Journal of Sea Research 141 (2018) 99–111

Contents lists available at ScienceDirect

Journal of Sea Research

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

Assessing ecological and fisheries implications of the EU landing obligation in Eastern Mediterranean

Dimitrios K. Moutopoulos[a,*], Konstantinos Tsagarakis[b], Athanassios Machias[b]

[a] Department of Fisheries-Aquaculture Technology, TEI of Western Greece, Mesolonghi 30200, Greece
[b] Hellenic Centre for Marine Research, Institute of Marine Biological Resources and Inland Waters, 46.7 km Athinon-Souniou Ave., P.O. BOX 712, Anavyssos 19013, Greece

ARTICLE INFO

Keywords:
Food web model
Multi-gear discards
Minimum landing sizes
Ionian Sea
Mediterranean Sea

ABSTRACT

Discards are of primary target for the European Union policy and concerns have been expressed on the consequances that the landing obligation may have on the fisheries resources and other ecosystem components. In this context, we used an ecosystem modelling approach based on a previously constructed food web model for the Greek Ionian Sea to explore changes in food web components and fisheries due to the application of the landing obligation. Time series were also used to tune the trophic relationships during a hindcast period (1998–2014) and six scenarios were explored after 2015 simulating the current policy; a partial and a total discard ban (implemented after 2017) under both constant and decreasing fishing effort. Results indicated that, under constant fishing effort, changes in the management of unwanted catches (from discarding to landing them) had a significant consequences on certain functional groups, especially on marine birds which were even more adverse in the scenario tuned for the total discard ban. However, the new management practices seem pointless for the sustainability for most of the stocks, because there were no changes in the main commercial fish species apart from few exceptions (e.g. flatfish, deep water shrimps, continental shrimps) in which biomass changes were generally low. In contrast, simulations of declining fishing effort affected to higher extent more groups, whereas additionally representing changes in discarding policies had little effect. The model presented here is intended to shed light in the importance of discards in the food-web structure and subsequently to incentivize the practices to avoid producing discards in the first place.

1. Introduction

In the context of the reformed Common Fisheries Policy (EU 1380/, 2013), the European Commission gradually implemented the obligation to land all fisheries catches based on a timetable starting in 2015 for small and large pelagic fish and ending in 2019 for all other species with catch limits and, in the Mediterranean for species that minimum sizes under the EU Regulation 1967/2006 have been set. Discards have ecological, economical and managerial ramifications, limiting ecosystem recovery (Sarda et al., 2015), decreasing financial return for fishermen (Bellido et al., 2017) and increasing the uncertainty of fisheries monitoring assessements, respectively. This is because discards are included in the unreported portion of the catch, the proper estimation of which is a primary target of the European Union policy (European Commission, 2011). On the other hand, discards constitute important food source for marine scavengers (e.g., Groenewold and Fonds, 2000) as well as for seabirds (e.g., Votier et al., 2013) and concerns have been expressed on the consequences that the landing obligation (LO) may have on the fisheries resources and other ecosystem components (Sarda et al., 2015).

A well-established ecological modelling approach to quantitatively place fisheries in an ecosystem context (Christensen and Maclean, 2004) is the use of Ecopath with Ecosim (EwE) (Pauly et al., 2000; Christensen and Walters, 2004). Although, a large number of different ecosystem models have been implemented for assessing ecosystem-based management (e.g., Atlantis: Fulton and Smith, 2004; EwE: Coll and Libralato, 2012; Atlanits vs EwE: Forrest et al., 2015; and comparisons of three different ecosystem models: Uusitalo et al., 2016), few applications deal with the evaluation of magement scenarios for discard policies (i.e., EwE model on the discards of European hake and Norway lobster: Angelini et al., 2016; EwE on banning discards in Australia: Fondo et al., 2015; StrathE2E model on the discards in North Sea: Heath et al., 2014). This is the case for the present study that integrates the available information for developing a “close to reality” EwE model and

* Corresponding author.
E-mail address: dmoutopo@teimes.gr (D.K. Moutopoulos).

https://doi.org/10.1016/j.seares.2018.08.006
Received 20 March 2018; Received in revised form 6 July 2018; Accepted 30 August 2018
Available online 02 September 2018
1385-1101/

its dynamic expansion (Ecosim; Christensen and Walters, 2004) to be used as policy advisory tool for the evaluation of the discard ban and its effects on the structure and functioning of the ecosystem. Significant attention should be also given to the specific characteristics of the study area that should be taken into account to the implementation of fisheries policy.

Specifically, in the study area (Pilling et al., 2008): (a) a variety of fishing gears are used and numerous species with different life-histories are exploited, all increasing the uncertainty on the determination of gear-specific mortality rates (trawlers: Machias et al., 2001; small-scale artisanal vessels: Tzanatos et al., 2007) and thus the complexity of fishing effects on ecosystems, (b) gaps in biological and fisheries data exist (Pilling et al., 2008), and (c) discrepancies and misreporting estimates in the official landings data bias downwards fishing mortality (Moutopoulos and Koutsikopoulos, 2014). Including the discarded proportion in the model would reduce the uncertainty on the estimation of fishing mortality per species, adjust the diet composition of some scavenging groups of species and estimate the indirect effects in the food-web. More specifically, the developed model aims to: (a) highlight the importance of discards in the food-web, (b) provide quantitative estimates of ecosystem responses to changes in the availability of discards focusing on species of conservation concerns and benthic communities, (c) investigate the ecological role of species or species groups in order to examine policies for an ecosystem approach to fisheries management, (d) explore several scenarios on the discarded quantites, including the application of the LO according to the EU 1380/2013 and a total discard ban.

2. Materials and methods

2.1. The study area

The Greek Ionian Sea (Greece) is characterized by keypoint elements such as (for review see Moutopoulos et al., 2013): (a) narrow continental shelf and large sea area with depth > 400 m (including the Greek Trench that exceeds 4000 m along the western and southwestern Greek coast), (b) very limited fishing exploitation beyond 400 m, and thus species at this depth are considered to be in a rather unexploited stage (Mytilineou et al., 2007), (c) limited nutrient and Chl-a concentrations with zooplankton standing stocks being in similar status to the eastern Mediterranean pelagic areas (Ramfos et al., 2006) and (d) presence of spawning areas for commercial demersal, pelagic (i.e. sardine, *Sardina pilchardus*) and large pelagic (swordfish, *Xiphias gladius* and tuna, *Thunnus thynnus*) fish species. In addition, the Ionian Sea is important for several species of conservation concern and marine megafauna in general, as it supports important colonies of seabirds such as the yellow-legged gull *Larus michahellis* and the Scopoli's shearwater *Calonectris diomedea* (Karris et al., 2017), a large population and important nesting sites for the loggerhead sea turtle *Caretta caretta,* as well as foraging areas for monk seals and dolphins (Bearzi et al., 2005) that are interacting positively (e.g. through discards use and fish location) and negatively (e.g., bycatch, competition for space) with local fisheries. The ecosystem modeled covers an area of 49,149 km^2 at depths ranging between 50 and 1100 m (Fig. 1), whereas estuaries, lagoons and enclosed gulfs were excluded from the analysis due to their highly variable primary productivity.

2.2. Modelling approach

The Ecopath module of the Ecopath with Ecosim software (Pauly et al., 2000; Christensen and Walters, 2004; http://www.ecopath.org) was implemented to describe annual biomass flows in the Ionian Sea food web, based on an existing model representing the Ionian ecosystem in the 2000s (Moutopoulos et al., 2013). The EwE methodology is widely used and has been described in detail in several works (e.g., Christensen and Walters, 2004; Moutopoulos et al., 2013). In brief, the energy balance within each group (i) is ensured through the following two equations:

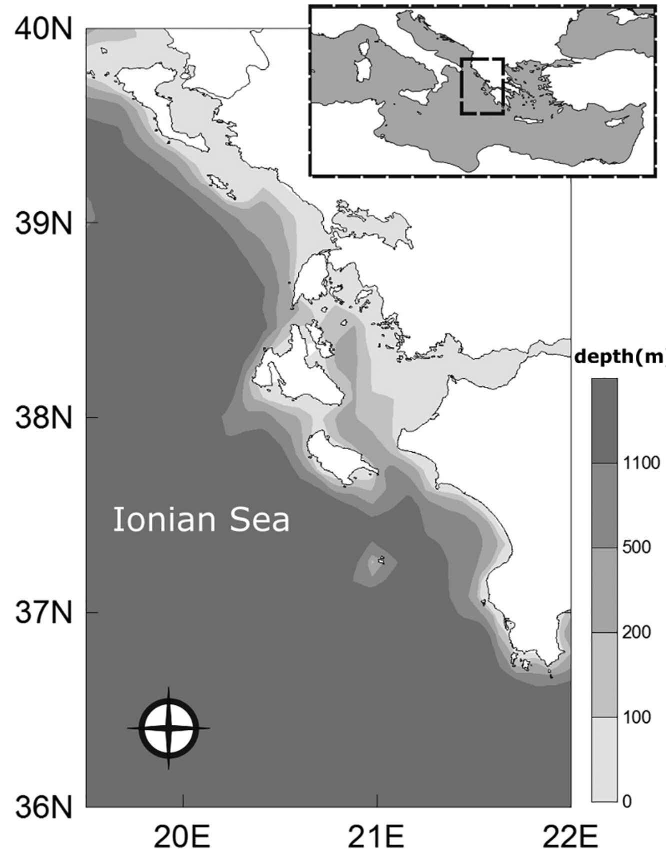

Fig. 1. Study area.

$$\text{Production} = \text{predation mortality} + \text{fishing mortality} + \text{other mortality} + \text{biomass accumulation} + \text{net migration} \quad (1)$$

$$\text{Consumption} = \text{production} + \text{respiration} + \text{unassimilated food} \quad (2)$$

The input parameters required for each group are the dietary preferences (diet matrix DC_{ij} as fraction of prey i in the diet of predator j), exports by different fishing activities including by-catch and discards and three out of four basic parameters: biomass (B_i), production rate (P/B), consumption rate (Q/B), and Ecotrophic Efficiency (EE_i; fraction of the production that is utilised within the system by predators or exported). For all modeled groups EE_i was the missing parameter and was estimated by EwE. One exception concerned *Dicentrarchus labrax-Sparus aurata* species due to the absence of reliable biomass estimations. In this case an input EE value of 0.80 was used following an EwE model in an adjacent area (Thyrrenian Sea: Brando et al., 2004) and we let the model estimate the biomass.

The EE, the growth efficiency (P/Q) and the respiration rate (R/B) by group allow to assess whether the food web model is balanced and realistic, namely: when (a) EE < 1 for all groups; (b) 0.10 < P/Q < 0.35 for all groups with some exceptions (Christensen and Walters, 2004; Heymans et al., 2016); and (c) R/B consistent with group's metabolism, i.e. high values for small organisms and top predators (Christensen and Walters, 2004).

In Ecosim the system of algebraic equations of Ecopath is used to set up a system of differential equations to estimate biomass fluxes (Christensen and Walters, 2004).

Consumption rates (Q/B) are calculated in Ecosim based on the "foraging arena" theory where Bi's are divided into vulnerable and invulnerable fractions to account for hiding and other behavioral