Marine Policy 77 (2017) 144–151

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Discard management: A spatial multi-criteria approach

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ARTICLE INFO

Keywords:
Bayesian models
Cantabrian Sea
Discard drivers
Fishery management

ABSTRACT

Discard management needs to draw on scientific research and advice, usually supported by specific statistical modeling analysis. A wide range of statistical analysis methods were applied to fishery data in an attempt to distinguish factors that influence the species discard composition. While such approaches are important, they are still incomplete for disaggregating the economic and spatial-temporal factors for analyzing of this process and obtain a whole view of this issue. Our study aims to fill this gap by identifying, describing, and quantifying factors that influence discards of trawl fisheries using a multivariate approach based on five complementary aspects: "economic", "vessel characteristics", "spatial", "temporal" and "environmental". In addition, a spatial multi-criteria approach were used to investigate discard hot-spot areas using ecological criteria such as vulnerability and resilience of the discarded species. Using these ecological criteria will concentrate conservation efforts on the most relevant sites minimizing discards of a variety of potentially vulnerable species. This approach was applied to a case study of a multi-species demersal bottom trawl fisheries in north Spain, Cantabrian Sea (ICES area VIIIc). Results showed how spatial and economic factors highly affect species discard composition, identifying specific spatial-temporal discard hot-spots to be preferentially avoided by fishers. Mitigation measures for future fisheries management strategies should be implemented at multiple stages of the discarding process, both in the selection of the fishing grounds and the economic valorization of the discarded species.

1. Introduction

Fisheries exploitation influences not only target species stocks but it can also affect the entire community structure by removing non-target species through the by-catch/discard process, changing the total biomass, species composition and diversity around the fishing area [1,2]. Indeed, this process is considered to be responsible for economic loss and it has ecological effects on keystone and vulnerable species which are important for ecosystems performance and structure [2,3]. As consequence, discards are being placed as a central problem in the EU fisheries reform agenda, introducing new regulations to limit their amount and impact [4].

Understanding the importance of the different factors influencing the species discard composition could become a critical step in designing management programs which maximize landings and minimize discards, especially for mixed-species fisheries.

In this context different methods have been applied in an attempt to achieve this aim [1,5,6]. While such approaches are relevant, they are still incomplete for disaggregating the economic and spatial-temporal factors influencing species discard composition and obtaining a whole view of the issue. Indeed discards are a result of choices made at various stages during the fishing process including a broad range of factors. This study aims to fill this gap, identifying, describing and quantifying factors that influence the species discards composition of bottom trawl fisheries by means of a spatial-temporal explicit multivariate approach. In particular, five different aspects: "economic", "vessel characteristics", "spatial", "temporal" and "environmental", are used to create a complete framework for a comprehensive understanding of the spatial-temporal variation of discards in a given fishery.

In addition, discard hot-spot areas are identified using a multi-criteria approach, rather than allocating these locations on a species-specific basis or the total amount of discards. Indeed, approaches using these common criteria to assess on high density discard areas, have resulted in the recommendation to avoid or limit fishing activity over very large areas [3,7,8], which is usually nonviable in most contexts, especially given the social and economic relevance of fishing resources. In this study, a different approach to the problem is suggested, focusing efforts in analysis potentially vulnerable species due to their life history traits, which would optimize the total amount of habitat protection needed for minimizing discards of key sensitive species.

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http://dx.doi.org/10.1016/j.marpol.2016.12.022
Received 10 November 2016; Received in revised form 26 December 2016; Accepted 27 December 2016

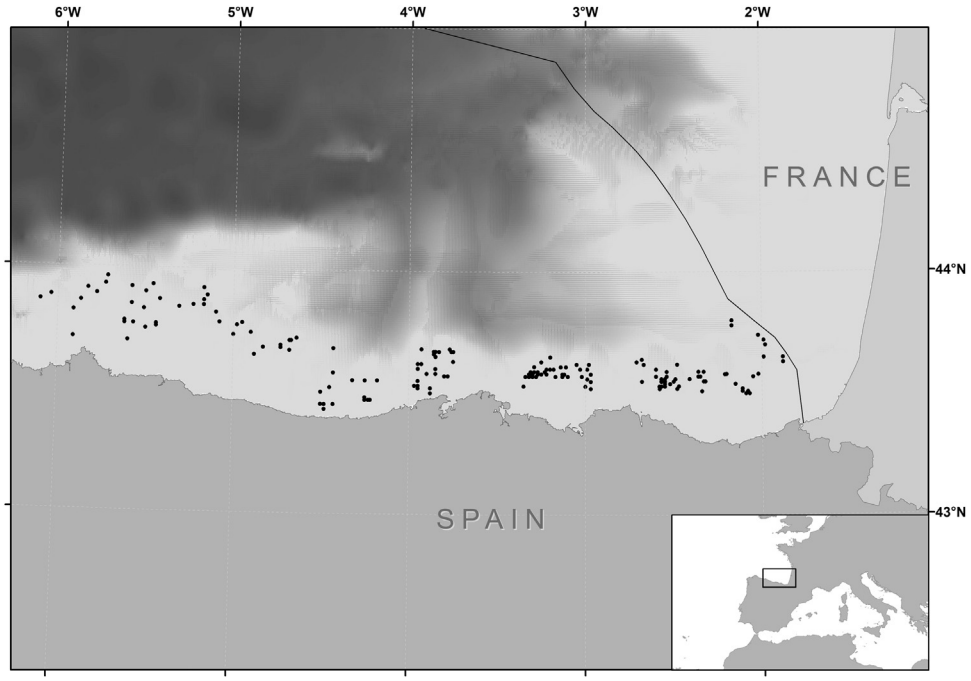

Fig. 1. Situation map and locations of the hauls collected by on-board observers on fishing trawlers in the Cantabrian Sea (2004–2008).

To achieve such objective, two different ecological criteria are implemented, species vulnerability and resilience, highlighting areas showing discards of the most vulnerable and less resilient discarded species. The use of both ecological criteria will concentrate conservation efforts on main relevant sites for minimizing discards of a variety of sensitive species.

2. Material and methods

2.1. Discard data

The reference fleet for this study was the bottom trawl mixed-species fishery which operates in the Cantabrian Sea (Fig. 1).

This trawl fleet is composed of vessels belonging to the mix strategy métier, targeting mainly European hake (*Merluccius merluccius*), anglerfishes (*Lophius piscatorius* and L. *budegassa*) and megrim species (*Lepidorhombus whiffiagonis* and L. *boscii*) [9]. This fleet operates at Avilés, Gijón, and Santander (north Spain), and is regulated by several quota and fishing effort measures are enforced as they belong to the Atlantic Fishery Management System [7,9].

The species discard composition dataset was obtained from the Spanish Discard Sampling Program operated by the Instituto Español de Oceanografía (IEO) for the period 2004–2008 in the International Council for the Exploration of the Sea (ICES) division VIIIc. Here, discards include all non-retained catch including both live released and dead discarded organisms.

The sampling protocol of this on-board observers program is similar to that of other European observer programs operating under the European Data Collection Regulation [10,11]. In particular, fishing data is gathered in a “per haul” basis based on a stratified random sampling that considers the “Fishery Unit” as a group of homogeneous fishing fleets, sharing similar fishing gear, target species and fishing area during a specific period of time (see [12] for further details).

2.2. Thematic group variables

Variables used as possible factors that could affect the species discard composition were aggregated in five different thematic groups including “economic”, “vessel characteristics”, “spatial”, “temporal” and “environmental” aspects.

Specifically, the “economic” group includes as variables the ex-vessel price and landed value by species. Indeed, for fishers, markets conditions (what can be marketed and at which price) are often mainly drivers of retained species selection. Ex-vessel prices were extracted from the “Sea Around Us” Project database (www.searoundus.org [13]) and landed value was obtained by multiplying the ex-vessel price for the total retained catch by species per haul. The average dollar conversion rate for the period is 1 USD=0.8916 EUR (http://usd.es.fxexchangerate.com/ at the moment of the sampling collection).

The “vessel characteristics” group is composed by vessel characteristics as the size and the Gross Register Tonnage (GRT) that could influence to the selection of the fishing ground, as well the storage capacity.

The observed species discard composition might be influenced by the species composition in surrounding locations due to contagious abiotic and biotic processes that are not related to the environmental characteristics. Therefore, we incorporate the spatial structure of the data by means of the “spatial” group which includes the mean latitude and longitude for each fishing haul.

Similarly, temporal factors may affect species discard composition as they are closely related with the life cycle of the species. The temporal pattern was included in our analysis by means of the year and the quarter when the fishing hauls were performed.

Environmental features can affect the selection of the fishing ground where fishers go and consequently the type and amount of discards [4]. Here, both oceanographic and bathymetric features of the studied habitat were added in the analysis. Particularly, Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) were extracted from the NASA Earth Observation project (http://neo.sci.gsfc.nasa.gov/) as monthly means. Bathymetry and slope were extracted from the MARSPEC database [14], while the type of the seabed was extracted from the IEO geomorphological database and coded as categorical variable: 1, mud; 2, sand; 3, gravel; and 4, rock. Each environmental variable was averaged to a grid of 1 km×1 km cells covering the entire prediction area.

Finally, before their use for analysis and modeling all the variables were explored in order to identify possible collinearity issues, correlation, outliers, and missing data [15].