SPATIAL MODELING OF THE EUROPEAN SARDINE HABITAT IN THE EASTERN MEDITERRANEAN BASIN USING GIS TOOLS

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Abstract
Acoustic survey data from June 2004 and 2005 were combined with environmental satellite data to investigate the spatial distribution of the European sardine in the Greek seas (Eastern Mediterranean basin). The link between the presence of sardine with environmental variables was identified by GAMs, while GIS techniques were applied, to map the areas where this set of environmental parameters is present, implying the existence of potential sardine habitat.
Keywords : Aegean Sea, Acoustics, Mapping.

Introduction
The present work is a first approach to identify the environmental characteristics that describe areas that serve as potential habitat of the European sardine (*Sardina pilchardus W.*) in the Greek Seas (Eastern Mediterranean Sea) during June. For this purpose acoustic data together with environmental satellite data were used and a specific set of environmental parameters associated with sardine's presence was defined. GIS techniques were applied to map the areas where this set of environmental parameters is met, implying the existence of potential habitat of sardine stocks, which is essential for management purposes.

Materials and Methods
Acoustic data were collected during two research surveys (June 2004 and 2005) on board the R/V Philia, in the Aegean Sea by a Biosonic Split Beam DT-X echosounder at 38kHz. Sardine echoes were discriminated based on the characteristic echogram shape of the schools and integrated per 1 nautical mile. Environmental data (i.e., mean monthly values of sea surface temperature-SST in ^{o}C, chlorophyll-a CHLO in mg/m^3, sea surface salinity-SSS, sea level anomaly-SLA in cm and photosynthetic active radiation-PAR in Ein/m^2/day) were derived from satellite imagery using GIS procedures ([1]). Generalized Additive Models (GAMs) were applied in a presence/absence approach in Thracian Sea on pooled data from the examined years, in order to identify the link of sardine's presence with environmental variables and define the set of the parameters values that describe potential areas of sardine presence. Thracian Sea was used as a pilot area, being characterized by strong heterogeneity of environmental conditions. Model selection was based on the minimization of the AIC criterion with a backward selection method [2], a binomial error distribution and the cubic spline smoother (s) was chosen as appropriate. In a next step, GIS techniques used the specific range of values from Thracian Sea (indicated by GAMs results to have a positive effect on sardine presence), to map those areas in the Greek Seas as well as the entire Mediterranean basin, where the specific environmental conditions are met, using mean monthly satellite data from June 2004 and 2005. Acoustic data from Thermaikos and Evoikos gulf in June 2004 and June 2005 as well as acoustic data from past studies in Central Aegean and Ionian Sea in June 1998 and June 1999 ([3]) were used for the cross validation of the results.

Results and Discussion
GAMs results of the final selected model [s(SST,df=4)+s(PAR,df=4) +s(CHLO,df=4), p<0.01, Deviance explained = 25.9%] indicated a certain range of values of the environmental parameters within the available ones, that there was a higher probability of finding sardine present. GIS mapping of the estimated conditions of environmental parameters derived from the Thracian Sea seems to describe quite reasonably also the areas of the actual sardine distribution in the Thermaikos and Evoikos gulfs in June 2004 and 2005, as well as in the Central Aegean and Ionian Seas as data from June 1998 and 1999 ([3]) are showing in Fig. 1. Mapping also indicated the specific set of environmental conditions for other areas in the Mediterranean Sea (e.g. the Adriatic Sea, the north Tyrrhenian Sea) as well as areas in the Eastern Mediterranean basin where the distribution of sardine is unknown (e.g. in the Nile Delta area, Fig. 2). The use of data from additional areas as well as pooled data from several years could better define the set of the environmental parameters that characterize the areas of the main sardine's concentrations and improve estimations results.

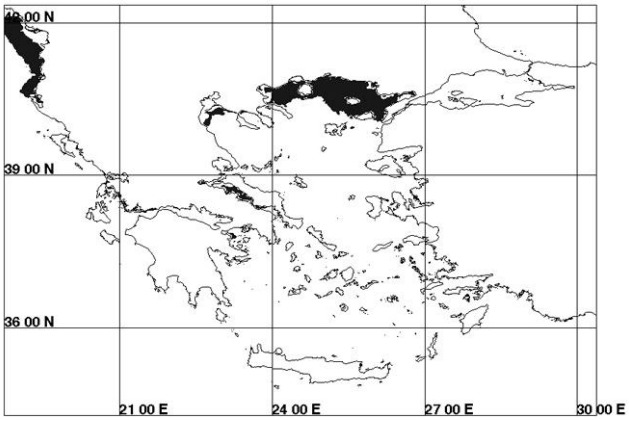

Fig. 1. A GIS extrapolated map of sardine's potential habitat in the Aegean and Ionian Seas based on the set of the parameter values estimated from the Thracian Sea acoustic data and mean monthly satellite data from June 2004.

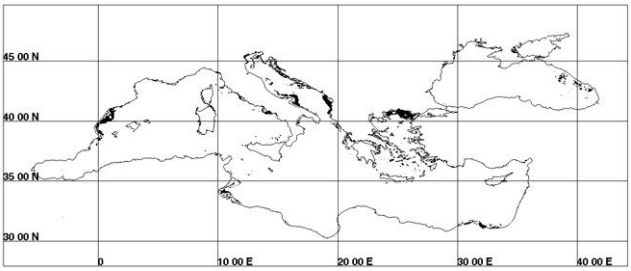

Fig. 2. A GIS extrapolated map of sardine's potential habitat in the Mediterranean basin based on the set of the parameter values estimated from the Thracian Sea acoustic data and mean monthly satellite data from June 2004.

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