SPATIAL ANALYSIS OF CETACEAN STRANDINGS IN GREEK SEAS IN RELATION TO FISHING GROUNDS, POTENTIAL FEEDING GROUNDS AND SURFACE CIRCULATION

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Abstract

This study investigates the distribution and causes of cetacean strandings in Greek waters between 2010-2021. A total of 1378 strandings of 9 cetacean species were studied, using the stranding database of the Hellenic Center for Marine Research.

The study revealed clustered spatial distributions of strandings, with hotspot areas identified by species. Generalized additive models indicated a positive relationship between strandings and small scale fishing effort and a significant role of the coastline in recording stranding events. Additionally, the Leeway model was used to estimate the possible origin of strandings in the Pagasitikos gulf and surrounding areas. The study highlights the importance of understanding the factors contributing to cetacean mortality in the sea and the need for conservation measures to reduce direct human-induced threats such as entanglement in fishing gear and noise pollution.

Introduction

The Mediterranean region is home to a diverse array of cetacean species, including the Tursiops truncatus, Stenella coeruleoalba and Delphinus delphis[1]. However, these marine mammals are under threat from anthropogenic pressures such as overfishing, bycatch, pollution, climate change, and underwater noise. These threats have a significant impact on cetacean populations due to their long lifespan, low reproductive potential, small population sizes, and late maturity[1].

After death a cetacean carcass may float, or sink and later bloat to refloat if ambient temperature and pressure allow sufficient decomposition gas formation and expansion[2]. Various scenarios are possible: an animal could die at sea remaining there or floating ashore, or strand on a beach alive, where it dies and, if cast high enough, remain beached to be scavenged or decompose[2]. Strandings of cetacean carcasses can provide important information about species biodiversity in a region, the health and status of cetacean populations, , relative abundance and population trends, and the factors that lead to cetacean mortality.

This study aimed to investigate the spatial distribution of cetacean strandings in Greek coastal waters, Aegean and Ionian Seas, (a) by identifying cetacean stranding hotspots in the study area, (b) examine the relationship of fishing grounds and potential feeding grounds on strandings through modeling with Generalized Additive Models and (c) investigate the role of surface sea circulation on the drift of cetacean carcasses with Leeway model, in order to assess possible origin locations in an area after a stranding event.

Table 1. Best GAM model for each forward selection step. ssf25: The extent (km^2) of fishing grounds, rocky: % of rocky coastline, log coastline: logarithm of coastline length (km).

Selection step	Model terms	AIC	Deviance explained (%)
1	s(ssf 25)	1079.6	50.1
2	s(ssf 25) + s(rocky)	945.3	59.7
3	s(ssf 25) + s(rocky) + s(log coastline)	918.2	61.9

Materials and Methods

The study area is comprised of the entire coastal waters of Greek seas , located in eastern Mediterranean Sea. The study area was divided into 102 subareas, based on the high topographic complexity of the region, to assume homogenous coast characteristics and oceanographic conditions within each subarea (Figure 1).

The kernel density estimation (KDE) was calculated in order to determine spatial hotspots for the total strandings. Using rule of thumb, isotropic Gaussian kernel function was selected with fixed 10km smoothing bandwidth at 1x1 km pixel resolution. KDE map was normalized (0-1) and truncated from values <0.1 to allow for better visualization.

To model the potential relationships between cetacean strandings and the fishing pressure, potential feeding grounds and coastline, Generalized Additive Models (GAMs) were applied. The number of total strandings was used as dependent variable. For each subarea the following were used as independent variables: the percentage of rocky coastline, the coastline length (km), the extent (km^2) of the fishing grounds[3] and the extent (km^2) of the potential feeding grounds, expressed as bottom trawl undersized discarded catch[4]. The selection of the smooth predictor terms was done with a forward approach using penalized regression splines and Poisson distribution. The degree of smoothing was chosen based on the observed data and the restricted maximum likelihood (REML). The selection of the most appropriate model achieved through the minimization of the Akaike Information Criterion and deviance explained (%).

In order to assess the possible origin of a cetacean carcass after a stranding event, an approach of using the search and rescue (SAR) stochastic ensemble trajectory model, “Leeway model” [5]. The approach used, was selecting a subarea, the Pagasitikos gulf – Oreoi strait – Skiathos island, in central west Aegean Sea, where 9 positions of possible origin of cetacean carcass were selected. The Leeway model was run with each possible starting position for 8 days. The model shows the average drift path of the objects during the simulation period and the ending position at the end of simulation.

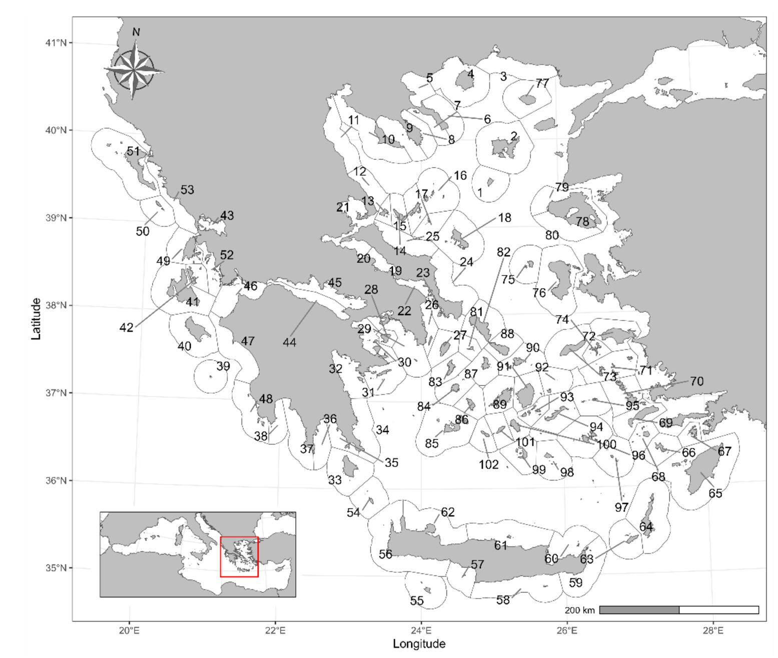

Figure 1. Study area with the 102 subareas division

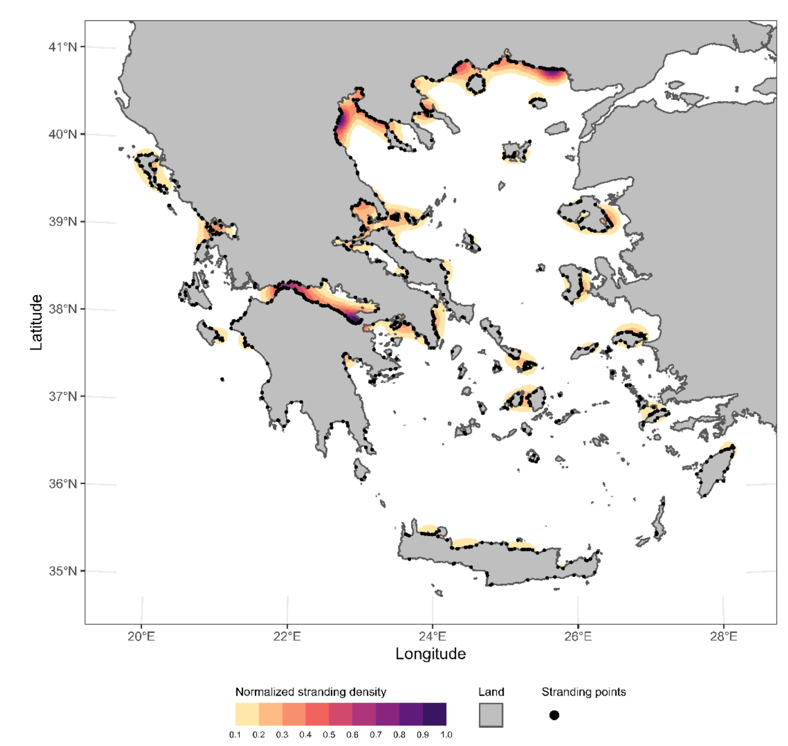

Figure 2. KDE map of total strandings

Results

Normalized KDE map of the total cetacean strandings show stranding hotspots at the northern coast of Aegean Sea (gulfs of Thermaikos, Thracian Sea), Korinthiakos and Pagasitikos gulfs – Sporades islands in central Aegean Sea and Amvrakikos gulf of Ionian Sea (Figure 2). Minor hotspots were observed in Lesvos, Chios and Samos islands of east Aegean Sea and at Cyclades island complex in central Aegean Sea (Figure 2).

Final selected GAM model (Table 1, model explaining 61.9% of deviance), indicate a positive relation with more extended fishing grounds, a negative relationship with the percentage of rocky shores and an increase with the coastline length (Figure 3).

Results of the Leeway model on the 9 starting points of potential cetacean carcass origin locations, shows the mean path of each object from each starting position during the simulation period (Figure 4).

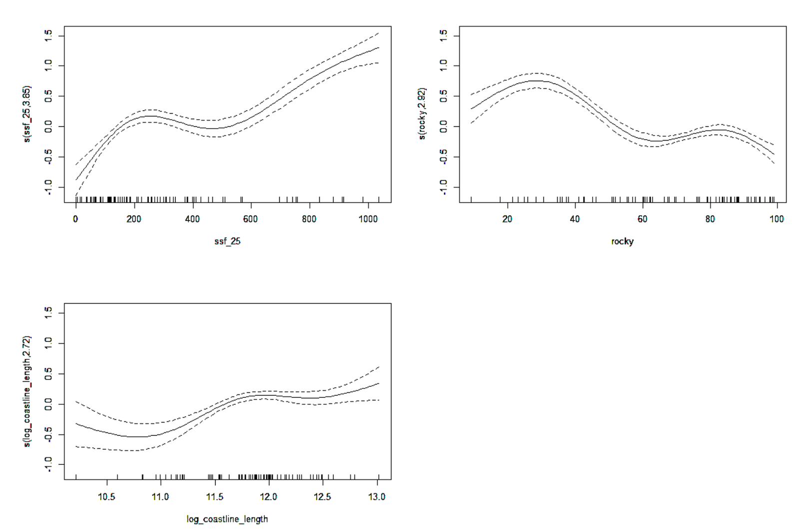

Figure 3. Final selected gam model term smooths.

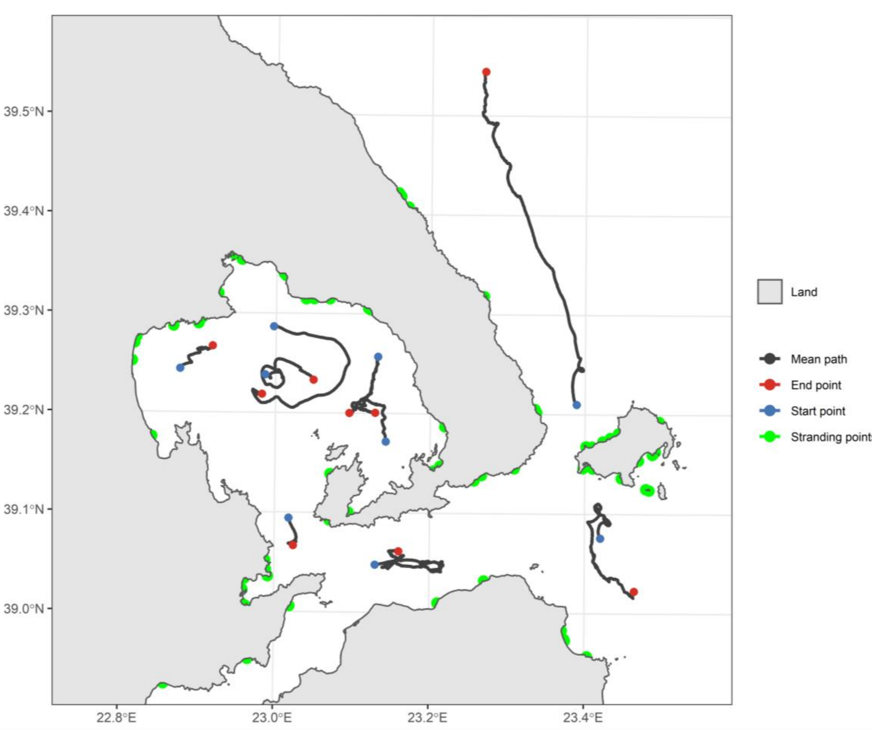

Figure 4. Leeway model objects drift.

Discussion

Hotspots mapped in this study show a high overlap with the preferential habitat[6] of the most common coastal dolphin species in the area, *Tursiops truncatus*. This study suggests, fishing grounds extent to be a main factor in modeling cetacean strandings accounting for 50.1% of deviance.

Carcasses in Pagasitikos gulf show a cyclonic drifting motion, with the most possible origin of strandings on the northern gulf, are animals that died inside the gulf. Inside the area of Oreoi strait there is an unclear, irregular back and forth motion, making impossible to identify a possible area of origin. Near Skiathos island there is clear drift motion to the outward of the island toward north and south.

Conclusion

- Cetacean strandings showed clustered distribution with hotspots throughout the study area
- GAMs showed a potential relationship between strandings and small scale fisheries
- Importance of shore characteristics in reporting cetacean strandings
- First time assessment of potential cetacean stranding origin location in Mediterranean Sea

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