

Extent of Occurrence, Area of Occupancy, and Species Distribution Model of striped dolphin within the Gulf of Corinth (Greece)

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Abstract - The striped dolphin (*Stenella coeruleoalba*) is one of the most abundant cetaceans of the Mediterranean Sea, nevertheless it is classified as a “vulnerable” species for the Mediterranean basin, according to IUCN experts. Information about its distribution, population size, interaction with human activities, are crucial for its conservation. The Gulf of Corinth is a Protected Area that belongs to the European Network “Natura 2000”, and that is classified as an Important Marine Mammal Area, for the presence in its waters of the following species of cetaceans: striped dolphin (*Stenella coeruleoalba*), common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*). Striped dolphin is the most abundant species of the Gulf. It may be sighted in single species group or in mixed group with common dolphin and/or Risso’s dolphins. Investigating striped dolphin distribution within the Gulf of Corinth it is crucial for the conservation of this protected species in this Protected Area. During the summers of the years from 2009 to 2017, 168 surveys were carried out for monitoring striped dolphins’ presence and distribution. 194 sightings of striped dolphins were realised. In order to investigate the distribution of striped dolphin within the Gulf of Corinth three different approaches have been employed: Species Distribution Model, Extent of Occurrence, Area of Occupancy. A Species Distribution Model was developed by employing Maxent. The Extent of Occurrence and the Area of Occupancy of the species were identified with QGIS. A comparison between the area highlighted with the three different geographical approaches was then carried out. This study shows that Extent of Occurrence and Area of Occupancy are useful tools that could be integrated with the results of a Species Distribution Model for a better conservation of a species within an investigated area.

I. INTRODUCTION

The striped dolphin (*Stenella coeruleoalba*) is a cosmopolitan species found in pelagic and tropical waters. In the Mediterranean Sea, it is considered the most abundant cetacean species, nevertheless its conservation status is classified as “Vulnerable” [1].

The Gulf of Corinth presents favourable characteristics to the presence of the striped dolphin. Indeed, it is characterized by deep waters and steep slopes. Previous studies conducted in the Gulf of Corinth showed the presence of single species striped dolphin groups, and of mixed groups, where striped dolphins are associated with common dolphins and exceptionally with Risso’s dolphin [2].

By employing geographical sightings data (coordinates), different areas of distribution, taken into consideration for the conservation of a species, can be determined: the Extent of Occurrence, which takes in consideration the Minimum Convex Polygon that includes all the sightings observed in an area; the Area of Occupancy, that is the portion of the area, within the Extent of Occurrence, occupied by the considered species.

Geographical information about the presence of a species could be also employed to model species distribution within a specific area in relation to different sets of variables: topographic, oceanographic, anthropogenic, etc.

In the present study the three different approaches have been employed for highlighting the most important areas for the conservation of the striped dolphin within the Gulf of Corinth.

II. METHODS

A. The area of study: the Gulf of Corinth

The Gulf of Corinth belongs to the Ionian Sea (Eastern Mediterranean) (Figure 1, 2). It is a semi-closed basin of 2400 km² [2]. The Rion Strait, which is 2km wide and 65m deep, links the Gulf to the Ionian Sea on its western side. The artificial channel of Corinth, with a maximum depth of 8m, leads to the Saronic Gulf and the Aegean Sea, on its eastern side.

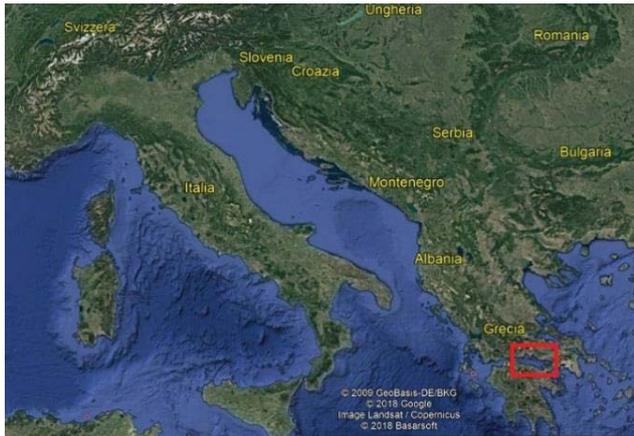


Figure 1: the red box shows the position of the Gulf of Corinth within the Eastern Mediterranean Sea

In Figure 2, bathymetry is indicated by variations of colour, from light blue (neritic waters) to dark blue (pelagic waters).

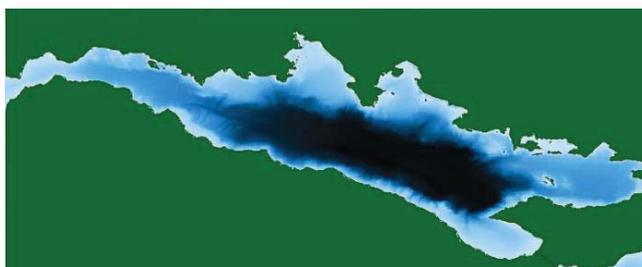


Figure 2: Gulf of Corinth's bathymetry

Even if it is a semi-closed basin, the Gulf of Corinth presents a high variety of marine habitats, including pelagic waters, with upwelling currents induced by the wind [3]. Due to that the Gulf of Corinth offers the perfect conditions for the survival of many cetacean species, particularly of the pelagic striped dolphin.

The Gulf of Corinth is a Protected Area that belongs to the European Network "Natura 2000" due the presence in its waters of: bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), common dolphin (*Delphinus delphis*), loggerhead sea turtle (*Caretta*

caretta), green sea turtle (*Chelonia mydas*). Due to

presence of highly vulnerable cetaceans the Gulf of Corinth is also classified an Important Marine Mammal Area (IMMA) by IUCN Marine Mammal Protected Areas Task Force.

B. Data collection

Geographical data about striped dolphin presence and distribution were collected from a 12m sailing boat, during the summer seasons of the years 2009-2017. Monitoring activity was always conducted by a minimum of two observers, in standard weather conditions (Beaufort ≤ 3 , Douglas ≤ 3 , visibility ≥ 5 miles). Information about date, daytime, weather conditions, geographic coordinates, group size (number of specimens) and depth (m) were recorded for each sighting.

To analyse striped dolphins' distribution, the study area was overlapped by a grid with cells of 1x1 kilometre, with oceanographic conditions similar to the area around the monitored portion. Three topographic variables were selected for analysing striped dolphin's distribution: bathymetry, slope and distance from coastline. A mean value of each variable was attributed to each cell of the grid. Each variable was elaborated with QGIS software starting from a bathymetry raster file with 180x180 meters of resolution. Monitoring effort (kilometres) and encounter rate (number of sightings/kilometres of effort in a cell) were also calculated for each 1km² cell of the grid.

C. Species Distribution Model

Distribution models are used to develop hypothesis about ecological processes that determine the distribution of a species in a defined area. The analysis of the distribution of anthropic activities and their overlapping with hotspots of biodiversity allows highlighting which are the best ways to manage and protect a particular species. The environmental factors selected by the model are those which are the most important for the distribution of a species.

For the purpose of the present study a predictive map of suitable habitat distribution of the striped dolphins was obtained in R studio (dismo library) with Maxent (ver. 3.4.1, [4]) using sighting coordinates and the three rasters of the considered topographic variables. A default options with 10'000 background points was then employed.

D. Extent of Occurrence (EO) and Area of Occupancy (AO)

According to the IUCN, the Extent of Occurrence is the area within the shortest continuous limit that can be

drawn to assemble all the presence points of a taxon, which means the Minimum Convex Polygon. The points can be linked with lines making sure they are not crossed. The Area of Occupancy is defined as the smallest essential area, in the extent of occurrence, for the survival of a taxon. Usually, it is determined by using a grid with 4 km² cells [5].

Using the coordinates registered during each sighting, the Extent of Occurrence was defined. Concerning the Area of Occupancy, a grid with cells of 1 km² was created, more accurate because of the small area taken in exam, and all the cells containing sighting were selected to determine the total Area of Occupancy.

III. RESULTS AND DISCUSSION

168 surveys were conducted from June 2009 to September 2017. 5812 km were monitored, and a total of 524 hours were spent looking for dolphins, with a total number of 194 realized sightings. Tables 1 and 2 respectively report information about survey effort (number of surveys, km and time spent looking for striped dolphins) and monitoring results (number of sightings and mean sighting frequency).

year	n° surveys	monitoring time (hours)	km tot
2009	18	47,80	564,36
2010	27	46,67	445,86
2011	31	92,71	971,52
2012	23	69,70	685,6
2013	6	17,63	150,12
2014	12	41,33	557,05
2015	16	40,08	829,98
2016	23	105,58	940,19
2017	12	62,68	667,7

Table 1: number of surveys, monitoring time and distance covered per year

year	n° sightings	mean sightings frequency
2009	28	0,30
2010	18	0,47
2011	37	0,46
2012	29	0,43
2013	7	0,30
2014	13	0,26
2015	13	0,41
2016	24	0,69
2017	21	0,44

Table 2: number of sightings and mean sightings frequency per year

A. The Species Distribution Model obtained with Maxent

Maxent model was performed to highlight suitable areas of distribution of striped dolphin within the Gulf of Corinth, employing sightings data and three topographic variables: depth, slope, distance from shore.

The obtained model is shown in Figure 3.

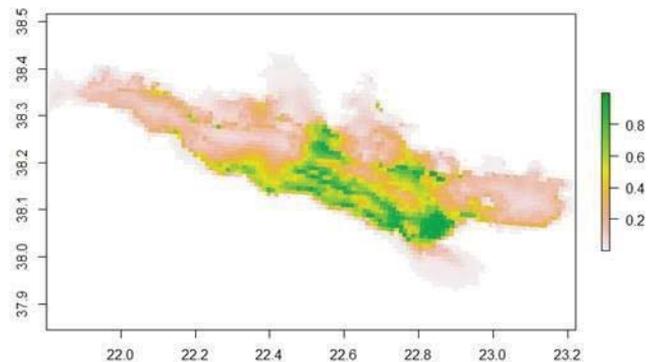


Figure 3: prevision model

The AUC (Area Under the ROC Curve) value for this model is 0,845, and it classifies the model as moderately accurate. Depth is the variable that contributes the most to the model (70.6%), followed by slope (14.9%) and distance from the shore (14.5%).

B. Delimitation of Extent of Occurrence and Area of Occupancy

Using the positions of all the sightings, the minimum convex polygon was defined connecting the ones that include all the other points. The determined Extent of Occurrence for striped dolphins of the Gulf of Corinth measures 634 km² and it is shown in Figure 4.

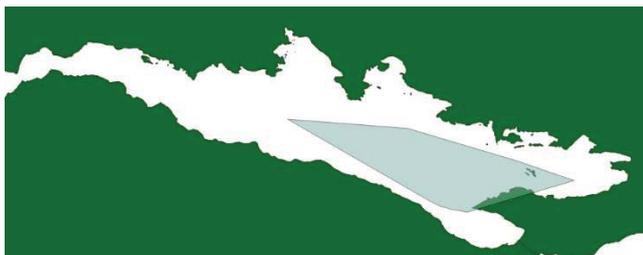


Figure 4: Extent of Occurrence

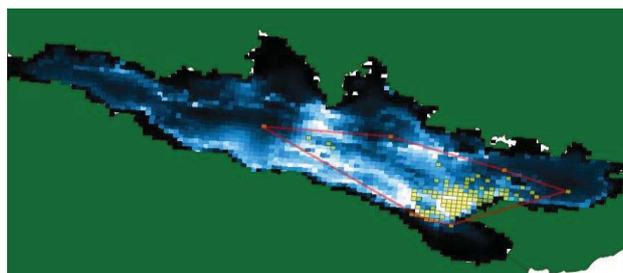


Figure 7: overlapping of the areas highlighted with the three geographical approaches

The reference grid with 1 km² cells allowed calculating the Area of Occupancy, which extension for the Gulf of Corinth is 96 km² (Figures 5-6).

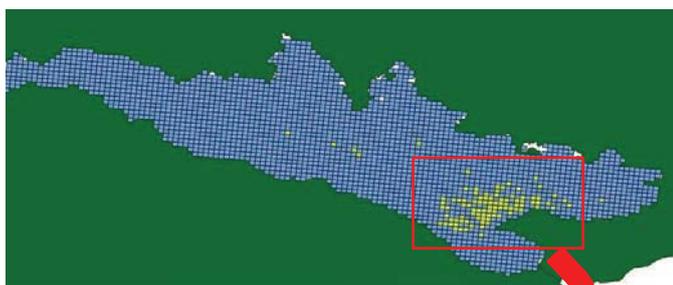


Figure 5: Area of Occupancy

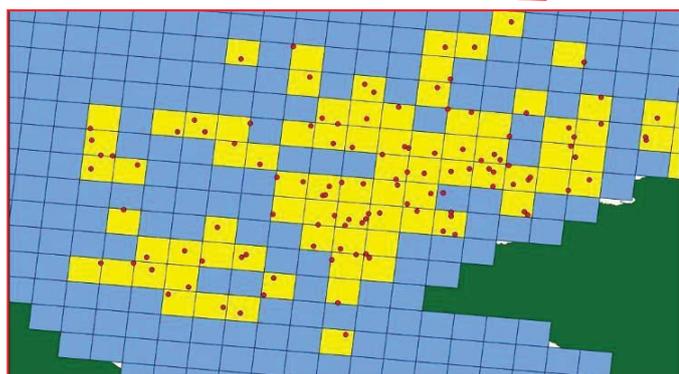


Figure 6: detail of Area of Occupancy

C. The comparison between the Species Distribution Model obtained with Maxent, the Extent of Occurrence, and the Area of Occupancy

By employing the software QGIS the area highlighted with the three different geographical approaches were overlapped. The result of this overlapping is shown in Figure 7.

The Species Distribution Model obtained employing Maxent highlights area that are not pointed out by the Extent of Occurrence and Area of Occupancy approaches, but that result highly suitable for the species. This area is located in the Northern and Southern portion of the Gulf of Corinth as well as in its Western one.

Therefore, the overlapping by the Species Distribution Model, the Extent of Occurrence, and the Area of Occupancy allowed defining some areas where a major attention should be paid in the future, intensifying monitoring activity.

On the other hand, some sightings fall in areas where the model highlights a low probability for the presence of the species in exam. A future introduction of a greater number of environmental and anthropic variables into the model could lead to a model that would better fit sighting data.

The determination of Species Distribution Model, Extent of Occurrence, and Area of Occupancy is essential to define the areas where management and protection efforts should be concentrated, and for assuring the conservation of the striped dolphin in the waters of the Gulf of Corinth.

IV. CONCLUSIONS

The present study shows that the Extent of Occurrence and the Area Occupancy are useful tool that could be integrated with the results of Species Distribution Model for a better conservation of a protected species within a Protected Area.

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