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Modelling trawling discards of the Alboran fisheries in the Mediterranean Sea

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ABSTRACT

The ecosystem processes underlying the discard rates of the demersal otter-trawl fishery in the Alboran Sea, Western Mediterranean are investigated. We evaluate whether environmental and climatic variability, measured from operational oceanographic data, allow assessment of discarded species abundances. Monthly data collected by onboard fishery observers during 2011 and 2012 in the Northern Alboran Sea served as a case study of the trawling fishery's dynamics. The study area was split into west and east zones to account for differences in the Atlantic and Mediterranean Sea water influences, for distinct geomorphology and for species composition of catches. Sixteen species divided in three groups were analysed: species without discards, those partially discarded and those completely discarded. Applying Gaussian Generalized Additive Models (GAM), we tested the relationships of standard oceanographic data products and climatic variability with discard abundances. These variables were sea surface temperature (SST) and chlorophyll a (chl-a) from satellite imagery, as indicators of environmental conditions, and the North Atlantic Oscillation index (NAO) as a climatic indicator. Models were applied for target and bycatch species partially discarded. These were the following species: gadoid like European hake (*Merluccius merluccius*), Blue Whiting (*Micromesistius poutassou*), Seabreams (*Pagellus acarne*, and *Pagellus erythrinus*), and Mackerels (*Trachurus mediterraneus*, *Trachurus picturatus* and *Trachurus trachurus*). Surface seawater temperature was a relevant variable in coastal and eastern, more haline Mediterranean waters. Climatic variability represented by NAO was useful for assessing discard rates in the more productive western zone. Chlorophyll a showed less relevance for discard prediction models, but it was more related in the coastal zones. Including oceanographic data products and climatic patterns in GAM models of fishery discards provides a new perspective that may improve our predictive capabilities for management decisions.

1. Introduction

Ecosystem-based fishery management (EBFM) is a new direction for fishery management adopted by the current European Union Common Fishery Policy (CFP). The overall objective of EBFM is to sustain healthy marine ecosystems and the fisheries they support. In particular, EBFM should (i) avoid degradation of ecosystems, as measured by indicators of environmental quality and system status; (ii) account for the requirements of other ecosystem components (e.g., nontarget species, protected species, habitat considerations, and various trophic interactions). Ecosystem-based fishery management recognizes the physical, biological, economic and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition (Pikitch et al., 2004)

As one facet of EBFM, the new European Union Common Fishery Policy (CFP), introduces a discard ban in European waters. This is a landing obligation for all species that are regulated by a Minimum Conservation Reference Size (MCRS) in the Mediterranean Sea, except for tunas that are managed by quotas (EU, 2013). In the otter-trawl Mediterranean fishery, the proportion of discards has been found to be below 5% of total catch for almost all of its target species (Tsagarakis et al., 2017). For these cases the new EU regulation allows '*de minimis exemptions*', which enable discard of a small

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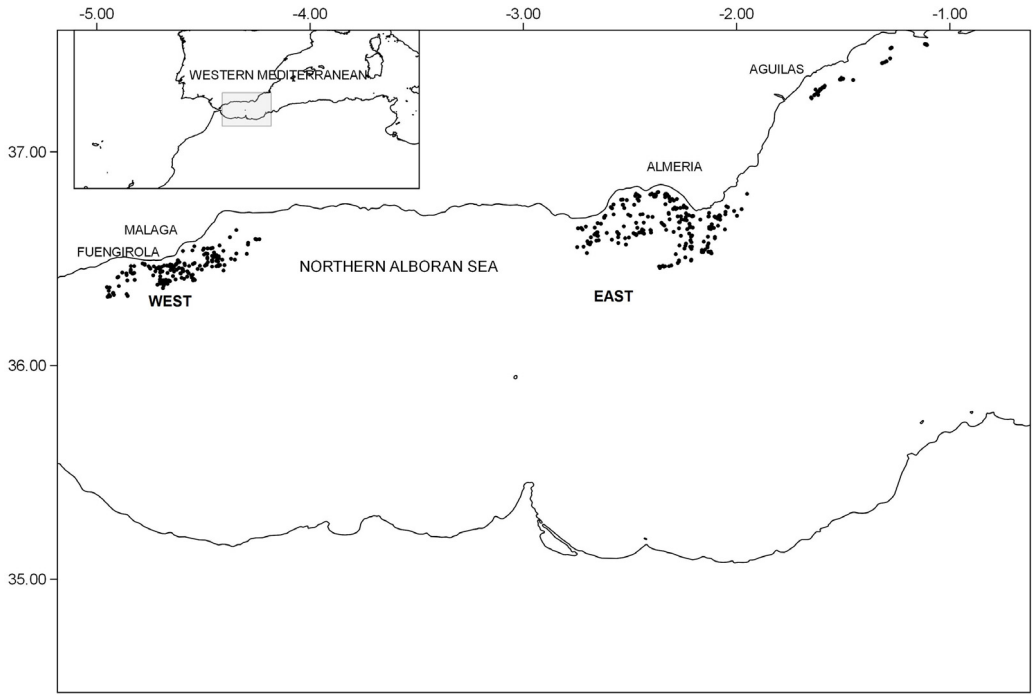

Fig. 1. Map of sampling locations and harbours in the Northern Alboran Sea. WEST= Málaga and Fuengirola harbours. EAST= Almeria and Aguilas harbours.

percentage of catches. The exemptions are applied when there are high chances of survival for the species or when reducing discards is either too difficult or too expensive, e.g. increasing mesh size to improve gear selectivity (EU, 2013). The implementation of these agreements and the specification of the percentage of discards under the '*de minimis exemptions*' depends on the development of adequate scientific information. However, in practice bycatch species can have discards as high as 100%, even in the case of edible species. The integrated CFP contemplates that, from January 2016 to December 2019 discard prohibitions would only affect target and bycatch species under Minimum Conservation Reference Size (MCRS) regulations. The plan prescribes a progressive introduction of discard bans for all species, by 2020 requiring fishermen to retain their entire catches. That will in turn require landing more and more species in coming years, until entire catches are completely landed. Ideally, the otter trawl fishery should evolve to reduce the catch of bycatch species that are now discarded. The current approaches for fisheries management are based on effort control and gear selectivity. Although useful to reduce discards (Ordines et al., 2007; Guijarro et al., 2017), these will be not enough to avoid the unwanted bycatch. Thus, investigation of natural behaviour patterns of captured species and their relationship with environmental conditions may be a critical key to limiting and preventing these captures (Glass, 2000). Fluctuations in time and space of biological processes such as recruitment, migration or habitat preferences, are linked with the environment, and are one of the main that cause smaller and smaller sizes of captured fishes, which is also provoking discards. Understanding the relations between catch composition and environmental forcing could provide a way to model the probabilities of unwanted bycatch and offer new management possibilities.

Our aim is to investigate the climatic and sea surface conditions underlying discard abundances of the demersal otter-trawl fishery in the Northern Alboran Sea in the Western Mediterranean using operational oceanographic data sources as explanatory variables. The study was developed in two areas of the Alboran Sea that have different oceanographic characteristics. They are separated by the Almeria-Oran front, a barrier crossing the Alboran Sea from northwest to southeast (Allen et al., 2001). The area located to the east of the front corresponds to a more haline zone. The area to the west is a less haline transitional zone, where waters incoming from the Atlantic and under the influence of Guadalmine River discharge meet the more haline Mediterranean waters. Both areas are fished on a daily basis bottom trawlers working from the continental shelf to the middle of the slope.

2. Materials and methods

2.1. Study area

Otter trawl fishing grounds in the Northern Alboran Sea were split into two subareas (Fig. 1): i) The Northwestern Alboran Sea (called West herein), where Fuengirola harbour is the main sampling base, and ii) the Northeastern Alboran Sea (called East herein) where Almeria and Aguilas are the main harbours.

These two subareas are separated by a distance of about 175 km. In the West the fishing zone is on a narrow shelf (10 km average) with low gradient slopes. In the East fishing exploits all of the wide continental shelf (21 km average) of Almeria Bay, where the shelf-break and slope have steep slopes in its northern part. Sampling on board was carried out from vessels with similar technical characteristics (Table 1).

The Alboran Sea is considered a transition zone between the distinctive hydrographic characteristics of the Atlantic and the Western Mediterranean. In each subarea different target species and sizes are found, which in turn depend on factors such as species ontogenic distributions, bottom substrates and geomorphological characteristics.

2.2. Data gathered

Discard data were collected according to the European Union (EU) discards sampling framework (EU, 2008). Sampling was carried out on a monthly basis; observers went aboard different vessels every month, sampling all hauls carried out on the daily boat trips. Between one and five hauls (called herein Fishing Operations,

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