frontiers
in Marine Science

ORIGINAL RESEARCH
published: 16 March 2017
doi: 10.3389/fmars.2017.00072

Mediterranean Sea: A Failure of the European Fisheries Management System

***Massimiliano Cardinale*[1]*, *Giacomo Chato Osio*[2] *and Giuseppe Scarcella*[3]**

[1] Department of Aquatic Resources, Marine Research Institute, Swedish University of Agricultural Sciences, Lysekil, Sweden, [2] Directorate D - Sustainable Resources, Unit D.02 Water and Marine Resources, European Commission Joint Research Centre (JRC), Ispra, Italy, [3] Institute of Marine Sciences of the Italian National Research Council, Ancona, Italy

North East Atlantic and the Mediterranean Sea fisheries are governed by the European Common Fisheries Policy (CFP). Despite the fact that both areas are managed under the same broad fishery management system, a large discrepancy in management performance occurs, with recent considerable improvement of stock status witnessed in the North East Atlantic and a rapidly deteriorating situation in the Mediterranean Sea. The control of fishing effort combined with specific technical measures, such as gear regulation, establishment of a minimum conservation reference size, and selective closure of areas and seasons, is the main management strategy adopted by Mediterranean Sea EU countries. On the other hand TAC (Total Allowable Catches) is the major regulatory mechanisms in the North East Atlantic. Here, we analyzed all available stock assessment and effort data for the most important commercial species and fleets in the Mediterranean Sea since 2003. The analysis shows that there is no apparent relationship between nominal effort and fishing mortality for all species. Fishing mortality has remained stable during the last decade, for most species, with a significant decline observed only for red mullet and giant red shrimp but an increase for sardine stocks. Also, current F is larger or much larger than F_{MSY} for all species. Despite catch advice are produced by STECF each year, the realized catches have usually been much larger than the scientific advice. A recent analysis argued that this dichotomy might be due to several factors, such as the better enforcement of monitoring control and surveillance in North East Atlantic, the more complex socio-economic situation and the less effective management governance in the Mediterranean Sea. Here we argue instead that major reasons for the alarming situation of Mediterranean Sea stocks can be found in the ineffectiveness of the current effort system to control F, the continuous non-adherence to the scientific advice and inadequacies of existing national management plans as a key management measure. It is therefore undoubted that alternatives management measures as a TAC based system are necessary if Europe is willing to achieve the objectives of the CFP before 2020 in the Mediterranean Sea.

Keywords: Mediterranean, common fishery policy, management, effort, failure

Edited by:
Lyne Morissette,
M - Expertise Marine, Canada

Reviewed by:
Mary Ann Palma-Robles,
University of Wollongong, Australia
Angel Pérez-Ruzafa,
University of Murcia, Spain

****Correspondence:***
Massimiliano Cardinale
massimiliano.cardinale@slu.se

Specialty section:
This article was submitted to
Marine Affairs and Policy,
a section of the journal
Frontiers in Marine Science

Received: *16 September 2016*
Accepted: *28 February 2017*
Published: *16 March 2017*

Citation:
Cardinale M, Osio GC and Scarcella G (2017) Mediterranean Sea: A Failure of the European Fisheries Management System. Front. Mar. Sci. 4:72. doi: 10.3389/fmars.2017.00072

INTRODUCTION

In 2002, the World Summit on Sustainable Development (WSSD; United nations, 2002) established the deadline for the recovery of world's depleted fish stocks to biomass levels that can produce the maximum sustainable yield (B_{MSY}) no later than 2015. The Common Fisheries Policy (CFP) fixes the rules and directions for a sustainable exploitation of marine resources exploited by European fishing fleets (Regulation (EU) No 1380/2013; EU, 2013). The main objective contained in Article 2(2) of the new CFP is the restoration and/or maintenance of populations of harvested species above B_{MSY} levels. This approach would ensure that fisheries are sustainable and profitable in the long term, and that comply with European Union (EU) environmental legislation, as well as with international law principles. All future fisheries measures, and all actions undertaken by EU and Member State institutions, must serve to deliver these objectives, complying with the requirement to set fishing levels below F_{MSY} [i.e., fishing mortality (F) that delivers B_{MSY}] and aimed at achieving stock levels above B_{MSY}. Any measures that take a different approach will be in breach of the CFP, i.e., unlawful.

The first time that the CFP has been enforced was in the 1970s and has been successively updated in 2002 and recently in 2014. The CFP keystone is the sustainable exploitation of marine resources both in environmental and socio-economic terms directing toward a dynamic fishing industry and ensuring a fair standard of living for fishing communities. The current CFP specifies that between 2015 and 2020 exploitation is carried out according MSY principles and is able to maintain fish stocks in the long term. In the case of the impact of fishing on the marine environment is not fully comprehended, the CFP adopts a precautionary approach and seeks for more selective fisheries with a complete ban of discards. Similarly, also the Marine Strategy Framework Directive (MSFD; EU-COM, 2008, 2010) requires EU Member States to take measures to achieve Good Environmental Status (GES) of all European marine waters by 2020.

After 8 years from the adoption of WSSD and the enforcement of MSFD with the definition of GES and targets in each Member State (MS), and the concurrent application of the CFP, Europe has made great progress toward MSY for stocks inhabiting the North East Atlantic (e.g., Cardinale, 2011; Cardinale et al., 2012; Fernandes and Cook, 2013) but it is still far from achieving its objectives for the Mediterranean Sea marine resources (e.g., Colloca et al., 2013; Vasilakopoulos et al., 2014). Notwithstanding the enforcement of the EU Data Collection Regulation (EU, 2000) in the early 2000s by all EU MSs, and the rapid increase in the number of assessed stocks by the General Fisheries Commission for the Mediterranean (GFCM) and the European Scientific, Technical and Economic Committee for Fisheries (STECF), Mediterranean Sea marine resources are still exploited above the levels that deliver the maximum sustainable yield and no signs of recovery are evident (Vasilakopoulos et al., 2014). Particularly, in the Mediterranean Sea, the achievements of WSSD targets is at risk to be further delayed by the management systems currently enforced at the national and EU level.

From the management perspective, Mediterranean Sea countries are limited mainly to control fishing effort and fishing capacity together with specific technical measures, such as gear regulation (mainly mesh size and net configuration, in particular for purse seine), establishment of a minimum conservation reference size, and closures of areas and seasons for fishing. Moreover, the Article 19 of Council Regulation (EU, 2006; hereafter referred to as "the Mediterranean Regulation") foreseen that management plans within their territorial waters are adopted for trawling and other fishing activities. In this context, it is important to notice that spatial and temporal closures apply mainly to trawls, which are prohibited within 3 nautical miles from the coast or within the 50 m isobath, where this is closer to the coast. Also, temporal closures regard bottom and mid-water trawl nets are mainly enforced for 30–45 days during summer (Demestre et al., 2008). A second set of management measures in the Mediterranean Sea incorporate the establishment of permanent marine protected areas. However, the extension of MPA is still rather limited in the Mediterranean Sea, covering around 9.5% of the EU water within 200 nm and being mostly located in the Western Mediterranean (http://www.eea.europa.eu/data-and-maps/figures/regional-seas-surrounding-europe-and-2).

Conservation reference points are established in national management plans in order to recover or maintain the stock within safe biological limits ensuring the sustainable exploitation of stocks and that impact of fishing activities on marine ecosystems is kept at sustainable levels. An important feature of these plans is that they should be solely adopted within the territorial waters of each MS, and thus do not consider the transboundary dimension of most of the stocks exploited in the Mediterranean Sea.

Here, we collated and analyzed all available information on Mediterranean Sea stocks. We analyzed the current stock status of Mediterranean Sea marine resources and compared it to the F_{MSY} target. We also explored the temporal trends in F to determine if the status of stock is improving or worsening. Further, we analyzed the relationship between F and nominal fishing effort for stocks fished by EU MSs only.

MATERIALS AND METHODS

We collated information on the Mediterranean fish stocks from relevant reports of STECF (https://stecf.jrc.ec.europa.eu/reports/medbs) and GFCM SAC (http://www.fao.org/gfcm/reports/statutory-meetings/en/), published over the period 2007–2015. These reports were used to extract estimates of fishing mortality (F), fishing mortality which corresponds to MSY (F_{MSY}), SSB (Stock spawning biomass), recruitment, catches, and advised catches for each stock. Collated data were stored in a database which contains all available information on the status of 142 stocks (as combination of species and GSAs (i.e., Geographical Sub-Areas) derived from assessments conducted between 2007 and 2014 (**Table 1**, **Figure 1**). In total, more than 500 stock assessments results were collated, which cover 26 different species and 27 GSAs or combination of GSAs. However, not all stocks

TABLE 1 | List of species and stocks (by GSA or combination of GSAs) collated in this study with the associated reference where the stock assessment has been conducted.

Scientific name	GSAs	References
Merluccius merluccius	1	GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2015a
		STECF, 2008b
		STECF, 2008c
		STECF, 2011a
		STECF, 2011b
		STECF, 2013a
		STECF, 2015b
	5	GFCM, 2007a
		GFCM, 2008a
		GFCM, 2009a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2014c
		GFCM, 2015a
		STECF, 2008b
		STECF, 2008c
		STECF, 2010a
		STECF, 2012a
		STECF, 2015b
	6	GFCM, 2007a
		GFCM, 2008a
		GFCM, 2009a
		GFCM, 2010a
		GFCM, 2012a
		GFCM, 2014c
		STECF, 2008a
		STECF, 2008b
		STECF, 2008c
		STECF, 2009a
		STECF, 2010a
		STECF, 2011b
		STECF, 2014a
		STECF, 2015b
	7	GFCM, 2008a
		GFCM, 2009a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2015a
		STECF, 2008a
		STECF, 2008b
		STECF, 2008c
		STECF, 2010a
		STECF, 2012a
		STECF, 2012b
		STECF, 2013a
		STECF, 2014a
		STECF, 2015b
	8	STECF, 2008b
	9	GFCM, 2007a
		GFCM, 2011a
		GFCM, 2015a
		STECF, 2008a
		STECF, 2008b
		STECF, 2008c
		STECF, 2009a
		STECF, 2010a
		STECF, 2011b
		STECF, 2014a
		STECF, 2015b
	10	GFCM, 2009a
		GFCM, 2014c
		STECF, 2008a
		STECF, 2008b
		STECF, 2009a
		STECF, 2010a
		STECF, 2012a
		STECF, 2013a
		STECF, 2015b
	11	STECF, 2008b
		STECF, 2008c
		STECF, 2009a
Merluccius merluccius	11	STECF, 2010a
		STECF, 2012a
		STECF, 2012b
		STECF, 2012d
		STECF, 2015b
	16	STECF, 2008a
	17	GFCM, 2014c
		STECF, 2008b
		STECF, 2008c
		STECF, 2010a
		STECF, 2012d
	18	GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2014c
		GFCM, 2015a
		STECF, 2008b
		STECF, 2012a
		STECF, 2013a
	19	GFCM, 2015a

(Continued)

TABLE 1 | Continued

Scientific name	GSAs	References
		STECF, 2008b
		STECF, 2012d
		STECF, 2013a
		STECF, 2016
	20	STECF, 2008b
		STECF, 2012c
	22	STECF, 2008a
	12-16	GFCM, 2014a
		GFCM, 2014c
		GFCM, 2015a
	15-16	STECF, 2008b
		STECF, 2008c
		STECF, 2010a
	1-5-6-7	STECF, 2015b
	17-18	STECF, 2016
	22-23	STECF, 2008b
		STECF, 2012c
	9-10-11	STECF, 2015b
Mullus barbatus	1	GFCM, 2008a
		STECF, 2008b
		STECF, 2011a
		STECF, 2011b
		STECF, 2015a
	5	GFCM, 2008a
		GFCM, 2010a
		GFCM, 2014a
		STECF, 2008b
		STECF, 2010a
		STECF, 2012a
		STECF, 2013a
	6	GFCM, 2008a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2014a
		STECF, 2008b
		STECF, 2008c
		STECF, 2010a
		STECF, 2013a
		STECF, 2014a
	7	GFCM, 2009a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2014c
		GFCM, 2015a
		STECF, 2008b
		STECF, 2010a
		STECF, 2012a
		STECF, 2012b
		STECF, 2014a
	8	STECF, 2008b
	9	GFCM, 2010a
		GFCM, 2011a
		STECF, 2008b
		STECF, 2008c
		STECF, 2009a
Mullus barbatus	9	STECF, 2010a
		STECF, 2011b
		STECF, 2012d
		STECF, 2014a
	10	GFCM, 2014a
		GFCM, 2014c
		STECF, 2008b
		STECF, 2008c
		STECF, 2010a
		STECF, 2012a
	11	STECF, 2008b
		STECF, 2010a
		STECF, 2012a
		STECF, 2012d
		STECF, 2013a
	15	GFCM, 2009a
	16	STECF, 2008b
	17	GFCM, 2014a
		GFCM, 2015a
		STECF, 2008b
		STECF, 2008c
		STECF, 2012b
		STECF, 2013a
	18	GFCM, 2015a
		STECF, 2008b
		STECF, 2012b
		STECF, 2015a
	19	GFCM, 2014a
		STECF, 2008b
		STECF, 2012d
		STECF, 2016
	20	STECF, 2008b
		STECF, 2012c
	25	GFCM, 2009a
		GFCM, 2011a
		GFCM, 2015a
		STECF, 2008b
		STECF, 2008c
		STECF, 2009a
		STECF, 2010a
	1-3	GFCM, 2015a
	15-16	GFCM, 2011a
		GFCM, 2012a

(Continued)

TABLE 1 | Continued

Scientific name	GSAs	References
		STECF, 2011b
		STECF, 2012b
	17-18	STECF, 2016
	22-23	STECF, 2008b
		STECF, 2012c
Boops boops	20	STECF, 2012c
	25	GFCM, 2011a
		GFCM, 2015a
	22-23	STECF, 2012c
Galeus melastomus	9	GFCM, 2011c
		STECF, 2011a
		STECF, 2011b
Lophius budegassa	1	STECF, 2015a
	5	STECF, 2012d
		STECF, 2015a
	6	STECF, 2012b
		STECF, 2015a
	7	STECF, 2012b
	15-16	GFCM, 2011a
		STECF, 2012b
Micromesistius poutassou	1	STECF, 2012d
	6	STECF, 2012b
		STECF, 2014a
	9	STECF, 2012b
		STECF, 2014a
Mullus surmuletus	5	GFCM, 2007a
		GFCM, 2008a
		GFCM, 2009a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2014c
		GFCM, 2015a
		STECF, 2010a
		STECF, 2013a
	9	GFCM, 2011a
		STECF, 2011a
		STECF, 2011b
	11	STECF, 2013a
	15	GFCM, 2009a
	20	STECF, 2012c
	25	GFCM, 2011a
	15-16	GFCM, 2014a
		STECF, 2013a
	22-23	STECF, 2012c
Pagellus bogaraveo	1-3	GFCM, 2008a
		GFCM, 2012a
Pagellus erythrinus	9	STECF, 2010a
		STECF, 2011b
	15-16	GFCM, 2011a
		GFCM, 2012a
		STECF, 2011b
		STECF, 2012b
Phycis blennoides	9	STECF, 2012d
Raja asterias	9	GFCM, 2011c
Raja clavata	9	GFCM, 2011c
	15-16	GFCM, 2011c
Scyliorhinus canicula	9	GFCM, 2011c
Solea solea	9	STECF, 2011a
	17	GFCM, 2007a
		GFCM, 2008a
		GFCM, 2010a
		GFCM, 2011a
		GFCM, 2012a
		GFCM, 2014a
		GFCM, 2015a
		STECF, 2009a
		STECF, 2010a
		STECF, 2011b
		STECF, 2012d
		STECF, 2013a
		STECF, 2016
Spiacara flexuosa	20	STECF, 2012c
	22-23	STECF, 2012c
Spiacara smaris	20	STECF, 2012c
	22-23	STECF, 2012c
	25	GFCM, 2014a
		STECF, 2011b
Trisopterus minutus	9	STECF, 2012b
Engraulis encrasicolus	1	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2009b
		GFCM, 2010b
		STECF, 2008c
		STECF, 2010a
	6	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2009b
		GFCM, 2010b

(Continued)

TABLE 1 | Continued

Scientific name	GSAs	References
		GFCM, 2011b
		GFCM, 2014b
		GFCM, 2014d
		STECF, 2008a
		STECF, 2008c
		STECF, 2010a
	7	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2009b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		GFCM, 2014d
		GFCM, 2015b
		STECF, 2008c
	9	STECF, 2010a
		STECF, 2011b
	16	GFCM, 2008b
		GFCM, 2009b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		STECF, 2009a
		STECF, 2010a
		STECF, 2012d
	17	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2009b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		STECF, 2008c
		STECF, 2009a
		STECF, 2012d
		STECF, 2013b
	18	GFCM, 2007b
	19	STECF, 2013a
	20	STECF, 2010a
	22	GFCM, 2009b
		STECF, 2008c
		STECF, 2009a
		STECF, 2010a
		STECF, 2012a
		STECF, 2013a
	17-18	GFCM, 2014d
		GFCM, 2015b
		STECF, 2014a
Sardina pilchardus	1	GFCM, 2007b

(Continued)

TABLE 1 | Continued

Scientific name	GSAs	References
		GFCM, 2008b
		GFCM, 2010b
		GFCM, 2014b
		STECF, 2008c
		STECF, 2010a
		STECF, 2013a
	3	GFCM, 2014d
		GFCM, 2015b
	6	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2014b
		GFCM, 2014d
		STECF, 2008a
		STECF, 2008c
		STECF, 2010a
		STECF, 2015a
	7	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		GFCM, 2014d
		GFCM, 2015b
		STECF, 2013a
	9	STECF, 2012b
		STECF, 2013a
		STECF, 2015a
	16	GFCM, 2008b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		GFCM, 2015b
		STECF, 2009a
		STECF, 2010a
		STECF, 2012d
	17	GFCM, 2007b
		GFCM, 2008b
		GFCM, 2010b
		GFCM, 2011b
		GFCM, 2012b
		GFCM, 2014b
		STECF, 2008c
		STECF, 2009a
		STECF, 2012a
		STECF, 2012d
		STECF, 2013a
	18	GFCM, 2007b
		STECF, 2013a

(Continued)

TABLE 1 | Continued

Scientific name	GSAs	References
	20	STECF, 2010a
	22	STECF, 2008c
		STECF, 2009a
		STECF, 2010a
		STECF, 2012a
	1-3	GFCM, 2012b
	17-18	GFCM, 2014d
		GFCM, 2015b
		STECF, 2014a

resulted in an analytical stock assessment. Also, data on fishing effort by fisheries in terms of Kw/Days at Sea (i.e., nominal effort) and Gross tonnage/Days at sea were extracted and collated for each GSA and fisheries. This represents the most complete database of stock assessment results for the Mediterranean region available to date.

For the exploration of temporal trends in F and effort, we selected the main species and fisheries operating in the Mediterranean Sea. The species selected were European hake, red mullet, deep-water rose shrimp, Norway lobster, giant red shrimp, blue and red shrimp, European anchovy, and sardine. The landings of these species in 2014 constituted approximately 55% of the total landings in the European GSAs of Mediterranean Sea and they are considered as the target species in all GSAs (2015-Economic Data Call; **Table 2**). The fisheries selected were demersal trawl operating on the shelf (hereafter defined as demersal coastal trawl), demersal trawl operating in the deep (hereafter defined as demersal deep trawl), purse seine, pelagic trawls and net, lines, and traps combined (hereafter defined as passive gears) (**Table 3**). The gears included in each of the fisheries selected are summarized in **Table 3**. Here, we used both nominal effort in Kw/Days at sea and Gross Tonnage/Days at sea as a measure of effort in the analysis.

Statistical Analysis

Generalized Additive Models (GAMs; Hastie and Tibshirani, 1990) were used to account for the unbalanced design in the data available between years and GSAs. The model non-linearity, a common characteristic of biological data, is one of the main benefits that GAMs can handle. Fishing mortality was scaled by the level of F_{MSY} in order to make the different stocks comparable in the analysis. A normal distribution (Minami et al., 2007) to model the ration F/F_{MSY} has been used.

For each species a GAM model was fitted:

$$F/F_{MSY} \sim s(\text{year}) + s(\text{effort}) + (\text{GSA})$$

For hake, demersal coastal trawl, mixed trawl and net, and lines effort were included. For red mullet, only demersal coastal trawl effort was considered. For deepwater pink shrimp and Norway lobster, mixed and deep demersal trawl effort was used while for anchovy and sardine, purse seines and pelagic trawlers effort was used (**Table 3**). The combination among species and gear/fisheries have been made in accordance with the last STECF available assessments (STECF, 2015a,b, 2016).

The isotropic smooth (i.e., thin plate regression spline) function (Wood, 2004) has been used to model Year and effort while GSA was modeled as a factor. The maximum number of knots was limited for the smooth term of effort ($k \leq 3$) and year ($k \leq 7$), in order to simplify the output interpretation. For each species model, two different link functions were tested, a log link which assumes constant variance and a identify link which assumes constant coefficient of variation and hence a variance proportional to the square of the mean. The best model was chosen using the AIC (Akaike Information Criteria) (Akaike, 1974). Effort data was available only from 2002 and thus only these years (i.e., 2002–2014) were included in the analysis.

The assumptions of variance homoscedasticity and normal distribution of data have been explored throughout the analysis of the residuals. Similarly, the residuals were employed to inspect analyses the departure from the model assumptions or other anomalies in the data or in the model fit using graphical methods (Cleveland, 1993).

Comparison between Forecast Catches and Real Catches

In most of the stock assessment carried out in the framework of GFCM and STECF short-term forecasts have been conducted for 2 or 3 years after the reference year of the assessment. The short-term predictions were usually implemented in R (https://www.r-project.org/) using the FLR libraries and based in most of the cases on the results of the Extended Survivor Analyses (XSA, Darby and Flatman, 1994) or other assessment models. Several scenarios of F were tested as well as the F which is in accordance with the F_{MSY}. The method employed allowed to estimate the catches relative to the F reference points assuming a constant recruitment in the following 2 years equal to the geometric mean of the previous 3 years. Such reference catches have been then compared with the real catches for each stock analyzed.

RESULTS

There is no difference in the model results when using Kw/Days at sea or Gross Tonnage/Days at sea and thus only results for Kw/Days at sea were presented here. This was expected as Kw/Days at sea and Gross Tonnage/Days at sea are highly significantly correlated for all GSA and fisheries selected here ($r^2 = 0.91; p < 0.05$).

Table 4 summarize the detailed results for all GAMs fitted. A total of eight GAMs were fitted. The significant effects for all models fitted are presented in **Figure 2**. Model assumptions of normality and homogeneity of variance have been respected, as showed by the analysis of the residuals (data not shown).

Generally all GAMs explained a rather large part of the deviance (76.3–95.1%) with an r^2 which ranged between 0.70 and 0.93. The log link was selected as the best model based on the AIC for hake, red mullet, Norway lobster, and sardine. The identity

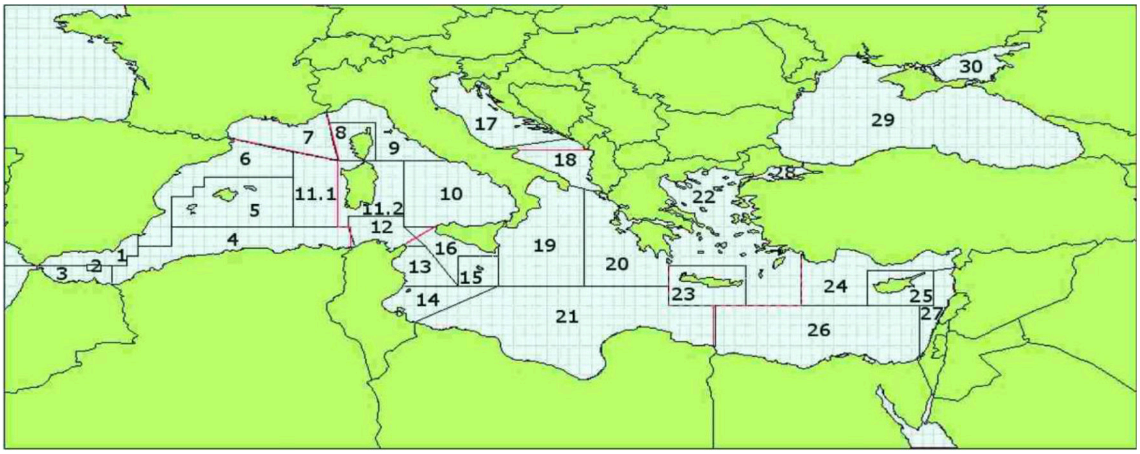

FIGURE 1 | Map of the GFCM Geographical Sub-Areas (GSAs) established in the resolution GFCM/33/2009/2 (GFCM, 2009d).

link resulted in the best model for deep water pink shrimp, giant red shrimp, blue and red shrimp, and sardine (**Table 4**).

Concerning the effect of the different predictors included in the models, the results of the GAM analysis showed that effort was not significantly related to F/F_{MSY} in any of the model fitted except for deep water pink shrimp (**Figure 2**). However, the shape of the effect of effort on F/F_{MSY} for deep water pink shrimp is contradictory to the expectations (i.e., decreasing F/F_{MSY} with increasing effort) and thus it was considered to be spurious. On the other hand, the effect of GSA was significant for all models. The year effect was significant only for red mullet, giant red shrimp (decreasing trend in F/F_{MSY} over time) and sardine (increasing trend of F/F_{MSY} over time).

The average ratio F/F_{MSY} is larger than 1 for all species, ranging from 1.7 to 8.1 (Giant red shrimp and hake, respectively; **Table 4**). Even for red mullet and giant red shrimp, for which the ratio F/F_{MSY} has significantly declined over time, the value of the last year (i.e., 2014) is still above 1 (2.5 and 1.1, for red mullet and giant red shrimp, respectively).

In **Table 5** are reported the comparisons between the forecasted yearly catches in accordance with F_{MSY} and the realized catches estimated for the target stocks previously analyzed. In almost all cases realized catches have been much larger than the forecasted ones, with an average catch over the analyzed time period (i.e., 2010–2014) being around 178% larger than the scientific advice.

DISCUSSION

In recent years European fisheries managers have witnessed the success of the European CFP in the north (i.e., North East Atlantic, Cardinale et al., 2012; Fernandes and Cook, 2013) and at the same time, its failure in the south (i.e., Mediterranean Sea, Colloca et al., 2013; Vasilakopoulos et al., 2014). Thus, despite the fact that both areas are managed under the same broad fishery policy (i.e., European CFP), a large discrepancy in management performance still occur between the North East Atlantic and the Mediterranean Sea.

The fishing mortality exerted on the North East Atlantic has shown a rapid and general decline during the last 15 years and even the spawning stock biomass has started to show clear signs of increasing for several stocks in the North East Atlantic area (www.ices.dk). On the other hand, Mediterranean stocks have largely declined in the last 15 years and their exploitation level has raised or remained above the F_{MSY} level during the same period of time (Vasilakopoulos et al., 2014; this paper). Here we showed that up to 2014, the average exploitation rate for the main demersal and small pelagic stocks of the Mediterranean Sea is around three times the estimated level of F_{MSY}, with a general similar pattern across species and area, which confirms analyses recently conducted (STECF, 2015c). Moreover, as we have mostly only a snapshot of the last decade for Mediterranean stocks (i.e., generally from the beginning of the 2000s to today), and, as F has been estimated to be very high since the beginning of the time series (Colloca et al., 2013; Vasilakopoulos et al., 2014), the decline in stock biomass might have started much before and being more pronounced than described by current assessment models. This has been demonstrated by those assessments with a longer time series, as small pelagics in the Adriatic Sea (time series: 1975–2014; GFCM, 2015b) and common sole in the Northern Adriatic Sea (time series: 1970–2014; GFCM, 2015a; STECF, 2016).

The CFP obviously applies to the Mediterranean Sea as well, although it has been argued that, as several Mediterranean stocks are shared with non EU countries on the southern part of the basin, the unsuccessful management of the CFP could be attributed to the fact that Europe has no jurisdiction on these stocks. However, there are several Mediterranean stocks that are solely distributed within EU territorial waters (i.e., several Spanish, France and Italian stocks located in GSAs 4–11) and for which therefore the CFP is the primary (and only) management instrument for assuring their long term sustainable exploitation. Here we showed that the average

TABLE 2 | Landings by species, GSA and gear in 2014 for species included in the GAM models (source: 2015 Economic data call).

Species	Fishery	GSA 1	GSA 5	GSA 6	GSA 7	GSA 8	GSA 9	GSA 10	GSA 11	GSA 15	GSA 16	GSA 17	GSA 18	GSA 19	GSA 20	GSA 22	GSA 23	GSA 25	Total
European anchovy	Demersal coastal trawl	0.3		106.1	1547.6	1.6	41.2	269.7			78.2	218.1	36.7	0.1	0.0	418.7			2718.0
	Passive gears	4.6		4.6	683.7	0.2	19.4	62.5				8.5		17.7		26.7		1.0	829.0
	Pelagic trawl										677.2	17012.8	2529.9						20211.0
	Purse seine	4467.2	277.3	14735.4	133.0		3390.8	3029.1			1349.6	11345.1	800.1	103.5	403.1	6556.1	1.3		46592.0
Sardine	Demersal coastal trawl	0.8		27.2	76.6	1.3	11.6	37.8			43.8	1646.8	11.6	21.6	6.0	70.9	1.7	0.2	1958.0
	Passive gears	88.8		8.9	75.2	0.7	10.8	78.9				28.8		29.6		758.8	0.0	0.3	1081.0
	Pelagic trawl										341.4	17011.2	1751.2						19104.0
	Purse seine	7444.3	138.3	7915.5	686.4		1782.4	729.6			1085.2	57438.5	605.4	83.6	520.1	4720.0	0.3		83150.0
Blue and red shrimp	Demersal deep trawl	198.3	112.0	419.0	34.8		83.6	7.3	89.8	1.3	116.6		2.7	299.5					1365.0
	Passive gears		0.0	0.2				1.4											1.6
Giant red shrimp	Demersal deep trawl	0.2	3.9	4.3	0.1		16.8	436.8	123.9	25.1	1310.2	3.9	8.1	320.0	25.5	0.6			2280.0
	Passive gears							17.2											17.0
Deep-water rose shrimp	Demersal coastal trawl	34.6	2.2	18.0	4.0	1.5	561.4	497.3	30.2	21.2	5310.4	572.3	615.5	421.5	20.3	2284.3	37.1		10432.0
	Passive gears		0.0	0.0	0.5	0.0	0.0	11.8		0.8		0.2	22.3	1.8	1.7	13.8			53.0
Norway lobster	Demersal coastal trawl	21.9	21.7	296.6	26.7	18.1	111.5	16.6	35.3	1.7	249.0	867.1	444.7	84.8	3.0	256.7	0.1	0.1	2455.0
	Passive gears	0.1	0.0	0.1	0.5	0.0	0.1	4.8	0.0			19.1	0.0		3.9	112.2			140.0
European hake	Demersal coastal trawl	124.6	90.2	1501.4	1529.2	5.8	1010.5	345.4	134.5	16.1	1376.0	2630.0	1560.0	209.9	300.4	1484.0	53.6	0.6	12372.0
	Passive gears	36.2	0.1	232.8	138.9	0.4	263.6	925.8	124.1	5.0	91.6	128.7	303.6	530.1	284.2	557.4	3.2	2.2	3627.0
Red mullet	Demersal coastal trawl	49.7	14.7	498.7	22.7		1098.3	342.0	258.6	12.1	417.4	3576.0	1218.8	102.7	118.3	746.4	107.1	15.7	8599.0
	Passive gears	10.8	0.3	62.2			83.2	95.9	5.4	0.2	2.6	38.8	53.4	148.4	185.6	816.9	26.0	8.8	1538.0
Total landings of species analyzed by GSA		12482.1	660.7	25831.0	4960.0	29.6	8485.3	6910.0	801.9	84.0	12449.0	112546.0	9964.0	2374.0	1872.0	18823.0	230.4	28.8	21852
Total landings by GSA		29467.1	2698.0	43775.8	14338.4	375.1	17419.5	18524.2	5981.5	2379.9	19,850.6	164808.1	19917.6	10104.1	6005.5	40642.8	1059.9	1218.9	398567
Percentage by GSA		42.4	24.5	59.0	34.6	7.9	48.7	37.3	13.4	3.5	62.7	68.3	50.0	23.5	31.2	46.3	21.7	2.4	54.8

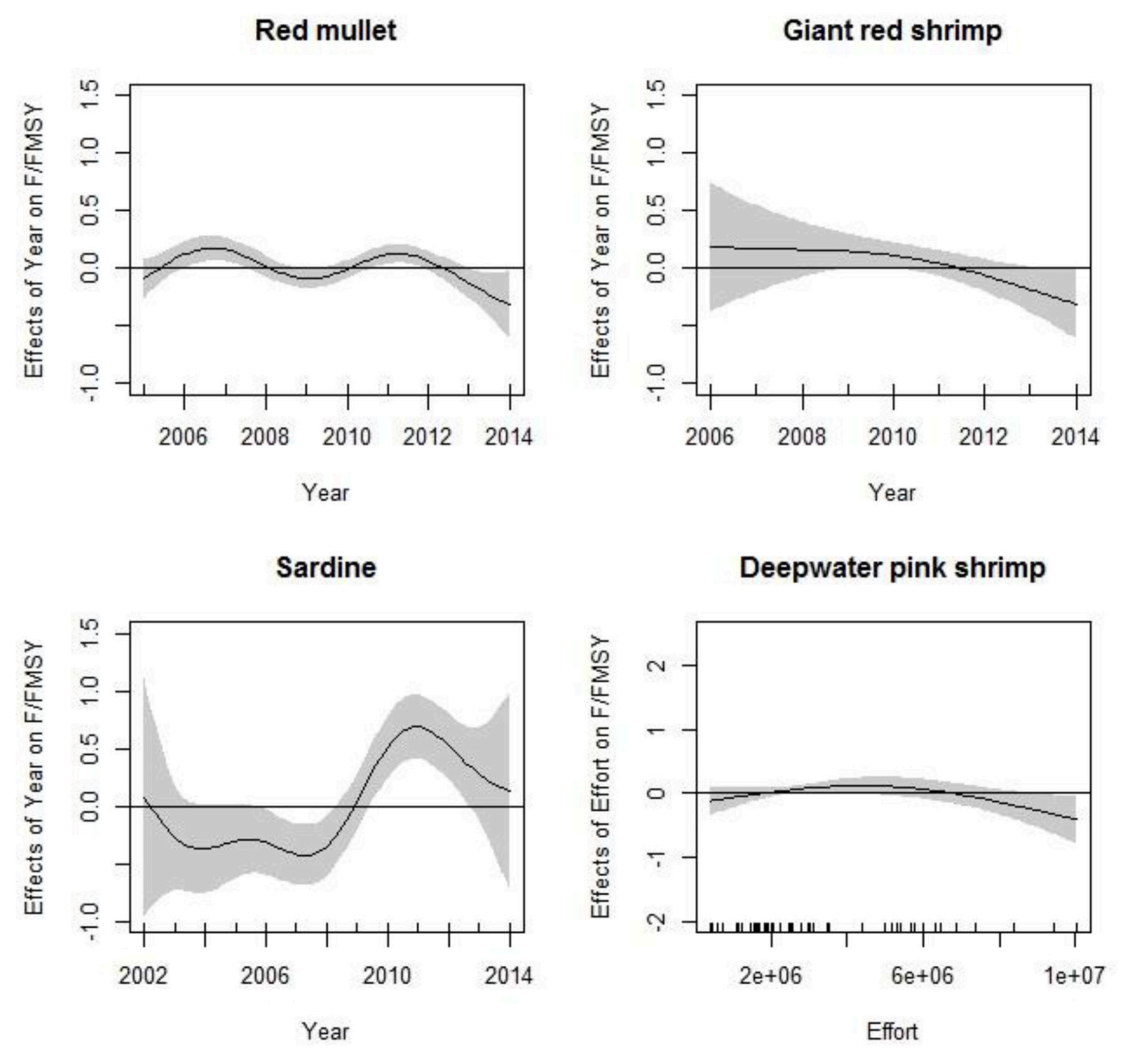

FIGURE 2 | Effect of the predictors (with the 95% confidence intervals) on the ratio between F/F_{MSY} for each model species. Only significant predictors were shown. For model details see Material and methods.

here demonstrated that putative management based mainly on reduction in nominal effort has failed in the Mediterranean Sea and it is most likely that it will most likely fail also in the near future. It is therefore undoubted that alternatives management measures as a TAC based system are necessary if Europe is willing to achieve the objectives of the CFP before 2020 in the Mediterranean Sea.

Another important measure for the management of the Mediterranean Sea stocks within the Mediterranean regulation is the implementation of national MP. Such MPs are allowed by the current Mediterranean Regulation and they are developed at the level of fisheries and/or gear types within national borders. Here, we argue that allowing national management is a clear weakness of the current Mediterranean Regulation as such plans are a very inefficient management measure since they disregard the real geographical distribution of the stocks and fisheries exploiting them. As a matter of fact, most of the stocks are exploited by multiple fisheries and often by different member states. Therefore, it is considered that for stocks shared both in terms of different countries and fleets exploiting them, a fishery management plan needs to include all fleets and countries exploiting the stock (STECF, 2012e). This is likely the reason why management plans in the North East Atlantic have been progressively successful in recent years (STECF, 2014b) while it has not been the case in the Mediterranean Sea (e.g., the multiannual MP for small pelagic in the Adriatic, GFCM/37/2013/1; GFCM, 2013, 2016) and it also clearly highlight another crucial weakness of the current Mediterranean regulation.

Within the framework of an Ecosystem Approach to Fisheries Management, a properly designed and integrated network of different types of MPA could potentially help in achieving

TABLE 5 | Difference (in %) between the scientific catch advice and the realized catches for each year and stock for which a short term forecast was carried out.

Stock	2010	2011	2012	2013	2014
ANE GSA 1		216	−25		
PIL GSA 1		−21	−23		
ARA GSA 6	390	176		70	−3
ARS GSA 9			123	−26	−30
DPS GSA 5		134	58		
DPS GSA 6			−1	−51	81
DPS GSA 9	33	132	88	94	-5
DPS GSA 10		47	54	72	
DPS GSA 18				40	−6
DPS GSA 19					4
DPS GSA 12-16		116	53		
HKE GSA 1			60	−27	418
HKE GSA 5	1,203	763	306	54	
HKE GSA 6		340	248	52	
HKE GSA 7		86	97	1,450	552
HKE GSA 9	352	259	289	91	
HKE GSA 10	128	172	219	58	374
HKE GSA 11			1,014	115	−66
HKE GSA 19					191
MUT GSA 6		54	254	47	
MUT GSA 7	174	140	−3	159	102
MUT GSA 9		72	31		
MUT GSA 10		−18	132	91	
MUT GSA 11	282	14	51		
MUT GSA 17					281
MUT GSA 18				221	147
MUT GSA 25	92	−19			
NEP GSA 5		170			
NEP GSA 6			294	163	
NEP GSA 9	89	55	83	41	

See ***Table 1*** *for references.*

a better exploitation pattern and the MSY sustainability target. However, the extension of MPA in the Mediterranean Sea is still rather limited (http://www.eea.europa.eu/data-and-maps/figures/regional-seas-surrounding-europe-and-2) and thus MPA are likely to contribute only little to the current management of Mediterranean stocks. It is also unquestionable that the complexity of the Mediterranean fisheries, with a large number of small vessels operating at a small spatial scale in very local fisheries, and the diverse cultural, social and economic characteristics of the countries sharing the resources pose significant challenges to sustainable management of Mediterranean marine resources (Piroddi et al., 2015). However, here we shown that even stocks mainly caught by trawlers and purse seines within EU waters, are fished not in accordance with the CFP MSY target and that management of these stocks is ineffective to control their level of exploitation. Moreover, these stocks have a central role in management resolutions as they are the key species of future Mediterranean management plans.

Vasilakopoulos et al. (2014) argued that the difference in fisheries management performances between the Northern and the Southern part of Europe pattern might be explained not only by the more sophisticated management regime and better compliance and enforcement of the North East Atlantic, but also by the socio-economic complexity and less effective governance system in the southern Europe (Smith and Garcia, 2014). Here, we showed instead that major reasons for the alarming situation of Mediterranean Sea stocks can be found in the ineffectiveness of the putative effort reductions to control fishing mortalities, the continuous non-adherence to the scientific advice, and the existence of ineffective national management plans as a primary management measure. The European CFP has failed to achieve MSY before 2015 for the Mediterranean Sea and will face large difficulties to reach MSY and MSFD targets before 2020 under the current management regime.

AUTHOR CONTRIBUTIONS

All authors listed, have made substantial, direct and intellectual contribution to the work, and approved it for publication.

REFERENCES

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Trans Automat. Control* 19, 716723.

Cardinale, M. (2011). Fishery reform: most stocks secure. *Nature* 476, 282. doi: 10.1038/476282a

Cardinale, M., Doerner, H., Abella, A., Andersen, J. L., Casey, J., Döring, R., et al. (2012). Rebuilding EU fish stocks and fisheries, a process under way? *Marine Policy* 39, 43–52. doi: 10.1016/j.marpol.2012.10.002

Carpenter, G., Kleinjans, R., Villasante, S., and O'Leary, B. C. (2016). Landing the blame: the influence of EU Member States on quota setting. *Marine Policy* 64, 9–15. doi: 10.1016/j.marpol.2015.11.001

Cleveland, W. S. (1993). *Visualizing Data.* Summit, NJ: Hobart Press.

Colloca, F., Cardinale, M., Maynou, F., Giannoulaki, M., Scarcella, G., Jenko, K., et al. (2013). Rebuilding Mediterranean fisheries: a new paradigm for ecological sustainability. *Fish Fish.* 14, 89–109. doi: 10.1111/j.1467-2979.2011.00453.x

Darby, C. D., and Flatman, S. (1994). *Virtual Population Analysis: Version 3.1 (Windows/DOS) User Guide.* MAFF Directorate of Fisheries Research IT Report 1, 85.

Demestre, M., De Juan, S., Sartor, P., and Ligas, A. (2008). Seasonal closures as a measure of trawling effort control in two Mediterranean trawling grounds: effects on epibenthic communities. *Mar. Pollut. Bull.* 56, 1765–1773. doi: 10.1016/j.marpolbul.2008.06.004

EU (2000). *Council Regulation (EC) No 1543/2000 of 29 June 2000 Establishing a Community Framework for the Collection and Management of the Data Needed to Conduct the Common Fisheries Policy*, EU.

EU (2006). *Council Regulation (EC) No 1967/2006 of 21 December 2006 Concerning Management Measures for the Sustainable Exploitation of Fishery Resources in the Mediterranean Sea, Amending Regulation (EEC) No 2847/93 and Repealing Regulation (EC) No 1626/94*, EU.

EU (2013). *Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, Amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and Repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC Official Journal of the European Union*. Brussels: EU.

EU-COM (2008). *Directive 2008/56/EC of the European Parliament and of The Council of 17 June 2008 Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive)*, EU-COM. Available online at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

EU-COM (2010). *Commission Decision of 1 September 2010 on Criteria and Methodological Standards on Good Environmental Status of Marine Waters, (2010/477/)*, EU-COM.

Fernandes, P. G., and Cook, R. M. (2013). Reversal of fish stock decline in the Northeast Atlantic. *Curr. Biol.* 23, 1432–1437. doi: 10.1016/j.cub.2013.06.016

GFCM (2007a). *Scientific Advisory Committee. 9th Meeting of the Sub-Committee on Stock Assessment (SCSA) Working Group on Demersals*, GFCM.

GFCM (2007b). *Scientific Advisory Committee (SAC).* Sub-Committee for Stock Assessment (SCSA). Report of the 8th Meeting of the Working Group on Small Pelagics, GFCM.

GFCM (2008a). *Scientific Advisory Committee. 10th Meeting of the Sub-Committee on Stock Assessment (SCSA) Working Group on Demersal Species, Including Joint Stock Assessments,* GFCM.

GFCM (2008b). *Scientific Advisory Committee. 9th Meeting of the Sub-Committee on Stock Assessment (SCSA) Working Group on Small Pelagics Species, Including Joint Stock Assessments,* GFCM.

GFCM (2009a). *Scientific Advisory Committee. SCSA Working Group on Demersal Species,* GFCM.

GFCM (2009b). *Scientific Advisory Committee. SCSA Working Group on Small Pelagic Species*, GFCM.

GFCM (2009c). *On the Management of Demersal Fisheries in the GFCM Area.* GFCM Resolution RES-GFCM/33/2009/1, GFCM.

GFCM (2009d). *Establishment of Geographical Sub-Areas in the GFCM Area Amending the Resolution GFCM/31/2007/2*. GFCM Resolution RES-GFCM/33/2009/2, GFCM.

GFCM (2010a). *Scientific Advisory Committee. Report of the SCSA Working Group on Stock Assessment of Demersal Species,* GFCM.

GFCM (2010b). *Scientific Advisory Committee. Report of the Scsa Working Group on Stock Assessment of Small Pelagic Species,* GFCM.

GFCM (2011a). *Scientific Advisory Committee. Report of the Working Group On Stock Assessment of Demersal Species,* GFCM.

GFCM (2011b). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Small Pelagic Species,* GFCM.

GFCM (2011c). *Scientific Advisory Committee. Report of the Workshop on Stock Assessment of selected species of Elasmobranchs in the GFCM area,* GFCM.

GFCM (2012a). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Demersal Species,* GFCM.

GFCM (2012b). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Small Pelagic Species,* GFCM.

GFCM (2013). *Recommendation GFCM/37/2013/1 on a Multiannual Management Plan for Fisheries on Small Pelagic Stocks in the GFCM-GSA 17 (Northern Adriatic Sea) and on Transitional Conservation Measures for Fisheries on Small Pelagic Stocks in GSA 18 (Southern Adriatic Sea)*, GFCM.

GFCM (2014a). *Scientific Advisory Committee.* Report of the Working Groups on Stock Assessment of Demersal species, including: workshop on the definition and estimation of reference points for Mediterranean and Black Sea fisheries (WGSAD), GFCM.

GFCM (2014b). *Scientific Advisory Committee. Report of the Working Groups on Stock Assessment of Small Pelagic species, including: workshop on the definition and estimation of reference points for Mediterranean and Black Sea fisheries (WGSASP),* GFCM.

GFCM (2014c). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Demersal Species (WGSAD),* GFCM.

GFCM (2014d). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Small Pelagics Species (WGSAD),* GFCM.

GFCM (2015a). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Demersal Species (WGSAD)*, GFCM.

GFCM (2015b). *Scientific Advisory Committee. Report of the Working Group on Stock Assessment of Small Pelagic species (WGSASP),* GFCM.

GFCM (2016). *The State of Mediterranean and Black Sea Fisheries*. FAO: GFCM.

Hastie, T., Tibshirani, R. (1990). *Generalized Additive Models*. London: Chapman and Hall.

Minami, M., Lennert-Cody, C. E., Gao, W., Roman-Verdesoto, M. (2007). Modelling shark by-catch: the zero-inflated negative regression model with smoothing. *Fish. Res.* 84, 210–221. doi: 10.1016/j.fishres.2006.10.019

Piroddi, C., Coll, M., Steenbeek, J., Macias Moy, D., Christensen, V. (2015). Modelling the Mediterranean marine ecosystem as a whole: addressing the challenge of complexity. *Mar. Ecol. Prog. Ser.* 533, 47–65. doi: 10.3354/meps11387

Ribeiro, C., Holmes, S., Scott, F., Berkenhagen, J., Demaneche, S., Prista, N., et al. (2016). *Report of the 2nd Workshop on Transversal Variables., 22-26 February 2016. A DCF ad-hoc workshop,* Nicosia.

Ribeiro, C., Holmes, S., Scott, F., Elliott, M., Ahvonen, A., Andres Calvo Santos, A., et al. (2015). *European Commission EUR27153 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen (IPSC). Report of the 1st Workshop on Transversal Variables (Linking economic and biological effort data (call) design).*

Smith, A. D., Garcia, S. M. (2014). Fishery management: contrasts in the Mediterranean and the Atlantic. *Curr. Biol.* 24, R810–2. doi: 10.1016/j.cub.2014.07.031

STECF (2008a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Report of the SGMED-08-02 Working Group on the Mediterranean Part II*, STECF.

STECF (2008b). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Report of the SGMED-08-03 Working Group on the Mediterranean Part III Joint Black Sea Working Group,* STECF.

STECF (2008c). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Report of the SGMED-08-04 Working Group on the Mediterranean Part IV*, STECF.

STECF (2009a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Report of the SGMED-09-02 Working Group on the Mediterranean Part I*, STECF.

STECF (2010a). *Scientific, Technical and Economic Committee for Fisheries (STECF). Assessment of Mediterranean Stocks Part I,* STECF.

STECF (2011a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Assessment of Mediterranean Sea stocks - Part 1 (STECF-11-08).* STECF.

STECF (2011b). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Assessment of Mediterranean Sea Stocks - Part 2 (STECF-11-14).* STECF.

STECF (2012a). *Report of the Scientific, Technical and Economic Committee for Fisheries (STEFC) on Assessment of Mediterranean Sea stocks (STECF 12-03),* STECF.

STECF (2012b). *Report of the Scientific, Technical and Economic Committee for Fisheries (STEFC) on Assessment of Mediterranean Sea Stocks – Part 1 (STECF 12-19),* STECF.

STECF (2012c). *Report of the Scientific, Technical and Economic Committee for Fisheries (STEFC) on assessment of Merluccius merluccius, Mullus barbatus, Mullus surmuletus, Boops boops, Spicara smaris, Spicara flexuosa and Nephrops norvegicus in Aegean and Ionian Waters (STECF 12-21),* STECF.

STECF (2012d). *Scientific, Technical and Economic Committee for Fisheries (STECF) – 2012 Assessment of Mediterranean Sea stocks part II (STECF 13-05). 2013*. Publications Office of the European Union: Luxembourg.

STECF (2012e). *Reports of the Scientific, Technical and Economic Committee for Fisheries (STECF) – 40th Plenary Meeting Report (PLEN-12-02). 2012.* Publications Office of the European Union: Luxembourg.

STECF (2013a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – 2013 Assessment of Mediterranean Sea stocks part I (STECF 13-22).* Publications Office of the European Union: Luxembourg.

STECF (2013b). *Scientific, Technical and Economic Committee for Fisheries (STECF) – 2013 Assessment of Mediterranean Sea stocks part II (STECF-14-08).* Publications Office of the European Union: Luxembourg.

STECF (2014b). *Scientific, Technical and Economic Committee for Fisheries (STECF) -Evaluation/Scoping of Management Plans - Evaluation of the Multiannual Management Plan for the North Sea Stocks of Plaice* *and Sole(STECF-14-03)*. Publications Office of the European Union: Luxembourg.

STECF (2014a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Assessment of Mediterranean Sea Stocks - Part 1 (STECF-14-17*. Publications Office of the European Union: Luxembourg.

STECF (2015a). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Mediterranean Assessments Part 2 (STECF-15-06)*. Publications Office of the European Union: Luxembourg.

STECF (2015b). *Scientific, Technical and Economic Committee for Fisheries (STECF) – Mediterranean Assessments Part 1 (STECF-15-18)*. Publications Office of the European Union: Luxembourg.

STECF (2015c). *Monitoring the Performance of the Common Fisheries Policy (STECF-15-04)*. Publications Office of the European Union: Luxembourg

STECF (2016). *Reports of the Scientific, Technical and Economic Committee for Fisheries (STECF) – Mediterranean assessments part 2 (STECF-16-08)*. Publications Office of the European Union: Luxembourg.

United nations (2002). *Plan of Implementation of the World Summit on Sustainable Development*. Available online at: www.un.org/esa/sustdev/documents/WSSD

Vasilakopoulos, P., Maravelias, C. D., Tserpes, G. (2014). The alarming decline of mediterranean fish stocks. *Curr. Biol.* 24, 1643–1648. doi: 10.1016/j.cub.2014.05.070

Wood, S. N. (2004). Stable and efficient multiple smoothing parameter estimation for generalized additive models. *J. Am. Stat. Ass.* 99, 673–686. doi: 10.1198/016214504000000980

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.