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Multi-zone marine protected areas: assessment of ecosystem and fisheries benefits using multiple ecosystem models

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Abstract:	The current alarming state of many coastal ecosystems calls for the development of tools to support recovery of exploited stocks, ensure their sustainable exploitation and protect marine ecosystems. Multi-zone marine protected areas (MPAs) are often advocated to reconcile conservation and fisheries benefits. However, whether such types of MPAs can really provide both benefits is still uncertain. Here, we analysed three existing Northwestern Mediterranean multi-zone MPAs (Cerbère-Banyuls, Cap de Creus and Medes Islands), each including a fully protected area, and one or more partially protected areas, using a comparative temporal ecosystem modelling approach. Unprotected areas surrounding the MPAs were also included. Our results showed similarities in ecosystem structure and functioning between the three multi-zone MPAs, potentially due to similarities in MPA configuration, enforcement and time since protection. The MPA providing the smallest benefits was the most recent and least enforced. Small-scale and recreational fisheries had strong negative impacts on target species and were driven by the competition for resources between both fisheries. Temporal increases of benefits were small, whenever detected, like slight recoveries of some target species and ecological indicators, mostly in Cerbère-Banyuls and Medes Islands MPAs. Our results confirm the benefits of protection to coastal marine resources and ecosystems when areas are enforced but highlight the current limitations of the three MPAs due to their small size and the significant impacts of small-scale and recreational fisheries. This study illustrates the capability to evaluate protection effects of small multi-zone MPAs with an ecosystem modelling perspective and represents the baseline to develop future scenarios of alternative management

	options to foster ecosystem recovery and resource rebuilding in the studied MPAs.
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11th of November 2019

Barcelona, Spain

To the editor of *Ocean and Coastal Management*,

Dear editor,

Please find attached our manuscript **"Multi-zone marine protected areas: assessment of ecosystem and fisheries benefits using multiple ecosystem models"** to be considered for publication in ***Ocean and Coastal management***. Our manuscript is intended to be a Research Article.

In this study we modelled three relatively well studied MPAs from the Northwestern Mediterranean Sea with a historical perspective: Cerbère-Banyuls, Cap de Creus and Medes Islands. Our aims were to: (1) quantify the main structural and functional traits of the three multi-zone MPAs, and (2) assess how exploitation and protection regimes affected these marine ecosystems over time, using a comparative approach to identify commonalities and differences between MPAs. The food web models were developed using the Ecopath with Ecosim (EwE) modelling approach. The baseline models of each MPA were built taking into account the contribution of each zone to the whole MPA based on a previous study that is already submitted (Vilas et al., submitted. Aquatic Conservation: Marine and Freshwater Ecosystems).

Our results showed similarities in ecosystem structure and functioning between the three multi-zone MPAs, potentially due to similarities in MPA configuration, enforcement and time since protection. Small-scale and recreational fisheries had strong negative impacts on target species and were driven by the competition for resources between both fisheries. Temporal increases of benefits were small, whenever detected, like slight recoveries of some target species and ecological indicators, mostly in Cerbère-Banyuls and Medes Islands MPAs. Our results confirm the benefits of protection to coastal marine resources and ecosystems when areas are enforced but highlight the current limitations of the three MPAs due to their small size and the significant impacts of small-scale and recreational fisheries.

This study presents the first development of MPAs temporal models that are nearly located, potentially constituting a network of protected areas with an historical perspective in the Mediterranean Sea. This study represents an important step forward in assessing multi-zone MPAs putative effects over time on recovering marine resources and ecosystems in the Northwestern Mediterranean Sea.

In this study we used recent developments of the EwE approach following the best practices. Specifically, we used the PREBAL analysis (Link et al., 2010. Ecological modelling 12, 1580-1591) to ensure that model parameters obeyed general ecologic principles and to guide the balancing procedure. In addition, we used the ECOIND plug-in (Coll et al., 2017. Environmental Modelling and Software 89, 120-130) and the Ecological Network Analysis module in EwE to calculate several ecological indicators. We also addressed uncertainty of input data on results by using the Monte Carlo uncertainty routine and the ECOIND and ECOSAMPLER plug-ins (Steenbeek et al., 2018. SoftwareX 7, 198-204).

I confirm that all coauthors of the manuscript agreed to be listed and approve the submitted version of the manuscript.

We confirm that the manuscript was not submitted to other journals and it is original.

We hope this study is of interest for ***Ocean and Coastal Management*** and we look forward to hearing from you,

Yours sincerely,

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Abstract

The current alarming state of many coastal ecosystems calls for the development of tools to support recovery of exploited stocks, ensure their sustainable exploitation and protect marine ecosystems. Multi-zone marine protected areas (MPAs) are often advocated to reconcile conservation and fisheries benefits. However, whether such types of MPAs can really provide both benefits is still uncertain. Here, we analysed three existing Northwestern Mediterranean multi-zone MPAs (Cerbère-Banyuls, Cap de Creus and Medes Islands), each including a fully protected area, and one or more partially protected areas, using a comparative temporal ecosystem modelling approach. Unprotected areas surrounding the MPAs were also included. Our results showed similarities in ecosystem structure and functioning between the three multi-zone MPAs, potentially due to similarities in MPA configuration, enforcement and time since protection. The MPA providing the smallest benefits was the most recent and least enforced. Small-scale and recreational fisheries had strong negative impacts on target species and were driven by the competition for resources between both fisheries. Temporal increases of benefits were small, whenever detected, like slight recoveries of some target species and ecological indicators, mostly in Cerbère-Banyuls and Medes Islands MPAs. Our results confirm the benefits of protection to coastal marine resources and ecosystems when areas are enforced but highlight the current limitations of the three MPAs due to their small size and the significant impacts of small-scale and recreational fisheries. This study illustrates the capability to evaluate protection effects of small multi-zone MPAs with an ecosystem modelling perspective and represents the baseline to develop future scenarios of alternative management options to foster ecosystem recovery and resource rebuilding in the studied MPAs.

Keywords: Northwestern Mediterranean Sea; Ecopath model; Marine Protected Areas, Small-scale fisheries; Recreational fisheries.

1. Introduction

Coastal and marine ecosystems provide multiple ecosystem goods and services, including seafood, coastal protection, carbon sequestration, recreational and other cultural services, and support for human livelihoods and well-being (Costanza et al., 1997; Martínez et al., 2007). However, the production of these ecosystem goods and services can be degraded as human demand for resources and the associated activities increase in number, frequency, magnitude and spatial coverage (MEA, 2005; Worm et al., 2006; Pauly and Zeller, 2016). Currently, marine ecosystems are under increasing threat from a range of stressors including overfishing, climate change, biological invasions, pollution, aquaculture and habitat modification, directly or indirectly caused by multiple human activities (Costello et al., 2010; Halpern et al., 2015). The interaction and cumulative effects of multiples stressors are highly complex and their combined impacts on marine ecosystems are largely unknown or even highly uncertain (Crain et al., 2009; Côté et al., 2016).

The Mediterranean Sea is not an exception. Although it is considered a hotspot of biodiversity (Coll et al., 2010), the Mediterranean Sea has a long history of human disturbance and exploitation (Lotze et al., 2011) with dramatic changes to its ecosystems taking place for long time, but especially during the last 50 years (Azzurro et al., 2011; Maynou et al., 2011; Piroddi et al., 2017). Because of intense human pressures, the Mediterranean Sea has been defined as a sea "under siege", and classified among the most impacted ecoregions of the world (Coll et al., 2012; Micheli et al., 2013; Halpern et al., 2015).

The recognition of the interactive nature of stressors and the interconnection between marine organisms, multiple human impacts, and ecosystem functioning and services has led to increasing demand for an ecosystem-based management (EBM) (Rosenberg and McLeod, 2005; Leslie and McLeod, 2007). The overall objective of this approach is to maintain ecosystems as a whole in healthy, productive and resilient conditions allowing them to provide the needed ecosystem services to society (McLeod et al., 2005). Within this context, Marine Protected Areas (MPAs hereafter) are considered to be a key management tool for EBM as they are expected to mitigate human impacts, recover exploited resources and promote their sustainable use, conserve or restore habitats and biodiversity, maintain and enhance ecosystem services and reduce conflicts between users (Lester et al., 2009; Halpern et al., 2010; Leenhardt et al., 2015). In fact, MPAs are being increasingly used worldwide for conservation and fisheries management purposes (Boonzaier and Pauly, 2016; Morgan et al., 2018). MPAs conservation benefits largely vary due to their intrinsic features, the level of enforcement, their conservation goals and organization (Guidetti et al., 2008; Di Franco et al., 2016; Giakoumi et al., 2018; Scianna et al., 2019). A MPA is a discrete area of the sea established to achieve the long-term conservation of natural resources therein (Claudet, 2011). The level of protection within MPAs can vary from areas of full protection or no-take areas (FPA), where all extractive activities (e.g. fishing) are prohibited while some non-extractive activities (e.g. diving) can be allowed; to areas of partial protection (PPA), where some human activities (e.g. small-scale and recreational fisheries) are allowed but regulated (Horta e Costa et al., 2016). In addition, networks of MPAs could provide greater benefits than the sum of individual MPAs benefits (Gaines et al., 2010; Grorud-Colvert et al., 2014). A network of MPAs is a "collection of individual MPAs that operates synergistically, at different spatial scales and with a range of protection levels that have been designed to fulfill ecological objectives more effectively than individual MPAs could alone" (IUCN-WCPA, 2008).

Within the EBM, ecological modelling has emerged as a suitable tool to integrate available ecological information into a coherent form to obtain insights about how ecosystems are structured, functioning, impacted by human activities and environment, and delivering ecosystem services (Link, 2010a; Christensen and Maclean, 2011). Although quantitative models have become a key tool to assess the extent to which MPAs are able to achieve their conservation objectives (Fulton et al., 2015a), the understanding of MPA effects on ecological processes and ecosystem function is still scarce (Cheng et al., 2019). For instance, it is mostly unknown if protection benefits inside fully protected areas extend to partially areas and beyond, and if those benefits have the potential to cascade through the ecosystem components. There is little evidence that multi-zone MPAs (i.e., those including both FPAs and PPAs) provide fisheries benefits inside partially protected areas and it is unknown what are the drivers of multi-zone MPAs. One of the most used approaches within the EBM is the Ecopath with Ecosim (EwE) modelling toolbox, which has been widely applied to model aquatic food webs and assess the impact of human activities (Heymans et al., 2014; Colléter et al., 2015).

Previously, several studies have modelled MPAs in the Mediterranean Sea (Albouy et al., 2010; Libralato et al., 2010; Valls et al., 2012; Prato et al., 2016; Vilas et al., Submitted). However, none of the existing studies modelled simultaneously the multi-zone nature of Mediterranean MPAs nor a series of MPAs that are nearly located, potentially constituting a network of protected areas. In addition, the study of long-term effects of MPAs has not been pursued due to difficulties to gather historical data about protection effects. In this study we modelled three relatively well studied MPAs from the northwestern Mediterranean Sea with a historical perspective: Cerbère-Banyuls, Cap de Creus and Medes Islands. Our aims were to: (1) quantify the main structural and functional traits of the three multi-zone MPAs, and (2) assess how exploitation and protection regimes affected these marine ecosystems over time, using a comparative approach to identify commonalities and differences between MPAs.

2. Materials & Methods

2.1. Study area

We studied three MPAs in the Northwestern Mediterranean Sea: Cerbère-Banyuls (France), Cap de Creus (Spain) and Medes Islands (Spain) (Fig. 1 and Table 1). These MPAs include one Fully Protected Area (FPA) and one (Cerbère-Banyuls and Medes Islands) or more (Cap de Creus) Partially Protected Areas (PPAs) (Fig. 1). While in FPA all extractive activities are forbidden, in PPAs both small-scale and recreational fisheries are allowed except in Medes Islands MPA, where recreational fisheries are prohibited.

The three MPAs comprise a similar depth range between 0 and 60 meters, and some vulnerable and/or endemic species inhabit their areas such as the Mediterranean seagrass (*Posidonia oceanica*), dusky grouper (*Epinephelus marginatus*) and red coral (*Corallium rubrum*). In addition to the protected zone scheme (FPA and PPA), we included in our study the immediate unprotected areas (UPAs) surrounding each MPA (Fig. 1 and Table 1), in order to add the adjacent ecosystem without protection where some species inhabiting the MPAs can theoretically forage and move to (Di Lorenzo et al., 2016). The boundaries of the unprotected areas were selected taking into account that they had similar features to the MPA, and they were adjacent to the MPA (Fig. 1).

2.2. Modelling approach – Ecopath and Ecosim

The three MPA models were developed using Ecopath with Ecosim approach (EwE 6.6 version) (Christensen and Walters, 2004; Christensen et al., 2008). We used the static Ecopath model to provide a quantitative representation of the food web as a “snapshot” in terms of flows and biomasses for a defined period of time. To develop the food-web model we used functional groups, which could be ontogenetic fractions of a species, single species or groups of species sharing common ecological and behavioral traits. The baseline models of each MPA were developed taking into account the contribution of each zone to the whole MPA based on a previous study (Vilas et al., Submitted). After the static models of the three MPAs were developed, we used the time-dynamic model Ecosim, which describes the temporal dynamics of species biomass and flows over time by accounting for changes in predation, consumption rate, fishing and the environment (Walters et al., 1997;

Christensen and Walters, 2004). A short description of the modelling approach is given in the Supplementary Online Material (SOM thereafter) 1; and a detailed explanation of the algorithms and equations of the EwE approach are given in Christensen and Walters (2004) and Heymans et al. (2016).

2.3. Functional groups and input data

2.3.1. Functional groups

A meta-web structure defined for the Western Mediterranean Sea model (Coll et al., 2019b) developed under the Safenet Project (Sustainable fisheries in EU Mediterranean waters through a network of MPAs) was used and adapted to our study area. Specifically, we removed those functional groups (hereafter FGs), which did not occur in the study area. The final food-web structure contained 64 FGs for Cerbère-Banyuls MPA and 67 FGs for Cap de Creus MPA and Medes Islands MPA (SOM 2).

2.3.2. Ecopath input data and balancing procedure

The Ecopath models represented a situation of the Cerbère-Banyuls MPA for 2013, while the Cap de Creus MPA and the Medes Islands MPA represented an average situation for the period 2005-2008 and 2000-2004, respectively. These periods of time to model the MPAs were selected considering the best available biomass data (SOM 2 for details on the parameterization of each functional group). Input parameters were obtained using similar procedures as those documented in Coll et al. (2006), Corrales et al. (2015), Piroddi et al. (2015) and Vilas et al. (Submitted). Biomass and catch data were scaled using data from models of each management unit (FPA, PPA and UPA) developed previously (Coll et al., 2019c; Vilas et al., Submitted) by the percentage of the area of each management unit to the whole MPA (Table 1).

Biomass estimates were obtained from different sources from the study area or surrounding areas (SOM 2 for details on parameterization of each functional group). The three MPA models shared biomass data on some FGs (marine mammals, seabirds, sea turtles, pelagic fish, some invertebrates' groups, primary producers, zooplankton and phytoplankton) due to the lack of local data and/or the closeness among these MPAs. Fish and invertebrate biomasses were estimated using data from (1) underwater visual census (UVC) (Claudet, 2013; Hereu Fina et al., 2017), (2) bottom trawl surveys performed in adjacent areas (Mediterranean International Trawl Surveys, MEDITS; see Bertrand et al. (2002)), and (3) additional information found in the literature. MEDITS trawling survey data was used to extract biomass estimates and was weighted by the bathymetry strata where species occurred. We extracted MEDITS trawling survey data from the closest stations to each MPA in order to have biomass data for those species that were not present during UVC. This assumption was assessed previously by expert knowledge from Safenet project (Coll et al., 2019c). For several pelagic fish species, available data from MEDITS and MEDIAS (acoustic) surveys were used. As these surveys did not fully cover coastal areas, scaling factors based on species depth distribution from AQUAMAPS (Kaschner et al., 2016) were used to correct biomass estimates of the pelagic fish groups.

Production (P/B, year^{-1}) and consumption (Q/B, year^{-1}) rates were estimated either using empirical equations (Heymans et al., 2016), taken from literature or from other models developed in the northwestern Mediterranean Sea (Coll et al., 2006; Corrales et al., 2015; Coll et al., 2019c). Additionally, local body lengths of reef-associated species obtained from UVC (Calò et al., 2018) were used to estimate those rates using empirical equations.

The trophic information to populate the diet matrix was compiled using published studies on stomach content analyses, giving preference to local or surrounding areas (SOM 2). Due to the small sizes of the investigated MPA and the capacity of some species to move greatly (Gell and Roberts, 2003; Grüss et al., 2011), we set a fraction of the diet composition as import for all MPA based on the time that these species spent foraging outside the areas and biological and ecological traits such as size, behavior and ecology of species of each functional group (Table 1 in SOM 3).

Catch data were obtained from different sources (database, literature and unpublished data) (SOM 2) and included recreational and small-scale catch. Small-scale fisheries in Cerbère-Banyuls were obtained from a local study (Prats, 2016), while for Cap de Creus and Medes Islands, landings were obtained from an official dataset of the regional government of Catalonia managed by the Institute of Marine Sciences (ICM-CSIC) (Tudó, 2017). For Cap de Creus, these landings were from Llançà, Port de la Selva, Cadaqués and Roses harbours, where the main fleet operating is coming from. These landings were scaled by the number of boats and months fishing inside the MPA (Gómez et al., 2006). For Medes Islands, landings were from l'Estartit harbour. To these official landings, we incorporated percentages of discards from a literature review based on the Spanish Mediterranean and Gulf of Cadiz region (Coll et al., 2014). Regarding recreational fisheries catch, we used information from Ivanhoff et al. (2010) (Cerbère-Banyuls), Lloret et al. (2008a) and Lloret et al. (2008b) (Cap de Creus) and Sacanell (2012) (Medes Islands).

To achieve mass-balance of the baseline models, we applied a manual procedure following a top-down approach modifying appropriate input parameters (Table 2 in SOM 3) (starting from the groups with higher trophic levels) and following the best practice guidelines provided in the literature (Heymans et al., 2016). In addition, the PREBAL analysis was used to ensure that the model parameters obeyed general ecologic principles and to guide the balancing procedure (Link, 2010b). Detailed explanations of these procedures are given in SOM 3 and the final diet matrixes are provided in SOM 4.

The pedigree routine (Christensen and Walters, 2004) was used to quantify the uncertainty associated with the input parameters and the quality of the models and to validate choices made in balancing the model. A detailed explanation of this routine is given in SOM 3.

2.3.4. Ecosim historical time series fitting.

The model representing Cerbère-Banyuls MPA ecosystem during the 2013−2017 period was fitted to time series of historical data, while for Cap de Creus MPA and the Medes Islands MPA, the Ecosim model was fitted to time series of 2008-2017 and 2004-2017, respectively (Table 1 in SOM 5). Overall, we used historical fishing effort trends to drive the fishing fisheries of the models, while biomass and catch time series were used to calibrate the model and compare predicted to observed results (Table 1 in SOM 5), respectively, following previous studies in the Mediterranean Sea and best practices of EwE (Coll et al., 2013; Heymans et al., 2016; Corrales et al., 2017).

Available time series of fishing activities included data on nominal fishing effort, expressed in number of boats per year for the small-scale fisheries and in hooks per day for the recreational fisheries. Data for the small-scale fisheries were obtained from IFREMER

(2015) (Cerbère-Banyuls) and from the Ministry of Agriculture, Livestock, Fisheries and Food of the Catalan Government (Cap de Creus and Medes Islands), while data for recreational fisheries were collected from IFREMER (2015) and Ivanhoff et al. (2010) (Cerbère-Banyuls MPA) and from Lloret et al. (2008a), Lloret et al. (2008b), Font and Lloret (2010) and Font and Lloret (2011) (Cap de Creus and Medes Islands MPAs).

Available relative and absolute observed biomass for most of the demersal groups were obtained from MEDITS survey and UVC (Claudet, 2013; Hereu Fina et al., 2017; Calò et al., 2018). No historical catch data were available for Cerbère-Banyuls MPA (Table 1 in SOM 5). Absolute observed landings data for Cap de Creus and Medes Islands MPA were obtained from an official dataset of the regional government of Catalonia managed by the Institute of Marine Sciences (ICM-CSIC) (Tudó, 2017). Regarding recreational fisheriess, historical catches of Cap de Creus and Medes MPA were reconstructed based on their historical effort trends.

To fit the Ecosim model of the three MPAs, we used the Stepwise Fitting Procedure (Scott et al., 2016), which automates the model fitting procedure described by Mackinson et al. (2009) and Heymans et al. (2016). The fitting procedure tests alternative hypotheses related to the impact of fishing, changes in predator-prey dynamics (vulnerabilities), changes in primary production (production anomalies) or all of the above together (Table 2) (Mackinson et al., 2009; Heymans et al., 2016). A primary production anomaly is a forcing function applied to the primary production rate (in our study both phytoplankton and benthic primary producers) that may represent historical productivity changes impacting biomasses through the ecosystem. During the fitting procedure, vulnerabilities and production anomalies were estimated to improve model fits by comparing model predictions to observed data using the sum of squares (SS) statistics. The fitting procedure finds the statistically “best fit” model based on Akaike’s Information Criterion (AIC), which penalizes for estimating too many parameters based on the number of time series available for estimating the SS (Mackinson et al., 2009; Heymans et al., 2016). In this study, the maximum number of parameters that could be estimated were 19 (Cerbère-Banyuls), 51 (Cap de Creus) and 48 (Medes Islands), respectively.

To choose the best final model, we manually evaluated whether the parameterization process led to credible and sensible behavior (Heymans et al., 2016), following previous studies (e.g., Corrales et al., 2017).

2.4. Model analyses and ecological indicators

2.4.1. Ecological indicators of initial conditions

To analyse the food-web structure of the three MPAs, we used the biomasses of selected FGs, trophic flows and trophic levels (TLs) within the flow diagram. The TL was also used to analyze the ecological position of the FG of the three MPA models (Lindeman, 1942; Stergiou and Karpouzi, 2001)

Several ecological indicators were also computed to describe the structure and functioning of the ecosystems and were divided into four groups using the ECOIND plug-in (Coll and Steenbeek, 2017):

(1) Biomass-based: calculated from the biomass of components included in the food-web model, they could provide valuable information to evaluate MPAs effectiveness (Micheli et al., 2004; Claudet et al., 2008). We included Total Biomass (TB, t·km^{-2}·year^{-1}), Biomass of Fish species (FB, t·km^{-2}·year^{-1}), and Kempton's Q diversity index (QI).

(2) Trophic-based: reflect the TLs for different groups of the food web, provide information on the structure of the ecosystem and are used to quantify the impact of fishing (Rochet and Trenkel, 2003). We selected TL of the community (TLc), TL of the community, TL of the community including organisms with TL ≥ 3.25 (TL3.25) and TL of the community including organisms with TL ≥ 4 (TL4).

(3) Species and size-based: based on species traits and conservation status, they could offer insights of the effects of MPAs (Claudet et al., 2010). We selected biomass of IUCN-endangered species biomass in the community (t·km^{-2}·year^{-1}), mean length of fish in the community (ML, cm) and mean life span of fish community (MLS, year).

(4) Catch-based: based on catch, they reflect the fishing strategy of the fisheries and are used to quantify the impact of fishing (Hilborn and Walters, 1992; Pauly et al., 1998). We

included total catch (TC $t \cdot km^{-2} \cdot year^{-1}$), trophic level of the catch (TLc), intrinsic vulnerability index of catch (VI).

The Mixed Trophic Impact (MTI) analysis was used to quantify the direct and indirect impact in the food web that a hypothetical increase in the biomass of one functional group would have on the biomasses of all the other functional groups in the food web, including the fishing fleets (Ulanowicz and Puccia, 1990; Christensen et al., 2008). To evaluate the impact of small-scale fisheries on the MPAs, the MTI was used to quantify the direct and indirect impact of each fishery on the functional groups for the studied MPAs, and their potential competition and trade-offs between them.

Finally, to identify the key species within the ecosystem (both keystone and structuring species), we calculated the keystoneness index (KS_i) developed by Valls et al. (2015) of the most important reef functional groups. A keystone group is defined as a predator species with a high and wide impact on the food web despite its low biomass (Paine, 1966, 1969; Valls et al., 2015).

2.4.2. Time-dynamic analyses

Once the fitting procedure was completed, we used the best fit model to examine biomass and catch time series predicted by the model to explore the dynamics of selected functional groups. We selected four target species due to their role in terms of biomasses and commercial interest: the common two-banded seabream (*Diplodus vulgaris*), white seabream (*D. sargus sargus*), common dentex (*Dentex dentex*) and groupers (this group was mainly represented by *Epinephelus marginatus*). These species play an important role in the ecosystem as high trophic level predators or intermediate trophic species and are of great importance in small-scale and recreational fisheries. In addition, the previous selection of ecological indicators from the ECOIND plug-in was used to describe ecological changes in the ecosystem over time (Coll and Steenbeek, 2017).

We addressed the impact of uncertainty in Ecopath input parameters on Ecosim outputs (biomass and catch trends, and ecological indicators) by using the Monte Carlo (MC) uncertainty routine and the ECOSAMPLER plug-in (Heymans et al., 2016; Coll and Steenbeek, 2017; Steenbeek et al., 2018). We ran 500 MC simulations based on the coefficient of variation obtained from the pedigree routine, which assesses the quality of the input data (SOM 3). Results from the MC simulations were used to plot the confidence intervals of the selected ecological indicators in Ecopath and to plot the 5th and 95th percentile confidence intervals for the fitted biomass and catch trends and for ecological indicators. Finally, we used the Spearman's rank correlation to evaluate if selected modelled results (time series of biomass, catch and ecological indicators) decreased or increased in time, following previous studies (e.g., Corrales et al., 2017).

3. Results

3.1. Structure and functional traits of the three MPAs

The pedigree index values of the three MPA models showed similar values, ranging from 0.41 to 0.51. The highest pedigree values were obtained for Cerbère-Banyuls (0.51), followed by Medes Islands (0.45) and Cap de Creus (0.41).

The visualization of trophic links and flows between functional groups highlighted the complexity of these coastal ecosystems due to the large number of trophic links between functional groups and the important role of detritus (FG 65) and other macro-benthos (FG 51) in transferring energy up to the food web (Fig. 2).

The functional groups of the models ranged from trophic level (TL) of 1 for primary producers (FG. 60-67) and detritus groups (FG 66-67) to TL = 4.2 for both groups of dolphins (FG 1-2) (Fig. 2 and Table 3 in SOM 3). Invertebrates groups were classified with a TL between 2 and 3.5, with benthopelagic cephalopods showing higher TLs. Fish had TLs between 3 and 4, with the exception of salema (FG 33) and mugilidae (FG 34), which showed lower TL due to their herbivorous and detritivore behaviors. Overall, similar TLs were found for the three MPAs.

Total and fish biomass displayed similar patterns, with the highest biomass values found for Cerbère-Banyuls and Medes Islands and lower values in Cap de Creus (Fig. 3). Conversely, Kempton's Q Index presented a higher value in Cap de Creus, followed by Medes Islands and Banyuls-Cerbère (Fig. 3). With the exception of TL of the community 4, trophic based indicators also presented higher values for Cerbère-Banyuls, followed by

Medes Islands and Cap de Creus (Fig. 3). Species and size-based indicators showed that Cerbère-Banyuls presented the highest values for ML of fish community and IUCN species B, followed by Cap de Creus and Medes Islands (Fig. 3), while MLS of fish community was higher in Cap de Creus, followed by Cerbère-Banyuls and Medes Islands (Fig. 3). Total catch showed similar values between Cap de Creus and Medes Islands, while Cerbère-Banyuls had the lowest value (Fig. 3). TL of the catch and the Intrinsic Vulnerability Index presented similar values in Cerbère-Banyuls and Cap de Creus, while Medes Islands had the lowest value (Fig. 3).

The keystoneness index identified groupers (FG 27), common dentex (FG 24), other commercial medium demersal fishes (FG 31) and non-commercial medium demersal fishes (FG 32) as keystones species in the three MPAs, followed by red scorpionfish (*Scorpaena scrofa*) (FG 25) and Scorpaenidae (FG 26).

The MTI analysis highlighted that the small-scale fisheries had the most widespread negative impact on many FG of all MPAs, especially in Cerbère-Banyuls, while the impact of recreational fisheries was more prominent in Cap de Creus and Medes Islands (Fig. 5). This analysis showed strong negative impact of fisheries on target species such as other large pelagic species (FG 8), common dentex (FG 24), and groupers (FG 27) while competitors or preys of those species may be positively impacted such as white seabream (FG 22), common two-banded seabream (FG 23) and brown meagre (*Sciaena umbra*) (FG 28) (Fig. 5). Results also highlighted that each fishery had a negative impact on itself due to self-competition for resources according to the MTI results and that competition between fisheries was complex (Fig 5). While small-scale fisheries had positive impacts on recreational fisheries in Cerbère-Banyuls MPA, recreational fisheries had slightly negative impacts on small-scale fisheries (Fig. 5a). On the contrary, small-scale fisheries had negative impacts on recreational fisheries in Cap de Creus and Medes Islands MPAs, while recreational fisheries had positive impacts on the small-scale fisheries (Fig. 5b and c).

3.2. Temporal changes of MPAs

The best-fitted food wed temporal models were obtained when trophic interactions, fishing, and primary production anomaly were included in the model configuration for all MPAs

(Step 8 in Table 3). However, for all MPAs the best model was not able to reproduce the trends of white seabream, common two-banded seabream, common dentex and groupers satisfactorily, which we selected as target groups of this study. Therefore, we moved through the fitting procedure analysis to find the model that was able to reproduce the trends of most of the groups (and specifically the target groups) and was highly significant. We finally choose a model fit with 12 vulnerabilities and 3 spline points, 15 vulnerabilities and 3 spline points, and 11 vulnerabilities and 5 spline points for Cerbère-Banyuls, Cap de Creus and Medes Islands models respectively, as the best options (Step 8 in Table 3).

Observed biomass and catch time series were satisfactorily reproduced by model predictions for most of the target groups (Fig. 6 and SOM 6, 7 and 8) when using the chosen fitted model. The temporal models showed a non-significant biomass pattern of white seabream in Cerbère-Banyuls, firstly decreasing and later increasing, and in Cap de Creus, where firstly increased and later decreased, while in Medes Islands it presented a significant decreasing biomass trend (Fig 6). The models showed similar biomass patterns for common two-banded seabream, highlighting a non-significant trend in Cerbère-Banyuls and Cap de Creus and a significant decreasing trend in Medes Islands (Fig. 6). We observed a significant decreasing biomass trend of common dentex in Cerbère-Banyuls, while in Cap de Creus and Medes this group showed non-significant biomass trends (Fig. 6). The results highlighted a non-significant biomass pattern of groupers in Cerbère-Banyuls (Fig 6), while they significantly increased in Cap de Creus and Medes Islands (Fig 6). However, in Medes Islands the model did not capture well the overall declining trend of observations for groupers biomass.

Regarding the temporal changes of ecological indicators, the Kempton's Index showed a non-significant trend in Cerbère-Banyuls and Cap de Creus, while in Medes Islands, the Kempton's Index significantly increased during the simulated period (Fig. 7). The TL of the community presented a non-significant pattern in Cerbère-Banyuls and Cap de Creus, while in Medes Islands significantly decreased (Fig. 7). IUCN species biomass significantly declined in Cerbère-Banyuls, while in Cap de Creus and Medes Islands presented non-significant patterns (Fig. 7). Total catches highlighted non-significant trends in Cerbère-

Banyuls and Cap de Creus (in the last one firstly increasing and then decreasing), while in Medes Islands, total catches significantly decreased (Fig. 7).

4. Discussion

Due to the deteriorating condition of many coastal ecosystems, there is a pressing need to better understand how current management options assist in recovering and conserving these ecosystems. Within this context, we developed a food-web modelling approach to quantitatively assess multi-zone MPAs putative effects over time on recovering marine resources and ecosystems in the Northwestern Mediterranean Sea.

Overall, ecological indicators showed similar patterns, with highest values in Banyuls-Cerbère MPA, followed by Medes Islands and Cap de Creus MPAs. This may be related to differences in the ecological effectiveness of the three MPAs, which is partly explained by MPA design, management and implementation features (e.g. the extend of area protected, fully protected area enforcement, time since protection, MPA organization) (Claudet et al., 2008; Guidetti et al., 2008; Edgar et al., 2014; Giakoumi et al., 2017; Di Franco et al., 2018). The lack of enforcement is one of the most relevant issues concerning MPAs in the Mediterranean context (Fenberg et al., 2012). Within this context, while Cerbère-Banyuls and Medes MPAs are considered to have a high level of enforcement (Sala et al., 2012; Giakoumi et al., 2017), Cap de Creus has been considered a MPA only on paper due to a lack of sufficient enforcement (Lloret et al., 2008a; Lloret et al., 2008b). In fact, total catches were higher in Cap the Creus than in the other two MPA; with Cerbère-Banyuls presenting the lowest total catches. Total catches are expected to be higher in well designed and enforced MPAs (Halpern et al., 2009; Di Lorenzo et al., 2016), so our results could be explained by the allowed and/or real fishing effort and the small effects of these MPAs in PPAs and adjacent areas. Horta e Costa et al. (2016) presented a novel classification system for MPAs by scoring allowed uses in each management unit based on their impacts on biodiversity. In this scale, Cerbère-Banyuls obtained a rate of 4.7, being a highly protected area and Medes 6.4 being less well protected (Horta e Costa et al., 2016). Although Cap de Creus was not included in this study, we could expect a higher MPA index because of its smaller FPA and allowed uses. These features (smallest FPA and weak enforcement) and the fact that Cap de Creus is the newest (Table 1) MPA in the study, could suggest that the year of establishment, enforcement and the size of protected areas have a strong effect on MPA effects, in line with other studies (Claudet et al., 2008; Guidetti et al., 2008).

Our results also indicated that both the small-scale and recreational fisheries can have a notable impact affecting organisms from lower to higher trophic levels. According to our study, small-scale fisheries had the largest negative ecological impacts. In fact, this fishery tends to develop its main activity inside the MPA or in surrounding areas (Goñi et al., 2008; Stelzenmüller et al., 2008). Recreational fisheries seemed to have larger impacts in the Spanish MPAs (Cap de Creus and Medes Islands MPA), while they had a negligible impact in Cerbère-Banyuls MPA, although the impact of recreational fisheries could be similar than the small-scale fisheries, as highlighted in coastal waters of Cap de Creus by Lloret et al. (2008a). This could be related to cultural reasons, differences in enforcement of each MPA and/or the reliability of catch data between study sites. In addition, our results highlighted that despite the recreational fisheries seemed to have an overall lower negative impact, it had stronger negative impacts on vulnerable species such as common dentex and groupers in Cap de Creus and Medes Islands MPAs, in line of the observed impact of small-scale and recreational fisheries on vulnerable species (Lloret et al., 2019), which is an important fact to consider when establishing plans for these species. Our results also highlighted the competition for resources between both (small-scale and recreational) fisheries. Competition between both fisheries has become an important issue in coastal areas (especially in surrounding areas of MPAs), as they target similar species and fishing grounds (Chuenpagdee and Jentoft, 2018; Lloret et al., 2018). In small and touristic areas such as the ones in the present study, a strong competition between small-scale and recreational fishers could be expected due to the decline of the small-scale fisheries and the increasing importance of recreational fisheries as a leisure activity (Gómez and Lloret, 2017).

The temporal dynamic model of Cerbère-Banyuls predicted an increasing biomass pattern of white seabream and common two-banded seabream while common dentex and groupers largely decreased. The decrease of common dentex and groupers could be related to the impact of fishing, although fishing effort did not increase during the study period and initial fishing mortalities were not high. The increase of both seabreams could be explained by the reduction of their predators. In fact, common dentex and groupers are the most important predators of these species in terms of total consumption.

In contrast, the temporal dynamic model of Cap de Creus predicted a decreasing biomass pattern of white seabream, common two-banded seabream and common dentex while groupers increased. These results suggest a recovery of groupers population in Cap de Creus (Hereu Fina et al., 2017), despite low level of enforcement, that could cause biomass reductions of their preys such as both seabreams. Similarly, the temporal dynamic model of Medes Islands highlighted decreasing trends for white seabream, common two-banded seabream and common dentex, while groupers slightly increased. These results evidence that under protection the food-web effects can play an important role and there are winners and losers as a result of the new ecological state, where results of protection can include cascading effects of predators on preys species (Edgar et al., 2014; Cheng et al., 2019) as well as an increase in competitive interactions (Micheli et al., 2004).

Ecological indicators are important within the EBM framework because they are quantitative representations of ecosystem status and provide a mean for evaluating the impact of human activities in marine ecosystems and the effectiveness of management measures (Shin and Shannon, 2010; Tam et al., 2017). In our study, ecological indicators showed overall contrasting results, as some indicators indicated recovery (e.g. Kempton's Q in the three MPAs) while others showed degradation patterns (e.g., TL of the community in the three MPAs). These contrasting results could respond to the limitation in historical data to represent ecosystem dynamics in the study area and could indicate limited recovery of species and ecosystems in the three MPAs.

The most notable effects of MPAs are an increase in abundance, average size and biomass inside protected areas (Lester et al., 2009; Giakoumi et al., 2017). Due to the increased density inside the MPA, adults and juveniles may migrate to adjacent areas (spillover effect) and therefore, increase fisheries yields in adjacent areas (Goñi et al., 2008; Di Lorenzo et al., 2016). Larger abundance and sizes would imply an increase in reproductive potential of species and eggs and larvae from recovered populations could then be exported to external unprotected locations, including adjacent ones (Gell and Roberts, 2003; Harrison et al., 2012). In addition, MPAs could restore ecosystem functioning (Cheng et al., 2019). Although some of our temporal results showed potential recoveries (some target species, increases of predators and declines of prey, and some ecological indicators), our study evidences that they are still far from what we would expect from the temporal protection effects of MPAs, highlighting an overall modest historical positive effect of protection on these MPAs. These results are in line with Hereu Fina et al. (2017), which have pointed out illegal fishing as one of the main reasons for a lack of recovery and have called for further enhance the enforcement in Mediterranean MPAs.

Overall the input data used was of acceptable quality compared to the distribution of pedigree values in other existing models (Morissette, 2007; Lassalle et al., 2014), although they are among the lowest values in the Mediterranean Sea (Corrales et al., 2015). This could be due to the challenges of modelling small and local coastal areas, where specific data is a strong requirement. In fact, limitations of available data are a common concern for most Mediterranean MPAs (Prato et al., 2016; Vilas et al., Submitted) despite there are monitoring programs inside these MPAs.

In general, there is a lack of biomass estimates for many functional groups, especially regarding benthic invertebrates. Obtaining realistic estimates of total catch (official and Illegal, Unregulated and Unreported (IUU)) is a challenging task worldwide (Pauly and Zeller, 2016) and even more in the Mediterranean Sea (Coll et al., 2014; Pauly et al., 2014). In our study this challenge is higher due to the importance of recreational fishers and illegal fishing in coastal areas, specifically in MPA and surrounding areas (e.g., Lloret et al., 2008b; Ben Lamine et al., 2018).

The ability of ecosystem models to replicate trends increases with data availability, quality, and the length of historical data provided (Giron-Nava et al., 2017). Within this context, in Cerbère-Banyuls a maximum of four data points of biomass per functional group were available for the fitting procedure. The Medes Islands MPA model had the longest available time series, and thus presented a better and more informative fit, while the Cap de Creus MPA model showed an intermediate situation. This limited the capability to calibrate and validate the models and to track ecosystem dynamic status. Therefore, our results highlight the need to further monitor MPAs within the Mediterranean Sea and should inform future scientific research objectives in the area.

Because of the caveats explained above, uncertainties in model outputs were high. Despite these limitations, the models presented in this study were developed using the best available data, including several sources of information including unpublished and *ad hoc* field data, expert knowledge and published data, and following the best practices in ecosystem modelling development (Heymans et al., 2016). These models represent a useful tool to integrate such amount of information into a coherent picture of the ecosystems and confirm the capability of EwE to evaluate protection effects within an ecological perspective in small MPAs even in cases of data limitations. As new information is generated, the present models can be updated and further developed, improving model quality and becoming increasingly valuable tools for evaluating management options in the three MPAs.

Human activities have been concentrated in coastal ecosystems, resulting in a major modification of these marine areas (Halpern et al., 2015). Since coastal areas account for a large amount of the global ecosystem services (Costanza et al., 1997), there is a need for the restoration of coastal marine ecosystems in order to ensure their ecological role. In addition, in recent decades, marine ecosystems have been increasingly impacted by other stressors, directly or indirectly induced by multiple anthropogenic activities (Halpern et al., 2015). For example, climate change and alien species are already heavily impacting Mediterranean ecosystems, especially in the Eastern Mediterranean Sea (Lejeusne et al., 2010; Katsanevakis et al., 2014). Organisms and ecosystems already stressed by fishing are more vulnerable to these additional stressors (Occhipinti-Ambrogi and Savini, 2003; Poloczanska et al., 2016). MPAs, when properly managed, have demonstrated to be an effective tool to protect target species and habitats to local stressors such as fishing (Sala et al., 2017), while their role in promoting resilience to regional and global stressors such biological invasions and climate change is debated (Giakoumi and Pey, 2017; Roberts et al., 2017; Giakoumi et al., 2019). In highly impacted and crowded areas like the Northwestern Mediterranean Sea, the establishment of well-designed networks of well-enforced MPA is necessary to achieve “clean, healthy and productive” oceans (Good Environmental Status) according to the Marine Strategy Framework Directive (Fenberg et al., 2012).

Within the EBM, ecosystem models and ecological forecasts have become an essential analytical and decision-making tool despite their limitations due to high uncertainties and complex ecosystem characteristics (Link et al., 2012; Collie et al., 2014; Maris et al., 2017). They have the potential to provide insights of possible future impacts on marine ecosystems and can offer guidance to decision-makers by evaluating the trade-off between different management units and identify those measures that have the potential to meet conservation objectives (Fulton et al., 2015b; Acosta et al., 2016). This study is the baseline to develop future scenarios of alternative management options in order to maximize the impacts of MPAs to their surrounding areas and fisheries sustainability by alternative MPAs configurations. In addition, due to the vicinity of the three MPAs along a latitudinal gradient, this study is a part of a nested modelling approach with different geographic scales with the aim to assess the current effects of the actual MPA network and to perform simulations of alternative MPA network configuration (Coll et al., 2019a).

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Tables legends

Table 1. Surface area (km²) covered by management units (MU) and year of creation of each Marine Protected Area (MPA) of Cerbère-Banyuls, Cap de Creus and Medes Islands. FPA= Fully protected Area, PPA= partially protected area, UPA= unprotected area flanking the MPA.

Table 2. Overall fitting procedure applied to the three MPA models following the methodology suggested by Mackinson et al. (2009) and Heymans et al. (2016).

Table 3. Results of the fitting procedure of the three MPA of Cerbère-Banyuls, Cap de Creus and Medes Islands. The table shows the statistically "best" model for each step. Vs = number of vulnerabilities estimated, PPsp = number of primary production spline points, k = number of parameters (Vs + PPsp), %IF = improved fit compared to the baseline AICc. The "best" models are highlighted in bold.

Figure legends

Figure. 1. The study area encompassing the three multi-zone MPAs in the Northwestern Mediterranean Sea with the fully protected areas (FPAs), partially protected areas (PPAs) and unprotected neighboring areas (UPAs).

Figure. 2. Flow diagram of Cerbère-Banyuls (a), Cap de Creus (b) and Medes Island (c) MPA models. The numbers identify the functional groups of the model (listed in SOM 2). The size of each circle is proportional to the biomass of the functional group. The thickness of the connecting lines is proportional to the magnitude of their trophic flows.

Figure. 3. Ecological indicators estimated for the three multi-zone MPA models of Cerbère-Banyuls, Cap de Creus and Medes Islands. Boxplot shows the distribution of values for an ecological indicator derived from the Monte Carlo routine while the dot represents the value of the indicator in the baseline Ecopath balanced model.

Figure. 4. Functional groups plotted against Keystone Index (KS) (Valls et al., 2015) and trophic level for Cerbère-Banyuls (a), Cap de Creus (b) and Medes (c) multi-zone MPA models. The numbers identify the functional groups of the model (listed in SOM 2). The size of the circles is proportional to the biomass of the functional group.

Figure. 5. Mixed Trophic Impact (MTI) analysis of the three MPA applied to the fisheries in a) Cerbère-Banyuls, b) Cap de Creus, and c) Medes Islands multi-zone MPA models.

Figure. 6. Predicted (solid lines) versus observed (dots) biomass ($t\cdot km^{-2}$) values for target species of Cerbère-Banyuls, Cap de Creus and Medes Islands multi-zone MPAs models. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman’s rank correlation test.

Figure. 7. Temporal trends of ecological indicators of Cerbère-Banyuls, Cap de Creus and Medes Islands multi-zone MPAs models. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman’s rank correlation test.

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Modelling approach – Ecopath and Ecosim

The static Ecopath model provides a quantitative representation of the food web as a “snapshot” in terms of flows and biomasses for a defined period of time. To develop the food-web model we used functional groups, which consist of ontogenetic fractions of a species, single species or groups of species sharing common ecological and behavioral traits.

Ecopath is a mass-balanced model that is parameterized based on two master equations describing the production (Eq. 1) and consumption (Eq. 2) of each functional group (Christensen and Walters, 2004; Christensen et al., 2008).

Production = predation mortality + fishing mortality + other mortality + biomass accumulation + net migration (Eq. 1)

Consumption = production + respiration + unassimilated food (Eq. 2)

For each functional group, three of the four basic parameters (biomass (*B*), production (*P/B*) and consumption (*Q/B*) rates, and ecotrophic efficiency (*EE*)) are required and the forth is estimated. In addition, for each functional group the diet composition is required as well as the catch by fleet. A detailed explanation of the algorithms and equations of the approach and its main advantages and limitations are described in Christensen and Walters (2004) and Heymans et al. (2016).

Ecosim describes the temporal dynamics of species biomass and flows over time by accounting for changes in predation, consumption rate, fishing and the environment (Walters et al., 1997; Christensen and Walters, 2004). Ecosim uses a set of differential equations to describe biomass dynamics, expressed as:

$$\frac{dB_i}{dt} = \left(\frac{P}{Q}\right)_i \cdot \sum Q_{ji} - \sum Q_{ij} + I_i - (M_i + F_i + e_i) \cdot B_i \qquad \text{(Eq. 3)}$$

where dB_i/dt is the growth rate of group (i) during time t in terms of its biomass B_i; $(P/Q)_i$ is the net growth efficiency of group (i); M_i is the non-predation mortality rate; F_i is the fishing mortality rate; e_i is the emigration; and I_i is the immigration rate (Christensen and Walters, 2004).

Consumption rates (Q_{ij}) are calculated based on the “foraging arena” theory, which divides the biomass of a prey into a vulnerable and a non-vulnerable fraction and the transfer rate or vulnerability between the two fractions determines the trophic flow between the predator and the prey. The vulnerability concept incorporates density-dependency and expresses how far a group is from its carrying capacity (Christensen and Walters, 2004; Christensen et al., 2008). Default values of vulnerability ($v_{ij} = 2$) represents a mixed trophic flow, a low value ($v_{ij} < 2$) indicates a “bottom-up” flow and a situation closer to carrying capacity, while a high value ($v_{ij} > 2$) indicates a “top-down” flow and a situation further away from carrying capacity (Walters and Martell, 2004; Ahrens et al., 2012). For each predator-prey interaction, consumption rates are calculated as:

$$Qij = \frac{a_{ij}*v_{ij}*B_i*P_j*T_i*T_j*M_{ij}/D_j}{v_{ij}+v_{ij}*T_i*M_{ij}+a_{ij}*M_{ij}*P_i*T_j/D_j} * f(Env_{function}, t) \qquad \text{(Eq. 4)}$$

where a_{ij} is the rate of effective search for prey (i) by predator (j), T_i represents prey relative feeding time, T_j is the predator relative feeding time, B_i is prey biomass, P_j is predator abundance, M_{ij} is the mediation forcing effects, and D_j represents effects of handing time as a limit to consumption rate (Christensen et al., 2008; Ahrens et al., 2012). Environmental response functions ($f(Env_{function}, t)$) can be used to account for external drivers that change over time, such as temperature. A detailed explanation of the algorithms and equations of the EwE approach are given in Christensen and Walters (2004) and Heymans et al. (2016).

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Table 1. Species composition, methods and references used to estimate the basic input parameters of the three MPA Ecopath models of Cerbère-Banyuls, Cap de Creus and Medes Islands.

Basic Input parameters	Method	Source
1. Bottlenose dolphins (BOD): *Tursiops truncatus*		
B		(Forcada et al., 2004)
P/B	Life history table	(Barlow and Boveng, 1991)
Q/B	From modified energy requirement equation: E =aW$^{0.714}$	(Blanco et al., 2001; Hunter, 2006; Kastelein et al., 2003; Pauly et al., 1998; Pavan et al., 2013)
D		(Blanco et al., 2001)
2. Striped dolphins (STD): *Stenella coeruleoalba*		
B		(Forcada and Hammond, 1998)
P/B	Life history table	(Barlow and Boveng, 1991)
Q/B	From modified energy requirement equation: E =aW$^{0.714}$	(Di-Méglio et al., 1996; Hunter, 2006; Marsili et al., 1997; Pauly et al., 1998; Pavan et al., 2013)
D		(Aznar et al., 2017)
3. Endangered and pelagic seabirds (ENS): *Calonectris diomedea, Hydrobates pelagicus melitensis, Puffinus yelkouan, Puffinus mauretanicus*		
B		(Abelló and Oro, 1998; Amengual et al., 1999; Arcos et al., 2012; Arroyo et al., 2016; Bourgeois et al., 2011; du Rau et al., 2015; Gallo-Orsi, 2003; Genovart et al., 2016; Grémillet et al., 2014; Paracuellos and Jerez, 2003; Paracuellos and Nevado, 2003; Pettex et al., 2017; Thibault et al., 1996; Zotier et al., 1999)
P/B	Mortality (z)= -ln(Survival rate)	(Krebs, 1989)
Q/B	Yearly food intake (including breeding and no breeding seasons)/B	(Karpouzi et al., 2007; Paleczny, 2012)
D		(Arcos and Oro, 2002; Bourgeois et al., 2011; Granadeiro et al., 1998)
4. Gulls and cormorants (GUC): *Larus audouinii, Larus genei, Larus melanocephalus, Larus michahellis, Phalacrocorax aristotelis, Phalacrocorax carbo*		
B		(Abelló and Oro, 1998; Amengual et al., 1999; Arcos et al., 2012; Arroyo et al., 2016; Bourgeois et al., 2011; du Rau et al., 2015; Gallo-Orsi, 2003; Genovart et al., 2016; Grémillet et al., 2014; Paracuellos and Jerez, 2003; Paracuellos and Nevado, 2003; Pettex et al., 2017; Thibault et al., 1996; Zotier et al., 1999)
P/B	Mortality (z)= -ln(Survival rate)	(Krebs, 1989)
Q/B	Yearly food intake (including breeding and no breeding seasons)/B	(Karpouzi et al., 2007; Paleczny, 2012)
D		(Goutner, 1994; Morat et al., 2014; Talmat-Chaouchi et al., 2014; Van Eerden and Munsterman, 1986)
5. Terns (TER): *Sterna albifrons, Sterna caspia, Sterna hirundo, Sterna nilotica, Sterna sandvicensis*		
B		(Abelló and Oro, 1998; Amengual et al., 1999; Arcos et al., 2012;

		Arroyo et al., 2016; Bourgeois et al., 2011; du Rau et al., 2015; Gallo-Orsi, 2003; Genovart et al., 2016; Grémillet et al., 2014; Paracuellos and Jerez, 2003; Paracuellos and Nevado, 2003; Pettex et al., 2017; Thibault et al., 1996; Zotier et al., 1999)
P/B	Mortality (z)= -ln(Survival rate)	(Krebs, 1989)
Q/B	Yearly food intake (including breeding and no breeding seasons)/B	(Karpouzi et al., 2007; Paleczny, 2012)
D		(Dies et al., 2005)
6. Loggerhead turtle (LGT): *Caretta caretta*		
B		(de Segura et al., 2006; Lauriano et al., 2011)
P/B	Mortality (z)= -ln(Survival rate)	(Casale et al., 2015; Casale and Heppell, 2016; Krebs, 1989)
Q/B	Yearly food intake/B	(Hatase and Tsukamoto, 2008)
D		(Cardona et al., 2012a)
7. Non-commercial large pelagic fish (NLP): *Cetorhinus maximus, Mobula mobular, Mola mola*		
B		(di Sciara et al., 2015; Mancusi et al., 2005) and International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Fortuna et al., 2014; Parker and Stott, 1965; Powell, 2003)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Coull et al., 1989; Matthews and Parker, 1950)
D		(Grémillet et al., 2017)
8. Other large pelagic fish (OLP): *Coryphaena hippurus, Lichia amia, Seriola dumerili*		
B		(Morales-Nin and Azevedo, 2004) and International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Gatt et al., 2015; Morey et al., 2003)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Gatt et al., 2015; Morey et al., 2003)
D		(Cardona et al., 2012b; Coetzee, 1982)
9. Mackerels (MCK): *Scomber scombrus, Scomber colias, Scomber spp.*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Campillo, 1992; Velasco et al., 2011)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997; Torres et al., 2012)
D		(Apostolidis and Stergiou, 2014; Cardona et al., 2012b)
10. Horse mackerels (HRM): *Trachurus trachurus, Trachurus mediterraneus, Trachurus picturatus*		

B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{∞} and k parameter from (Vasconcelos et al., 2006; Zupa et al., 2006)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Torres et al., 2012)
D		(Buttay, 2009; Cardona et al., 2012b; Cresson et al., 2014)
11. Other medium pelagic fish (OMP): *Alosa fallax, Caranx rhonchus, Pomatomus saltatrix, Sphyraena sphyraena*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{∞} and k parameter from (Allam et al., 2004; Backus, 1962; Coull et al., 1989; Douchement, 1981; Quignard and Douchement, 1991)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Quignard and Douchement, 1991; Stergiou and Moutopoulos, 2001a; Torres et al., 2012)
D		(Dhieb et al., 2001; Kalogirou et al., 2012; Karachle, 2008; Mostarda et al., 2007)
12. European sardine (ESA): *Sardina pilchardus*		
B		Mediterranean International Acoustic Survey (MEDIAS) (MEDIAS, 2012), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{∞} and k parameter from (De Ranieri, 2011)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Demirhindi, 1961)
13. European anchovy (EAN): *Engraulis encrasicolus*		
B		Mediterranean International Acoustic Survey (MEDIAS) (MEDIAS, 2012), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{∞} and k parameter from (Colloca et al., 2013)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Tudela and Palomera, 1997)
14. Other small pelagic fish (OSP): *Cubiceps gracilis, Spicara flexuosa, Spicara maena, Spicara smaris, Spicara spp., Sprattus sprattus*		
B		International Bottom Trawl Survey in the Mediterranean

		(MEDITS) (Bertrand et al., 2002), and scaled with Aquamaps (Kaschner et al., 2016)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Apostolidis and Stergiou, 2014; Passelaigue, 1974; Zavodnik, 1969)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997; Sinovčić et al., 2004)
D		(Cresson et al., 2014; Khoury, 1987; Tičina et al., 2000)
15. Anglerfish (ANG): *Lophius budegassa, Lophius piscatorius*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Scientific and for Fisheries (STECF), 2013; Tsimenidis, 1980)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Apostolidis and Stergiou, 2014; Merella et al., 1997)
D		(López et al., 2016; Macpherson, 1981)
16. European conger (ECO): *Conger conger*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Campillo, 1992)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)
D		(Bell, 1983)
17. European hake (EHK): *Merluccius merluccius*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Campillo, 1992)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Aldebert and Recasens, 1995)
D		(Mellon-Duval et al., 2017)
18. Poor cod (PCO): *Trisopterus capelanus*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Planas and Vives, 1952)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)

D		(Biagi et al., 1992)
19. Common pandora (CPA): *Pagellus erythrinus*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
B Medes		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Planas and Vives, 1952)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Cresson et al., 2014)
20. Sparidae (SPA): *Boops boops, Diplodus annularis, Diplodus cervinus, Diplodus puntazzo, Oblada melanura, Pagrus pagrus, Sparus aurata, Spondyliosoma cantharus*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco 2017) and k parameter from (Derbal and Kara, 2006; Froglia, 1984; Girardin, 1978; Quignard, 1986; Vassilopoulou, 1989)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992; Merella et al., 1997)
D		(Bell, 1983; Benchalel et al., 2010; Chessa et al., 2004; Cresson et al., 2014; Labropoulou and Papadopoulou-Smith, 1999; Lenfant and Olive, 1998; Rosecchi and Nouaze, 1985; Sala and Ballesteros, 1997)
21. White seabream (WSE): *Diplodus sargus*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco 2017) and k parameter from (Man-Wai and Quignard, 1982)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Cresson et al., 2014)
22. Common two-banded seabream: *Diplodus vulgaris*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)

B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco 2017) and k parameter from (Girardin, 1978)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Bell, 1983)
23. Common dentex (DEN): *Dentex dentex*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco 2017) and k parameter from (Morales-Nin and Moranta, 1997)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morales-Nin and Moranta, 1997)
D		(Morales-Nin and Moranta, 1997)
24. Red scorpionfish (RSC): *Scorpaena scrofa*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Bradai and Bouain, 1988)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003) and L_{max} from UVC (Di Franco, 2017)
D		(Bell, 1983)
25. Scorpaenidae (SCO): *Chelidonichthys cuculus, Chelidonichthys obscurus, Eutrigla gunardus, Lepidotrigla cavillona, Scorpaena elongate, Scorpaena notata, Scorpaena porcus, Scorpaena spp.*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013) and International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Bradai and Bouain, 1988; Ordines et al., 2009)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003)
D		(Bell, 1983; Colloca et al., 1994; Labropoulou and Plaitis, 1997;

		Moreno-Amich, 1994; Ordines et al., 2012)
26. Groupers: *Epinephelus marginatus*		
B Banyuls		Underwater Visual Census (UVC) (Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Bouchereau et al., 1999; Girardin, 1978)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly 1990); *a* and *b* parameters from (Morey et al. 2003)
D		(Linde et al., 2004)
27. Brown meagre: *Sciaena umbra*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Hereu Fina and Quintana Pou, 2012; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Chauvet, 1991)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003)
D		(Karachle, 2008)
28. Labridae and serranidae (LAS): *Coris julis, Labrus merula, Labrus viridis, Serranus cabrilla, Serranus scriba, Symphodus cinereus, Symphodus doderleini, Symphodus mediterraneus, Symphodus ocellatus, Symphodus roissali, Symphodus rostratus, Symphodus spp., Symphodus tinca*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Cheung et al., 2013; Froese and Binohlan, 2003; Gordoa et al., 2000; Papaconstantinou et al., 1994)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Gordoa et al., 2000; Merella et al., 1997; Morey et al., 2003; Stergiou and Moutopoulos, 2001b; Valle et al., 2003)
D		(Arculeo et al., 1993; Bell, 1983; Kabasakal, 2001)
29. Flatfish (FLA): *Arnoglossus thori, Arnoglossus laterna, Buglossidium luteum, Citharus linguatula, Lepidorhombus whiffiagonis, Scophthalmus rhombus, Solea solea, Symphurus nigrescens*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Deniel, 1990; García-Rodríguez and Acón, 2000; Giovanardi

	Mortality (z)= F+M	and Piccinetti, 1984; Landa et al., 1996; Stergiou and Politou, 1995; Vianet et al., 1989)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997; Morey et al., 2003; Vianet et al., 1989)
D		(Bell, 1983; Cresson et al., 2014; Darnaude et al., 2004; De Juan et al., 2007; Fanelli et al., 2009; Macpherson, 1981; Morte et al., 1999; Pellegrini and Barghigiani, 1989; Wyche and Shackley, 1986)
30. Other commercial medium demersal fish (CMD): *Dicentratus labrax, Phycis phycis*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(Hereu Fina et al., 2017)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{∞} and k parameter from (Morey et al., 2003; Nony, 1983; Stergiou and Politou, 1995)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Cresson et al., 2014; Macpherson, 1981)
31. No commercial medium demersal fish (NMD): *Muraena helena*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Matić-Skoko et al., 2014)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003)
D		(Sallami et al., 2014)
32. Salema (SAL): *Sarpa salpa*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_{\infty} + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Verlaque, 1985)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_{\infty} + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003)
D		(Verlaque, 1985)
33. Mugilidae (MUG): *Chelon labrosus*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)

P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Morey et al., 2003)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Campillo, 1992)
D		(Blanco et al., 2003)
34. Red mullet (RMU): *Mullus barbatus*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
B Medes		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Levi et al., 1992)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)
D		(Esposito et al., 2014)
35. Surmullet (SUR): *Mullus surmuletus*		
B Banyuls		(Claudet, 2013)
B Cap de Creus		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
B Medes		(García-Rubies and i Limousin, 1990; Macpherson et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Campillo, 1992)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)
D		(Bell, 1983)
36. No commercial small demersal fish (NSD): *Blennidae, Chromis chromis, Gobius sp.*		
B		(García-Rubies and i Limousin, 1990)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_{max} from UVC (Di Franco, 2017) and k parameter from (Maiorano et al., 2010; Merella et al., 1997; Morey et al., 2003; Sangun et al., 2007)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Lamprakis et al., 2003; Morey et al., 2003)
D		(Bell, 1983; Karachle, 2008; Pinnegar et al., 2000; Zander and Berg, 1984)
37. Small-spotted catshark (SPC): *Scyliorhinus canicula*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Županovic, 1961)

Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)
D		(Macpherson, 1981)
38. Rays and skates (RSK): *Raja asterias*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Abdel-Aziz, 1992)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Merella et al., 1997)
D		(Navarro et al., 2013)
39. Torpedos (TOR): *Torpedo marmorata*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B	$\log M = -0.0066 - 0.279 \cdot \log L_\infty + 0.6543 \cdot \log k + 0.4634 \cdot \log T$ Mortality (z)= F+M	Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Duman and Başusta, 2013)
Q/B	$\log Q/B = 6.37 - 1.5045 \cdot \log T' - 0.168 \cdot \log W_\infty + 0.1399 \cdot Pf + 0.2765 \cdot HD$	Empirical equation from (Pauly, 1990); *a* and *b* parameters from (Morey et al., 2003)
D		(Barría et al., 2015)
40. Coastal benthic cephalopods (CBC): *Octopus vulgaris, Sepia officinalis*		
B		(Valls et al., 2012)
P/B		(Brey, 1990)
Q/B	$Q/B = 0.0683 + 0.0474(W)$	(Rodhouse and Nigmatullin, 1996); W from (Palomera et al., 2015)
D		(Castro and Guerra, 1990; Quetglas et al., 1998)
C		(Ivanoff et al., 2010; Prats, 2016)
41.. Benthopelagic cephalopods (BPC): A*lloteuthis media, Alloteuthis spp., Alloteuthis subulata, Illex coindetii, Loligo spp., Loligo vulgaris*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B		(Brey, 1990)
Q/B	$Q/B = 0.0683 + 0.0474(W)$	(Rodhouse and Nigmatullin, 1996); W from (Palomera et al., 2015)
D		(Martínez-Baena et al., 2016; Rosas-Luis and Sánchez, 2015; Valls et al., 2015)
42. Other benthic cephalopods (BCE): *Eledone cirrhosa, Eledone moschata, Sepia elegans, Sepia spp, Sepietta oweniana, Sepiola intermedia, Sepiola spp.*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B		(Brey, 1990)
Q/B	$Q/B = 0.0683 + 0.0474(W)$	(Rodhouse and Nigmatullin, 1996); W from (Palomera et al.,

		2015)
D		(Castro and Guerra, 1990; Šifner and Vrgoč, 2009; Valls, 2017)
43. Bivalves (BIV): *Bivalvia spp, Pinna nobilis*		
B Banyuls		(De Juan et al., 2011; Preuvost, 2011)
B Cap de Creus		*estimated*
B Medes		*estimated*
P/B		(Brey, 1990)
Q/B		(Coll, 2018)
D		(Sarà et al., 2003)
44. Gastropods (GAS): *Gastropoda spp*		
B Banyuls		(De Juan et al., 2011)
B Cap de Creus		*estimated*
B Medes		*estimated*
P/B		(Brey, 1990)
Q/B		(Heymans et al., 2016)
D		(Mazzella and Russo, 1989)
45. European lobster (LOB): *Palinurus elephas*		
B Banyuls		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
B Cap de Creus		(Hereu Fina and Quintana Pou, 2012)
B Medes		(Hereu Fina and Quintana Pou, 2012)
P/B		(Heymans et al., 2016)
Q/B		Empirical equation from (Pauly, 1980); L_∞ and k parameter from (Sardà, 2000)
D		(Goñi et al., 2001)
46. Other commercial decapods (OCD): *Maja squinado, Squilla mantis*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Bernárdez et al., 2000; Froglia, 1989)
47. Non-commercial decapods (NDC): *Dardanus arrosor, Dromia personata, Ethusa mascarone, Goneplax romboides, Liocarcinus depurator, Maja brachydactila, Medorippe lanata, Pagurus excavatus, Pagurus spp, Pilumnus spp, Pisa armata*		
B		*estimated*
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Abelló and Cartes, 1987)
48. Purple sea urchin (PSU): *Paracentrotus lividus*		
B Banyuls		(Schvartz and Labbe, 2012)
B Cap de Creus		(Hereu Fina and Quintana Pou, 2012)

B Medes		(Hereu Fina and Quintana Pou, 2012)
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Murillo-Navarro and Jiménez-Guirado, 2012)
49. Other sea urchins (OSU): *Arbacia lixula, Sphaerechinus granularis*		
B Banyuls		(Schvartz and Labbe, 2012)
B Cap de Creus		(Hereu Fina and Quintana Pou, 2012)
B Medes		(Hereu Fina and Quintana Pou, 2012)
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Rodríguez, 1972)
50. Sea cucumbers (SCU): *Holothuria spp*		
B		*estimated*
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Coulon and Jangoux, 1993)
51. Other macro-benthos (OMB): Actinaria sp, Ascidiacea sp., *Asteroidea sp., Ophiuroidea sp., Polychaeta sp., Porifera sp*		
B		*estimated*
P/B		(Brey, 1990)
Q/B		(Pauly et al., 1993b)
D		(Rodríguez, 1972)
52. Jellyfish (JLL): *Aequorea forskalea, Aurelia aurita, Chrysaora hysoscella, Hydrozoa, Pelagia noctiluca, Rhizostoma pulmo, Pleurobrachia pileus*		
B		International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B		(Coll, 2018)
Q/B		(Coll, 2018)
D		(Sabatés et al., 2010)
53. Salps (SAL): *Thalia democratic, Salpa fusiformis, Salpa maxima, Pyrosoma, Pyrosoma atlanticum*		
B		(Pascual Torner, 2016) and International Bottom Trawl Survey in the Mediterranean (MEDITS) (Bertrand et al., 2002)
P/B		(Coll, 2018)
Q/B		(Coll, 2018)
D		(Pascual Torner, 2016)
54. Red coral (RCO): *Corallium rubrum*		
B Banyuls		(Septentrion Environement, 2015)
B Cap de Creus		(Coll, 2018)
B Medes		(Coll, 2018)
P/B		(Coll, 2018)
Q/B		(Coll, 2018)

D		(Tsounis et al., 2006)
55. Other corals and gorgonians (CGO): *Bryozoa, Alcyonium acaule, Alcyonium palmatum, Alcyonium spp., Eunicella cavolini, Eunicella filiformis, Eunicella singularis*		
B Banyuls		(Schvartz and Labbe, 2012)
B Cap de Creus		(Coll, 2018)
B Medes		(Coll, 2018)
P/B		(Coll, 2018)
Q/B		(Coll, 2018)
D		(Rossi, 2001)
56. Macro zooplankton (MAZ)		
B		(Gaudy et al., 2003)
P/B		(Heymans et al., 2016)
Q/B		(Coll, 2018)
D		(Båmstedt and Karlson, 1998)
57. Meso and micro zooplankton (MMZ)		
B		(Gaudy et al., 2003)
P/B		(Coll, 2018)
Q/B		(Coll, 2018)
D		(Calbet et al., 2002)
58. Suprabenthos (SUB)		
B		*estimated*
P/B		(Corbera et al., 2013)
Q/B		(Coll, 2018)
D		(Cartes et al., 2001)
59. Mediterranean seagrass (POS): *Posidonia oceanica*		
B Banyuls		(Ferrari, 2006)
B Cap de Creus		(Hereu Fina and Quintana Pou, 2012)
B Medes		(Hereu Fina and Quintana Pou, 2012)
P/B		(Coll, 2018)
60. Other seagrasses:		
B Banyuls		*nonpresent*
B Cap de Creus		(EMODnet, 2014)
B Medes		(EMODnet, 2014)
P/B		(Coll, 2018)
61. Erected algae (EAL):		
B Banyuls		*nonpresent*
B Cap de Creus		(Giannoulaki, 2013)
B Medes		(Giannoulaki, 2013)
P/B		(Coll, 2018)
62. Seaweeds (SEA):		

B Banyuls		(Mellado, 2006)
B Cap de Creus		(Giannoulaki, 2013)
B Medes		(Giannoulaki, 2013)
P/B		(Coll, 2018)
63. Small phytoplankton (SMP):		
B		(Joint Research Centre, 2017a)
P/B		(Joint Research Centre, 2017b)
64. Large phytoplankton (LPH):		
B		(Joint Research Centre, 2017a)
P/B		(Joint Research Centre, 2017b)
65. Detritus (DET):		
B		(Pauly et al., 1993a)
66. Discards and by-catch (DIB) – (except FPA)		
B Banyuls		(Prats, 2016)
B Cap de Creus		(Tudó, 2017)
B Medes		(Tudó, 2017)
67. Recreational fishery (RFI) – (except FPA)		
C Banyuls		(Ivanoff et al., 2010)
C Cap de Creus		(Sacanell, 2012)
C Medes		(Sacanell, 2012)
68. Artisanal fishery (AFI) – (except FPA)		
C Banyuls		(Prats, 2016)
C Cap de Creus		(Tudó, 2017)
C Medes		(Tudó, 2017)

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Table 1. Values used to calculate import estimations in the diet of the functional groups based on their behaviour and size for the management units models of the three MPAs models in the NW Mediterranean Sea (Vilas et al., in preparation). These values were slightly decreased in the three models of this study taking into account expert knowledge of the project and the fact that the modelled areas are higher (whole MPA's).

Behavior	value
demersal	0.2
benthopelagic	0.5
pelagic	0.8
sessile	0
benthic	0.1
passive pelagic	0.3

size	value
small	0.2
medium	0.5
large	0.8

Table 2. Initial (in bold) and estimated input data of the three MPA models in the NW Mediterranean Sea (Ba = Cerbère-Banyuls; C = Cap de Creus; M = Medes Islands). B = final biomass (t·km^{-2}); P/B = production/biomass (year^{-1}); Q/B = consumption/biomass (year^{-1}); EE = ecotrophic efficiency; P/Q = production/consumption ratio; landings and discards (t·km^{-2}·year^{-1}).

Functional group		B			P/B			Q/B			EE			P/Q			Landings			Discards		
		Ba	C	M	Ba	C	M	Ba	C	M	Ba	C	M	Ba	C	M	Ba	C	M	Ba	C	M
1	**Bottlenose dolphins**	**0.01**	**0.01**	**0.01**	**0.07**	**0.07**	**0.03**	**12.81**	**12.81**	**12.81**	0.00	0.00	0.00	0.01	0.01	0.00	-	-	-	-	-	-
2	**Striped dolphins**	**0.01**	**0.01**	**0.01**	**0.03**	**0.03**	**0.03**	**14.11**	**14.11**	**14.11**	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
3	**Endangered and pelagic seabirds**	**0.00**	**0.00**	**0.00**	**0.41**	**0.41**	**0.41**	**73.75**	**73.75**	**73.75**	0.00	0.00	0.00	0.01	0.01	0.01	-	-	-	-	-	-
4	**Gulls and cormorants**	**0.00**	**0.00**	**0.00**	**0.31**	**0.31**	**0.31**	**70.80**	**70.80**	**70.80**	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
5	**Terns**	**0.00**	**0.00**	**0.00**	**0.29**	**0.29**	**0.29**	**85.40**	**85.40**	**85.40**	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
6	**Loggerhead turtles**	**0.01**	**0.01**	**0.01**	**0.20**	**0.20**	**0.20**	**2.52**	**2.52**	**2.52**	0.00	0.00	0.00	0.08	0.08	0.08	-	-	-	-	-	-
7	**Non-commercial large pelagic fishes**	**0.01**	**0.01**	**0.01**	**0.14**	**0.14**	**0.14**	**1.63**	**1.63**	**1.63**	0.00	0.00	0.00	0.08	0.08	0.08	-	-	-	-	-	-
8	**Other large pelagic fishes**	**0.00**	**0.00**	**0.00**	0.41	0.50	0.41	**4.13**	**4.96**	**4.13**	0.02	0.89	0.45	**0.10**	**0.10**	**0.10**	**0.00**	**0.00**	**0.00**	-	-	-
9	**Mackerels**	**0.00**	**0.00**	**0.01**	0.88	0.88	**0.86**	**7.31**	**7.32**	**7.31**	0.98	0.34	0.58	**0.12**	**0.12**	0.12	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
10	**Horse mackerels**	**0.01**	**0.02**	**0.00**	0.85	0.86	0.87	**7.10**	**7.19**	**7.26**	0.75	0.49	0.73	**0.12**	**0.12**	**0.12**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
11	**Other medium pelagic fishes**	**0.00**	**0.00**	**0.00**	0.71	**0.77**	**0.69**	**6.47**	**5.19**	**6.47**	0.46	0.10	0.60	**0.11**	0.15	0.11	**0.00**	**0.00**	**0.00**	-	-	-
12	**European sardine**	**0.03**	**0.05**	**0.06**	1.63	1.64	1.64	**10.87**	**10.91**	**10.91**	0.99	0.71	0.53	**0.15**	**0.15**	**0.15**	-	-	-	-	-	-
13	**European anchovy**	**0.02**	**0.01**	**0.01**	1.63	1.63	1.63	**10.84**	**10.88**	**10.88**	0.97	0.91	0.63	**0.15**	**0.15**	**0.15**	-	-	-	-	-	-
14	**Round sardinella**	-	**0.00**	**0.00**	-	1.38	1.38	-	**9.18**	**9.18**	-	0.85	0.77	-	**0.15**	**0.15**	-	-	-	-	-	-
15	**Other small pelagic fish**	**0.07**	**0.04**	**0.03**	**1.21**	**1.31**	**1.30**	**9.85**	**12.04**	**9.85**	0.85	0.96	0.77	0.12	0.11	0.13	**0.00**	**0.00**	-	-	**0.00**	-
16	**Anglerfish**	**0.05**	**0.01**	**0.01**	0.47	**0.58**	**0.58**	**4.30**	**4.30**	**4.30**	0.34	0.64	0.63	**0.11**	0.13	0.13	**0.01**	**0.00**	**0.00**	**0.00**		-
17	**European conger**	**0.02**	**0.01**	**0.00**	0.56	**0.57**	**0.64**	**4.63**	**4.63**	**4.63**	0.16	0.63	0.74	**0.12**	0.12	0.14	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
18	**European hake**	**0.03**	**0.02**	**0.04**	0.67	**0.71**	**0.59**	**5.59**	**5.62**	**5.62**	0.43	0.74	0.63	**0.12**	0.13	0.11	**0.00**	**0.01**	**0.01**	**0.00**	-	-
19	**Poor cod**	**0.02**	**0.01**	**0.01**	1.16	1.16	1.16	**9.65**	**9.69**	**9.69**	0.53	0.90	0.73	**0.12**	**0.12**	**0.12**	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**

20	**Common pandora**	**0.11**	**0.02**	**0.05**	0.75	0.88	**0.82**	**6.27**	**6.27**	**6.27**	0.88	0.90	0.91	**0.12**	**0.14**	0.13	**0.00**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**
21	**Sparidae**	**18.27**	**3.70**	**10.37**	1.08	1.03	1.03	**8.99**	**8.58**	**8.60**	0.83	0.54	0.41	**0.12**	**0.12**	**0.12**	**0.01**	**0.03**	**0.03**	**0.00**	**0.00**	**0.00**
22	**White seabream**	**2.06**	**5.32**	**5.95**	0.86	0.96	0.86	**7.18**	**8.01**	**7.18**	0.99	0.19	0.13	**0.12**	**0.12**	**0.12**	**0.00**	**0.01**	**0.00**	-	**0.00**	**0.00**
23	**Common two-banded seabream**	**4.17**	**4.70**	**5.31**	0.84	0.96	0.88	**7.02**	**7.96**	**7.32**	0.82	0.24	0.14	**0.12**	**0.12**	**0.12**	**0.00**	**0.00**	**0.00**	-	-	-
24	**Common dentex**	**2.24**	**0.99**	**0.74**	0.58	0.62	0.62	**5.26**	**5.13**	**5.13**	0.25	0.06	0.06	**0.11**	**0.12**	**0.12**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**
25	**Red scorpionfish**	**2.17**	**0.74**	**0.75**	0.71	0.72	0.71	**5.93**	**6.01**	**5.88**	0.69	0.23	0.19	**0.12**	**0.12**	**0.12**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**
26	**Scorpaenidae**	**0.27**	**0.20**	**0.27**	0.85	**0.87**	**0.95**	**7.06**	**7.00**	**7.06**	0.99	0.65	0.46	**0.12**	0.12	0.13	**0.00**	**0.00**	**0.03**	**0.00**	**0.00**	**0.00**
27	**Groupers**	**12.53**	**2.10**	**1.69**	**0.18**	**0.23**	**0.22**	**3.54**	**3.91**	**3.91**	0.00	0.01	0.00	0.05	0.06	0.06	**0.00**	**0.00**	**0.00**	-	-	**0.00**
28	**Brown meagre**	**3.47**	**0.26**	**0.24**	0.78	0.76	0.76	**6.48**	**6.35**	**6.35**	0.16	0.29	0.37	**0.12**	**0.12**	**0.12**	**0.00**	**0.00**	**0.00**	-	**0.00**	-
29	**Labridae and serranidae**	**7.87**	**4.59**	**12.86**	1.44	1.30	1.24	**10.29**	**10.84**	**10.29**	0.91	0.65	0.39	**0.14**	**0.12**	**0.12**	**0.01**	**0.00**	**0.00**	-	**0.00**	-
30	**Flatfishes**	**0.07**	**0.02**	**0.02**	1.31	**1.17**	**1.35**	**10.94**	**10.37**	**9.49**	0.42	0.66	0.92	**0.12**	0.11	0.14	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**
31	**Other commercial medium demersal fish**	**11.48**	**0.27**	**0.21**	0.53	0.58	**0.48**	**5.25**	**5.25**	**5.25**	0.05	0.60	0.70	**0.10**	**0.11**	0.09	**0.00**	**0.01**	**0.01**	-	**0.00**	**0.00**
32	**No commercial medium demersal fish**	**5.38**	**0.12**	**0.21**	0.47	**0.48**	**0.49**	**4.70**	**4.70**	**4.70**	0.05	0.49	0.25	**0.10**	0.10	0.11	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
33	**Salema**	**35.43**	**7.65**	**33.28**	1.40	1.34	1.40	**9.32**	**8.90**	**9.32**	0.17	0.10	0.02	**0.15**	**0.15**	**0.15**	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
34	**Mugilidae**	**16.98**	**0.81**	**2.95**	0.91	1.00	0.88	**6.07**	**6.66**	**5.84**	0.28	0.21	0.05	**0.15**	**0.15**	**0.15**	**0.00**	**0.01**	**0.00**	-	**0.00**	**0.00**
35	**Red mullet**	**0.30**	**0.02**	**0.01**	1.05	1.05	**1.07**	**7.47**	**7.47**	**7.47**	0.81	0.80	0.88	**0.14**	**0.14**	0.14	**0.00**	**0.01**	**0.00**	-	**0.00**	**0.00**
36	**Surmulet**	**0.75**	**0.06**	**0.84**	0.92	**0.98**	**0.95**	**6.58**	**6.58**	**6.58**	0.80	0.97	0.10	**0.14**	0.15	0.14	**0.00**	**0.00**	**0.01**	-	**0.00**	**0.00**
37	**No commercial small demersal fish**	**3.35**	**1.20**	**3.35**	1.42	**1.35**	**1.34**	**11.85**	**9.89**	**9.89**	0.94	0.86	0.51	**0.12**	0.14	0.14	**0.00**	**0.00**	-	-	-	-
38	**Small-spotted catshark**	**0.01**	**0.04**	**0.00**	0.68	**0.65**	**0.65**	**6.20**	**6.20**	**6.20**	0.26	0.02	0.26	**0.11**	0.10	0.10	**0.00**	**0.00**	**0.00**	-	**0.00**	-
39	**Rays and skates**	**0.03**	**0.04**	**0.03**	0.71	**0.68**	**0.79**	**5.94**	**5.97**	**5.97**	0.03	0.02	0.16	**0.12**	0.11	0.13	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
40	**Torpedos**	**0.01**	**0.01**	**0.00**	**0.51**	0.50	0.50	**4.98**	**5.00**	**5.00**	0.14	0.01	0.04	0.10	**0.10**	**0.10**	**0.00**	-	-	**0.00**	-	-
41	**Coastal benthic cephalopods**	**3.00**	0.45	**0.23**	**1.57**	**1.61**	**1.57**	**11.01**	**11.01**	**11.01**	0.89	**0.80**	0.91	0.14	0.15	0.14	**0.00**	**0.08**	**0.01**	-	**0.01**	**0.00**
42	**Benthopelagic cephalopods**	**0.07**	**0.01**	**0.02**	**1.72**	**1.72**	**1.72**	**16.53**	**16.53**	**16.53**	0.29	0.83	0.80	0.10	0.10	0.10	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
43	**Other benthic cephalopods**	**0.17**	**0.02**	**0.01**	**1.66**	**1.66**	**1.66**	**11.97**	**11.97**	**11.97**	0.76	0.89	0.86	0.14	0.14	0.14	-	**0.00**	**0.00**	-	**0.00**	**0.00**
44	**Bivalves**	12.39	8.51	13.42	**1.20**	**1.20**	**1.20**	**5.00**	**5.00**	**5.00**	**0.80**	**0.80**	**0.80**	0.24	0.24	0.24	-	-	-	-	-	-

45	**Gastropods**	5.81	2.30	4.57	**1.64**	**1.64**	**1.64**	6.83	6.83	6.83	**0.80**	**0.80**	**0.80**	**0.24**	**0.24**	**0.24**	-	-	-	-	-	-
46	**European lobster**	**0.01**	**0.00**	**0.00**	1.21	1.21	1.21	**6.05**	**6.05**	**6.05**	0.23	0.82	0.95	**0.20**	**0.20**	**0.20**	**0.00**	-	**0.00**	**0.00**	-	-
47	**Other commercial decapods**	**0.00**	**0.00**	**0.00**	**3.04**	**3.00**	**2.88**	**16.20**	**16.20**	**16.20**	0.95	0.50	0.98	0.19	0.19	0.18	**0.00**	**0.00**	**0.00**	-	**0.00**	**0.00**
48	**Non-commercial decapods**	17.57	6.67	11.25	**3.98**	**3.98**	**3.98**	**16.50**	**16.50**	**16.50**	**0.80**	**0.80**	**0.80**	0.24	0.24	0.24	-	-	-	-	-	-
49	**Purple sea urchin**	**9.80**	**4.24**	**9.80**	**0.88**	**0.88**	**0.88**	**6.00**	**6.00**	**6.00**	0.70	0.75	0.58	0.15	0.15	0.15	-	**0.00**	**0.03**	-	**0.00**	**0.00**
50	**Other sea urchin**	**0.80**	**0.33**	**0.80**	**0.82**	**0.82**	**0.82**	**6.00**	**6.00**	**6.00**	0.54	0.60	0.66	0.14	0.14	0.14	-	-	-	-	-	-
51	**Sea cucumbers**	2.42	0.75	1.37	**0.89**	**0.89**	**0.89**	**8.00**	**8.00**	**8.00**	**0.80**	**0.80**	**0.80**	0.11	0.11	0.11	-	-	-	-	-	-
52	**Other macro-benthos**	131.32	46.68	86.89	**3.51**	**3.51**	**3.51**	**12.71**	**12.71**	**12.71**	**0.80**	**0.80**	**0.80**	0.28	0.28	0.28	-	-	-	-	-	-
53	**Jellyfish**	**0.00**	**0.00**	**0.00**	**1.99**	**1.99**	**1.99**	**10.00**	**10.00**	**10.00**	0.57	0.76	0.65	0.20	0.20	0.20	-	-	-	-	-	-
54	**Salps and other gelatinous zooplankton**	**0.01**	**0.01**	**0.01**	**2.02**	**2.02**	**2.02**	**10.00**	**10.00**	**10.00**	0.28	0.30	0.30	0.20	0.20	0.20	-	-	-	-	-	-
55	**Red coral**	**0.05**	**0.03**	**0.10**	**0.22**	**0.22**	**0.22**	**3.00**	**3.00**	**3.00**	0.00	0.00	0.00	0.07	0.07	0.07	-	-	-	-	-	-
56	**Other corals and gorgonians**	**0.65**	**0.17**	**0.74**	**0.22**	**0.22**	**0.22**	**3.00**	**3.00**	**3.00**	0.32	0.38	0.17	0.07	0.07	0.07	-	-	-	-	-	-
57	**Macrozooplankton**	**0.63**	**0.63**	**0.63**	15.00	15.00	15.00	**50.00**	**50.00**	**50.00**	0.95	0.87	0.99	**0.30**	**0.30**	**0.30**	-	-	-	-	-	-
58	**Meso and microzooplankton**	**3.74**	**3.74**	**3.74**	**41.70**	**41.70**	**41.70**	**120.00**	**120.00**	**120.00**	0.88	0.56	0.92	0.35	0.35	0.35	-	-	-	-	-	-
59	**Suprabenthos**	26.10	11.19	23.12	**8.20**	**8.20**	**8.20**	**50.00**	**50.00**	**50.00**	**0.90**	**0.80**	**0.80**	0.16	0.16	0.16	-	-	-	-	-	-
60	**Mediterranean seagrass**	**22.43**	**53.77**	**14.80**	**2.35**	**2.35**	**2.35**	-	-	-	0.65	0.06	0.90	-	-	-	-	-	-	-	-	-
61	**Other seagrasses**	-	**0.88**	**0.89**	-	**4.04**	**4.04**	-	-	-	-	0.35	0.76	-	-	-	-	-	-	-	-	-
62	**Erected algae**	-	**9.58**	**8.51**	-	**0.70**	**0.70**	-	-	-	-	0.08	0.14	-	-	-	-	-	-	-	-	-
63	**Seaweeds**	**7.62**	**4.19**	**7.62**	**0.70**	**0.70**	**0.70**	-	-	-	0.40	0.27	0.36	-	-	-	-	-	-	-	-	-
64	**Small phytoplankton**	**0.94**	**0.88**	**1.01**	**162.95**	**162.95**	**162.95**	-	-	-	0.99	0.85	0.88	-	-	-	-	-	-	-	-	-
65	**Large phytoplankton**	**8.45**	**7.87**	**9.05**	**129.37**	**129.37**	**129.37**	-	-	-	0.31	0.22	0.27	-	-	-	-	-	-	-	-	-
66	**Detritus**	**1073.63**	**926.79**	**1235.30**	-	-	-	-	-	-	0.97	0.68	0.98	-	-	-	-	-	-	-	-	-
67	**Discards and by-catch**	**0.00**	**0.01**	**0.01**	-	-	-	-	-	-	0.87	0.29	0.52	-	-	-	-	-	-	-	-	-

Table 3. Output estimates the 3 modelled MPA in the NW Mediterranean Sea (Ba = Cerbère-Banyuls; C = Cap de Creus; M = Medes Islands). TL = Trophic Level; F = fishing mortality (year^{-1}); M2= predation mortality (year^{-1}); M0 = other natural mortality (year^{-1}); F/Z = exploitation rate (fishing mortality (F) / total mortality (Z)); FD = flow to detritus (t·km^{-2}·year^{-1}).

	Functional group	**TL**			**F**			**M2**			**M0**			**F/Z**			**FD**		
		Ba	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**
1	**Bottlenose dolphins**	4.18	4.16	4.23	-	-	-	-	-	-	0.07	0.07	0.03	-	-	-	0.04	0.04	0.04
2	**Striped dolphins**	4.16	4.19	4.21	-	-	-	-	-	-	0.03	0.03	0.03	-	-	-	0.03	0.03	0.03
3	**Endangered and pelagic seabirds**	3.98	4.00	4.00	-	-	-	-	-	-	0.41	0.41	0.41	-	-	-	0.01	0.01	0.01
4	**Gulls and cormorants**	4.02	4.05	4.05	-	-	-	-	-	-	0.31	0.31	0.31	-	-	-	0.00	0.00	0.00
5	**Terns**	3.98	3.98	3.99	-	-	-	-	-	-	0.29	0.29	0.29	-	-	-	0.00	0.00	0.00
6	**Loggerhead turtles**	3.31	3.31	3.31	-	-	-	-	-	-	0.20	0.20	0.20	-	-	-	0.01	0.01	0.01
7	**Non-commercial large pelagic fishes**	3.75	3.75	3.75	-	-	-	-	-	-	0.14	0.14	0.14	-	-	-	0.00	0.00	0.00
8	**Other large pelagic fishes**	3.99	4.08	4.02	0.01	0.44	0.19	-	-	-	0.40	0.06	0.23	0.02	0.89	0.45	0.00	0.00	0.00
9	**Mackerels**	3.50	3.51	3.51	0.27	0.19	0.05	0.59	0.58	0.45	0.02	0.58	0.36	0.31	0.14	0.06	0.00	0.01	0.02
10	**Horse mackerels**	3.47	3.48	3.48	0.21	0.09	0.20	0.43	0.44	0.43	0.21	0.44	0.24	0.25	0.09	0.23	0.02	0.03	0.01
11	**Other medium pelagic fishes**	3.90	3.93	3.94	0.03	0.37	0.29	0.29	0.49	0.12	0.39	0.69	0.28	0.05	0.24	0.42	0.00	0.00	0.01
12	**European sardine**	2.95	2.95	2.95	-	-	-	1.61	1.16	0.86	0.02	0.48	0.77	-	-	-	0.06	0.12	0.17
13	**European anchovy**	3.01	3.01	3.01	-	-	-	1.58	2.38	1.03	0.05	0.14	0.60	-	-	-	0.05	0.03	0.04
14	**Round sardinella**	-	3.12	3.12	-	-	-	-	1.67	1.06	-	0.20	0.32	-	-	-	-	0.00	0.00
15	**Other small pelagic fish**	3.02	3.02	3.02	0.01	0.01	-	1.03	1.25	1.00	0.18	0.05	0.31	0.00	0.01	-	0.15	0.11	0.07
16	**Anglerfish**	3.95	4.00	4.00	0.16	0.37	0.36	0.00	0.00	0.00	0.31	0.21	0.21	0.34	0.63	0.63	0.06	0.01	0.01
17	**European conger**	3.87	3.97	3.96	0.05	0.30	0.37	0.04	0.06	0.11	0.47	0.21	0.17	0.09	0.52	0.57	0.03	0.01	0.00
18	**European hake**	3.91	3.94	3.93	0.02	0.39	0.27	0.27	0.14	0.10	0.38	0.18	0.22	0.03	0.55	0.46	0.04	0.03	0.06
19	**Poor cod**	3.35	3.35	3.35	0.00	0.01	0.08	0.61	1.04	0.77	0.54	0.12	0.31	0.00	0.01	0.07	0.05	0.02	0.02

20	**Common pandora**	3.28	3.25	3.28	0.04	0.30	0.31	0.62	0.49	0.43	0.09	0.09	0.08	0.05	0.34	0.38	0.15	0.03	0.06
21	**Sparidae**	2.96	2.98	3.00	0.00	0.01	0.00	0.90	0.55	0.42	0.18	0.47	0.61	0.00	0.01	0.00	36.13	8.09	24.18
22	**White seabream**	3.20	3.25	3.27	0.00	0.00	0.00	0.86	0.18	0.11	0.00	0.78	0.75	0.00	0.00	0.00	2.97	12.68	13.00
23	**Common two-banded seabream**	3.10	3.14	3.14	0.00	0.00	0.00	0.69	0.23	0.13	0.15	0.72	0.75	0.00	0.00	0.00	6.48	10.89	11.77
24	**Common dentex**	3.77	3.89	3.89	0.00	0.01	0.00	0.15	0.03	0.04	0.43	0.58	0.58	0.00	0.01	0.00	3.32	1.59	1.19
25	**Red scorpionfish**	3.47	3.51	3.59	0.00	0.01	0.01	0.49	0.16	0.13	0.22	0.55	0.57	0.00	0.01	0.01	3.06	1.30	1.31
26	**Scorpaenidae**	3.52	3.52	3.53	0.00	0.02	0.11	0.84	0.55	0.33	0.01	0.30	0.51	0.00	0.02	0.11	0.39	0.34	0.51
27	**Groupers**	3.78	3.96	3.95	0.00	0.00	0.00	-	-	-	0.18	0.22	0.22	0.00	0.01	0.00	11.12	2.11	1.70
28	**Brown meagre**	3.23	3.30	3.32	0.00	0.00	0.00	0.13	0.22	0.28	0.65	0.54	0.48	0.00	0.00	0.00	6.76	0.47	0.42
29	**Labridae and serranidae**	3.10	3.11	3.11	0.00	0.00	0.00	1.31	0.84	0.48	0.13	0.46	0.75	0.00	0.00	0.00	17.19	12.05	36.14
30	**Flatfishes**	3.23	3.24	3.24	0.01	0.23	0.50	0.54	0.55	0.73	0.77	0.40	0.11	0.01	0.19	0.37	0.20	0.04	0.04
31	**Other commercial medium demersal fish**	3.25	3.50	3.51	0.00	0.05	0.03	0.02	0.30	0.31	0.50	0.23	0.15	0.00	0.08	0.06	17.80	0.35	0.25
32	**No commercial medium demersal fish**	3.51	3.80	3.81	0.00	0.00	0.02	0.03	0.23	0.10	0.44	0.25	0.37	0.00	0.01	0.04	7.44	0.15	0.28
33	**Salema**	2.09	2.09	2.09	0.00	0.00	0.00	0.24	0.13	0.02	1.16	1.21	1.38	0.00	0.00	0.00	107.13	22.84	107.80
34	**Mugilidae**	2.20	2.30	2.30	0.00	0.01	0.00	0.25	0.20	0.04	0.66	0.79	0.83	0.00	0.01	0.00	31.77	1.73	5.90
35	**Red mullet**	3.15	3.16	3.15	-	0.34	0.33	0.85	0.50	0.61	0.20	0.20	0.13	-	0.33	0.31	0.51	0.03	0.02
36	**Surmulet**	3.24	3.25	3.24	-	0.04	0.01	0.73	0.90	0.08	0.19	0.03	0.85	-	0.04	0.01	1.12	0.08	1.82
37	**No commercial small demersal fish**	2.98	2.99	2.99	0.00	0.00	-	1.34	1.17	0.68	0.08	0.19	0.66	0.00	0.00	0.00	8.22	2.59	8.86
38	**Small-spotted catshark**	3.62	3.67	3.63	0.03	0.01	0.14	0.15	0.00	0.03	0.51	0.64	0.48	0.04	0.01	0.22	0.01	0.08	0.01
39	**Rays and skates**	3.73	3.74	3.75	0.01	0.01	0.13	0.02	0.00	0.00	0.69	0.66	0.66	0.01	0.02	0.16	0.06	0.08	0.06
40	**Torpedos**	3.93	3.98	3.99	0.05	-	-	0.02	0.00	0.02	0.45	0.50	0.48	0.10	-	-	0.02	0.01	0.00
41	**Coastal benthic cephalopods**	3.28	3.36	3.36	0.00	0.18	0.05	1.40	1.11	1.38	0.17	0.32	0.14	0.00	0.11	0.03	7.13	1.14	0.54
42	**Benthopelagic cephalopods**	3.47	3.60	3.63	0.00	0.03	0.26	0.50	1.39	1.11	1.22	0.30	0.34	0.00	0.02	0.15	0.32	0.04	0.06
43	**Other benthic cephalopods**	3.25	3.25	3.25	-	0.00	0.05	1.25	1.48	1.37	0.40	0.18	0.23	-	0.00	0.03	0.48	0.06	0.04
44	**Bivalves**	2.07	2.07	2.07	-	-	-	0.96	0.96	0.96	0.24	0.24	0.24	-	-	-	27.77	19.06	30.06
45	**Gastropods**	2.11	2.12	2.11	-	-	-	1.31	1.31	1.31	0.33	0.33	0.33	-	-	-	17.77	7.05	13.99
46	**European lobster**	3.16	3.16	3.16	0.09	-	0.82	0.19	0.99	0.33	0.92	0.22	0.06	0.08	-	0.68	0.03	0.00	0.00

47	**Other commercial decapods**	3.08	3.07	3.08	0.16	0.12	0.07	2.73	1.37	2.75	0.15	1.51	0.06	0.05	0.04	0.03	0.01	0.02	0.01
48	**Non-commercial decapods**	2.72	2.75	2.74	-	-	-	3.18	3.18	3.18	0.80	0.80	0.80	-	-	-	100.97	27.34	46.10
49	**Purple sea urchin**	2.00	2.00	2.00	-	0.00	0.00	0.61	0.66	0.50	0.27	0.22	0.37	-	0.00	0.00	26.14	11.10	27.19
50	**Other sea urchin**	2.00	2.00	2.00	-	-	-	0.44	0.49	0.54	0.37	0.33	0.28	-	-	-	2.21	0.91	2.14
51	**Sea cucumbers**	2.00	2.00	2.00	-	-	-	0.71	0.71	0.71	0.18	0.18	0.18	-	-	-	8.18	2.52	4.62
52	**Other macro-benthos**	2.02	2.03	2.03	-	-	-	2.81	2.81	2.81	0.70	0.70	0.70	-	-	-	759.72	270.03	502.65
53	**Jellyfish**	3.07	3.07	3.07	-	-	-	1.13	1.50	1.30	0.86	0.48	0.69	-	-	-	0.01	0.01	0.01
54	**Salps and other gelatinous zooplankton**	2.04	2.04	2.04	-	-	-	0.58	0.60	0.61	1.45	1.43	1.41	-	-	-	0.02	0.02	0.02
55	**Red coral**	2.46	2.46	2.46	-	-	-	-	-	-	0.22	0.22	0.22	-	-	-	0.04	0.02	0.08
56	**Other corals and gorgonians**	2.17	2.17	2.17	-	-	-	0.07	0.08	0.04	0.15	0.14	0.18	-	-	-	0.49	0.13	0.58
57	**Macrozooplankton**	2.63	2.63	2.63	-	-	-	14.26	13.05	14.91	0.74	1.95	0.09	-	-	-	13.13	13.90	12.72
58	**Meso and microzooplankton**	2.00	2.00	2.00	-	-	-	36.82	23.19	38.40	4.88	18.51	3.30	-	-	-	197.86	248.85	191.96
59	**Suprabenthos**	2.17	2.16	2.15	-	-	-	7.38	6.56	6.56	0.82	1.64	1.64	-	-	-	412.88	186.24	384.65
60	**Mediterranean seagrass**	1.00	1.00	1.00	-	-	-	1.53	0.14	2.13	0.82	2.21	0.22	-	-	-	18.41	118.70	3.32
61	**Other seagrasses**	-	1	1	-	-	-	-	1.43	3.08	-	2.61	0.96	-	-	-	-	2.29	0.86
62	**Erected algae**	-	1	1	-	-	-	-	0.06	0.10	-	0.64	0.60	-	-	-	-	6.17	5.11
63	**Seaweeds**	1	1	1	-	-	-	0.28	0.19	0.25	0.42	0.51	0.45	-	-	-	3.19	2.15	3.43
64	**Small phytoplankton**	1	1	1	-	-	-	161.77	138.94	142.78	1.18	24.02	20.17	-	-	-	1.11	21.02	20.30
65	**Large phytoplankton**	1	1	1	-	-	-	39.51	28.03	35.08	89.86	101.34	94.28	-	-	-	759.42	797.91	853.34
66	**Detritus**	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	**Discards and by-catch**	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.01	0.01

Table 4. Output estimates the 3 modelled MPA in the NW Mediterranean Sea (Ba = Cerbère-Banyuls; C = Cap de Creus; M = Medes Islands). R/A = Respiration/Assimilation ratio; R/B = Respiration/Biomass ratio (year^{-1}); P/R = Production/Respiration ratio; NE = Net Efficiency.

	Functional group	**R/A**			**R/B**			**P/R**			**NE**		
		Ba	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**	**Ba**	**C**	**M**
1	**Bottlenose dolphins**	0.99	0.99	1.00	10.18	10.18	10.22	0.01	0.01	0.00	0.01	0.01	0.00
2	**Striped dolphins**	1.00	1.00	1.00	11.25	11.25	11.25	0.00	0.00	0.00	0.00	0.00	0.00
3	**Endangered and pelagic seabirds**	0.99	0.99	0.99	58.59	58.59	58.59	0.01	0.01	0.01	0.01	0.01	0.01
4	**Gulls and cormorants**	0.99	0.99	0.99	56.32	56.32	56.32	0.01	0.01	0.01	0.01	0.01	0.01
5	**Terns**	1.00	1.00	1.00	68.03	68.03	68.03	0.00	0.00	0.00	0.00	0.00	0.00
6	**Loggerhead turtles**	0.90	0.90	0.90	1.81	1.81	1.81	0.11	0.11	0.11	0.10	0.10	0.10
7	**Non-commercial large pelagic fishes**	0.89	0.89	0.89	1.16	1.16	1.16	0.12	0.12	0.12	0.11	0.11	0.11
8	**Other large pelagic fishes**	0.88	0.87	0.88	2.89	3.47	2.89	0.14	0.14	0.14	0.13	0.13	0.13
9	**Mackerels**	0.85	0.85	0.85	4.97	4.98	4.99	0.18	0.18	0.17	0.15	0.15	0.15
10	**Horse mackerels**	0.85	0.85	0.85	4.83	4.89	4.94	0.18	0.18	0.18	0.15	0.15	0.15
11	**Other medium pelagic fishes**	0.86	0.81	0.87	4.46	3.38	4.48	0.16	0.23	0.15	0.14	0.19	0.13
12	**European sardine**	0.81	0.81	0.81	7.06	7.09	7.09	0.23	0.23	0.23	0.19	0.19	0.19
13	**European anchovy**	0.81	0.81	0.81	7.05	7.07	7.07	0.23	0.23	0.23	0.19	0.19	0.19
14	**Round sardinella**	-	0.81	0.81	-	5.97	5.97	-	0.23	0.23	-	0.19	0.19
15	**Other small pelagic fish**	0.85	0.86	0.83	6.67	8.32	6.57	0.18	0.16	0.20	0.15	0.14	0.17
16	**Anglerfish**	0.86	0.83	0.83	2.97	2.86	2.86	0.16	0.20	0.20	0.14	0.17	0.17
17	**European conger**	0.85	0.84	0.83	3.15	3.13	3.06	0.18	0.18	0.21	0.15	0.16	0.17
18	**European hake**	0.85	0.84	0.87	3.80	3.78	3.90	0.18	0.19	0.15	0.15	0.16	0.13
19	**Poor cod**	0.85	0.85	0.85	6.56	6.59	6.59	0.18	0.18	0.18	0.15	0.15	0.15
20	**Common pandora**	0.85	0.83	0.84	4.26	4.14	4.20	0.18	0.21	0.20	0.15	0.18	0.16
21	**Sparidae**	0.85	0.85	0.85	6.11	5.83	5.84	0.18	0.18	0.18	0.15	0.15	0.15

22	**White seabream**	0.85	0.85	0.85	4.89	5.45	4.89	0.18	0.18	0.18	0.15	0.15	0.15
23	**Common two-banded seabream**	0.85	0.85	0.85	4.77	5.41	4.98	0.18	0.18	0.18	0.15	0.15	0.15
24	**Common dentex**	0.86	0.85	0.85	3.63	3.49	3.49	0.16	0.18	0.18	0.14	0.15	0.15
25	**Red scorpionfish**	0.85	0.85	0.85	4.03	4.09	4.00	0.18	0.18	0.18	0.15	0.15	0.15
26	**Scorpaenidae**	0.85	0.85	0.83	4.80	4.73	4.69	0.18	0.18	0.20	0.15	0.15	0.17
27	**Groupers**	0.94	0.93	0.93	2.65	2.90	2.90	0.07	0.08	0.08	0.06	0.07	0.07
28	**Brown meagre**	0.85	0.85	0.85	4.41	4.32	4.32	0.18	0.18	0.18	0.15	0.15	0.15
29	**Labridae and serranidae**	0.83	0.85	0.85	6.79	7.37	7.00	0.21	0.18	0.18	0.18	0.15	0.15
30	**Flatfishes**	0.85	0.86	0.82	7.44	7.12	6.24	0.18	0.16	0.22	0.15	0.14	0.18
31	**Other commercial medium demersal fish**	0.88	0.86	0.89	3.68	3.63	3.72	0.14	0.16	0.13	0.13	0.14	0.11
32	**No commercial medium demersal fish**	0.87	0.87	0.87	3.29	3.28	3.26	0.14	0.15	0.15	0.13	0.13	0.13
33	**Salema**	0.81	0.81	0.81	6.06	5.79	6.06	0.23	0.23	0.23	0.19	0.19	0.19
34	**Mugilidae**	0.81	0.81	0.81	3.94	4.33	3.79	0.23	0.23	0.23	0.19	0.19	0.19
35	**Red mullet**	0.83	0.83	0.82	4.93	4.93	4.91	0.21	0.21	0.22	0.18	0.18	0.18
36	**Surmulet**	0.83	0.81	0.82	4.34	4.28	4.32	0.21	0.23	0.22	0.18	0.19	0.18
37	**No commercial small demersal fish**	0.85	0.83	0.83	8.06	6.56	6.57	0.18	0.21	0.20	0.15	0.17	0.17
38	**Small-spotted catshark**	0.86	0.87	0.87	4.28	4.31	4.31	0.16	0.15	0.15	0.14	0.13	0.13
39	**Rays and skates**	0.85	0.86	0.84	4.04	4.10	3.99	0.18	0.16	0.20	0.15	0.14	0.16
40	**Torpedos**	0.87	0.88	0.87	3.47	3.50	3.50	0.15	0.14	0.14	0.13	0.13	0.13
41	**Coastal benthic cephalopods**	0.82	0.82	0.82	7.24	7.20	7.24	0.22	0.22	0.22	0.18	0.18	0.18
42	**Benthopelagic cephalopods**	0.87	0.87	0.87	11.50	11.50	11.51	0.15	0.15	0.15	0.13	0.13	0.13
43	**Other benthic cephalopods**	0.83	0.83	0.83	7.92	7.91	7.92	0.21	0.21	0.21	0.17	0.17	0.17
44	**Bivalves**	0.60	0.60	0.60	1.80	1.80	1.80	0.67	0.67	0.67	0.40	0.40	0.40
45	**Gastropods**	0.60	0.60	0.60	2.46	2.46	2.46	0.67	0.67	0.67	0.40	0.40	0.40
46	**European lobster**	0.71	0.75	0.75	3.02	3.63	3.63	0.40	0.33	0.33	0.29	0.25	0.25
47	**Other commercial decapods**	0.73	0.77	0.78	8.30	9.96	10.08	0.37	0.30	0.29	0.27	0.23	0.22
48	**Non-commmercial decapods**	0.66	0.70	0.70	7.58	9.23	9.23	0.53	0.43	0.43	0.34	0.30	0.30
49	**Purple sea urchin**	0.76	0.76	0.76	2.72	2.72	2.72	0.32	0.32	0.32	0.24	0.24	0.24

50	**Other sea urchin**	0.77	0.77	0.77	2.78	2.78	2.78	0.29	0.29	0.29	0.23	0.23	0.23
51	**Sea cucumbers**	0.81	0.81	0.81	3.91	3.91	3.91	0.23	0.23	0.23	0.19	0.19	0.19
52	**Other macro-benthos**	0.54	0.54	0.54	4.11	4.11	4.11	0.85	0.85	0.85	0.46	0.46	0.46
53	**Jellyfish**	0.75	0.75	0.75	6.01	6.01	6.01	0.33	0.33	0.33	0.25	0.25	0.25
54	**Salps and other gelatinous zooplankton**	0.75	0.75	0.75	5.98	5.98	5.98	0.34	0.34	0.34	0.25	0.25	0.25
55	**Red coral**	0.91	0.91	0.91	2.18	2.18	2.18	0.10	0.10	0.10	0.09	0.09	0.09
56	**Other corals and gorgonians**	0.91	0.91	0.91	2.18	2.18	2.18	0.10	0.10	0.10	0.09	0.09	0.09
57	**Macrozooplankton**	0.50	0.50	0.50	15.00	15.00	15.00	1.00	1.00	1.00	0.50	0.50	0.50
58	**Meso and microzooplankton**	0.42	0.42	0.42	30.30	30.30	30.30	1.38	1.38	1.38	0.58	0.58	0.58
59	**Suprabenthos**	0.77	0.77	0.77	26.80	26.80	26.80	0.31	0.31	0.31	0.23	0.23	0.23
60	**Mediterranean seagrass**	-	-	-	-	-	-	-	-	-	-	-	-
61	**Other seagrasses**	-	-	-	-	-	-	-	-	-	-	-	-
62	**Erected algae**	-	-	-	-	-	-	-	-	-	-	-	-
63	**Seaweeds**	-	-	-	-	-	-	-	-	-	-	-	-
64	**Small phytoplankton**	-	-	-	-	-	-	-	-	-	-	-	-
65	**Large phytoplankton**	-	-	-	-	-	-	-	-	-	-	-	-
66	**Detritus**	-	-	-	-	-	-	-	-	-	-	-	-
67	**Discards and by-catch**	-	-	-	-	-	-	-	-	-	-	-	-

PREBAL analysis and balancing procedure

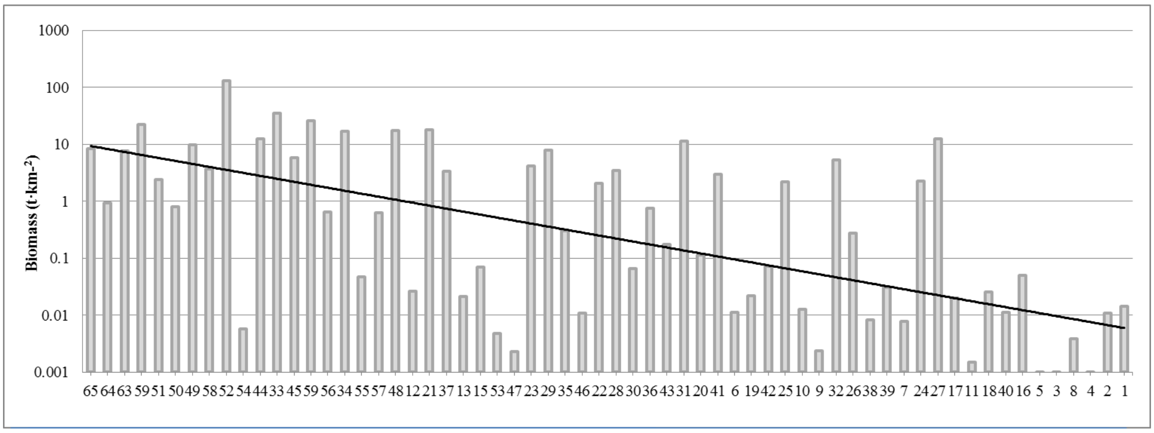
An Ecopath model is considered ecologically and thermodynamically balanced under the following conditions: (1) estimated EE < 1 for all functional groups, (2) values of P/Q (production/consumption rate or gross efficiency of food conversion, GE) are between 0.1 and 0.35 with the exception of some fast growing groups, (3) R/A (respiration/food assimilation) < 1, (4) R/B (respiration/biomass) are between 1 and 10 for fishes and higher values for small organisms, (5) NE (net efficiency of food conversion) > GE and (6) P/R (production/respiration) < 1 (Christensen et al., 2008; Heymans et al., 2016) (Table 2 in the manuscript and Table 3 in SOM 3).

Initial results of the three MPA models showed that the EE > 1 for several groups. To achieve mass-balance, we applied a manual mass-balanced procedure following a top-down approach modifying appropriate input parameters (starting from the groups with higher trophic levels) and following the best practice guidelines provided in the literature (Heymans et al., 2016).

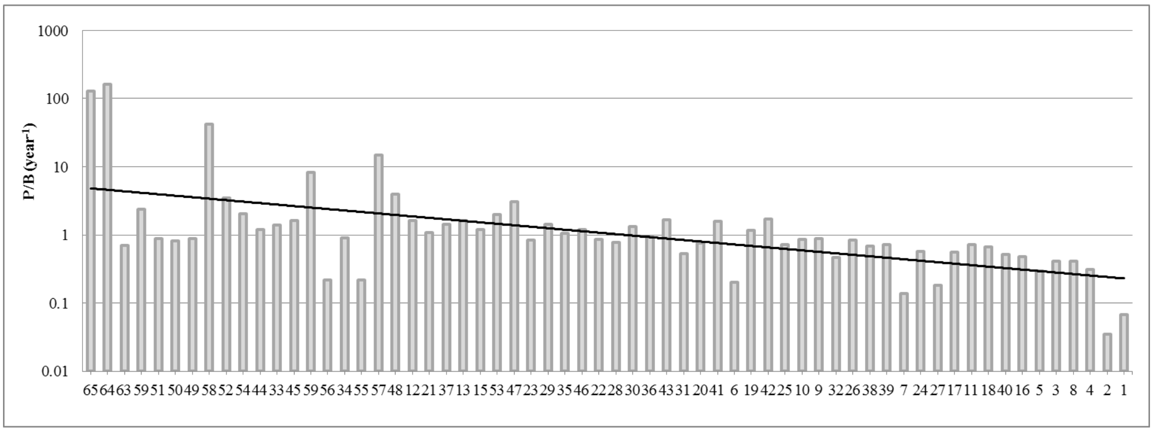
In order to ensure that the model parameters obeyed general ecologic principles and to guide the balancing procedure we used the PREBAL analysis (Link, 2010). This analysis highlighted that some P/B and Q/B values had to be adjusted since they were too low or too high based on their trophic levels based on previous modelling developments (Corrales et al., 2015; Corrales et al., 2017) (see Fig. 1, 2 and 3).

After testing the model parameters with PREBAL, biomass and diets were readjusted where needed, as in other Ecopath models developed in the Mediterranean Sea (Coll et al., 2006; Tsagarakis et al., 2010; Corrales et al., 2015). For pelagic fish groups (mackerels, horse mackerels, European sardine, European anchovy and other small pelagic fish), we added immigration biomass the because studied areas are relatively small compared to the dispersal rate of those species (e.g., Papetti et al., 2013). Finally, the diet matrix was slightly adjusted to take into account the abundances of species in the ecosystem (SOM 4).

a)



b)



c)

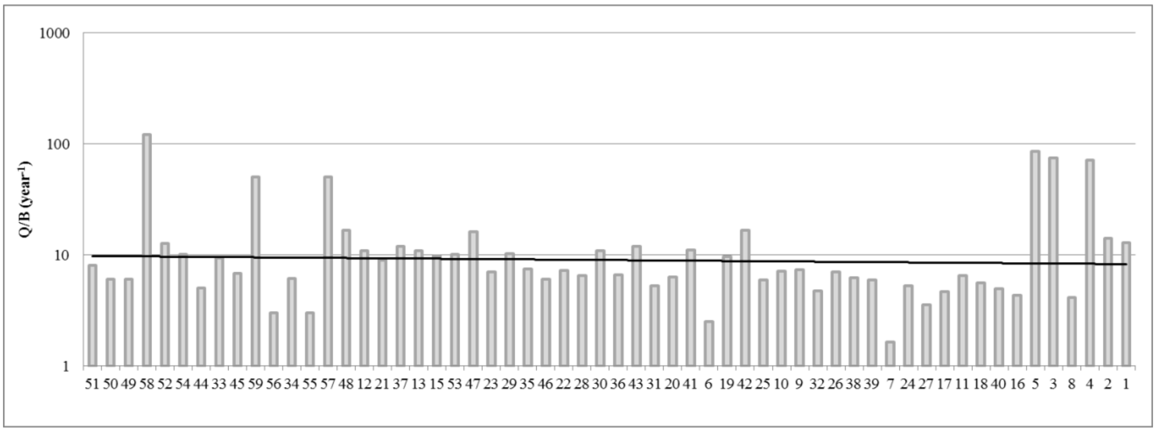
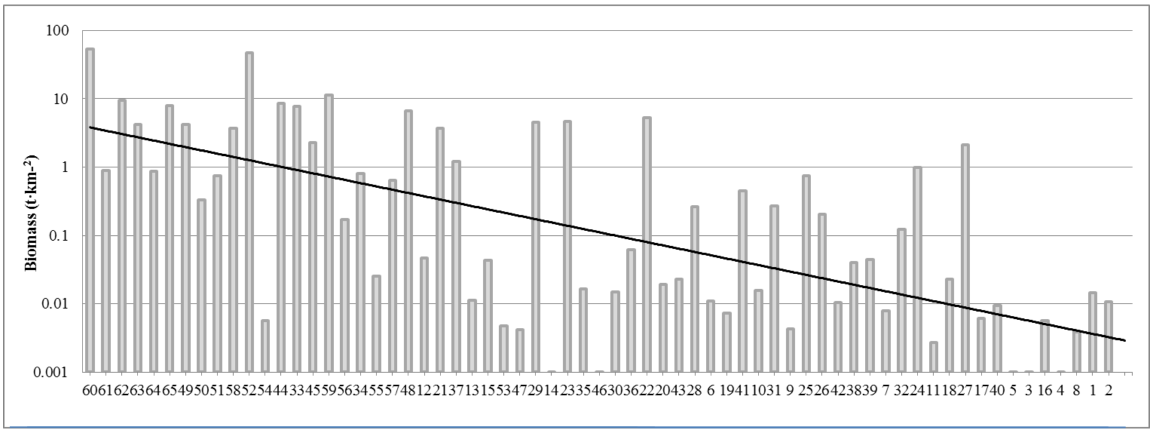
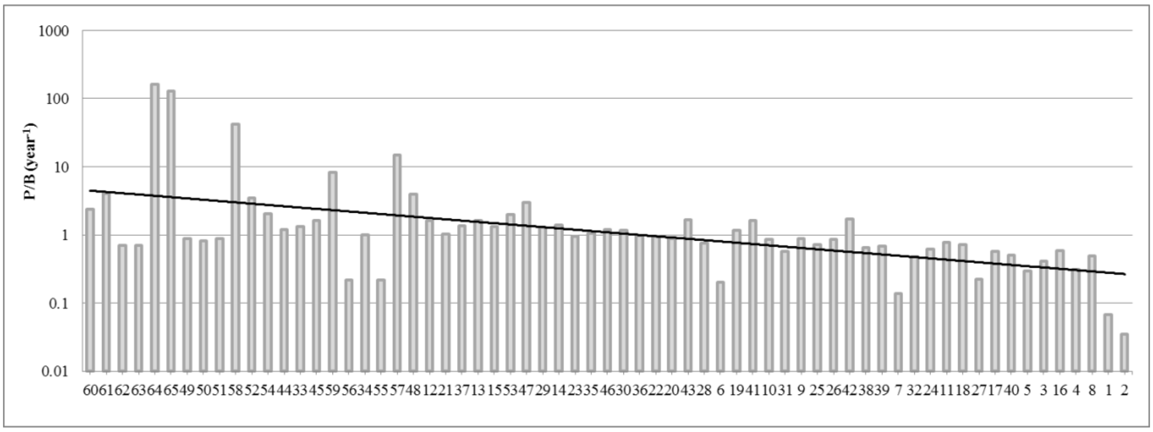


Fig. 1. PREBAL of the Cerbère-Banyuls MPA plotting Biomass estimates (t·km-^{2}) (a), Production/Biomass ratio (year^{-1}) (b), and Consumption/Biomass ratio (year^{-1}) (c) on a log scale vs species ranked by trophic level, from the lowest to highest trophic level. Trend lines are given. Numbers in identify the functional groups of the model.

a)



b)



c)

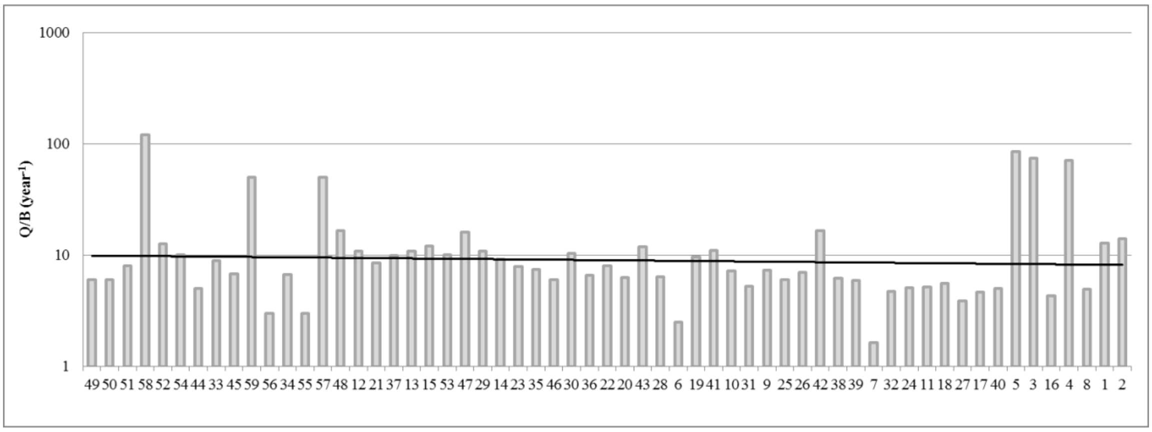


Fig. 2. PREBAL of the Cap de Creus MPA plotting Biomass estimates (t·km-^{2}) (a), Production/Biomass ratio (year^{-1}) (b), and Consumption/Biomass ratio (year^{-1}) (c) on a log scale vs species ranked by trophic level, from the lowest to highest trophic level. Trend lines are given. Numbers in identify the functional groups of the model.

a)

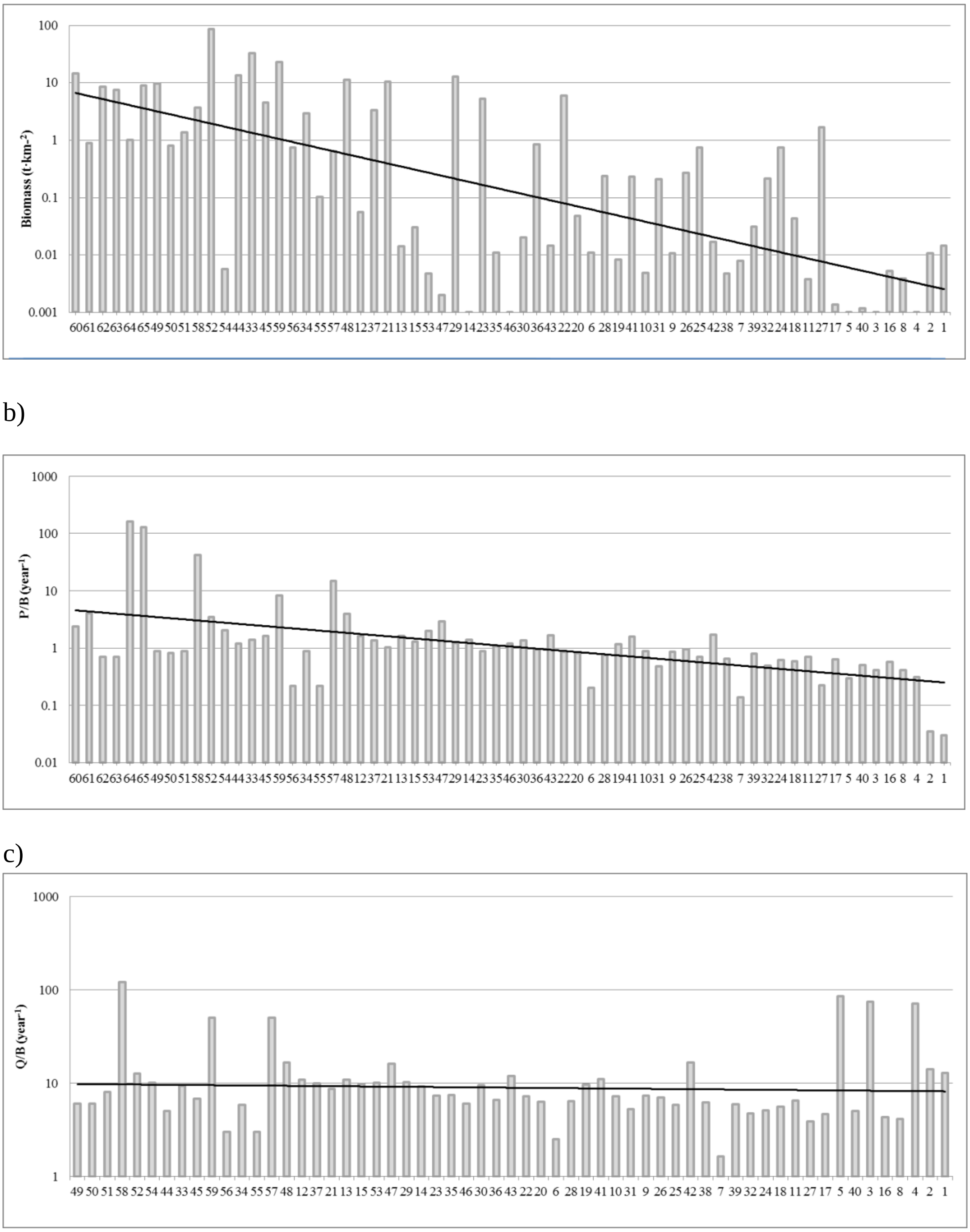


Fig. 3. PREBAL of the Medes Islands MPA plotting Biomass estimates (t·km-^{2}) (a), Production/Biomass ratio (year^{-1}) (b), and Consumption/Biomass ratio (year^{-1}) (c) on a log scale vs species ranked by trophic level, from the lowest to highest trophic level. Trend lines are given. Numbers in identify the functional groups of the model.

Pedigree routine

The pedigree routine (Christensen and Walters, 2004) was used to quantify the uncertainty associated with the input parameters and the quality of the models and to validate choices made in balancing the model. For each input data, pedigree values were assigned manually to record the degree of confidence associated with the data except for diet pedigree values, which were obtained from the predator point of view considering four diet features (region, year, type of data and method). With the information for each functional group, the pedigree index was calculated for the overall model. The pedigree index ranges between 0 (low quality) and 1 (high quality), allowing a description of the quality of the model that can be compared to other models. The confidence intervals for the pedigree analysis and index values used are described in Table 4.

Table 4. Confidence intervals and index values used to describe the uncertainty for each input parameter of the balanced Ecopath model (as default parameters).

Parameter	Option	Index value	CI (%)
Biomass			
	Estimated by Ecopath	0.0	±80
	From other model	0.0	±80
	Guesstimate	0.0	±80
	Approximate or indirect method	0.4	±50
	Sampling/locally, low precision	0.6	±40
	Sampling/locally, high precision	0.8	±10
PB/ and Q/B			
	Estimated by Ecopath	0.0	±80
	Guesstimated	0.1	±70
	From other model	0.2	±60
	Empirical relationship	0.5	±50
	Similar species, similar system, low precision	0.6	±40
	Similar species, same system, low precision	0.7	±30
	Same species, similar system, low precision	0.8	±20
	Same species, same system, high precision	1	±10
Diet			
	From other model	0.1	±80
	General knowledge of related groups/species	0.1	±70
	General knowledge for same groups/species	0.2	±60
	Qualitative diet composition study	0.5	±50

	Quantitative (but limited) diet composition study	0.6	±40
	Quantitative (detailed) diet composition study	0.7	±30
Catch			
	From other model	0.1	±90
	National statistics	0.5	±50
	Intermediate (local study and national statistics)	0.6	±40
	Local study, low precision/incomplete data	0.7	±30
	Local study, high precision/complete data	0.9	±10

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Table 1. Diet composition matrix for the Cerbère-Banyuls MPA model. Cells in grey are values lo

	Prey \ predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	**Bottlenose dolphins**								
2	**Striped dolphins**								
3	**Endangered and pelagic seabirds**								
4	**Gulls and cormorants**								
5	**Terns**								
6	**Loggerhead turtles**								
7	**Non-commercial large pelagic fishes**								
8	**Other large pelagic fishes**								
9	**Mackerels**	▨	▨	▨	0.01	0.01			0.01
10	**Horse mackerels**	0.01	0.01	0.01	0.02	0.01	▨		0.01
11	**Other medium pelagic fishes**			▨	▨	▨			▨
12	**European sardine**	0.04	0.03	0.04	0.05	0.08			0.02
13	**European anchovy**	0.03	0.03	0.05	0.02	0.02	▨		0.01
14	**Other small pelagic fish**	0.03	0.03	0.03	0.01	0.08			0.01
15	**Anglerfish**	▨							
16	**European conger**	▨							
17	**European hake**	0.01	▨						
18	**Poor cod**	▨	0.01		▨				
19	**Common pandora**	▨	0.01		▨				
20	**Sparidae**	0.01	0.02		0.02				0.08
21	**White seabream**				▨				
22	**Common two-banded seabream**				▨				
23	**Common dentex**								▨
24	**Red scorpionfish**								
25	**Scorpaenidae**				▨				
26	**Groupers**								
27	**Brown meagre**								
28	**Labridae and Serranidae**				0.01				
29	**Flatfishes**	▨	▨		0.01				
30	**Other commercial medium demersal fish**	0.01	0.02		0.01				
31	**No commercial medium demersal fish**	▨	▨						
32	**Salema**				▨				
33	**Mugilidae**				▨	▨			
34	**Red mullet**				▨				
35	**Surmulet**								
36	**No commercial small demersal fish**	▨	0.01	0.05	0.01				0.01
37	**Small-spotted catshark**								
38	**Rays and skates**								▨
39	**Torpedos**								
40	**Coastal benthic cephalopods**	0.01							
41	**Benthopelagic cephalopods**	0.03	0.03	0.02			▨		0.01
42	**Other benthic cephalopods**	0.01	0.01						
43	**Bivalves**				▨				
44	**Gastropods**				▨				
45	**European lobster**								
46	**Other commercial decapods**								
47	**Non-commmercial decapods**				0.01		0.01		

48	**Purple sea urchin**								
49	**Other sea urchin**								
50	**Sea cucumbers**								
51	**Other macro-benthos**						0.03		
52	**Jellyfish**						0.04	0.13	0.01
53	**Salps and other gelatinous zooplankton**						0.08	0.05	0.01
54	**Red coral**								
55	**Other corals and gorgonians**								
56	**Macrozooplankton**							0.02	0.03
57	**Meso and microzooplankton**							0.01	
58	**Suprabenthos**						0.04		
59	**Mediterranean seagrass**								
60	**Seaweeds**								
61	**Small phytoplankton**								
62	**Large phytoplankton**								
63	**Detritus**								
64	**Discards and bycatch**			0.01					
	Import	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

ower than 0.01. The numbers identify the functional groups of the model.

9	10	11	12	13	14	15	16	17	18	19	20	21
		0.01										
	0.01	0.07				0.01		0.03				
0.01	0.02	0.07				0.01		0.02				
	0.01	0.04						0.03				
						0.02						
		0.02				0.02		0.01				
		0.01										
		0.08				0.07	0.04	0.07			0.01	
						0.03	0.02	0.03				
						0.04	0.03	0.03				
								0.01				
						0.04	0.01	0.01				
						0.07	0.07	0.04			0.01	0.02
						0.01	0.04			0.03		
		0.02				0.08	0.20	0.01				
						0.01	0.02					
							0.01					
								0.01				
		0.09				0.07		0.06	0.05	0.01		0.01
						0.01						
						0.01		0.01				
0.01	0.01	0.01										
						0.01		0.01				
							0.06			0.03	0.01	0.04
							0.02			0.05	0.01	0.01
						0.08	0.11	0.03	0.04	0.12	0.10	0.13

										0.05	0.03	0.02
										0.03		
										0.04	0.01	
						0.08	0.08	0.02	0.23	0.11	0.27	0.27
0.03	0.02											
0.18	0.16	0.07	0.07	0.01	0.01				0.22	0.13		0.01
0.11	0.13		0.36	0.50	0.49					0.07	0.01	0.03
		0.03				0.04		0.06	0.17		0.11	0.12
										0.03		
												0.01
			0.03								0.05	
			0.03								0.05	
											0.04	0.02
0.65	0.65	0.50	0.50	0.50	0.50	0.30	0.30	0.50	0.30	0.30	0.30	0.30
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

22	23	24	25	26	27	28	29	30	31	32	33	34
	0.17			0.11	0.04	0.01		0.03	0.14			
	0.03			0.01	0.01			0.01	0.01			
	0.02			0.02	0.01			0.01	0.03			
								0.01				
				0.01				0.01				
				0.01								
	0.04	0.15	0.13	0.06	0.02		0.05	0.02	0.03			0.02
	0.01											
	0.12			0.07				0.07				
	0.03			0.03				0.04	0.01			
	0.02											
	0.01								0.02			
	0.05	0.05	0.08	0.02			0.11	0.01	0.02			
		0.01	0.01	0.07					0.04			
0.05		0.03	0.03			0.05	0.01	0.01	0.01			
0.01		0.01	0.01			0.03	0.01	0.01	0.02			
0.09		0.16	0.19	0.03	0.11	0.09	0.15	0.10	0.16			0.07

0.02					0.01	0.01						
					0.01							
0.38		0.19	0.15	0.04	0.27	0.29	0.19	0.36	0.33		0.09	0.43
0.01		0.03	0.04		0.02			0.01			0.01	
0.03		0.04	0.02		0.02	0.04		0.01			0.03	0.02
0.10		0.18	0.19	0.01	0.14	0.27	0.21	0.16	0.04	0.04	0.01	0.31
										0.09		
						0.00						
										0.07		
										0.30		
0.03					0.04	0.05	0.11	0.01			0.56	
0.30	0.50	0.15	0.15	0.50	0.30	0.15	0.15	0.15	0.15	0.50	0.30	0.15
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

35	36	37	38	39	40	41	42	43	44	45	46	47
		0.04	0.02	0.03		0.01						
		0.02		0.03		0.01						
		0.04	0.02	0.03		0.02						
			0.01									
			0.05	0.08	0.02	0.03						
			0.02	0.01	0.01							
			0.02	0.02	0.01							
			0.01									
0.03		0.06	0.02	0.06	0.03	0.01				0.02	0.02	
			0.02	0.02								
			0.01									
			0.01	0.05							0.01	
			0.04	0.12								
			0.06	0.05	0.01	0.04	0.08			0.02	0.02	
		0.05				0.01						
						0.01						
		0.06				0.01						
0.02	0.01	0.02			0.02		0.05			0.19	0.09	0.01
	0.01	0.01			0.05	0.00	0.03			0.24	0.03	
0.17	0.07	0.20	0.17	0.08	0.21	0.09	0.11			0.09	0.06	0.00

										0.04	0.04	
										0.03	0.02	
										0.06	0.11	0.00
0.35	0.56	0.18	0.16	0.07	0.47	0.04	0.40			0.12	0.23	0.34
	0.02	0.03			0.01	0.07	0.02	0.02	0.02		0.05	0.01
0.03	0.09					0.03		0.05	0.08		0.04	0.09
0.24	0.13	0.09			0.05	0.07	0.21			0.07	0.10	0.23
										0.02	0.05	
								0.17				
								0.57				
	0.12				0.01	0.04		0.20	0.90		0.03	0.33
0.15		0.20	0.35	0.35	0.10	0.50	0.10			0.10	0.10	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

48	49	50	51	52	53	54	55	56	57	58

			0.01							0.06
				0.01						
				0.10		0.10	0.05	0.01		
			0.01	0.57	0.03	0.30	0.10	0.49	0.01	0.05
			0.00							0.03
0.06										
0.01	0.01									
			0.01	0.01	0.05	0.05	0.08	0.09	0.22	
			0.01	0.02	0.72	0.15	0.05	0.17	0.38	
0.93	0.99	1.00	0.77			0.40	0.73	0.05	0.20	0.66
										0.00
			0.20	0.30	0.20			0.20	0.20	0.20
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2. Diet composition matrix for the Cap de Creus MPA model. Cells in grey are values lower than 0.0

	Prey \ predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	**Bottlenose dolphins**								
2	**Striped dolphins**								
3	**Endangered and pelagic seabirds**								
4	**Gulls and cormorants**								
5	**Terns**								
6	**Loggerhead turtles**								
7	**Non-commercial large pelagic fishes**								
8	**Other large pelagic fishes**								
9	**Mackerels**	▨	▨	▨	0.01	▨			0.01
10	**Horse mackerels**	0.01	0.01	0.01	0.01	0.01			0.02
11	**Other medium pelagic fishes**			▨	▨	▨			▨
12	**European sardine**	0.05	0.04	0.06	0.06	0.09			0.01
13	**European anchovy**	0.03	0.01	0.01	0.01	0.02	▨		0.01
14	**Round sardinella**	▨	▨	▨	▨	▨			▨
15	**Other small pelagic fish**	0.03	0.03	0.03	0.01	0.07			0.01
16	**Anglerfish**	▨							
17	**European conger**	▨							
18	**European hake**	▨	▨						
19	**Poor cod**	0.01	0.01		▨				
20	**Common pandora**	▨	▨		▨				
21	**Sparidae**	0.01	0.02		0.02				0.05
22	**White seabream**				▨				
23	**Common two-banded seabream**				▨				
24	**Common dentex**								▨
25	**Red scorpionfish**								
26	**Scorpaenidae**				▨				
27	**Groupers**								
28	**Brown meagre**								
29	**Labridae and serranidae**				0.01				
30	**Flatfishes**	▨	▨		0.01				
31	**Other commercial medium demersal fish**	0.01	0.02		0.01				
32	**No commercial medium demersal fish**	▨	▨						
33	**Salema**				▨				
34	**Mugilidae**				▨	▨			
35	**Red mullet**				▨				
36	**Surmulet**								
37	**No commercial small demersal fish**	▨	0.01	0.05	0.01				0.01
38	**Small-spotted catshark**								
39	**Rays and skates**								▨
40	**Torpedos**								
41	**Coastal benthic cephalopods**	0.01	0.01						
42	**Benthopelagic cephalopods**	0.02	0.02	0.02			▨		0.01
43	**Other benthic cephalopods**	0.01	0.01						
44	**Bivalves**				▨				

45	**Gastropods**								
46	**European lobster**								
47	**Other commercial decapods**								
48	**Non-commmercial decapods**				0.01		0.01		
49	**Purple sea urchin**								
50	**Other sea urchin**								
51	**Sea cucumbers**								
52	**Other macro-benthos**						0.03		
53	**Jellyfish**						0.04	0.13	0.06
54	**Salps and other gelatinous zooplankton**						0.08	0.05	0.01
55	**Red coral**								
56	**Other corals and gorgonians**								
57	**Macrozooplankton**							0.02	0.01
58	**Meso and microzooplankton**							0.01	
59	**Suprabenthos**						0.04		
60	**Mediterranean seagrass**								
61	**Other seagrasses**								
62	**Erected algae**								
63	**Seaweeds**								
64	**Small phytoplankton**								
65	**Large phytoplankton**								
66	**Detritus**								
67	**Discards and by-catch**			0.01					
	Import	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

1. The numbers identify the functional groups of the model.

9	10	11	12	13	14	15	16	17	18	19	20	21	22
0.00									0.01				
	0.01	0.08					0.01		0.05				
0.01	0.02	0.03					0.01		0.01				
	0.01	0.06							0.05				
							0.02		0.01				
		0.02					0.02		0.02				
		0.01											
		0.09					0.07	0.04	0.09			0.01	
							0.03	0.02	0.04				
							0.04	0.03	0.04				
									0.02				
							0.04	0.01	0.02				
							0.07	0.07	0.05			0.01	0.03
							0.01	0.02	0.01		0.01		
		0.02					0.08	0.21	0.02				
							0.01	0.03					
									0.01				
								0.01					
								0.01	0.01				
		0.08					0.07		0.09	0.05	0.01		0.01
							0.01	0.00					
							0.01		0.01				
0.01	0.01	0.01											
							0.01		0.01				
								0.06			0.05	0.02	0.05

								0.02			0.05	0.01	0.01
							0.08	0.11	0.04	0.04	0.12	0.10	0.15
											0.05	0.03	0.02
											0.03		
											0.04	0.01	
							0.08	0.08	0.03	0.23	0.11	0.27	0.25
0.03	0.02												
0.18	0.16	0.06	0.07	0.01	0.09	0.01				0.22	0.13	0.01	0.01
0.11	0.13		0.36	0.50	0.41	0.49					0.07	0.01	0.06
		0.03					0.04		0.08	0.17		0.11	0.11
											0.03		
													0.01
			0.03									0.03	
			0.03									0.07	
												0.04	
0.65	0.65	0.50	0.50	0.50	0.50	0.50	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

23	24	25	26	27	28	29	30	31	32	33	34	35	36
	▨						▨	▨	▨				
	▨							▨	▨				
	▨							▨	▨				
	▨								▨				
				▨									
				▨									
	▨			▨			▨						
	0.10			0.09	0.04	▨		0.08	0.21				
	0.07			0.06	0.01			0.04	0.04				
	0.08			0.07	0.01			0.03	0.05				
								0.02	0.01				
	▨			0.01				0.02					
	▨			0.01				0.01					
				0.01									
	0.08	0.13	0.13	0.08	0.04	▨	0.05	0.05	0.14			0.02	0.03
					▨		▨	▨					
	0.01			0.01				▨	▨				
				▨									
	0.10			0.05				0.05					
	0.01			0.01				0.03	0.01				
	▨								▨				
	0.01								0.01				
	0.05	0.06	0.08	0.01			0.11	0.02	0.05				
		0.02	0.01	0.04					0.03				
	▨			▨									
		▨	▨	▨					0.01				
0.05		0.05	0.03			0.05	0.01	0.01	0.01		▨		0.02

0.01		0.03	0.01			0.03	0.01	0.01	0.02				
							0.01						
0.09		0.19	0.19	0.04	0.11	0.09	0.15	0.09	0.12			0.06	0.17
0.02					0.01	0.01							
					0.01								
0.38		0.12	0.15	0.01	0.25	0.30	0.19	0.23	0.12		0.09	0.43	0.35
0.01		0.03	0.03		0.02	0.01		0.01			0.03		
0.05		0.04	0.03		0.04	0.05		0.02			0.06	0.02	0.03
0.09		0.18	0.19	0.01	0.14	0.27	0.21	0.16	0.04	0.04	0.01	0.31	0.24
										0.09			
							0.00						
							0.00						
						0.00				0.00			
										0.14			
										0.23			
						0.04	0.11				0.51		
0.30	0.50	0.15	0.15	0.50	0.30	0.15	0.15	0.15	0.15	0.50	0.30	0.15	0.15
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

37	38	39	40	41	42	43	44	45	46	47	48	49	50
	0.01		0.01										
	0.05	0.03	0.07		0.01								
	0.03		0.04										
	0.05	0.03	0.05		0.04								
			0.01										
		0.01											
					0.01								
		0.01											
		0.07	0.13	0.02	0.04								
		0.04	0.05	0.01	0.01								
		0.02	0.04	0.01	0.01								
		0.01											
	0.03	0.03	0.07	0.06	0.01				0.02	0.02			
		0.02	0.02										
		0.01											
		0.01	0.04							0.01			
		0.04	0.10										
		0.08	0.06	0.02	0.05	0.08			0.02	0.02			
	0.04	0.01			0.02								
					0.01								
	0.07				0.01								
0.01	0.01	0.01		0.01		0.05			0.19	0.09	0.01		

0.01	0.01			0.05		0.03			0.24	0.03			
0.07	0.23	0.24	0.11	0.21	0.11	0.11			0.09	0.06			
									0.04	0.04			
									0.03	0.02			
									0.06	0.11			
0.56	0.15	0.21	0.06	0.43	0.04	0.40			0.12	0.23	0.34		
0.02	0.03			0.02	0.10	0.02	0.02	0.03		0.03	0.02		
0.09				0.01	0.09		0.04	0.07		0.06	0.10		
0.14	0.10			0.05	0.06	0.21			0.07	0.10	0.22		
												0.06	
													0.01
									0.02	0.05		0.01	
							0.17						
							0.57						
0.11							0.20	0.90		0.02	0.30	0.93	0.99
										0.01			
	0.20	0.15	0.15	0.10	0.40	0.10			0.10	0.10			
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

51	52	53	54	55	56	57	58	59

	0.01							0.05
		0.01						
		0.10		0.10	0.05	0.01		
	0.01	0.57	0.03	0.30	0.10	0.49	0.01	0.07
	0.00							0.03
		0.01	0.05	0.05	0.08	0.09	0.22	
	0.01	0.02	0.72	0.15	0.05	0.17	0.38	
0.99	0.96			0.40	0.73	0.05	0.20	0.85
								0.00
		0.30	0.20			0.20	0.20	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3. Diet composition matrix for theMedes Islands MPA model. Cells in grey are values lower than 0.0

	Prey \ predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	**Bottlenose dolphins**								
2	**Striped dolphins**								
3	**Endangered and pelagic seabirds**								
4	**Gulls and cormorants**								
5	**Terns**								
6	**Loggerhead turtles**								
7	**Non-commercial large pelagic fishes**								
8	**Other large pelagic fishes**								
9	**Mackerels**	0.01	0.01	▨	0.02	0.01			0.01
10	**Horse mackerels**	▨	▨	0.01	0.01	▨	▨		0.01
11	**Other medium pelagic fishes**			▨	▨	▨			▨
12	**European sardine**	0.06	0.05	0.07	0.05	0.08			0.02
13	**European anchovy**	0.01	0.01	0.02	0.02	0.02	▨		0.01
14	**Round sardinella**	▨	▨	▨	▨	▨			▨
15	**Other small pelagic fish**	0.03	0.03	0.03	0.01	0.08			0.01
16	**Anglerfish**	▨							
17	**European conger**	▨							
18	**European hake**	0.01	▨						
19	**Poor cod**	▨	0.01		▨				
20	**Common pandora**	▨	0.01		▨				
21	**Sparidae**	0.01	0.02		0.02				0.08
22	**White seabream**				▨				
23	**Common two-banded seabream**				▨				
24	**Common dentex**								▨
25	**Red scorpionfish**								
26	**Scorpaenidae**				▨				
27	**Groupers**								
28	**Brown meagre**								
29	**Labridae and serranidae**				0.01				
30	**Flatfishes**	▨	▨		0.01				
31	**Other commercial medium demersal fish**	0.01	0.02		0.01				
32	**No commercial medium demersal fish**	▨	▨						
33	**Salema**				▨				
34	**Mugilidae**				▨	▨			
35	**Red mullet**				▨				
36	**Surmulet**								
37	**No commercial small demersal fish**	▨	0.01	0.05	0.01				0.01
38	**Small-spotted catshark**								
39	**Rays and skates**								▨
40	**Torpedos**								
41	**Coastal benthic cephalopods**	0.01							
42	**Benthopelagic cephalopods**	0.03	0.03	0.02			▨		0.01
43	**Other benthic cephalopods**	0.01	0.01						
44	**Bivalves**				▨				
45	**Gastropods**				▨				
46	**European lobster**								
47	**Other commercial decapods**								

48	**Non-commmercial decapods**				0.01		0.01		
49	**Purple sea urchin**								
50	**Other sea urchin**								
51	**Sea cucumbers**								
52	**Other macro-benthos**						0.03		
53	**Jellyfish**						0.04	0.13	0.01
54	**Salps and other gelatinous zooplankton**						0.08	0.05	0.01
55	**Red coral**								
56	**Other corals and gorgonians**								
57	**Macrozooplankton**							0.02	0.03
58	**Meso and microzooplankton**							0.01	
59	**Suprabenthos**						0.04		
60	**Mediterranean seagrass**								
61	**Other seagrasses**								
62	**Erected algae**								
63	**Seaweeds**								
64	**Small phytoplankton**								
65	**Large phytoplankton**								
66	**Detritus**								
67	**Discards and bycatch**	▨	▨	0.01	▨	▨			
	Import	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

1. The numbers identify the functional groups of the model.

9	10	11	12	13	14	15	16	17	18	19	20	21
									0.01			
0.00												
	0.01	0.07					0.01		0.04			
0.01	0.02	0.06					0.01		0.01			
	0.01	0.03							0.03			
							0.02					
		0.02					0.02		0.01			
		0.01										
		0.09					0.07	0.04	0.07			0.01
							0.03	0.02	0.03			
							0.04	0.03	0.03			
									0.01			
							0.04	0.01	0.01			
							0.07	0.07	0.04			0.02
							0.01	0.04			0.03	
		0.02					0.08	0.20	0.01			
							0.01	0.02				
								0.01				
									0.01			
		0.08					0.07		0.06	0.05	0.01	0.01
							0.01					
							0.01		0.01			
0.01	0.01	0.01										
							0.01		0.01			
								0.06			0.03	0.01
								0.02			0.05	0.01

							0.08	0.11	0.03	0.04	0.12	0.10
											0.05	0.03
											0.03	
											0.04	0.01
							0.08	0.08	0.02	0.23	0.11	0.26
0.03	0.02											
0.18	0.16	0.06	0.07	0.01	0.09	0.01				0.22	0.13	0.01
0.11	0.13		0.36	0.50	0.41	0.49					0.07	0.01
		0.03					0.04		0.06	0.17		0.11
											0.03	
			0.03									0.05
			0.03									0.05
												0.04
0.65	0.65	0.50	0.50	0.50	0.50	0.50	0.30	0.30	0.50	0.30	0.30	0.30
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

22	23	24	25	26	27	28	29	30	31	32	33	34
		0.12			0.12	0.04	0.01		0.08	0.21		
		0.06			0.05	0.01			0.04	0.04		
		0.06			0.05	0.01			0.03	0.05		
									0.02	0.01		
					0.01				0.02			
					0.01				0.01			
					0.01							
0.04		0.08	0.21	0.13	0.08	0.04		0.05	0.05	0.14		
		0.01			0.01							
		0.10			0.05				0.05			
		0.01			0.01				0.03	0.01		
		0.01								0.01		
0.02		0.05	0.08	0.08	0.01			0.11	0.02	0.05		
			0.01	0.01	0.03					0.03		
										0.01		
0.04	0.05		0.03	0.03			0.05	0.01	0.01	0.01		
0.01	0.01		0.01	0.01			0.03	0.01	0.01	0.02		
								0.01	0.00	0.00		

0.13	0.09		0.16	0.19	0.04	0.11	0.09	0.15	0.09	0.12		
0.02	0.02					0.01	0.01					
						0.01						
0.24	0.38		0.10	0.15	0.01	0.25	0.29	0.19	0.23	0.12		0.09
0.01	0.02		0.03	0.04		0.04			0.02			0.03
0.05	0.04		0.04	0.02		0.02	0.05		0.01			0.06
0.12	0.10		0.18	0.19	0.01	0.14	0.27	0.21	0.16	0.04	0.04	0.01
											0.09	
0.01												
											0.07	
											0.30	
						0.02	0.04	0.11				0.51
0.30	0.30	0.50	0.15	0.15	0.50	0.30	0.15	0.15	0.15	0.15	0.50	0.30
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

35	36	37	38	39	40	41	42	43	44	45	46	47
			▨									
			▨		▨		▨					
			▨	▨			▨					
			0.04	0.02	0.06		0.02					
			0.02	▨	0.02		0.01					
			▨	▨	▨		▨					
			0.04	0.02	0.03		0.02					
					▨							
				▨								
							▨	▨				
				0.01								
				0.05	0.08	0.02	0.03					
				0.02	0.01	0.01	▨					
				0.02	0.02	0.01	▨					
				0.01								
0.02	0.03		0.06	0.02	0.06	0.06	0.01				0.02	0.02
				0.02	0.02							
				0.01								
				0.01	0.05							0.01
				0.04	0.12							
				0.06	0.05	0.02	0.04	0.08			0.02	0.02
					▨							
			0.05	▨	▨	▨	0.01	▨				
							0.01					
			0.06	▨	▨	▨	0.01	▨				
	0.02	0.01	0.02	▨		0.01		0.05			0.19	0.09
	▨	0.01	0.01	▨		0.05	▨	0.03			0.24	0.03
▨	▨	▨	▨	▨								

0.06	0.17	0.07	0.19	0.17	0.08	0.21	0.09	0.11			0.09	0.06
											0.04	0.04
											0.03	0.02
											0.06	0.11
0.43	0.35	0.56	0.18	0.16	0.04	0.43	0.03	0.40			0.12	0.23
		0.02	0.03			0.03	0.12	0.02	0.02	0.02		0.05
0.02	0.03	0.09					0.04		0.05	0.08		0.04
0.31	0.24	0.13	0.09			0.05	0.05	0.21			0.07	0.10
											0.02	0.05
									0.17			
									0.57			
									0.20	0.90		0.02
												0.01
0.15	0.15		0.20	0.35	0.35	0.10	0.50	0.10			0.10	0.10
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

48	49	50	51	52	53	54	55	56	57	58	59

0.01

▨

0.00											
0.34				0.01							0.05
					0.01						
					0.00						
0.01					0.10		0.10	0.05	0.01		
0.11				0.01	0.57	0.03	0.30	0.10	0.49	0.01	0.06
0.22											0.03
	0.06										
		0.01									
	0.01										
					0.01	0.05	0.05	0.08	0.09	0.22	
				0.01	0.02	0.72	0.15	0.05	0.17	0.38	
0.30	0.93	0.99	0.99	0.93			0.40	0.73	0.05	0.20	0.83
0.00											
				0.03	0.30	0.20			0.20	0.20	0.03
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 1. Time series used to fit the three MPA models to data (2013-2017, 2008-2017 and 2004-2017 for Cerbère-Banyuls, Cap de Creus and Medes Islands MPAs respectively). Data are organized by drivers and reference data for evaluating model fit (see 3 rightmost columns).

Functional group	**Time series of data**	**Cerbère-Banyuls**		**Cap de Creus**		**Medes Islands**		**To drive the model**	**To fit the model**	**To compare predicted results**
		Coverage	ref	Coverage	ref	Coverage	ref			
16. Anglerfish										
	Absolut biomass	2013-2016	MEDITS (Bertrand et al., 2002)	2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004, 2006, 2009,2012 and 2013	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
17. European conger										
	Absolut biomass	2013-2016	MEDITS (Bertrand et al., 2002)	2008, 2009, 2011 and 2013	MEDITS (Bertrand et al., 2002)	2004, 2005, 2009, 2012 and 2013	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
18. European hake										
	Absolut biomass	2013-2016	MEDITS (Bertrand et al., 2002)	2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004, 2006, 2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2007, 2012-2014 and 2017	ICM database and Sacanell (2012)			X
19. Poor cod										
	Absolut biomass	-		2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	-	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004, 2006-2008 and 2012	ICM database and Sacanell (2012)			X
20. Common pandora										
	Absolut biomass	-		2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004-2006, 2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
21. Sparidae										
	Relative biomass	2013,2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004-2009, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
22. White seabream										

	Relative biomass	2013-2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004, 2006-2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
23. Common two-banded seabream	Relative biomass	2013-2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004-2009, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
24. Common dentex	Relative biomass	2013, 2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004, 2006-2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
25. Red scorpionfish	Relative biomass	2013, 2015 and 2017	UVC (Claudet, 2013)						X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
26. Scorpaenidae	Relative biomass			2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	-			X	X
	Absolut catch			2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2016	ICM database and Sacanell (2012)			X
27. Groupers	Relative biomass	2013, 2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004, 2006-2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
28. Brown meagre	Relative biomass	2013-2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004, 2006-2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
29. Labridae and serranidae+	Relative biomass	2013-2015 and 2017	UVC (Claudet, 2013)	-		-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
30. Flatfishes	Absolut biomass	-		2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004-2006, 2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X

31. Other commercial medium demersal fish	Relative biomass	2013,2014 and 2015	UVC (Claudet, 2013)	2008, 2009, 2011, 2014 and 2016	UVC (Hereu et al., 2017)	2004-2009, 2011, 2014 and 2016	MEDITS (Bertrand et al., 2002) and UVC (Hereu, 2017)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
32. No commercial medium demersal fish	Relative biomass	2013, 2014 and 2017	UVC (Claudet, 2013)	2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
33. Salema	Absolut biomass	2013, 2014 and 2017	UVC (Claudet, 2013)	-		-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004, 2005, 2009-2014, 2016 and 2017	ICM database and Sacanell (2012)			X
34. Mugilidae	Absolut biomass	2013 and 2017	UVC (Claudet, 2013)	-		-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2006, 2008-2015, 2016 and 2017	ICM database and Sacanell (2012)			X
35. Red mullet	Absolut biomass	2013-2016	UVC (Claudet, 2013)	2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004-2006, 2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2008 and 2012-2014	ICM database and Sacanell (2012)			X
36. Surmullet	Absolut biomass	2013-2015 and 2017	UVC (Claudet, 2013)	2008, 2009, 2011 and 2014	MEDITS (Bertrand et al., 2002)	-	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2011 and 2014	ICM database and Sacanell (2012)			X
37. No commercial small demersal fish	Absolut biomass	2013-2015 and 2017	UVC (Claudet, 2013)	2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	-	ICM database and Sacanell (2012)			X
38. Small-spotted catshark	Absolut biomass	-		2008, 2011, 2012 and 2014	MEDITS (Bertrand et al., 2002)	2004 and 2012	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008, 2009, 2011, 2012, 2014 and 2016	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004, 2005, 2009-2013 and 2017	ICM database and Sacanell (2012)			X
39. Rays and skates	Absolut biomass	-		2008, 2011 and 2014	MEDITS (Bertrand et al., 2002)	2004-2006, 2012 and 2014	MEDITS (Bertrand et al., 2002)		X	X

	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
40. Torpedos										
	Absolut biomass	-		2008, 2009 and 2014	MEDITS (Bertrand et al., 2002)	-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	-	ICM database and Sacanell (2012)			X
41. Coastal benthic cephalopods										
	Absolut biomass	-		-		-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
42. Benthopelagic cephalopods										
	Absolut biomass	-		2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)	2004-2006, 2008, 2009 and 2011-2014	MEDITS (Bertrand et al., 2002)		X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2017	ICM database and Sacanell (2012)			X
43. Other benthic cephalopods										
	Absolut biomass	-		2008 and 2012-2014	MEDITS (Bertrand et al., 2002)	-			X	X
	Absolut catch	-		2008-2013 and 2015	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004-2008 and 2011	ICM database and Sacanell (2012)			X
46. European lobster	Absolut catch			-		2004-2017	ICM database and Sacanell (2012)			X
47. Other commercial decapods										
	Absolut biomass	-		-		-			X	X
	Absolut catch	-		2008-2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004, 2006, 2008-2011, 2013, 2014 and 2017	ICM database and Sacanell (2012)			X
49. Purple sea urchin										
	Relative biomass	-		-		2004, 2005, 2009-2012	UVC (Hereu et al., 2017)		X	X
	Absolut catch	-		2008, 2009, 2011, 2014 and 2017	ICM database; Lloret et al., 2008a and Lloret et al., 2008b;	2004 and 2016	ICM database and Sacanell (2012)			X
50. Other sea urchins	Relative biomass	-		-		2004, 2005, 2008-2011	UVC (Hereu et al., 2017)		X	X
64. Small phytoplankton	Relative biomass	2013-2017	Joint Research Center 2017a	2008-2017	Joint Research Center 2017a	2004-2017	Joint Research Center 2017a		X	X
65. Large phytoplankton	Relative biomass	2013-2017	Joint Research Center 2017a	2008-2017	Joint Research Center 2017a	2004-2017	Joint Research Center 2017a		X	X
All fleets	Relative effort	2013-2017	IFREMER (2015) data from WP2	2008-2017	Ministry of Agriculture, Livestock, Fisheries and Food of the Catalan Government and data from WP2	2004-2017	Ministry of Agriculture, Livestock, Fisheries and Food of the Catalan Government and data from 2	X		

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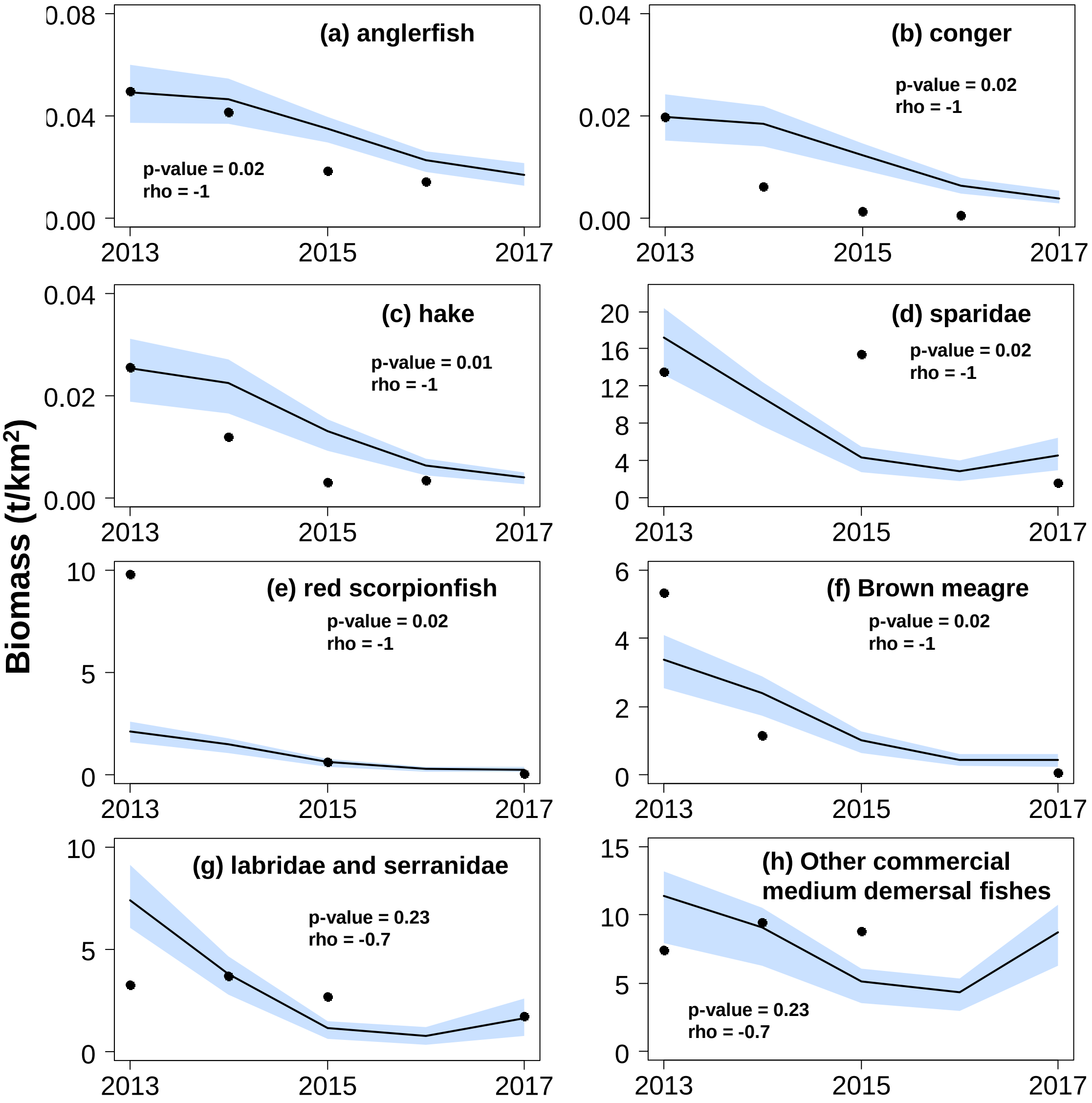
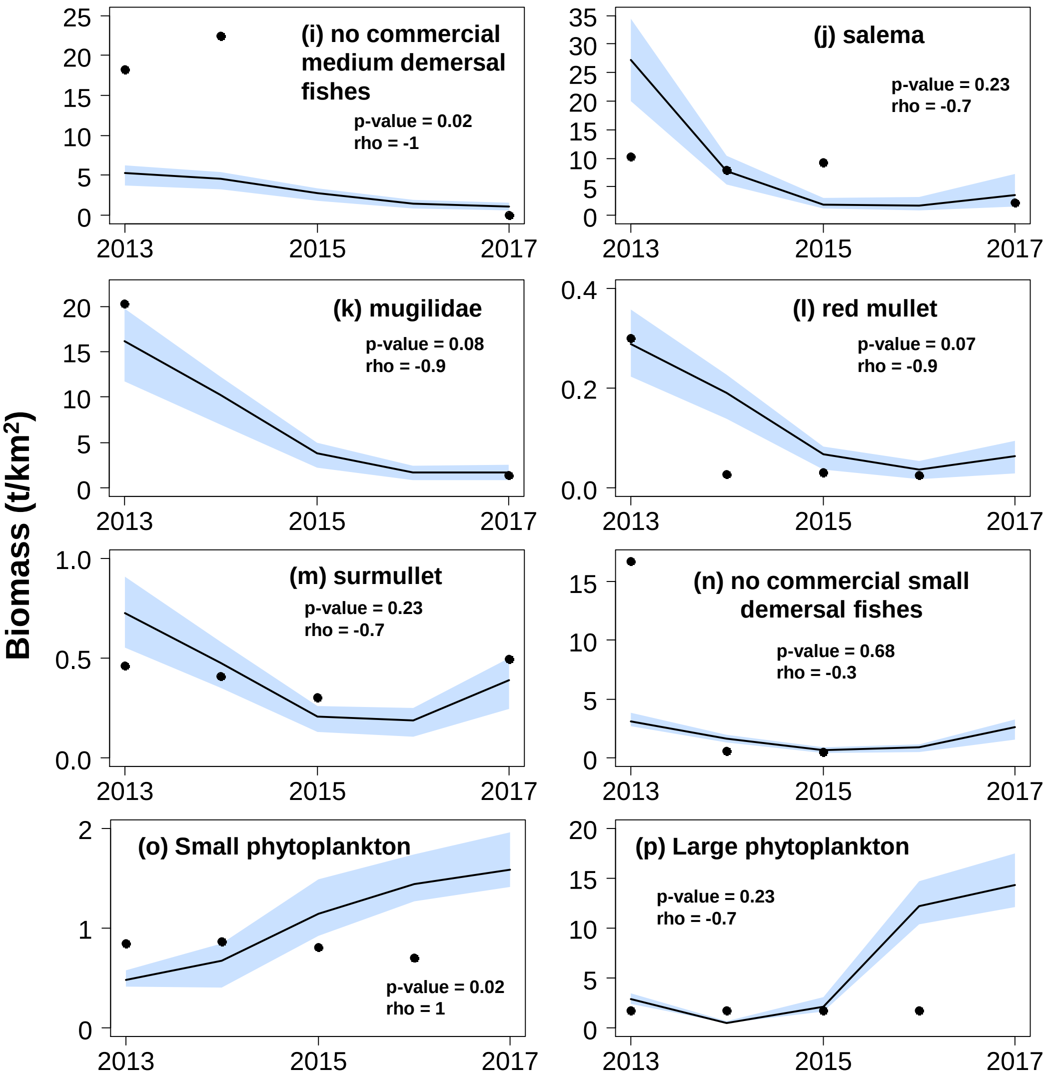
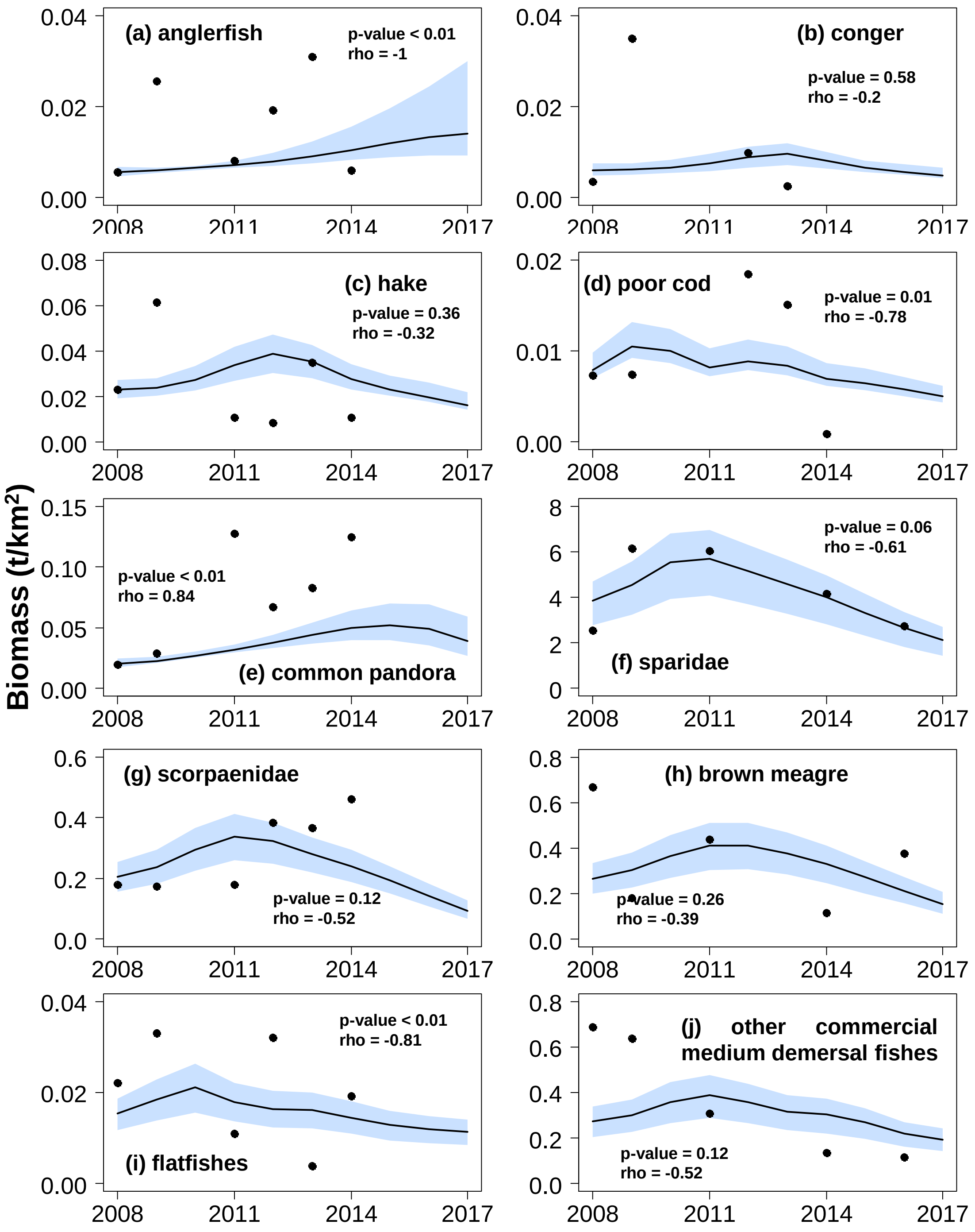
Figure. 1. Predicted (solid lines) versus observed (dots) biomass (t·km^{-2}) values for the groups with available data for the Cerbère-Banyuls MPA model for the period 2013-2017. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman's rank correlation test.




Biomass (t/km²)
(i) no commercial medium demersal fishes
p-value = 0.02
rho = -1
(j) salema
p-value = 0.23
rho = -0.7
(k) mugilidae
p-value = 0.08
rho = -0.9
(l) red mullet
p-value = 0.07
rho = -0.9
(m) surmullet
p-value = 0.23
rho = -0.7
(n) no commercial small demersal fishes
p-value = 0.68
rho = -0.3
(o) Small phytoplankton
p-value = 0.02
rho = 1
(p) Large phytoplankton
p-value = 0.23
rho = -0.7
2013
2015
2017
0
5
10
15
20
25
30
35
0.0
0.2
0.4
0.5
1.0
1
2

Click here to view linked References

Figure. 1. Predicted (solid lines) versus observed (dots) biomass (t·km^{-2}) values for the groups with available data for the Cap de Creus MPA model for the period 2008-2017. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman's rank correlation test.



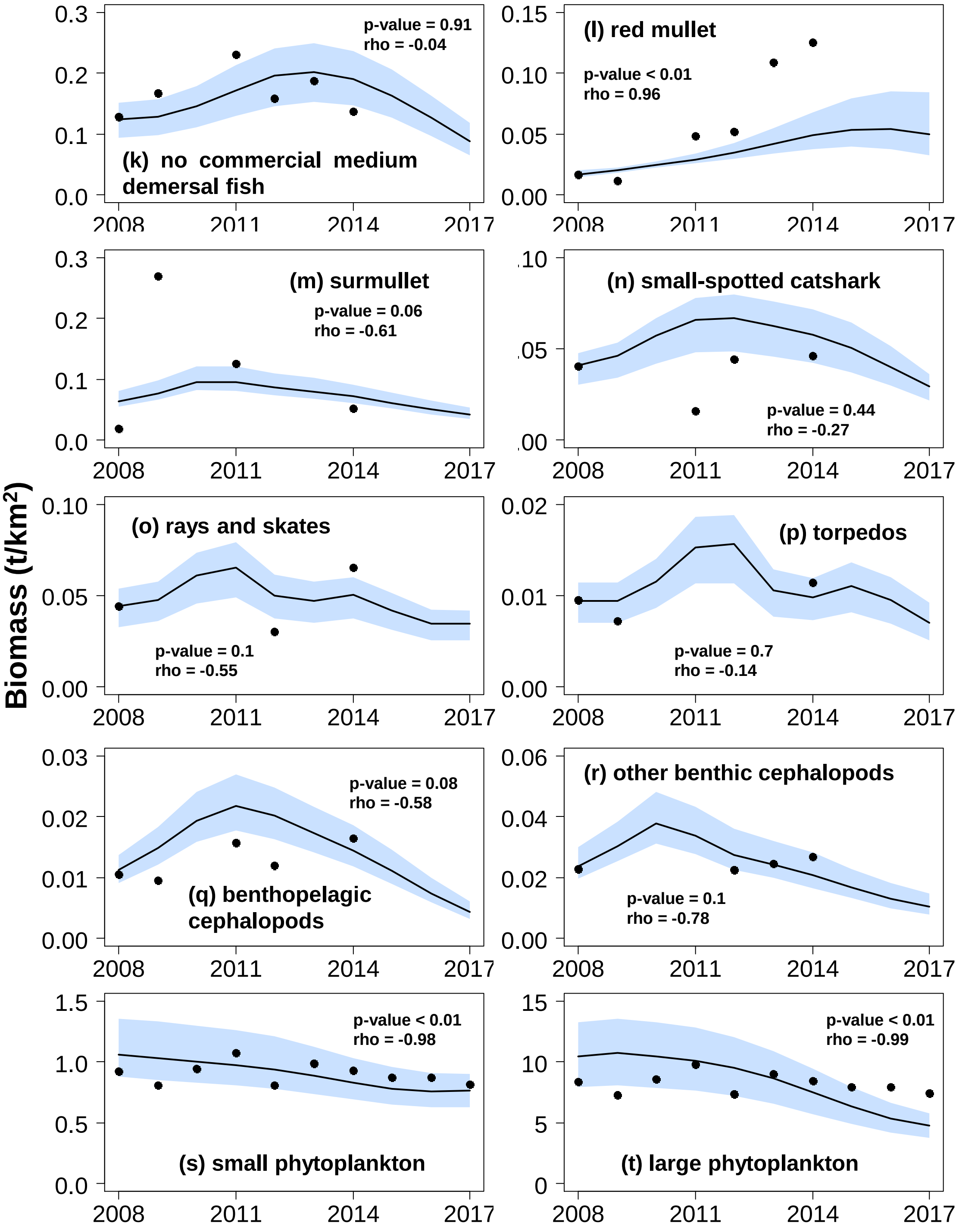
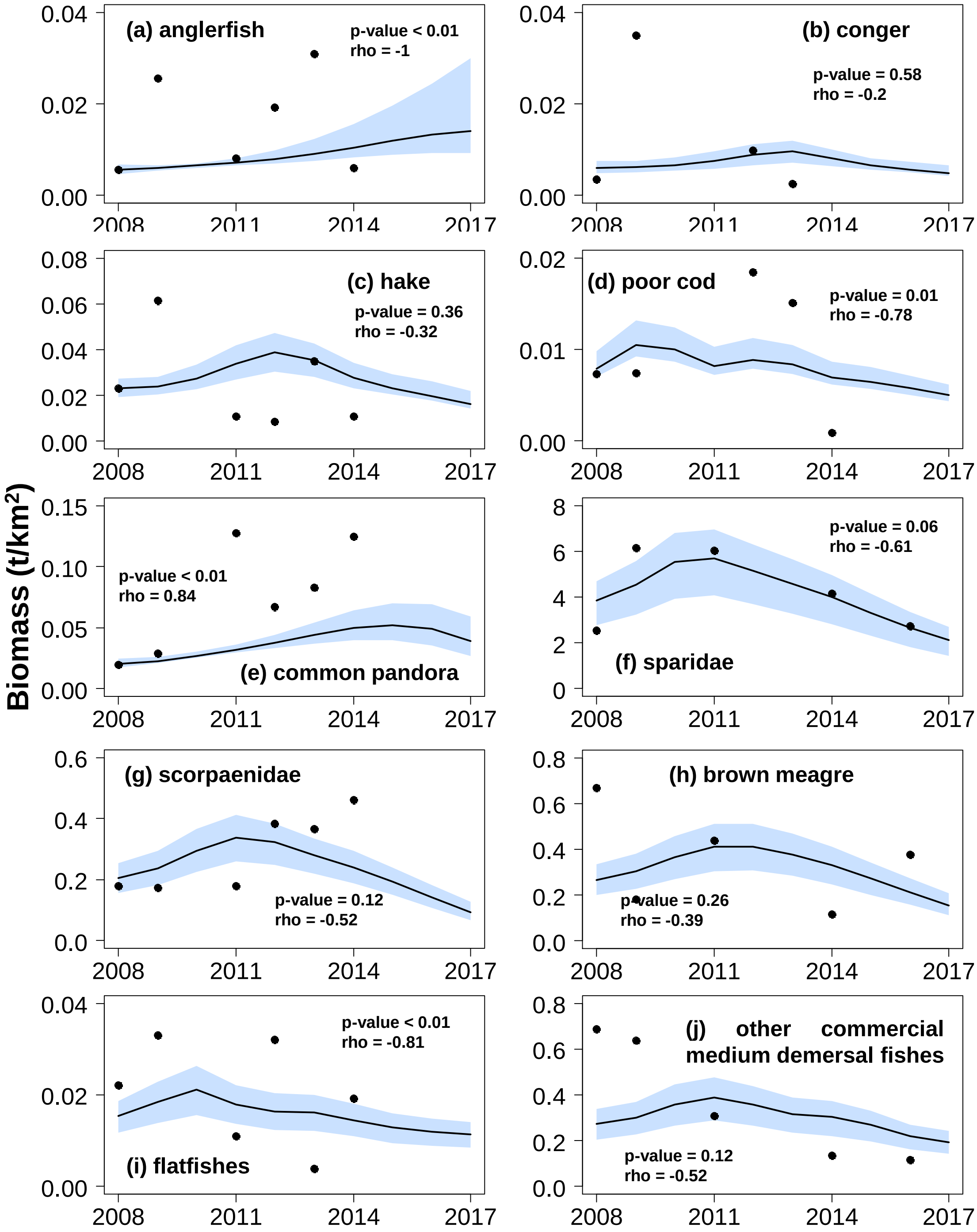
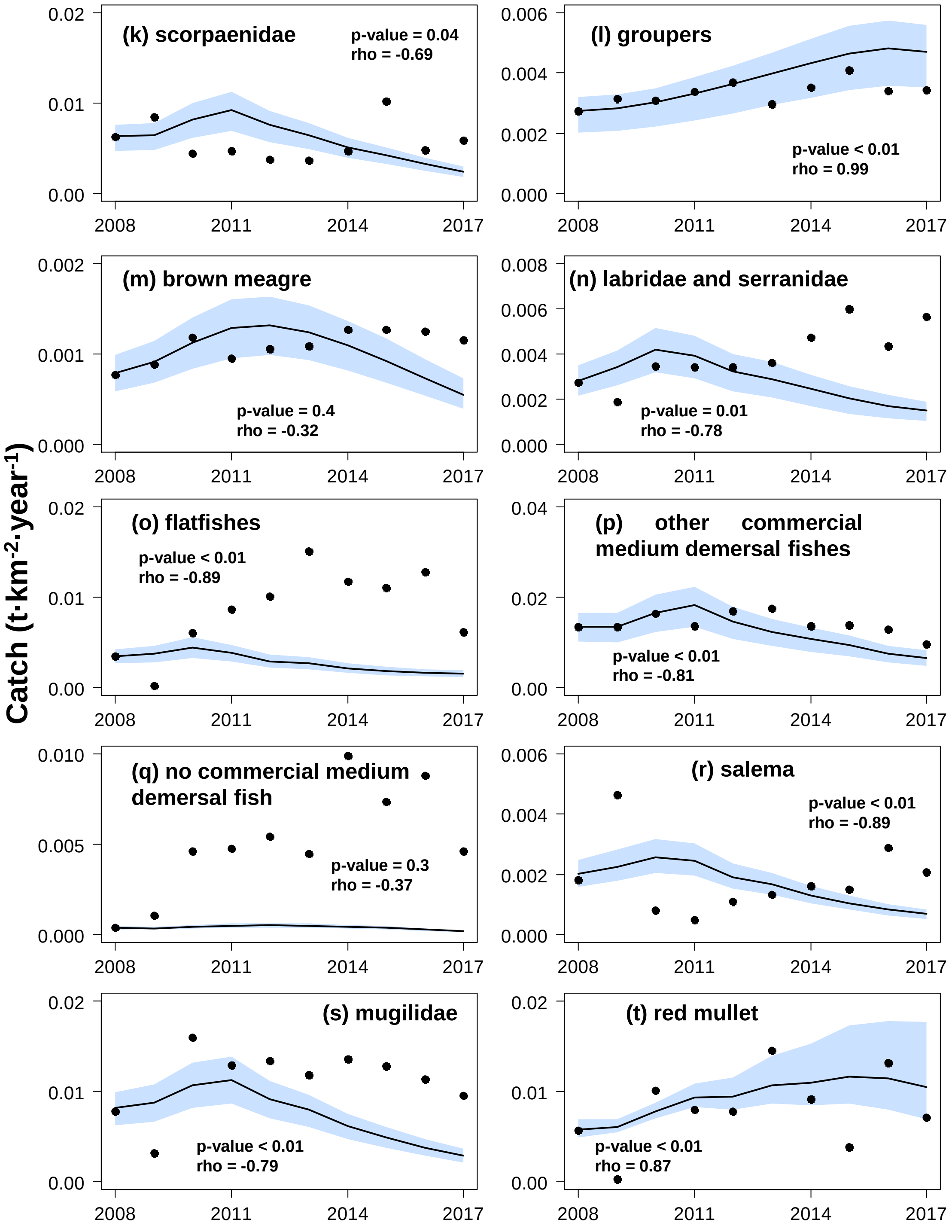

Biomass (t/km²)
(k) no commercial medium demersal fish
p-value = 0.91
rho = -0.04
0.3
0.2
0.1
0.0
(l) red mullet
p-value < 0.01
rho = 0.96
0.15
0.10
0.05
0.00
(m) surmullet
p-value = 0.06
rho = -0.61
0.3
0.2
0.1
0.0
(n) small-spotted catshark
p-value = 0.44
rho = -0.27
.10
.05
.00
(o) rays and skates
p-value = 0.1
rho = -0.55
0.10
0.05
0.00
(p) torpedos
p-value = 0.7
rho = -0.14
0.02
0.01
0.00
(q) benthopelagic cephalopods
p-value = 0.08
rho = -0.58
0.03
0.02
0.01
0.00
(r) other benthic cephalopods
p-value = 0.1
rho = -0.78
0.06
0.04
0.02
0.00
(s) small phytoplankton
p-value < 0.01
rho = -0.98
1.5
1.0
0.5
0.0
(t) large phytoplankton
p-value < 0.01
rho = -0.99
15
10
5
0
2008
2011
2014
2017

Figure. 2. Predicted (solid lines) versus observed (dots) catch (t·km^{-2}·year^{-1}) values for the groups with available data for the Cap de Creus MPA model for the period 2008-2017. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman's rank correlation test.




Catch (t·km-2·year-1)
(k) scorpaenidae
p-value = 0.04
rho = -0.69
0.02
0.01
0.00
(l) groupers
p-value < 0.01
rho = 0.99
0.006
0.004
0.002
0.000
(m) brown meagre
p-value = 0.4
rho = -0.32
0.002
0.001
0.000
(n) labridae and serranidae
p-value = 0.01
rho = -0.78
0.008
0.006
0.004
0.002
0.000
(o) flatfishes
p-value < 0.01
rho = -0.89
0.02
0.01
0.00
(p) other commercial medium demersal fishes
p-value < 0.01
rho = -0.81
0.04
0.02
0.00
(q) no commercial medium demersal fish
p-value = 0.3
rho = -0.37
0.010
0.005
0.000
(r) salema
p-value < 0.01
rho = -0.89
0.006
0.004
0.002
0.000
(s) mugilidae
p-value < 0.01
rho = -0.79
0.02
0.01
0.00
(t) red mullet
p-value < 0.01
rho = 0.87
0.02
0.01
0.00
2008
2011
2014
2017

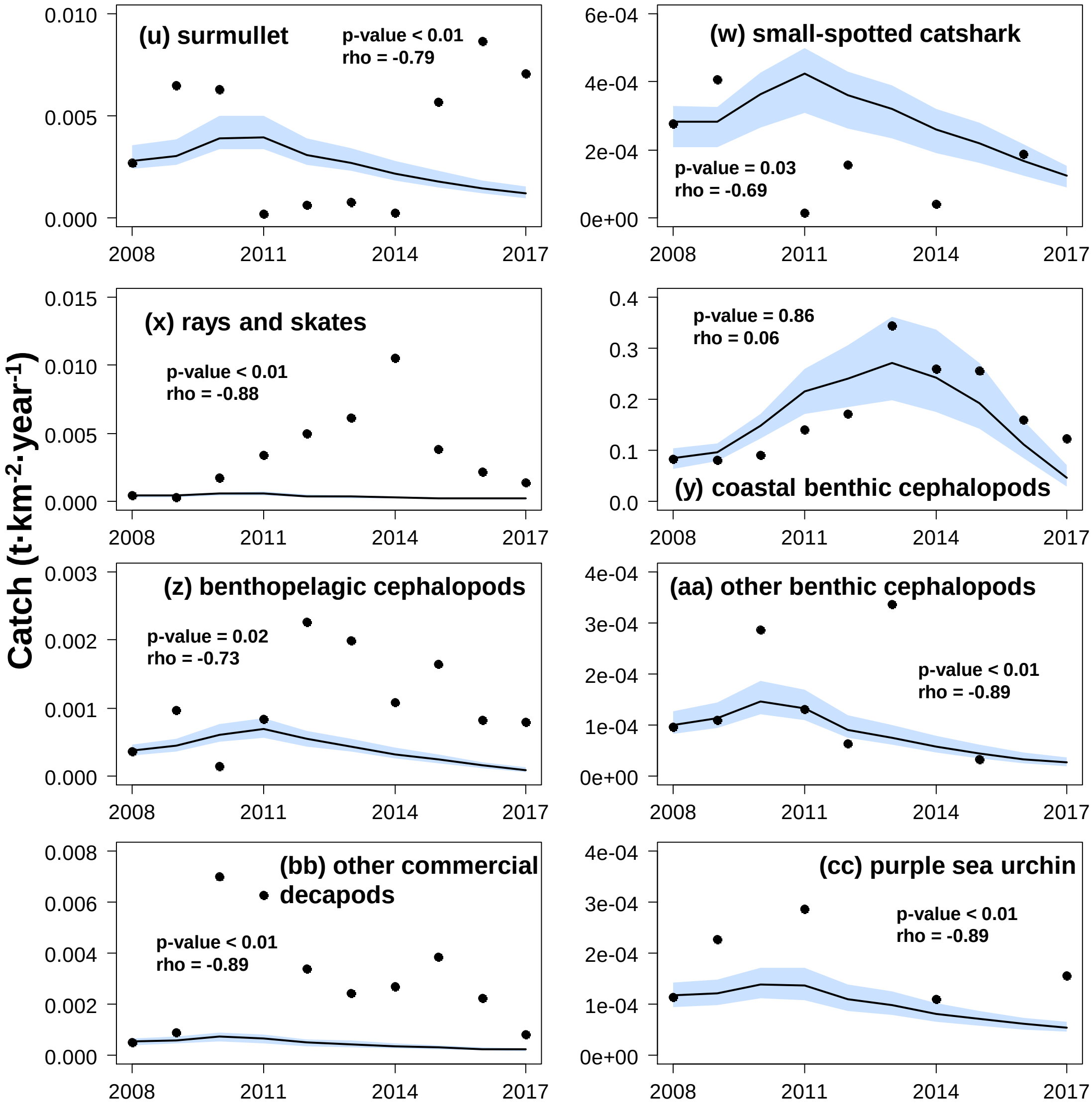
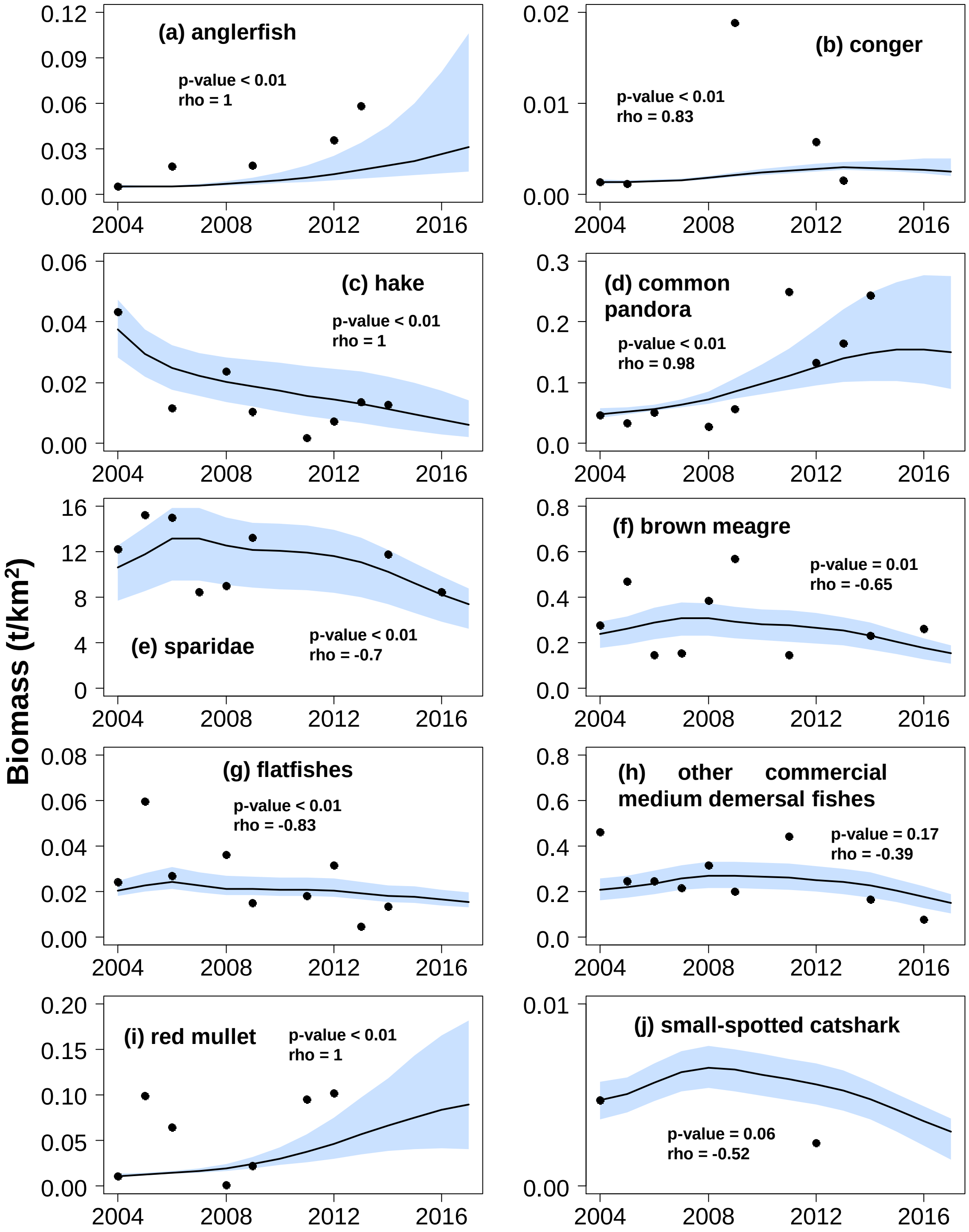

Catch (t·km-2·year-1)
(u) surmullet
p-value < 0.01
rho = -0.79
0.010
0.005
0.000
(w) small-spotted catshark
p-value = 0.03
rho = -0.69
6e-04
4e-04
2e-04
0e+00
(x) rays and skates
p-value < 0.01
rho = -0.88
0.015
0.010
0.005
0.000
(y) coastal benthic cephalopods
p-value = 0.86
rho = 0.06
0.4
0.3
0.2
0.1
0.0
(z) benthopelagic cephalopods
p-value = 0.02
rho = -0.73
0.003
0.002
0.001
0.000
(aa) other benthic cephalopods
p-value < 0.01
rho = -0.89
4e-04
3e-04
2e-04
1e-04
0e+00
(bb) other commercial decapods
p-value < 0.01
rho = -0.89
0.008
0.006
0.004
0.002
0.000
(cc) purple sea urchin
p-value < 0.01
rho = -0.89
4e-04
3e-04
2e-04
1e-04
0e+00
2008
2011
2014
2017

Figure. 1. Predicted (solid lines) versus observed (dots) biomass (t·km^{-2}) values for the groups with available data for the Medes MPA model for the period 2004-2017. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman’s rank correlation test.



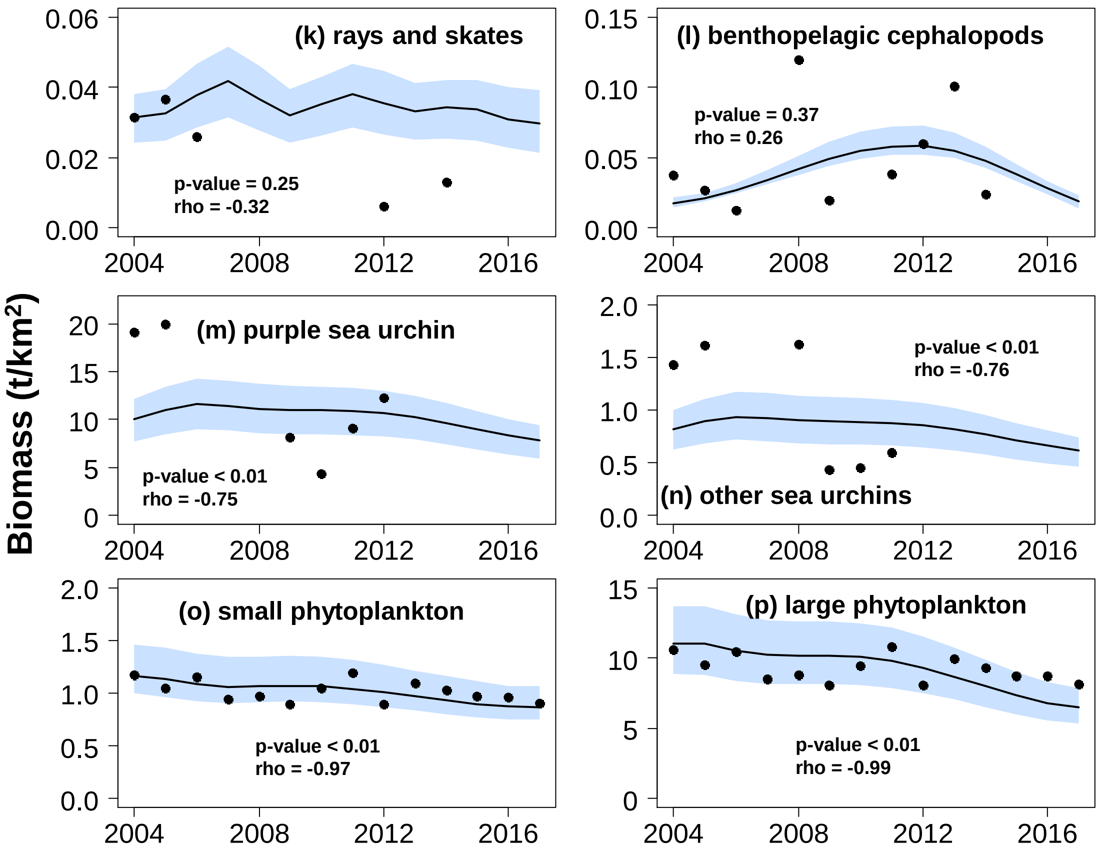
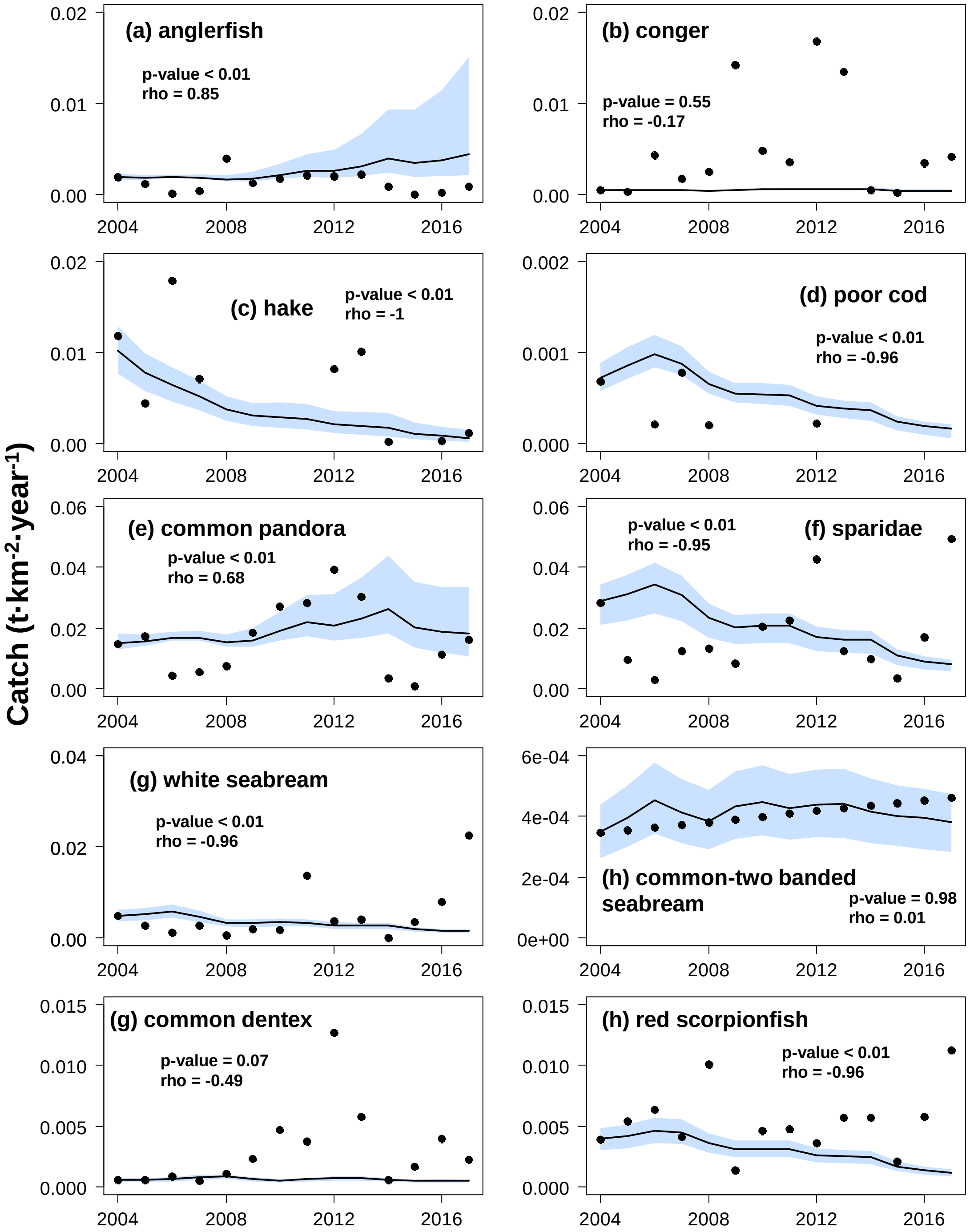
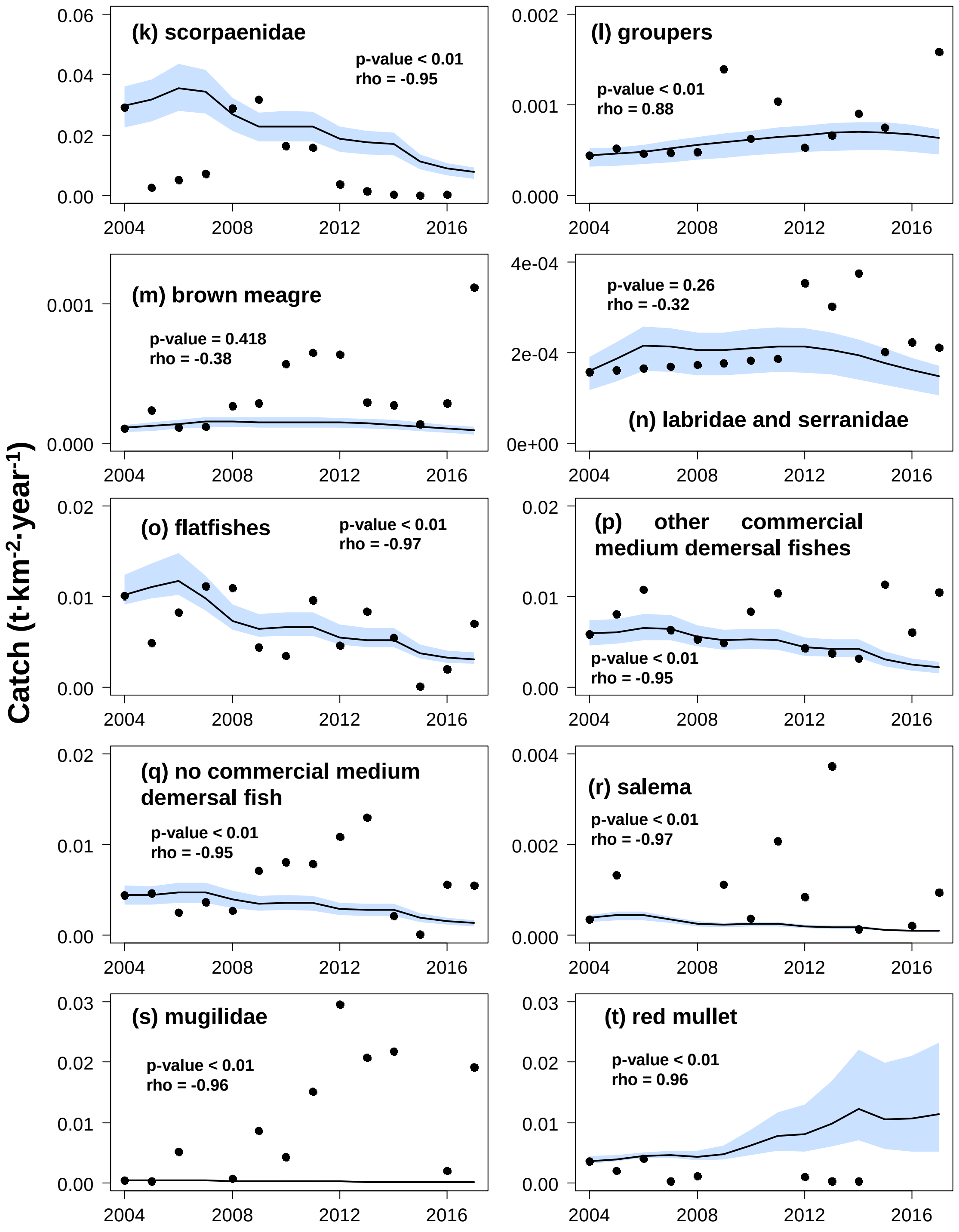

Biomass (t/km²)
(k) rays and skates
p-value = 0.25
rho = -0.32
0.00
0.02
0.04
0.06
(l) benthopelagic cephalopods
p-value = 0.37
rho = 0.26
0.00
0.05
0.10
0.15
(m) purple sea urchin
p-value < 0.01
rho = -0.75
0
5
10
15
20
(n) other sea urchins
p-value < 0.01
rho = -0.76
0.0
0.5
1.0
1.5
2.0
(o) small phytoplankton
p-value < 0.01
rho = -0.97
0.0
0.5
1.0
1.5
2.0
(p) large phytoplankton
p-value < 0.01
rho = -0.99
0
5
10
15
2004
2008
2012
2016

Figure. 2. Predicted (solid lines) versus observed (dots) catch (t·km^{-2}) values for the groups with available data for the Medes MPA model for the period 2004-2017. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman's rank correlation test.




Catch (t·km-2·year-1)
(k) scorpaenidae
p-value < 0.01
rho = -0.95
0.06
0.04
0.02
0.00
(l) groupers
p-value < 0.01
rho = 0.88
0.002
0.001
0.000
(m) brown meagre
p-value = 0.418
rho = -0.38
0.001
0.000
(n) labridae and serranidae
p-value = 0.26
rho = -0.32
4e-04
2e-04
0e+00
(o) flatfishes
p-value < 0.01
rho = -0.97
0.02
0.01
0.00
(p) other commercial medium demersal fishes
p-value < 0.01
rho = -0.95
0.02
0.01
0.00
(q) no commercial medium demersal fish
p-value < 0.01
rho = -0.95
0.02
0.01
0.00
(r) salema
p-value < 0.01
rho = -0.97
0.004
0.002
0.000
(s) mugilidae
p-value < 0.01
rho = -0.96
0.03
0.02
0.01
0.00
(t) red mullet
p-value < 0.01
rho = 0.96
0.03
0.02
0.01
0.00
2004
2008
2012
2016

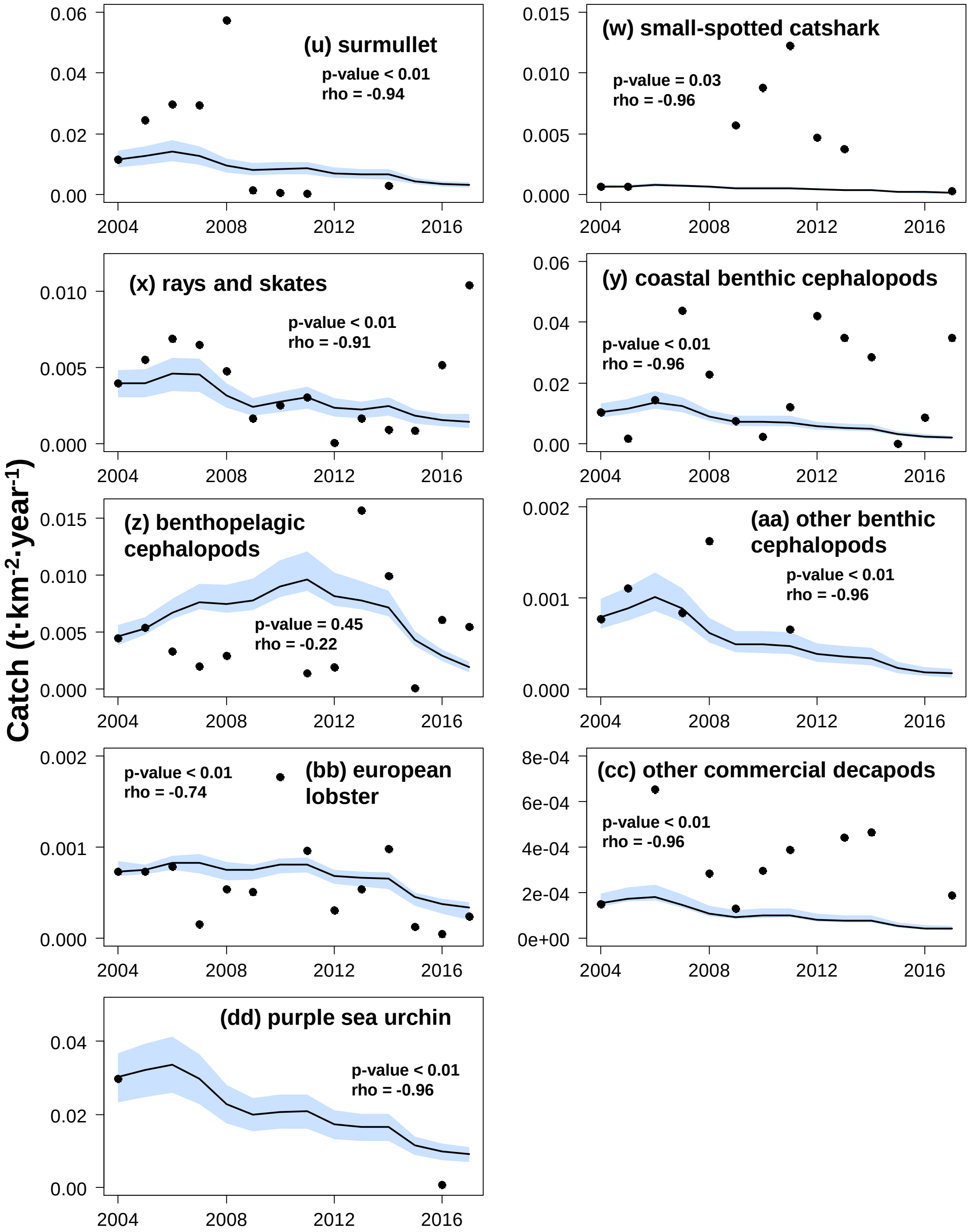
Catch ($t \cdot km^{-2} \cdot year^{-1}$)
(u) surmullet
p-value < 0.01
rho = -0.94
0.06
0.04
0.02
0.00
(w) small-spotted catshark
p-value = 0.03
rho = -0.96
0.015
0.010
0.005
0.000
(x) rays and skates
p-value < 0.01
rho = -0.91
0.010
0.005
0.000
(y) coastal benthic cephalopods
p-value < 0.01
rho = -0.96
0.06
0.04
0.02
0.00
(z) benthopelagic cephalopods
p-value = 0.45
rho = -0.22
0.015
0.010
0.005
0.000
(aa) other benthic cephalopods
p-value < 0.01
rho = -0.96
0.002
0.001
0.000
(bb) european lobster
p-value < 0.01
rho = -0.74
0.002
0.001
0.000
(cc) other commercial decapods
p-value < 0.01
rho = -0.96
8e-04
6e-04
4e-04
2e-04
0e+00
(dd) purple sea urchin
p-value < 0.01
rho = -0.96
0.04
0.02
0.00
2004
2008
2012
2016

Figure. 1. The study area encompassing the three multi-zone MPAs in the Northwestern Mediterranean Sea with the fully protected areas (FPAs), partially protected areas (PPAs) and unprotected neighboring areas (UPAs).

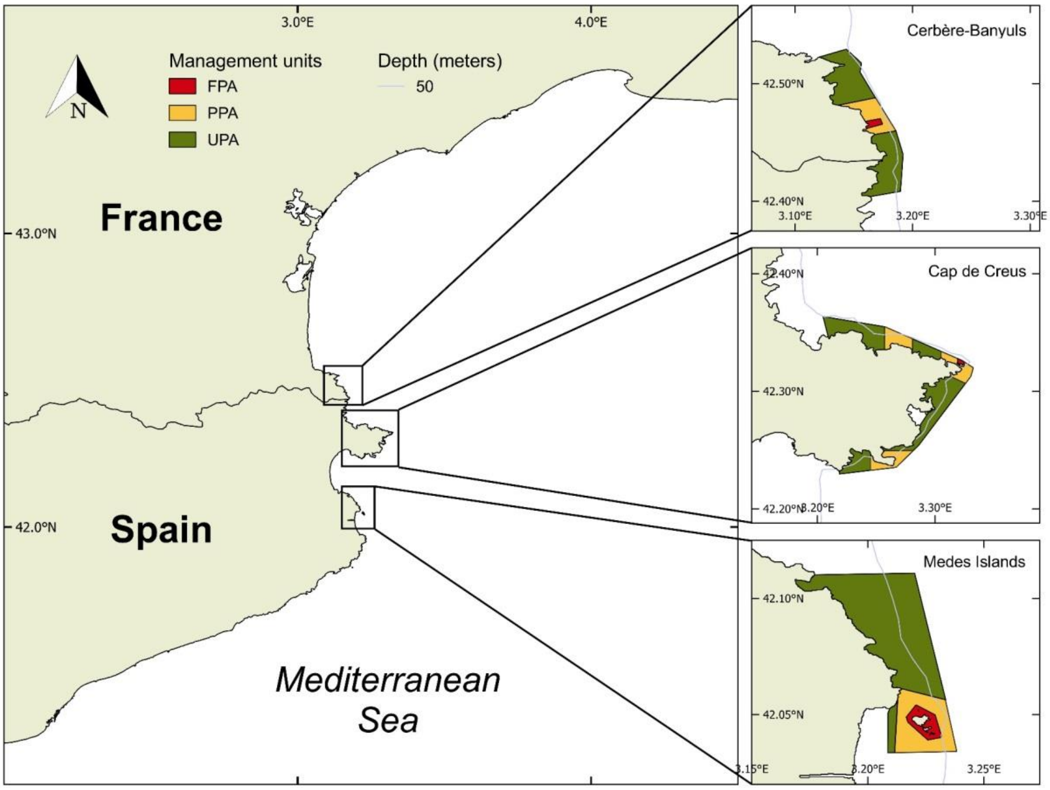


Figure. 2. Flow diagram of Cerbère-Banyuls (a), Cap de Creus (b) and Medes Island (c) MPA models. The numbers identify the functional groups of the model (listed in SOM 2). The size of each circle is proportional to the biomass of the functional group. The thickness of the connecting lines is proportional to the magnitude of their trophic flows.

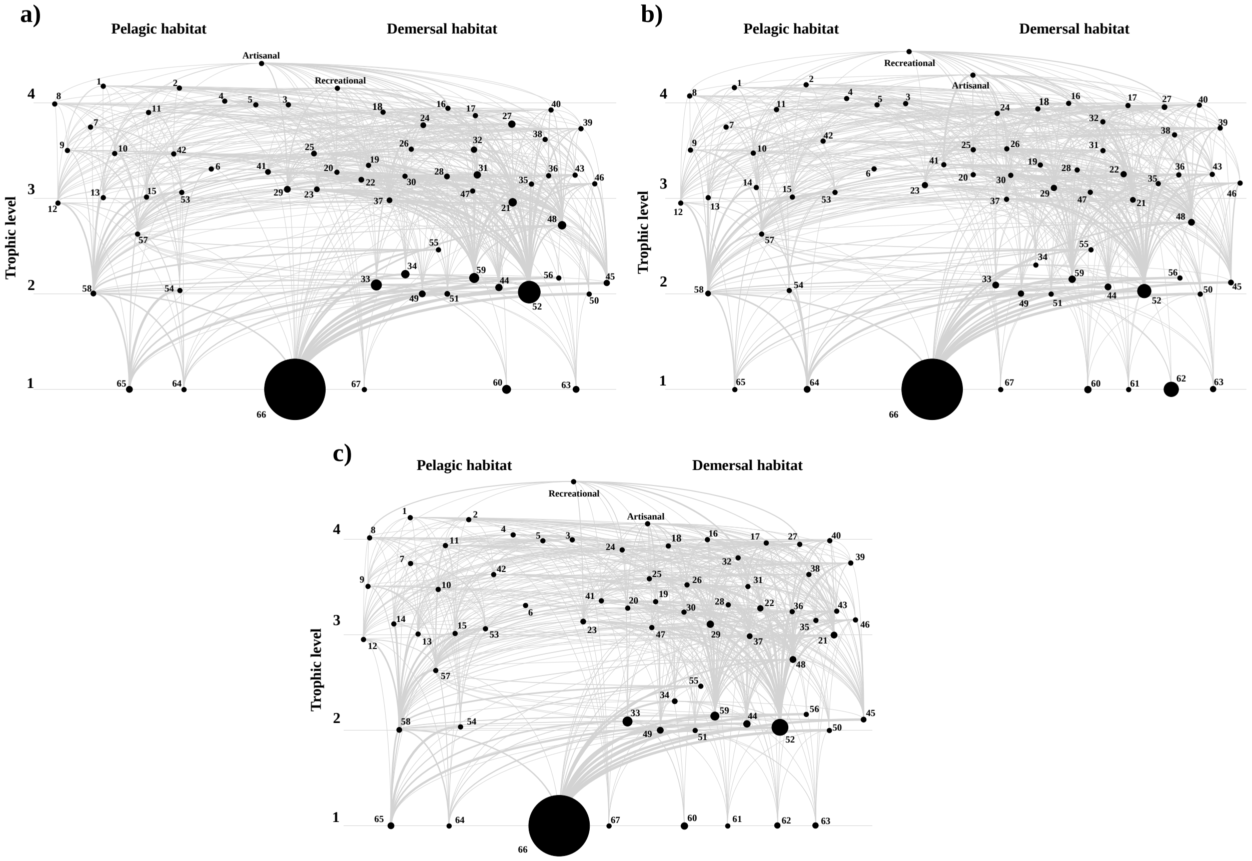


Figure. 3. Ecological indicators estimated for the three multi-zone MPA models of Cerbère-Banyuls, Cap de Creus and Medes Islands. Boxplot shows the distribution of values for an ecological indicator derived from the Monte Carlo routine while the dot represents the value of the indicator in the baseline Ecopath balanced model.

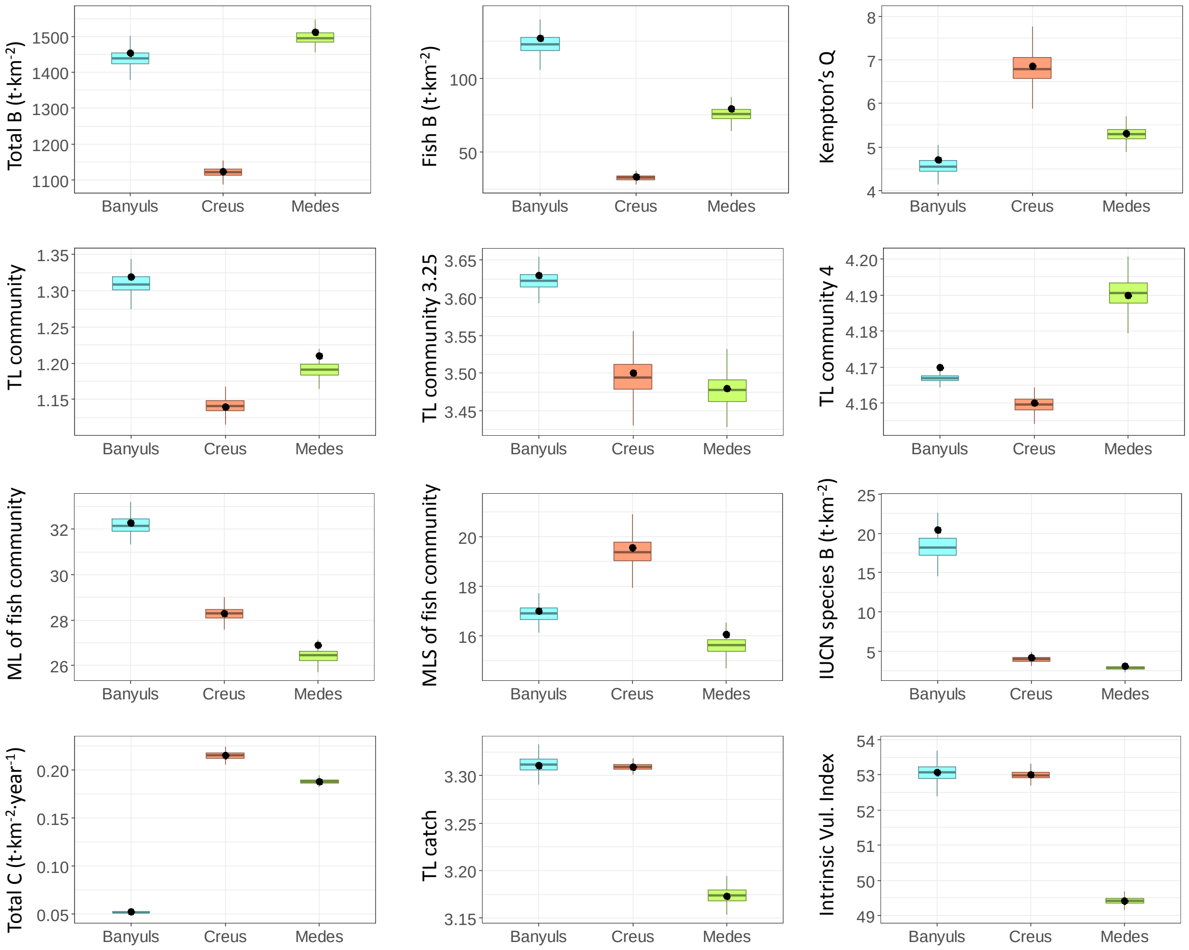


Figure. 4. Functional groups plotted against Keystone Index (KS) (Valls et al., 2015) and trophic level for Cerbère-Banyuls (a), Cap de Creus (b) and Medes (c) multi-zone MPA models. The numbers identify the functional groups of the model (listed in SOM 2). The size of the circles is proportional to the biomass of the functional group.

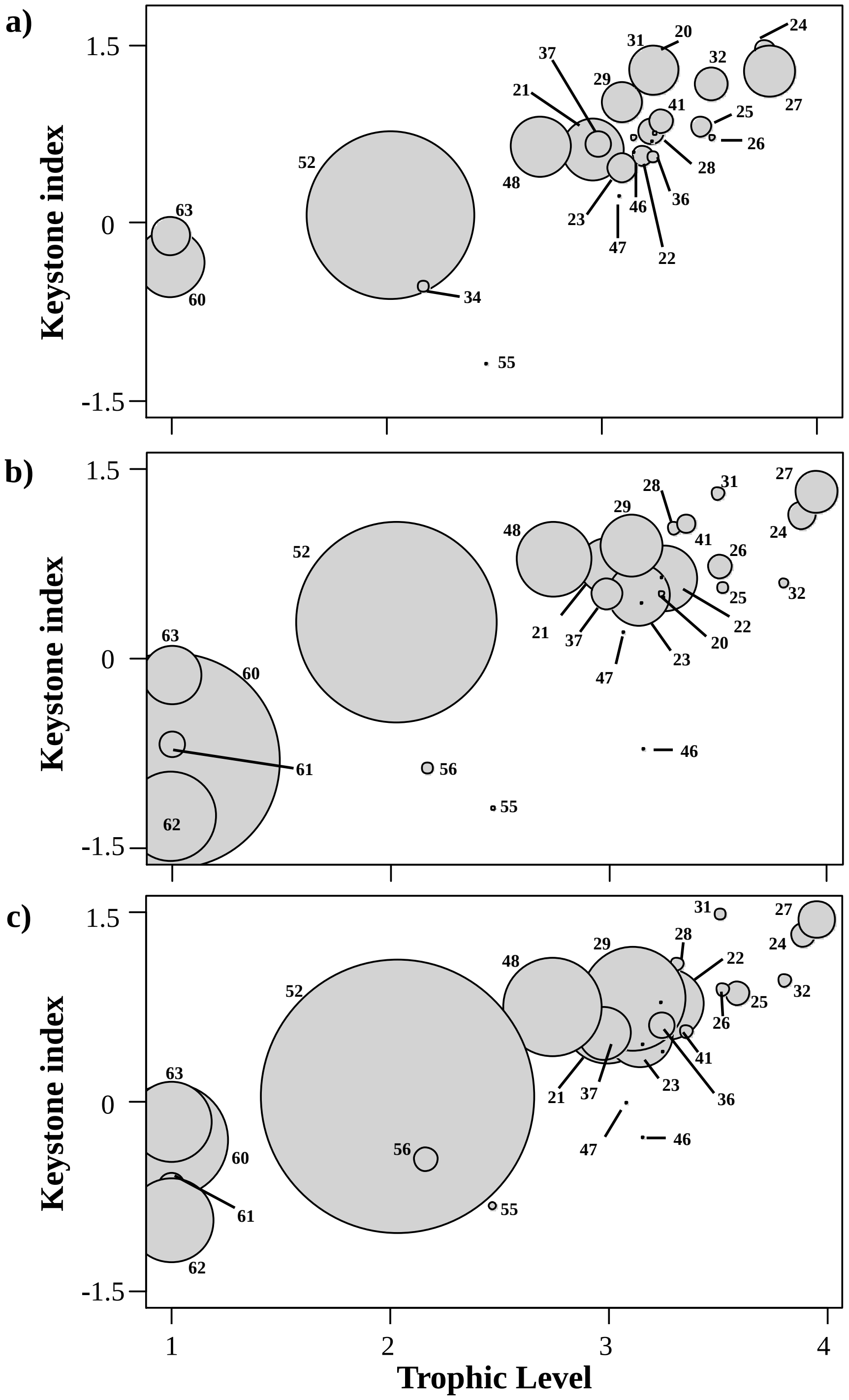


Figure. 5. Mixed Trophic Impact (MTI) analysis of the three MPA applied to the fisheries in a) Cerbère-Banyuls, b) Cap de Creus, and c) Medes Islands multi-zone MPA models.

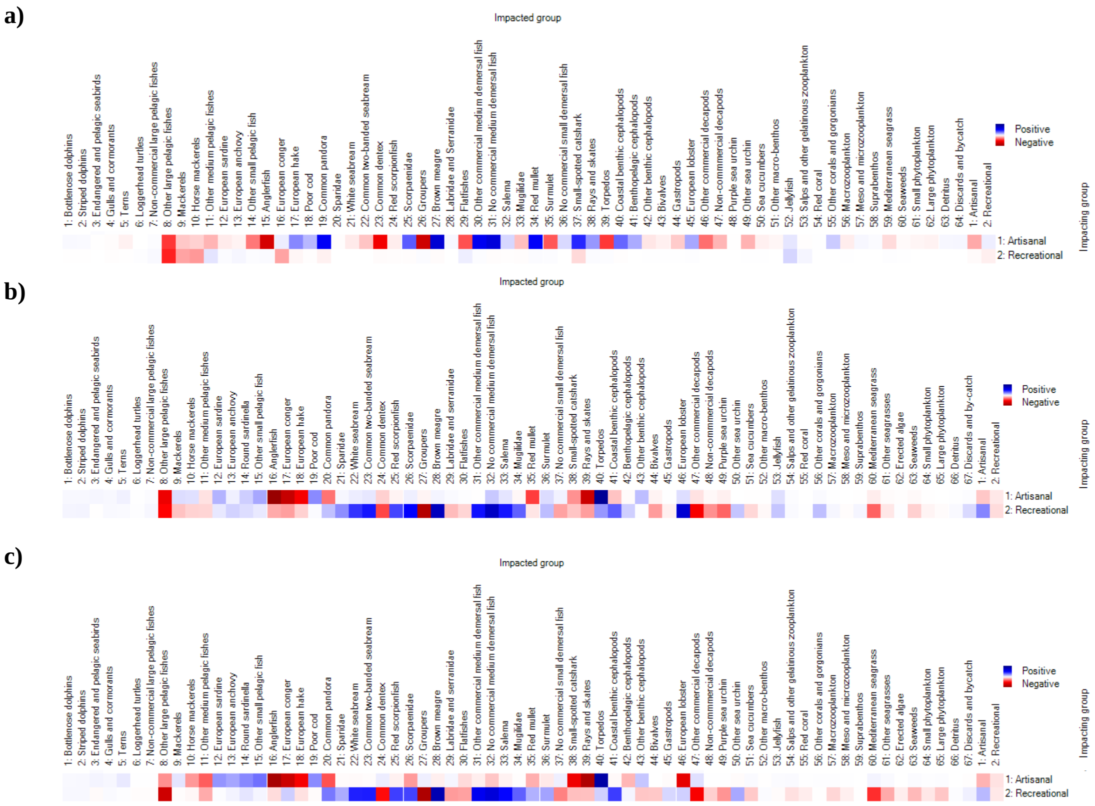


Figure. 6. Predicted (solid lines) versus observed (dots) biomass (t·km^{-2}) values for target species of Cerbère-Banyuls, Cap de Creus and Medes Islands multi-zone MPAs models. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman's rank correlation test.

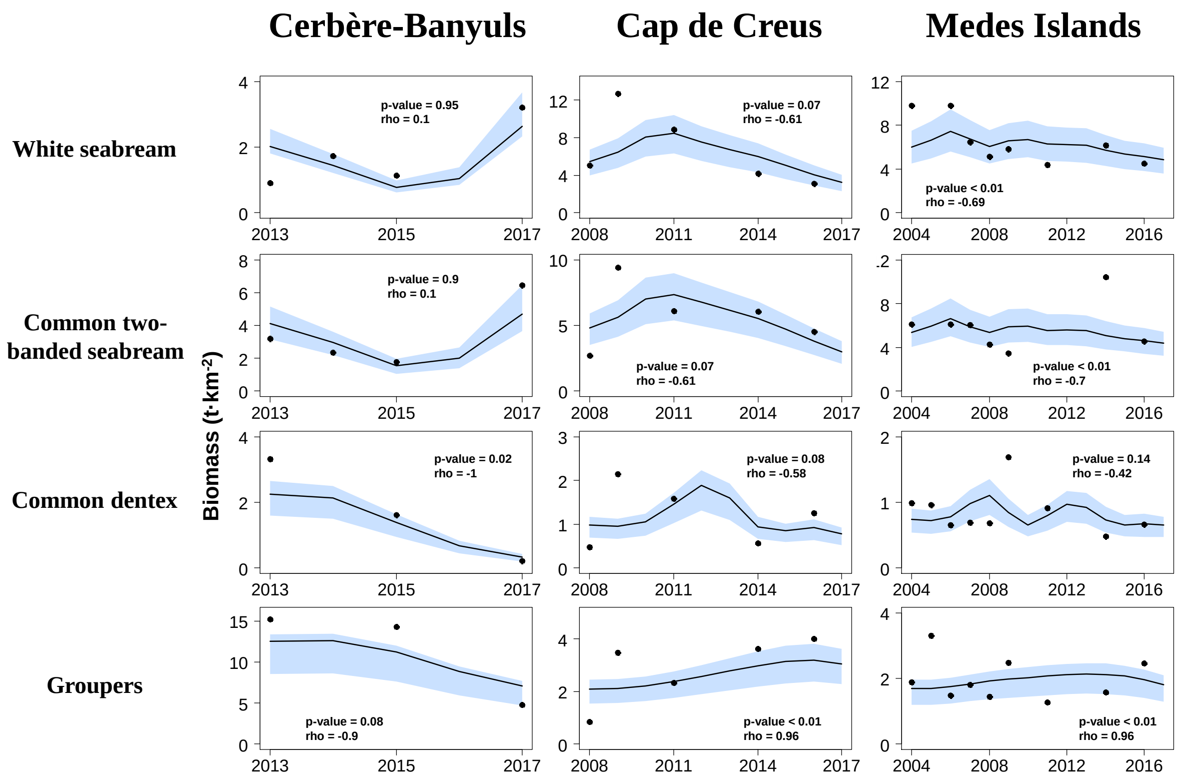


Figure. 7. Temporal trends of ecological indicators of Cerbère-Banyuls, Cap de Creus and Medes Islands multi-zone MPAs models. Blue shadows represent the 5% and 95% percentiles obtained using the Monte Carlo routine. Rho and p-values result from Spearman’s rank correlation test.