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A methodological approach to identify fishing grounds: A case study on Greek trawlers

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ABSTRACT

Identification of fishing grounds is crucial for a good understanding of fisheries practices and for proposing effective management measures. A methodology to map fishing grounds and analyze their spatial patterns was developed. The proposed approach combines VMS (Vessel Monitoring System) data, used for estimation of fishing effort, and catch data, used for modelling species presence. The methodology is based on the assessment of the probability of species presence using generalized additive models, the estimation of a presence threshold for binary classification of presence/absence, the spatial overlay between the probability of species presence and fishing effort to identify fishing grounds, and finally the analysis of spatial patterns to identify hot (clusters of high fishing effort and high probability of presence) and cold (clusters of low fishing effort and low probability of presence) spots. The methodology was applied in Greek waters to identify bottom trawl fishing grounds. Survey and commercial fishing data, collected from 1985 to 2008, were analysed. Fifteen demersal species were studied; all considered important target-species for bottom trawlers in the Mediterranean. The main fishing grounds in Greek waters for the fifteen studied species, as well as aggregated hot and cold spots, were identified and analyzed.

1. Introduction

Increased pressures and cumulative impacts on the marine realm (Halpern et al., 2008), call for a well-planned approach to the management of marine space. The definition and mapping of ecosystem and socio-economic components is a crucial part of the scoping process of marine spatial planning within an overall framework of ecosystem-based spatial management approach (Katsanevakis et al., 2011). In that context, the mapping of fishing activities and the identification of fishing grounds is of utmost importance. It is vital to define areas that are important for fisheries in marine spatial plans, and to estimate the cost of restricting fishing activities in specific areas. Estimating such costs is an essential component of systematic marine conservation planning, which aims to achieve conservation objectives at least cost (Ban and Klein 2009; Mazor et al., 2014).

The Mediterranean Sea is a semi-enclosed highly biodiverse basin (Coll et al., 2010). Its diverse ecosystem is affected by cumulative anthropogenic threats, including intense fishing practices and resource extraction (Coll et al., 2012; Micheli et al., 2013). Previous studies have revealed an increasing exploitation rate for harvested stocks in the Mediterranean Sea due to poor selectivity in exploitation patterns, the lack of viable management plans featuring both catch limits and effort controls, and poor compliance with and enforcement of regulations (Colloca et al., 2013; Vasilakopoulos et al., 2014). Exploitation status in the North East Atlantic, North Sea and the Baltic, has improved in recent years (Cardinale et al., 2013), but no such general trend has been reported in the Mediterranean Sea. Due to the limitations of previous fisheries management approaches, the European Union has started to move towards an ecosystem approach to fisheries (EAF: FAO, 2008), which considers the broader impact of fisheries on the ecosystem as a whole and vice versa. A high level of compliance, effective control and enforcement through the EAF and the ongo-

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ing Common Fisheries Policy framework (CFP: EC, 2011), are of critical importance for achieving more sustainable management of Mediterranean fisheries, and in particular of the bottom trawl fishery, whichis multispecies, targeting a highly diversified mix of fish, cephalopods and crustaceans (Colloca et al., 2003; Caddy, 2009; Katsanevakis et al., 2010).

In recent years, the application of a Vessel Monitoring System (VMS) in Europe allowed an analysis of the spatio-temporal distribution of fishing effort in high resolution (Lee et al., 2010), for vessels with total length >12 m (EC, 2003). The estimation of fishing effort from VMS data provides vital information for analyzing and monitoring the pressure and eventually the impact of fisheries on an ecosystem (Garcia et al., 2000). Several methods have been developed and applied to VMS data to obtain estimates of fishing effort (Lee et al., 2010; Hintzen et al., 2012; Russo et al., 2014). The diversity of these methods may, in part, reflect the different issues being addressed and the preferred scales of analysis (Lee et al., 2010). The application and validation of these methods depend on the frequency of VMS signals, the existence of electronic logbooks and the simultaneous existence of VMS signals and on board observations. In Greek waters, all bottom trawlers are VMS-equipped (Kavadas et al., 2014).

Although the term "fishing ground" is used extensively in the literature, there is no explicit and commonly accepted definition (Russo et al., 2013). The term appears in FAO's (1997) definition of fishing effort ("the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time"), which implies that fishing grounds should be defined as "the areas in which fishing effort is deployed". However, this definition is "intuitively vague" (Russo et al., 2013) and does not take into account fisher tactics, the dynamics of fishing activities, and the actual distribution of the target species. The latter authors have defined fishing grounds as "areas in which fishing activity is routinely carried out as a result of a strategy aimed to maximize economic gains". We herein further expand that definition to incorporate actual species occurrence, and we define the fishing grounds of a species or a group of species as "crucial areas characterised by both fishing activity and species presence as a result of a strategy to maximize catches and economic gains".

Spatial analytical techniques, based on observation, pattern detection, experimentation and modelling have been proven to be powerful tools for the study of the complex nature and spatial patterns and trends in fisheries (Fortin and Dale, 2005). The implementation of spatial analytical techniques has provided new perspectives in fisheries research and ecosystem-based management. Several methods focused on spatial indicators of fishing pressure, which can efficiently describe the effect of fishing on marine ecosystems (Fulton et al., 2005; Jennings, 2005). In addition, after the enforcement of VMS, many studies have focused on the development of a new generation of fishing pressure indicators (Lambert et al., 2012; Russo et al., 2013), the detection of patterns in fishing effort (Nilsson and Ziegler, 2007; Horta e Costa et al., 2013; Kavadas et al., 2015; Maina et al., 2015) and métier identification (Russo et al., 2011). Other studies have focused on predictive habitat modelling of species (Giannoulaki et al., 2011, 2013; Valavanis et al., 2004; Hattab et al., 2013) and hot spot identification in conservation and ecology (Colloca et al., 2009; Bartolino et al., 2011; Chang et al., 2012; Lucifora et al., 2012; Kirkman et al., 2013; Li et al., 2014), which are usually considered in the context of biodiversity assessments. Fewer studies have focused on the analysis of the spatial distribution of catches and fishing effort (Murawski et al., 2005; Batista et al., 2015; Jalali et al., 2015), by using fishing effort as a proxy to estimate patterns and trends in indices such as Catch per Unit Effort (CPUE). In this work, a novel methodological framework is proposed, based on previous spatial analytical techniques, for exploring the patchy distribution of fishing effort and species presence, as a baseline for the investigation and mapping of fishing grounds.

New insights for investigating spatial patterns are essential for a better understanding of fisheries dynamics and for proposing more effective management measures. In this context, a methodology for identifying fishing grounds and investigating the spatial patterns of exploitation was developed and applied in Greek Seas (central and eastern Mediterranean). The approach is based on combining the potential habitat use of fifteen demersal species, considered as the most important commercial species for the Greek bottom trawl sector, and the spatial distribution of fishing effort.

2. Material and methods

The steps for identifying and analysing fishing grounds are summarized in the flowchart of Fig. 1 and are hereafter described in detail. Four independent data sets were analyzed and modelled: VMS data from commercial bottom trawlers; catch data collected within the framework of national and international bottom trawl surveys; catch data collected by onboard observers within the framework of the Data Collection Regulation (DCR: EC, 2008a,b) and environmental data.

2.1. Data from surveys and onboard observers

Catch data from National surveys conducted during the period 1985–2002 and data collected within the framework of the International Bottom Trawl Survey in the Mediterranean (MEDITS) (2003–2008) were used. The dataset was supplemented with information collected by onboard observers within the framework of National research projects (1995–2001) and DCR (2003–2008). A total of 5183 hauls were included in the analysis, of which 970 were conducted in the Ionian Sea and 4213 in the Aegean Sea. The depth range varied between 50 and 500 m for commercial fishing and between 20 and 850 m for the research surveys. The integration of trawl survey data with commercial trawling data constitutes a non-standard but useful method that is used for modelling purposes and maximizes the reliability of results as regards the distribution of commercial demersal species (Fox and Starr, 1996; Abella et al., 1999). The data were used to model the spatial distribution of species presence, for the most important commercial species for bottom trawlers. The dataset was retrieved through the integrated fisheries information system IMAS-Fish (Kavadas et al., 2013).

Catchability differences between trawl survey and commercial trawling data are of less importance by using presence/absence and not biomass or abundance data. A binomial test was used to check for significant similarities between the two datasets, in the upper probability quartile >0.75 and confidence level = 0.99 (Conover, 1971; R Development Core Team, 2014). The recorded presences or absences for each species were compared at similar depth strata (<100 m, 100–200 m, 200–500 m, 500–850 m) between pairs of neighbouring hauls of the two sampling types. Survey hauls conducted in restricted areas were excluded according to EU Legislation.[1] Pairs of neighbouring hauls were identified using the proximity tool "near" of ESRI's ArcGIS toolboxes (ESRI, 2011), and the minimum distance between hauls was determined. The minimum distance between neighbouring hauls was in no case >8 km, indicating similar spatial patterns in the location of hauls between the two sampling types. Furthermore, the swept area (which may differ between and within sampling types) was

[1] The use of trawl nets shall be prohibited within 1.5 M of the coast. The use of towed gears shall be prohibited within 3 M of the coast or within the 50 m isobath where that depth is reached at a shorter distance from the coast (EC, 2006).