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Food-web structure of and fishing impacts on the Gulf of Cadiz ecosystem (South-western Spain)

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ABSTRACT

The Gulf of Cadiz (North-eastern Atlantic, Spain) is an exploited ecosystem characterized by high marine biodiversity and productivity. Over the last decade, the landings of fish stocks such as anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*) and hake (*Merluccius merluccius*) have been declining and currently remain low. A food-web model of the Gulf of Cadiz has been developed by means of a mass balance approach using the software EwE 6 to provide a snapshot of the ecosystem in 2009. The goals of this study were to: (1) characterize the food-web structure and functioning, (2) identify the main keystone groups of the ecosystem, (3) assess the impact of fishing to the Gulf of Cadiz compared to that in other essential marine ecosystems in the coastal area of Spain: Cantabrian Sea (North-eastern Atlantic) and Southern Catalan Sea (Mediterranean Sea), and (4) examine the limitations and weaknesses of the Gulf of Cadiz model for improvements and future research directions. The model consists of 43 functional groups, including the main trophic components of the system with emphasis target and non-target fish species. The main trophic flows are determined by the interaction between detritus, phytoplankton and micro- and mesozooplankton. Rose shrimp (*Parapenaeus longirostris*), cephalopods and dolphins present important overall effects as keystone species on the rest of the groups. The exploitation of fisheries composed mainly of trawlers, purse seiners and artisanal boats is intensive in the Gulf of Cadiz with all fleets exerting high impacts on most living groups of the ecosystem. The findings highlighted that the Gulf of Cadiz is a notably stressed ecosystem, displaying characteristics of a heavily exploited area. The comparative approach highlights that the three ecosystems display similarities with regard to structure and functioning such as the dominance of the pelagic fraction, a strong benthic-pelagic coupling, the important role of detritus, and the high impact of fishery exploitation.

1. Introduction

During the last decades, inefficient fisheries management together with illegal, unreported and unregulated (IUU) fishing practices in many marine ecosystems have caused the decline of fish stocks and therefore, major threats to marine biodiversity (e.g. Jackson et al., 2001; Agnew et al., 2009; Samhouri et al., 2009; Holt et al., 2011; Christensen and Walters, 2011). Consequently, fishing activities may alter the structure and functioning of marine food webs (Pauly et al., 1998a, 2002). This shows that fishery management based on single species is not sufficient and ongoing efforts to develop an ecosystem-based approach to fisheries (EAF) are urgently needed for integrating sustainable exploitation and marine ecosystems conservation (Garcia et al., 2003; Garcia and Cochrane, 2005; FAO, 2008). For the EAF, new methodological tools have been developed, such as ecological models (e.g. Christensen and Walters, 2004; Plagányi, 2007) and ecosystem indicators (e.g. Cury and Christensen, 2005; Shin and Shannon, 2010). These tools provide a framework for assessing the impacts of interactions between species and fisheries and their implications for marine fisheries management (Coll and Libralato, 2012).

The Ecopath with Ecosim (EwE) approach is currently one of the most used ecosystem modeling tools for building ecological models within the context of ecosystem-based approaches to marine resources management (Polovina, 1984; Christensen and Pauly, 1992; Pauly et al., 2000; Christensen and Walters, 2004, 2011). This ecological modeling tool contributes to the science of an

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