changes will affect the distribution and biology of *Caretta caretta* and *Chelonia mydas* in the Mediterranean Sea during their entire life cycles, and to provide a complete conservation plan including explicitly existing EU policies.

To achieve this aim, I will explore 3 specific research objectives:

1. Which climatic and land-use factors influence the distribution of nests and nesting habitat in the Mediterranean Sea? Can the impact of climate change on nesting physiology alter population biology for the species?
2. Can the possible alteration of ocean currents due to climate change influence the dispersion of young hatchlings?
3. Can the impact of climate change influence the distribution of foraging areas for adult animals?

**RESEARCH METHODOLOGY**

<u>Objective 1: Impact of climate change on the distribution of nesting habitat and nesting physiology</u>

I will collect nesting data from bibliographic sources, monitoring programs, and citizen science. The data collected will be organized in a database containing: the names of the place where the nests are located, the geographical coordinates, the number of nests, the year in which the nests were laid and the length of the beach. Data on the presence of nests will be coupled in a multi-temporal calibration approach (Maiorano et al., 2013) with both marine and land environmental variables, going from proxies for human pressures on beaches (e.g., tourist settlements, light pollution, etc.) to climate variables (e.g., sea surface temperature, temperature at the atmosphere, salinity, etc.). I will also consider nesting physiology and sex determination, I will collect in the field a database on nest parameters including physical characteristics (i.e., nest location, distance to water/vegetation, nest depth, etc.) and biological characteristics (clutch size, hatching success, hatchling biometrics). Furthermore, I will measure sand temperature and humidity using the HOBO U23 Pro v2 Temperature/Relative Humidity Data Loggers. These data loggers will be buried near nests at depths between 30 and 50 cm, which is a typical nesting depth for a sea turtle. In the same locations I will also collect local climate data (e.g., sea surface temperature, air temperature, etc). I will take advantage of the recently developed microclimate models (e.g., Kearney & Porter, 2017) and of their applications to the modelling of beach sand temperatures (e.g., Bentley et al., 2020), particularly important for the determination of sex.

<u>Objective 2: Influence of climate change on the dispersion of young hatchlings</u>
I will use state-of-the-art ecological models coupled with physical/oceanographical models (e.g., Putman et al., 2020), collaborating with the research group of Dr. Daniele Iudicone, physical oceanographer at the Stazione Zoologica Anton Dohrn (Naples). The data on mortality, hatching success, etc. already collected (see point above) will be considered together with oceanographic data for the Mediterranean Sea (e.g., currents, waves, tides, sea level, etc.). The dispersal of young sea turtles during their oceanic stage will be simulated using mechanistic movement models (Lett et al., 2008).

<u>Objective 3: Impact of climate change on the distribution of foraging areas</u>
Data on adult turtles obtained through satellite telemetry will be provided through a collaboration with Dr. Sandra Hochscheid, researcher at the Stazione Zoologica Anton Dohrn. Oceanographic and climate variables (e.g., sea surface temperature, sea surface current, bathymetry, etc.) will be obtained through existing databases (e.g., Marspec, Bio-Oracle, …). Data on animal movements will represent the source of information for the development of a habitat suitability model (HSM) (Coyne & Godley, 2005; Hawkes et., al 2007).

Finally, I will combine all these different models into a comprehensive map of overall suitability. Building a systematic conservation plan for Cheloniidae in the Mediterranean, I will use specifically tools like Marxan with Zones, Zonation ( Watts et al., 2009; Ball et al., 2011) and I will run scenarios to identify effective protected areas suggesting best practice in the types of data used (Maiorano et al., 2009; Mazor et al., 2016).

Contingency plan:
My proposal includes the use of published data and of newly collected data. Published data is already available, and all collaborations are already defined. However, the collection of new data is based economically on a LIFE project, which is being submitted as a collaboration between Sapienza, Stazione Zoologica Anton Dohrn and Legambiente (plus others). The availability of travel funds from the LIFE will allow for a data collection scheme which includes multiple countries. If the LIFE proposal is not funded, I will use data already collected by the Stazione Zoologica Anton Dohrn and I will

contact other countries that already have these data (e.g., Greece, Turkey, etc.) to solicit for further collaborations. Regarding reliability of citizen science data, I will not use all the available data in a random way, but I will select each occurrence based on, for example, the knowledge of expert researchers in the studied species.

The expected results that I will publish as separate papers are:

- A model predicting the current and future potentially suitable areas for the two species considered. I expect that climate suitability will be increasing through time in the western part of the Mediterranean basin, while it will decrease going towards the eastern part. The potential importance of the western Mediterranean beaches as possible nesting range for the sea turtles in the face of global warming would represent an important result to assist turtle conservation in a critical phase of a possible colonization event;
- A model predicting the impact of climate change on nesting physiology for the two species. As air temperatures rise, sand temperatures also increase, and this clearly affects hatchlings and alter sex ratios. Hotter temperatures will produce more female hatchlings in both species causing thus important effects on sea turtle populations;
- A model predicting density of juveniles and dispersal routes. Limited info is available on juvenile's distribution and dispersal and therefore this input will represent a fundamental gap filling for the Mediterranean basin. It will be also important to compare results for the two species to find out co-occurrences and/or particularities for the two species;
- A habitat suitability model for the foraging areas of the two species of sea turtles. I expect that both species will move their foraging habitat towards cooler regions, basically migrating in an opposite direction compared to the nesting period and therefore creating an opposite trend from two stages of the same life cycle;
- An integrated model for both species, including all fundamental aspects of the entire life cycle to be used for the management and conservation of Cheloniidae in the Mediterranean Sea.

**GANTT CHART**

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| collecting nesting data and creating database | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| collecting oceanographic data | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | |
| microclimate model calibration | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | | |
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| mechanistic movement model calibration | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | |
| writing and submitting third paper | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | | | | | |
| collecting satellite telemetry data of adult turtles | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | |
| habitat suitability model calibration | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | | |
| writing and submitting fourth paper | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | |
| creating an integrated models database | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | | | |
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