Project nº SSP8-006539
EMPAFISH
European Marine Protected Areas as tools for Fisheries management and conservation

Specific Programme "Integrating and strengthening the ERA" (6th Framework Programme), under the activity "Scientific Support to Policies" and the research priority for "Modernisation and sustainability of fisheries, including aquaculture-based production system".

Results of the bio-economic and cost-benefit analysis of selected case studies

Deliverable reference number: 25

Due date of deliverable: March 2007
Actual submission date: April 2008

Star date of project: 1st March 2005 ***Duration: 36 months***

Organisation name of lead contractor for this deliverable: Instituto de Ciencias del Mar (CSIC)

Revision: Final

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This publication has been developed in the framework of the project EMPAFISH (SSP8-006539) supported by the Commission of the European Communities within the Sixth Framework Programme. The views expressed in this work do not necessarily reflect those of EC or anticipates the Commission's future policy in the area.

Work Package: 5
Deliverable: D25
Dissemination Level: Public

Published by:

European Marine Protected Areas as tools for Fisheries management and conservation

Available from:
http://www.um.es/empafish

For further information, contact Dr. Francesc Maynou at maynouf@icm.csic.es
Institut de Ciències del Mar, CMIMA-CSIC. Psg. Marítim de la Barceloneta 37-49
08003-BARCELONA (Spain)

Results of the bio-economic and cost-benefit analysis of selected case studies

EMPAFISH deliverable 25

ToC

1 Introduction

Deliverable 20 (D20: Maynou and Boncoeur, 2007) of the EMPAFISH project provides a theoretical introduction to the simulation model "Bio-economic Analysis of Marine Protected Areas" (BEAMPA). The computer application associated to this model can be downloaded from the EMPAFISH project website (http://www.um.es/empafish). As reported in D20, the BEAMPA model is a spatial structured simulation model incorporating a fisheries bioeconomic model for extractive uses and a demand model for non-extractive (recreational) uses. The biological sub-model follows a partially age-structured model (Schnute and Richards, 2002), which describes the dynamics of the population as recruits and adults. The economic sub-model follows a standard cost and revenues economic fisheries model at the level of fleet or *métier*.

A model MPA is constructed on an arbitrary grid of square m x n cells. In each cell the protection type, the habitat type and the depth are set up, to define the MPA layout. Each cell has additional attributes regarding the biomass of the adult population, the number of recruits and the mean weight of the adult population, as well as the initial effort distribution and types of recreational uses permitted. This initial configuration of the model MPA can be projected forwards in time to simulate the likely development of the system under the initial conditions according to the equations of the model. The effect of policy or management measures can be tested by changing parameters of the different components of the model or by changing the initial configuration of the MPA layout. For details on the theoretical basis of the model refer to D20 (Maynou and Boncoeur, 2007).

1.1 Objectives of the BEAMPA simulation model

The current version of BEAMPA can be used to address both scientific questions and management questions. It is important to note that the model is a simulation model, not an optimization model, i.e. the results of a simulation scenario cannot be taken directly as an optimal management option. Due to the complexity of the model, the data needs are important and the problem of parameter estimation can be formidable. For this reason the user may choose to concentrate on parts of the model and weigh carefully the results of a simulation, as some of the parameters and processes (equations) used may be highly uncertain (e.g. refer to Hilborn and Walters, 1992 for a classical discussion of uncertainty in fisheries models).

The main scientific research questions that can be addressed by the current version of BEAMPA are:

- Examine the effect of adult biomass spillover on fisheries
- Assess parameter uncertainty on the robustness of simulation results (especially: mobility parameter, recruitment, natural mortality).

- Test different dispersion models (random, random walk, density-dependent)
- Evaluate different models of fishing effort redistribution (random, function of past profits, tradition)

The main management questions that can be directly addressed by BEAMPA are:

- Study the effect of changing the configuration of the MPA (layout, distribution of No Take Zone, network of MPAs)
- Test the effects of effort control on fisheries revenues
- Assess the impact of habitat degradation on recreational uses and total value of MPA

The results of a simulation run can be evaluated by the analysis of the indicators provided by BEAMPA, in tabular or graphical form. As the output capabilities of BEAMPA are limited it is recommended to export the output to a spreadsheet program for further analysis.

1.2 Analysis of output (table, chart)

After a simulation run is performed the results of the simulation ("output") can be analyzed in graphical ("Chart") or tabular ("Table") form.
The chart option gives access to the main indicators of the simulation arranged by protection zone. These main indicators are:

- Biological indicators: Total Biomass (in weight, g), Recruits (in number of individuals), Biomass of the adult population ("Survivors", in weight, g) and mean weight of the adult population ("Weight", g). These biological indicators can be examined by stock and zone (No Take Zone, Buffer, Open Access[1] or Total).
- Commercial fishing indicators: Fishing effort (in the units specified by the user), Total costs (in € or other monetary unit specified by the user), Total revenues (in € or other), Net revenues (in € or other) and Discounted net revenues (in € or other). These indicators can be examined by fleet and zone
- Bio-economic indicators: Fishing mortality (in yr-1), catch rate (in yr-1), catches (in weight, g) and revenues[2] of the target species (in € or other). These indicators can be examined for the interaction of fleet and stock and for each area.

The data used to draw the chart in the BEAMPA application can be selected and exported to an external application for further analysis.

The table option of the BEAMPA application gives access to all the state variables defined in the BEAMPA model by cell and iteration time. This large amount of data is organized under 4 main categories:

- Biological indicators at iteration t. Biomass, Recruit, Survivors and mean adult weight of each target species for each cell, defined as above.
- Commercial fishing indicators at iteration t. Fishing effort, Total costs, Total revenues and Net revenues of each fleet for each cell, defined as above.
- Bio-economic indicators at iteration t. Fishing mortality, catch rate, catches and revenues of the target species of each combination of stock and fleet and for each cell, defined as above.

---

[1] Note that in the BEAMPA model "Open Access" is defined as a zone of the model MPA where no *spatial* restrictions to fishing exists (there may exist other type of restrictions). If the fishing effort in the study area is regulated or limited, this zone will not be open access in strict sense..

[2] Note the difference between "revenues of the main species" and total revenues of the fleet. The latter incorporates the sum of revenues of each main species plus a pool of secondary species that are not explicitly model by the biological model.

- Recreational indicators at iteration t. Summarizing the number of users, aggregated budget, average unit price, total revenues, costs and profits of the producers of recreational activities.

2 *Parameterizing the model*

2.1 Parameterizing the model (general)

To use the BEAMPA application the MPA layout and simulation conditions should first be defined. Following the typology of users defined in D20 a simulation scenario should contain at least 1 extractive activity in the form of commercial fishing and any number of recreational activities. Recreational fishing should be modeled both as an extractive and recreational activity, by using the fisheries model with fish prices set to 0 and the recreational model properly parameterized.
The layout of the model MPA needs to be defined, possibly with the help of an external application (e.g. ArcGIS or similar) or manually within the BEAMPA application. In addition to defining the types of zones in the model MPA, the type of uses permitted in each zone must be defined (Interaction zone x use: 1 allowed, 0 not allowed).
Additional input parameters are the grid dimension (number of rows and cells), the cell size (in arbitrary surface units), the number of stocks and fleets, the number of recreational activities and the number of producers of these recreational activities. Other general input parameters are the opportunity cost, the discount rate and the simulation horizon (number of years of the projection). The effort units are also given as input parameter.
All the parameters used to build a simulation scenario represent the values at year 0 of the simulation and may be constant throughout the simulation horizon (*parameters* in strict sense) or vary according to the equations of the model if they are actually *state variables* of the model.

2.2 Biological parameters of exploited species

The biological parameters consist of 2 sets of parameters. First, the biological parameters of the partially-age structured model need to be supplied: W_{inf} (weight corresponding to L_{inf} of von Bertalanffy growth function, g), k (growth parameter of von Bertalanffy growth function), age at recruitment (yr), mean weight of recruits (g), natural mortality (M, yr^{-1}), mobility (fraction of biomass between 0 and 1 dispersing to a neighboring cell per iteration year) and dispersion model (1 by default).
Additionally, for each cell of the model MPA the initial distribution of adult biomass, number of recruits and mean weight of the adult biomass must be supplied. The estimation of these values for each cell is data-demanding and can be approached by spatial analysis of data from underwater visual censuses or fisheries (catch per unit effort) studies, or a combination of both approaches (e.g. Stelzenmüller et al., 2007).

2.3 Economic parameters of fisheries

The economic parameters of the fishery consist of 2 sets of parameters, the first one related to costs and the second one related to prices. The parameters related to costs include the commercial tax on revenues, daily costs related to effort (fuel costs in € day^{-1}; ice and bait costs in € day^{-1}; and other daily costs), the share of revenues to the vessel owner, the fishing activity in terms of hours day^{-1} and days yr^{-1} and annual compulsory (license fees, mooring fees, etc.) and maintenance costs. Other parameters related to costs are the proportion of fishing effort increase when there are positive profits, the crew size, and the vessel capital.

The parameters related to price include the ex-vessel price of the target species for each fishing gear and the price and catches of secondary species.

A parameter that controls effort distribution according to tradition can also be supplied ("Tradition"), ranging from 0 to 1. A parameter value of 1 means that fishing effort is applied to the same cells as in the original effort configuration at each iteration, regardless of potential profitability of neighboring cells. A parameter value smaller than 1 represents the factor of fishing effort that is redistributed to neighboring cells at each iteration following the perceived profitability of neighboring cells. The original effort configuration is set up on the cell-based grid in units of effort.

The fishing mortality (F, yr^{-1}) applied by each fleet to each target species need also be supplied. This parameter is usually derived by a Virtual Population Analysis or similar fisheries analytical techniques. The zones where fishing effort can be deployed and the target species of each fleet are set up in the interaction matrix.

2.4 Economic parameters of recreational uses

The recreational parameters consist of 2 sets of parameters, one related to the users of such activities ("Consumers") and the other regarding the cost structure of the companies producing the recreational activities ("Producers"). The parameters of the demand function for recreational users specified in the BEAMPA model (D20) are the perceived quality of the recreational activity (□) and the importance of ecosystem quality (□). The importance of non-congestion (□) is not used in the current version of the model and is set to 1 by default. Other parameters regarding the consumers of recreational users are the maximum number of users (permitted by law), the number of users at time 0 of the simulation ("frequentation"), the average individual budget (in € or other) devoted to this activity, and the unit price of the activity.

The set of parameters related to costs borne by the producer are similar to the cost parameters of the commercial fishing activity: tax on revenues, daily costs of fuel, labour and other daily costs, annual operating days, annual compulsory and maintenance costs, capital and revenues obtained from other activities.

The zones where recreational uses are permitted and the recreational uses offered by producers are set up in the interaction matrix.

3 Case studies

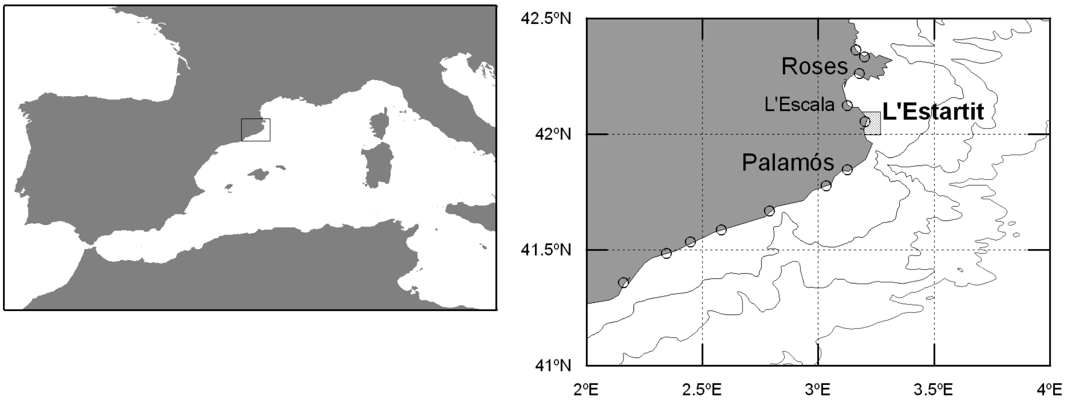
3.1 Medes Islands MPA

3.1.1 Description of the case study

The location of the Medes Islands MPA case study is shown in Fig.1. This case study is amply documented in other deliverables of the EMPAFISH project (refer especially to D3: Planes et al., 2006, D4: Vandeperre et al., 2006 and D22: Alban et al., 2006). Briefly, the MPA consists of an Integral Maine Reserve (No Take Zone) of 93 ha where all extractive uses are forbidden and a Partial Marine Reserve (Buffer area) of 418 ha where artisanal fishing is permitted to the local fleet based in L'Estartit. The local fleet having access to the area is defined by decree of the Ministry of Environment of Catalonia's Atonomous Government and in 2005 the number of vessels officially recognized where 21 (Decree 234/2004 of 16 March 2004). We must remark that this potential fleet consists of only 9 professional vessels, with 12 vessels own by retired fishers who fish in the Buffer area occasionally for own consumption. Outside this Buffer area artisanal fishing is carried out, in practice, entirely by the same local fleet of L'Estartit because the area is generally less than 50 m depth (forbidden to trawlers) and the nearest harbours with significant fishing fleets (Palamós and Roses, Fig. 1) are more than 20 nautical miles away. Regarding the composition of the active artisanal fleet, it must be noted that according to our socio-economic survey 2 from the 9 active vessels were specialized in fishing for *Ammodytes* sp. in the south of the study area (Fig. 1, bottom), which involve fishing gear and species not likely to be influenced by the MPA. For the purposes of this study, the active fishing fleet comprises 7 artisanal boats, 4 deploying mainly trammel nets and 3 deploying mainly gillnets.
Other uses that directly benefit from the protection regime in the study area are non-extractive, recreational uses, including mainly SCUBA diving and short trips (1-2 h) organized for the general public aboard glass-bottom boats. These two activities are the main sources of revenue to the local economy and are actually more important (economically) than the commercial fishery (D22: Alban et al., 2006). Other recreational uses, such as recreational fishing, kayaking, etc., are not considered in this case study due to the difficulty in *i)* isolating the effect of the MPA on these recreational uses that are otherwise practiced along the entire Catalonian coast, especially in summer, and *ii)* parameterizing a recreational model for these uses, due to lack of data.
The case study consists of a grid of 28 x 10 cells of 25 ha each (500 x 500 m) representing a model of the MPA layout as shown in Fig. 1, bottom (cf. with Fig. 2). The protection regimes of the model MPA were obtained by discretizing the real layout of the MPA using a Geographic Information System (ArcGIS 9.0). The difference between the areas of the real MPA and the model MPA is summarized in the following table:

	No Take Zone	Buffer Zone	Unregulated Zone
Real MPA	93 ha	418 ha	4989 ha
Model MPA	75 ha	650 ha	4775 ha

Note how, both in the real MPA and the model MPA, the protected areas are very small in comparison with the study area (around 1% of the study area is No Take Zone and around 10% of the study area is Buffer Zone).



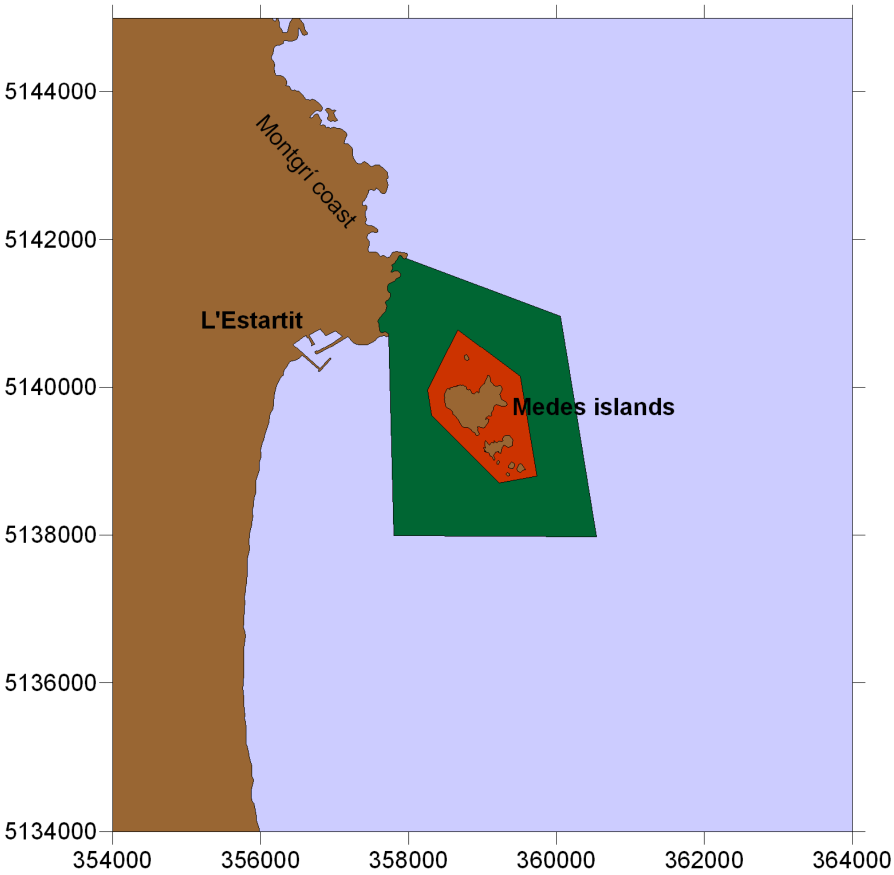


Fig.1. Top left: general map of southwestern Europe, showing the location of northeast Catalonia (rectangle). Top right: map of northeast Catalonia, showing the study area (L'Estartit) and close fishing harbours. Bottom: map of the Medes Islands Marine Protected Area. The first perimeter around the islands (red) shows the Integral Marine Reserve or No Take Zone, where no extractive uses are allowed. The second perimeter (green) shows the Partial Marine Reserve or Buffer area, where commercial fisheries are restricted to artisanal boats based in L'Estartit. The rest of the study area (blue) is open to commercial fishing, regulated by the general fishery normative that applies along the entire Catalonian coast.

The current design of the Medes Islands MPA as implemented in the model MPA is shown in Figs 2-4.

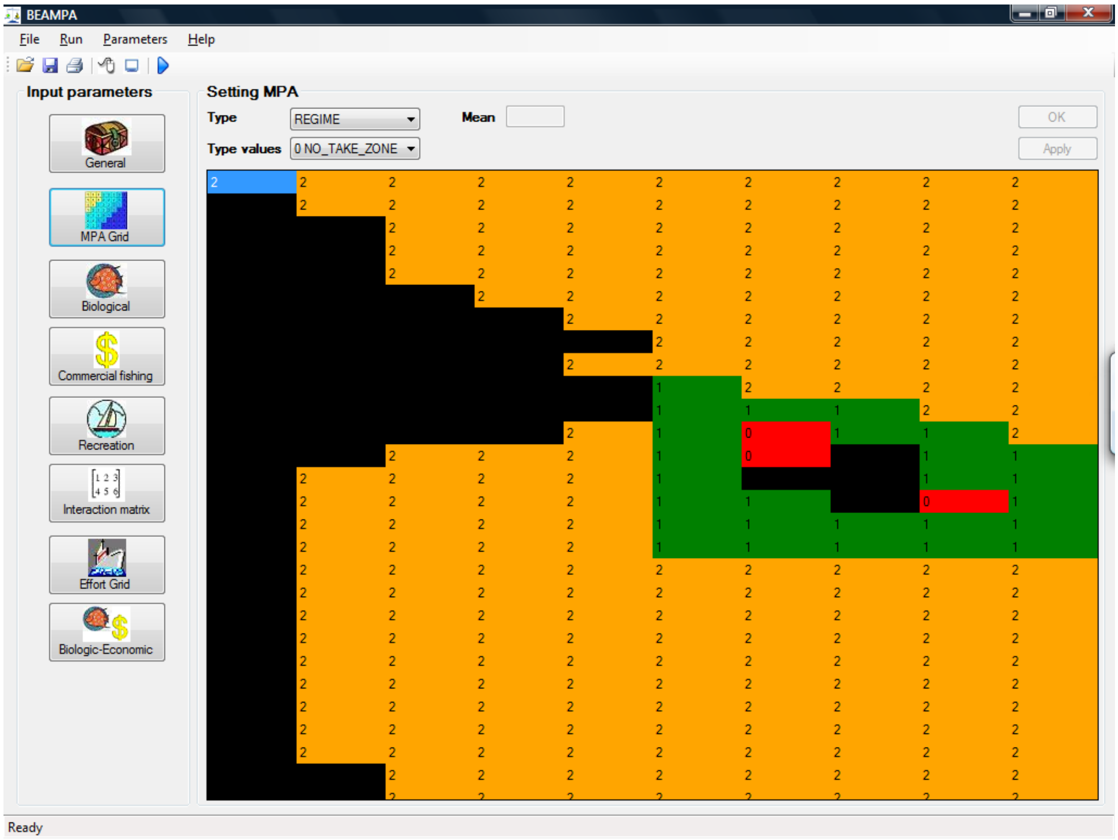


Fig. 2. Layout of the model MPA. Black: land; red cells: No Take Zone; green cells: Buffer Zone; orange cells: Unregulated Fishing Zone.

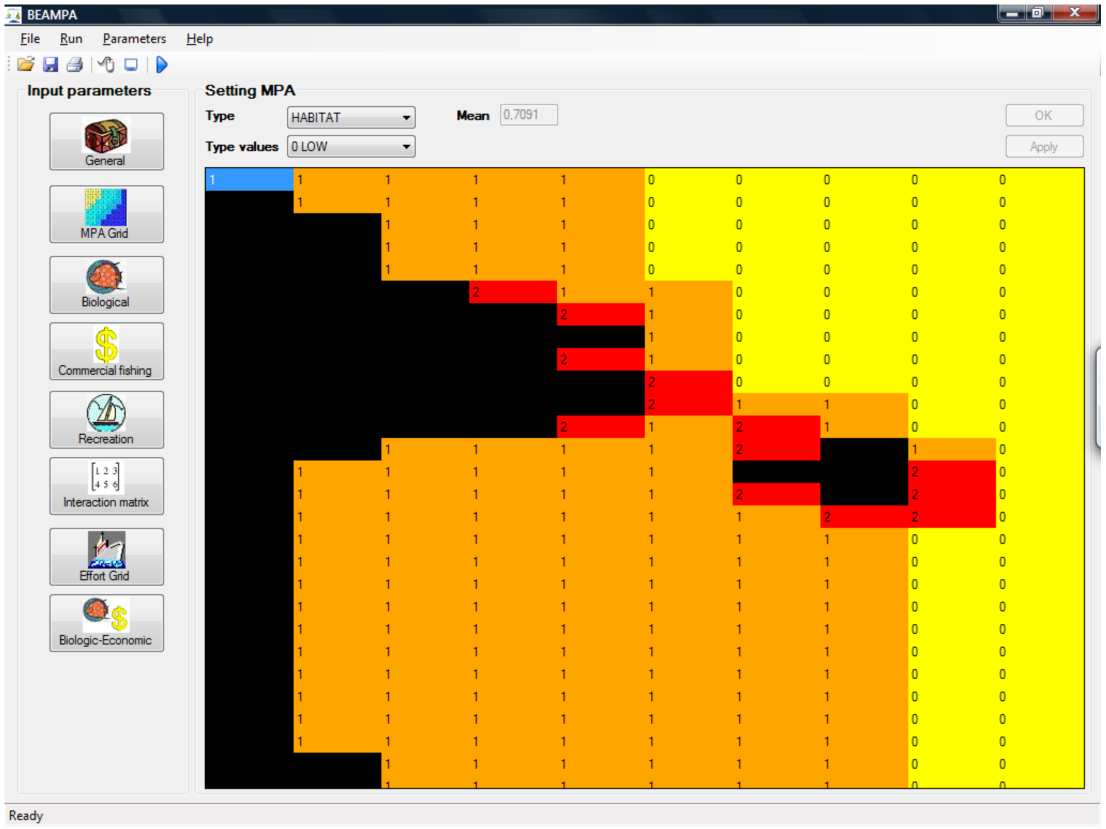


Fig. 3. Layout of habitat types in the model MPA. Black cells: land; red cells: rock or predominantly hard substrate; orange cells: predominantly sandy bottoms; yellow: predominantly muddy bottoms.

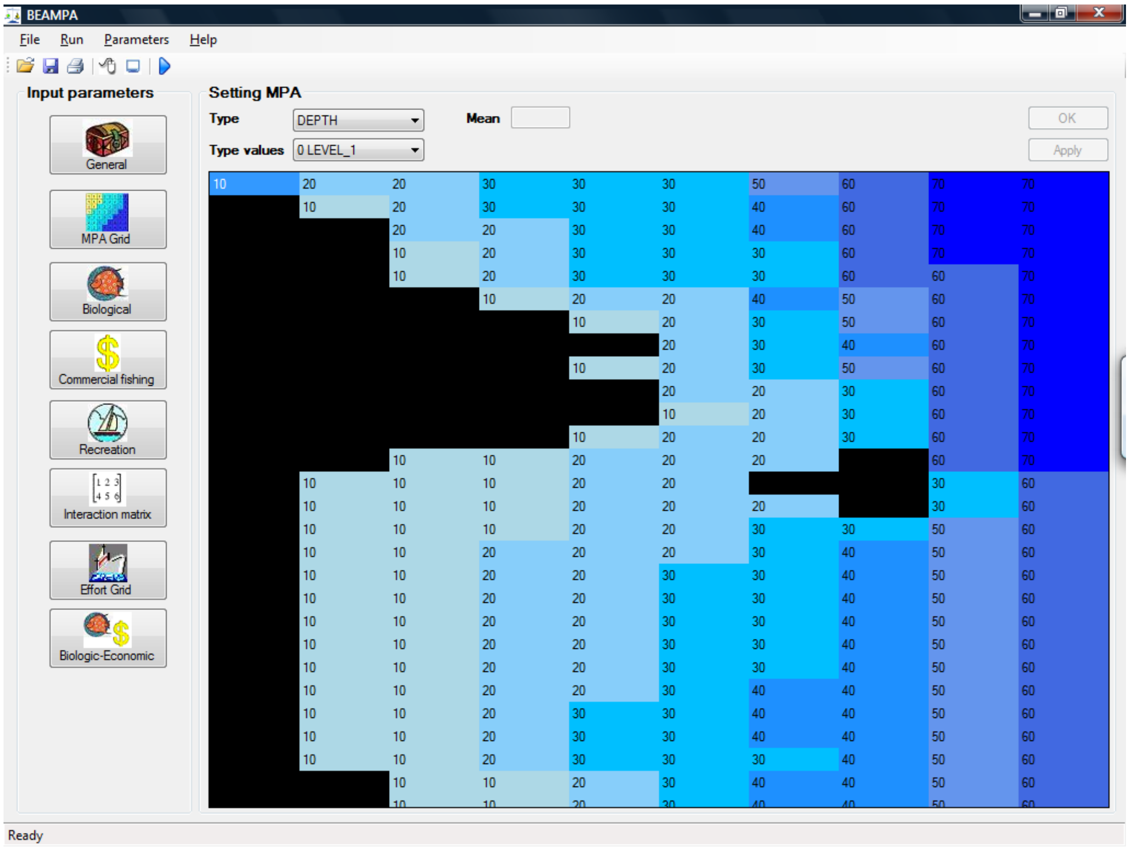


Fig. 4. Average depth in m of each cell in the model MPA. Black cells: land.

3.1.2 Commercial fishery

As in other small scale coastal fisheries, the commercial fishery around the Medes Islands MPA comprises a large variety of species (95 taxa identified during the on board samplings) and 8 fishing gears. The species and fishing gears selected for this application make a significant part of the volume of landings and income and are representative of other Mediterranean small scale coastal fisheries. Due to the lack of auction market in L'Estartit fish is sold directly to restaurants and all data reported here come from the sampling programme carried out in the period 2003-2005[3] in the framework of research projects. All data are averaged across the 3 year period and can be considered representative of the bio-economic situation of the early 21st century in the study area.

The average annual catch of the 6 selected species for the 2 fishing gears considered is given in the following table (bold face: species selected for the application of the bio-economic model):

[3] onboard sampling 2003-2004 corresponding to BIOMEX project (WP6, QLRT-2001-0891), and 2005 corresponding to EMPAFISH project (WP2, SSP8-006539).

Selected species	%		estimated catch (kg)	
	trammelnet	gillnet	trammelnet	gillnet
Merluccius merluccius	<1%	**15%**	9	**2297**
Pagellus erythrinus	2%	**11%**	174	**1004**
Mullus surmuletus	**9%**	<1%	**902**	71
Scorpaena porcus	**4%**	<1%	**239**	48
Sparus aurata	1%	**7%**	92	**1820**
Solea vulgaris	**5%**	<1%	**641**	71
Total general	100%	100%	9394	17203

Table 1: catches of the target species for the 2 fleets considered in the model and their percentual contribution to total estimated catch by fleet.

Note that the 3 selected species for trammel net make 18% of the total catch for this gear, while the 3 selected species make 33% of the total catch for gillnet. The revenues obtained from catches of other species are entered in the model as secondary species.

3.1.3 Biological parameters of the target species

To assess the current state of exploitation of the target species and to obtain parameter estimates for the bio-economic model a Virtual Population Analysis based on pseudo-cohorts was performed with the help of FISAT II and VIT (Gayanilo et al., 2002; Lleonart and Salat, 1997). The virtual population obtained with this analysis was distributed in recruits and adult population (spawners) in biomass, according to the specifications of the bio-economic model (D20).

species	*Merluccius merluccius*	*Pagellus erythrinus*	*Sparus aurata*	*Mullus surmuletus*	*Scorpaena porcus*	*Solea solea*
English common name	(European) hake	(Common) pandora	(Gilthead) seabream	(Striped) red mullet	(Black) Scorpionfish	(Common) sole
L_{inf} (cm)	95.00	60.00	57.70	39.65	31.00	47.20
W_{inf} (g)	5,408	4,639	2,689	1,134	524	761
k	0.090	0.255	0.270	0.300	0.162	0.274
t_0	-0.60	-0.04	0.00	0.00	0.00	0.00
M	0.15	0.34	0.50	0.43	0.47	0.58
Z	1.17	0.48	1.26	1.19	0.62	0.80
a	0.004	0.017	0.014	0.018	0.018	0.006
b	3.100	3.060	3.000	3.000	3.000	3.040
terminal F	1.02	0.14	0.76	0.76	0.15	0.22

Table 2: Basic biological parameters for the 6 species considered[4].

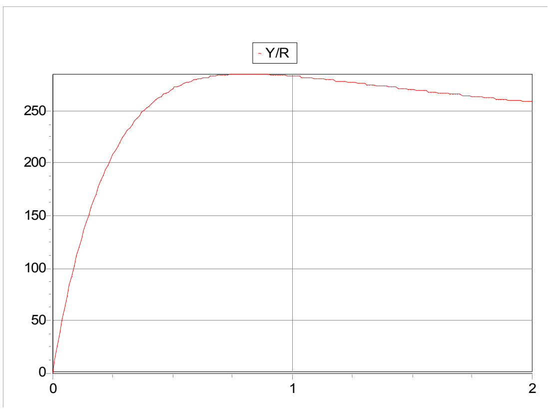
[4] Growth and mortality data were estimated from sampling data and complemented with parameters available in FISHBASE, www.fishbase.org.

species	*Merluccius merluccius*	*Pagellus erythrinus*	*Sparus aurata*	*Mullus surmuletus*	*Scorpaena porcus*	*Solea solea*
Biomass (B0, kg)	5,831.783	4,211.993	5,346.920	2,125.826	3,775.071	16,361.148
Mean ind. weight of recruits (g)	141	149	308	53	20	27
Number of recruits (R)	8,101	3,526	7,646	10,453	28,655	89,401
Mean ind. weight of the adult population (g)	343.13	993.87	731.76	242.67	90.39	183.7
Mobility	0.053	0.146	0.032	0.0694	0	0.040

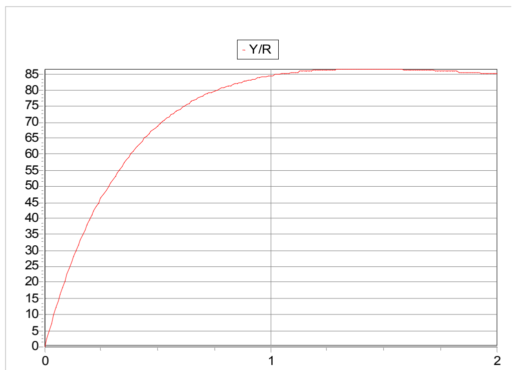
Table 3: Demographic parameters of the 6 species considered, corresponding to state variables at iteration 0.

The mobility parameter was estimated for each species following the approach in Murawski et al. (2004), which is based on observed catches per unit effort and constant rates of fishing and natural mortality. The mobility model did not produce a reliable estimate for *Scorpaena porcus* and the mobility value was set to 0 for this species, based on the assumption that this is a highly sedentary species.

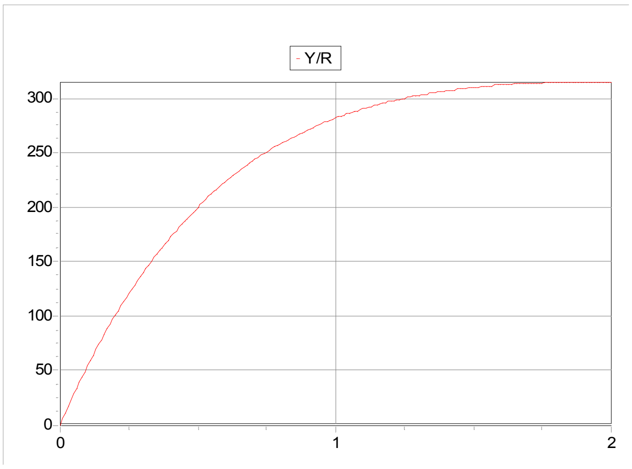
The state of exploitation six species was assessed by Virtual Population Analysis following the standard Yield per Recruit model. As shown in Fig. 5 for most species the current fishing mortality provides yield per recruit below the maximum yield per recruit. This suggests that the stocks are underexploited, except hake, for which current fishing mortality is slightly higher than the maximum yield per recruit.



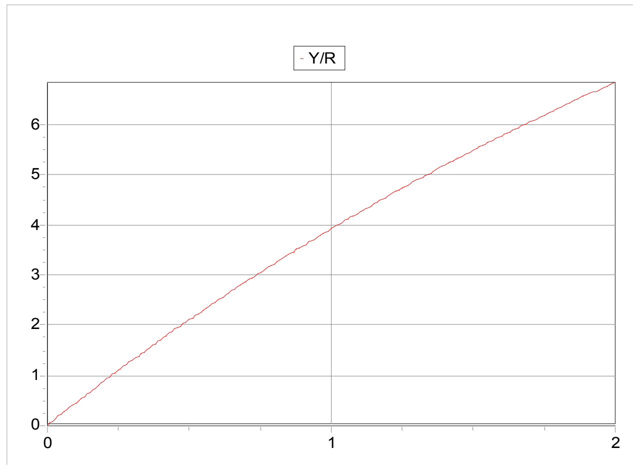
Merluccius merluccius



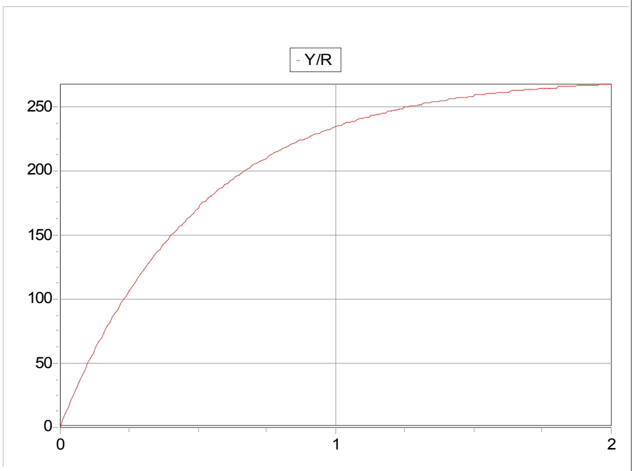
Mullus surmuletus



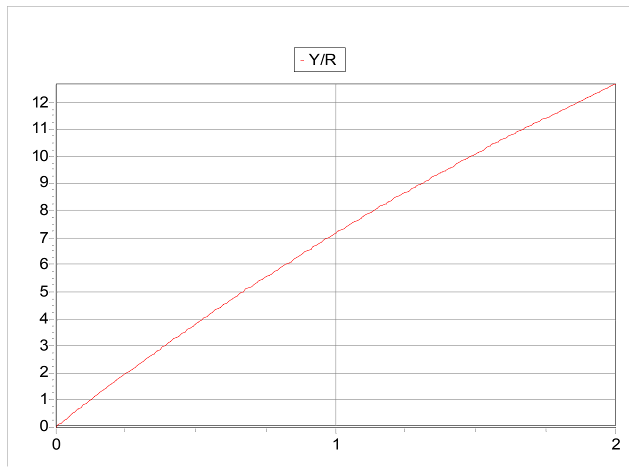
Pagellus erythrinus



Scorpaena porcus



Sparus aurata



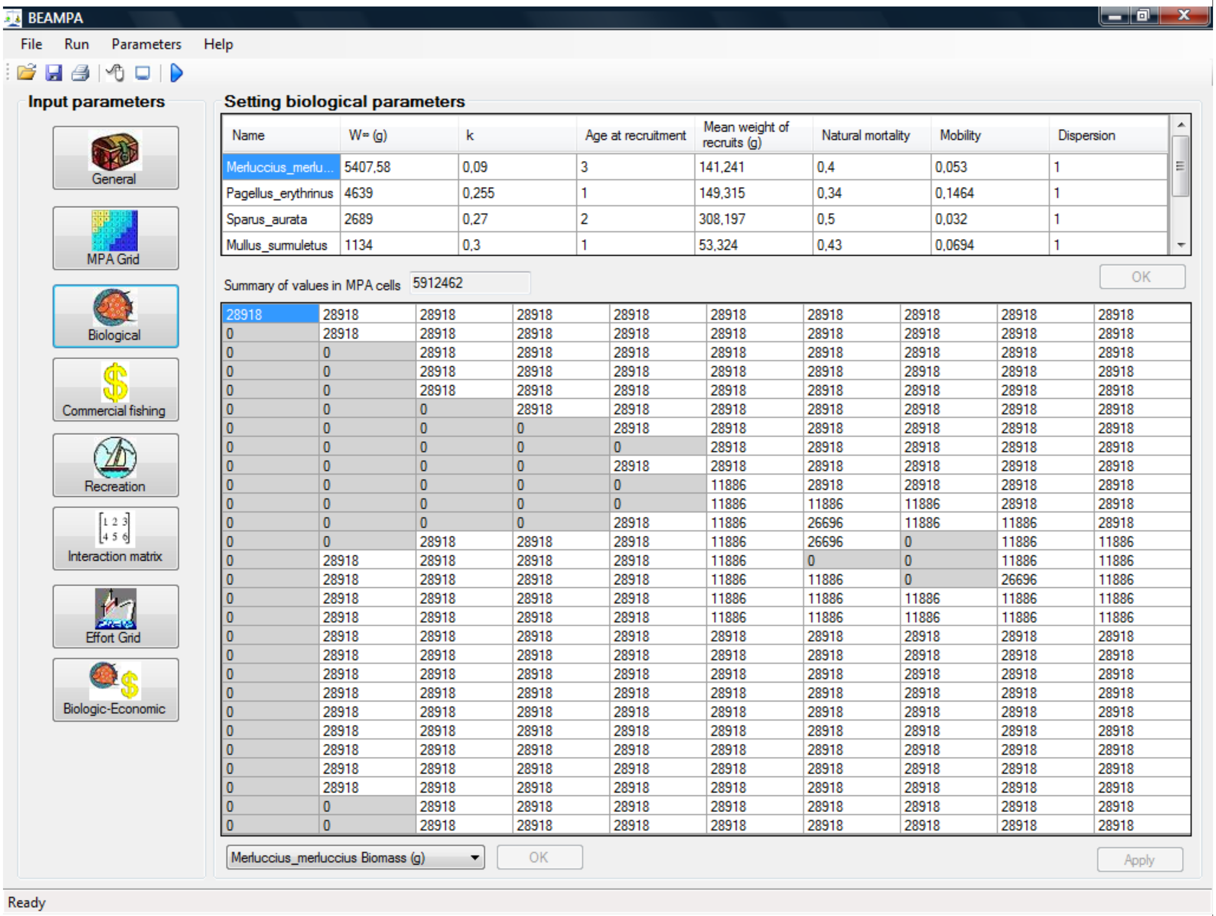
Solea vulgaris

Fig. 5. Results of Yield per Recruit analysis of the six main species. The value of 1 represents the current factor of fishing mortality.

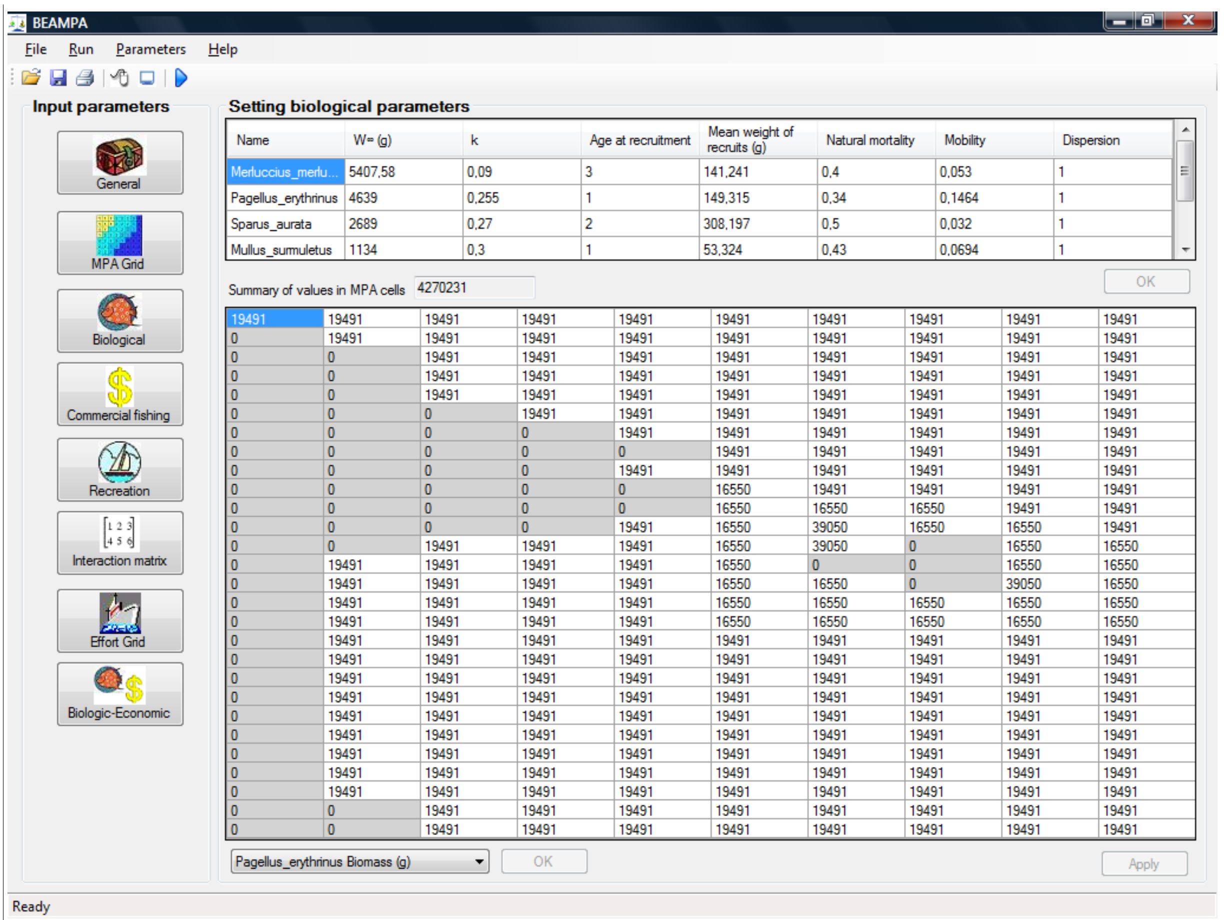
Total biomass was distributed in each cell according to the relative CPUEs observed (Table 4 and Fig. 6). Due to the little information on the spatial distribution of recruits and mean individual weights, these variables were randomly allocated in each cell, subject to the constraint of total recruitment and mean individual weights observed (Table 3).

	Biomass in NTZ cells	Biomass in Buffer cells	Biomass in Unregulated cells
Merluccius merluccius	26696	11886	28918
Pagellus erythrinus	39050	16550	19491
Sparus aurata	7032	14126	26348
Mullus surmuletus	4824	9152	9962
Scorpaena porcus	34988	13863	17601
Solea vulgaris	36018	22790	83177

Table 4: Initial allocation of total biomass (g) of each species by type of cell.



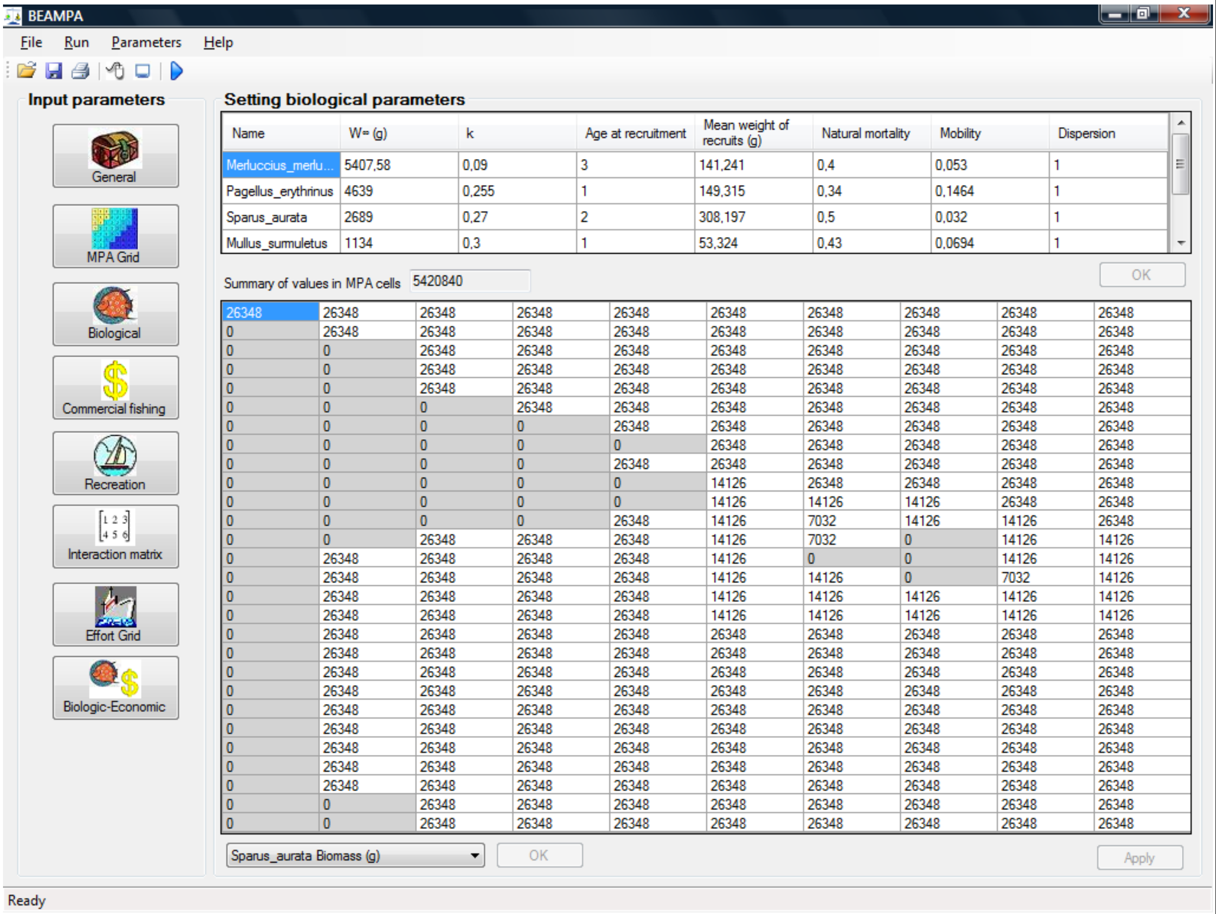
Merluccius merluccius



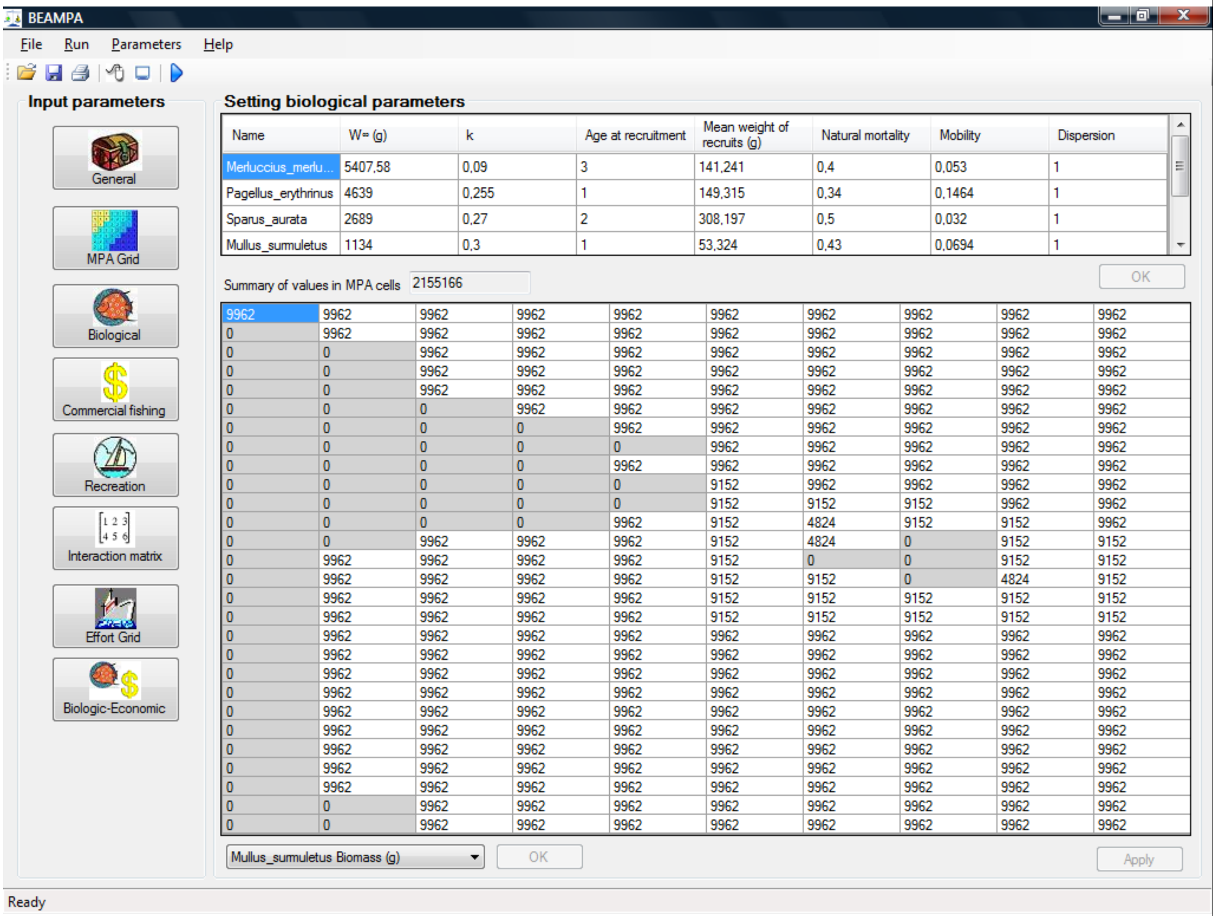
Name	W∞ (g)	k	Age at recruitment	Mean weight of recruits (g)	Natural mortality	Mobility	Dispersion
Merluccius_merlu...	5407,58	0,09	3	141,241	0,4	0,053	1
Pagellus_erythrinus	4639	0,255	1	149,315	0,34	0,1464	1
Sparus_aurata	2689	0,27	2	308,197	0,5	0,032	1
Mullus_surmuletus	1134	0,3	1	53,324	0,43	0,0694	1

19491	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	0	19491	19491	19491	19491	19491	19491	19491	19491
0	0	19491	19491	19491	19491	19491	19491	19491	19491
0	0	19491	19491	19491	19491	19491	19491	19491	19491
0	0	0	19491	19491	19491	19491	19491	19491	19491
0	0	0	0	19491	19491	19491	19491	19491	19491
0	0	0	0	0	19491	19491	19491	19491	19491
0	0	0	0	19491	19491	19491	19491	19491	19491
0	0	0	0	0	16550	19491	19491	19491	19491
0	0	0	0	0	16550	16550	16550	19491	19491
0	0	0	0	19491	16550	39050	16550	16550	19491
0	0	19491	19491	19491	16550	39050	0	16550	16550
0	19491	19491	19491	19491	16550	0	0	16550	16550
0	19491	19491	19491	19491	16550	16550	0	39050	16550
0	19491	19491	19491	19491	16550	16550	16550	16550	16550
0	19491	19491	19491	19491	16550	16550	16550	16550	16550
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	19491	19491	19491	19491	19491	19491	19491	19491	19491
0	0	19491	19491	19491	19491	19491	19491	19491	19491
0	0	19491	19491	19491	19491	19491	19491	19491	19491

Pagellus erythrinus



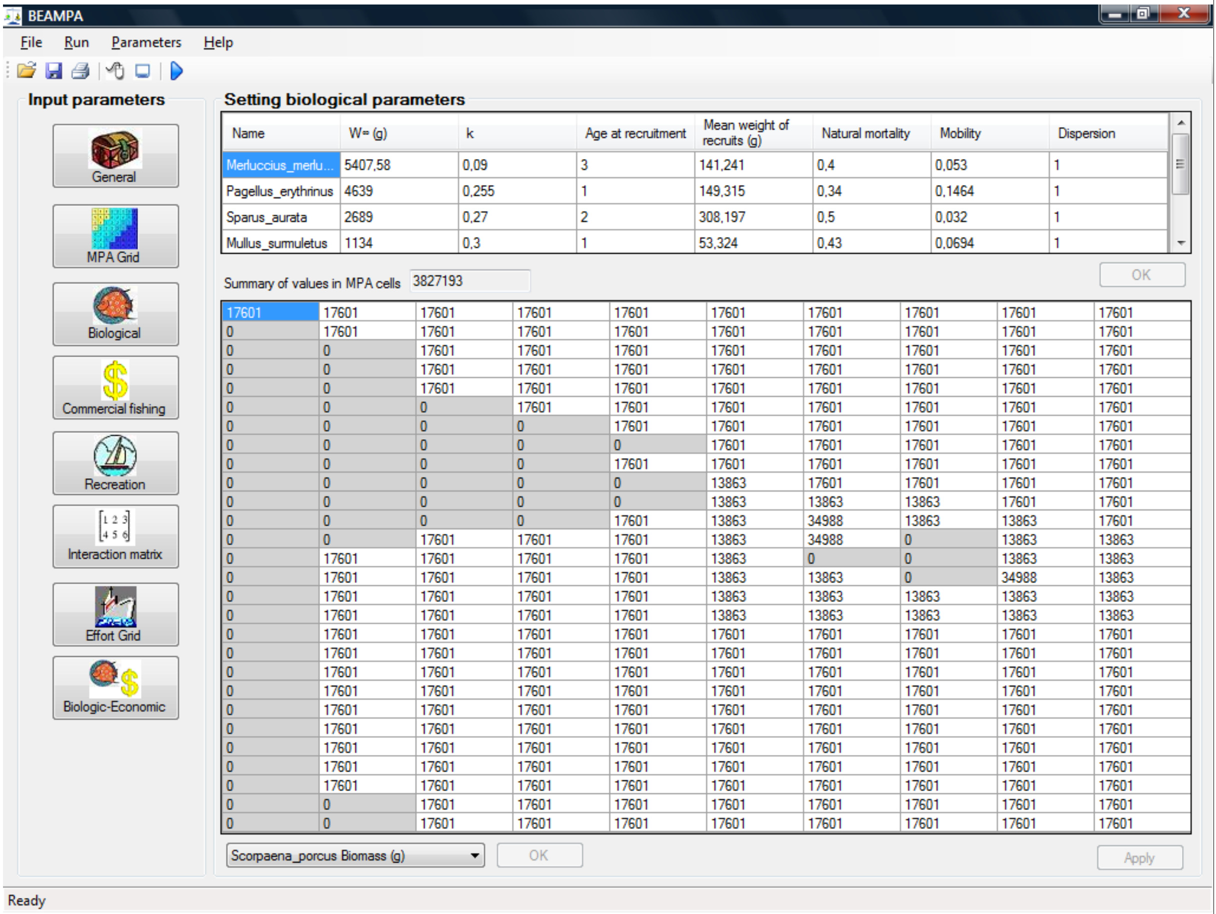
Sparus aurata



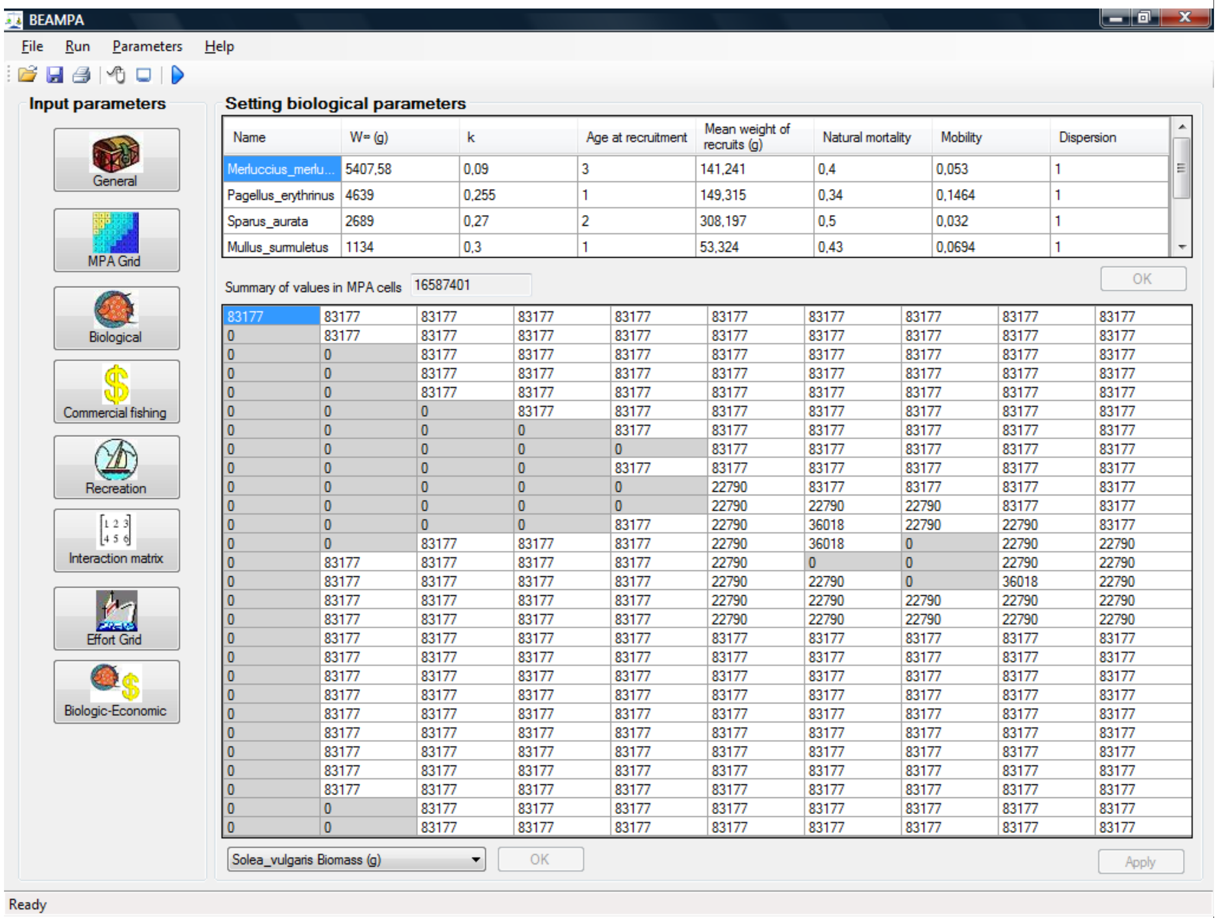
Name	W∞ (g)	k	Age at recruitment	Mean weight of recruits (g)	Natural mortality	Mobility	Dispersion
Merluccius_merlu...	5407,58	0,09	3	141,241	0,4	0,053	1
Pagellus_erythrinus	4639	0,255	1	149,315	0,34	0,1464	1
Sparus_aurata	2689	0,27	2	308,197	0,5	0,032	1
Mullus_surmuletus	1134	0,3	1	53,324	0,43	0,0694	1

9962	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	0	9962	9962	9962	9962	9962	9962	9962	9962
0	0	9962	9962	9962	9962	9962	9962	9962	9962
0	0	9962	9962	9962	9962	9962	9962	9962	9962
0	0	0	9962	9962	9962	9962	9962	9962	9962
0	0	0	0	9962	9962	9962	9962	9962	9962
0	0	0	0	0	9962	9962	9962	9962	9962
0	0	0	0	9962	9962	9962	9962	9962	9962
0	0	0	0	0	9152	9962	9962	9962	9962
0	0	0	0	0	9152	9152	9152	9962	9962
0	0	0	0	9962	9152	4824	9152	9152	9962
0	0	9962	9962	9962	9152	4824	0	9152	9152
0	9962	9962	9962	9962	9152	0	0	9152	9152
0	9962	9962	9962	9962	9152	9152	0	4824	9152
0	9962	9962	9962	9962	9152	9152	9152	9152	9152
0	9962	9962	9962	9962	9152	9152	9152	9152	9152
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	9962	9962	9962	9962	9962	9962	9962	9962	9962
0	0	9962	9962	9962	9962	9962	9962	9962	9962
0	0	9962	9962	9962	9962	9962	9962	9962	9962

Mullus surmuletus



Scorpaena porcus

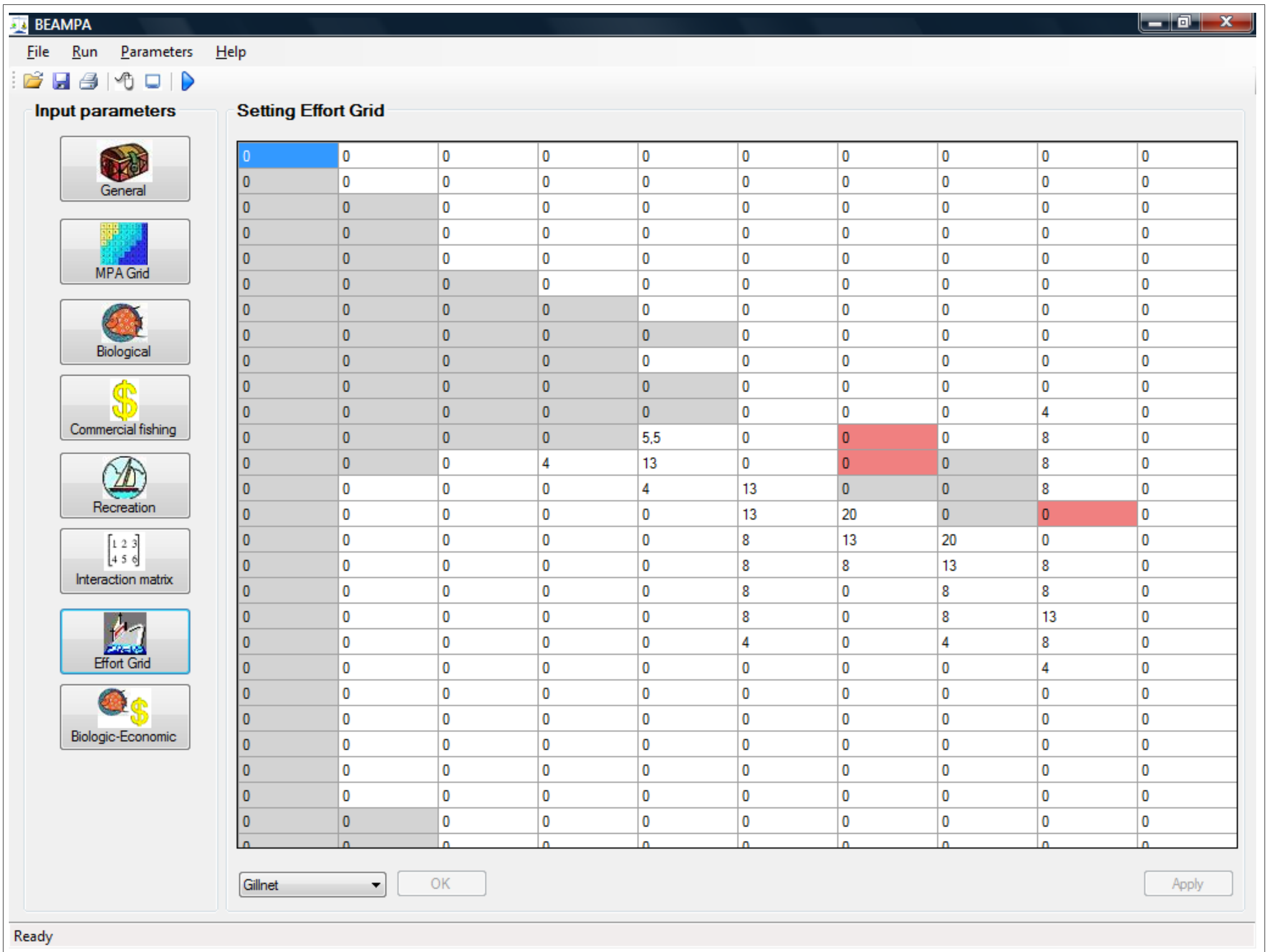


Solea vulgaris

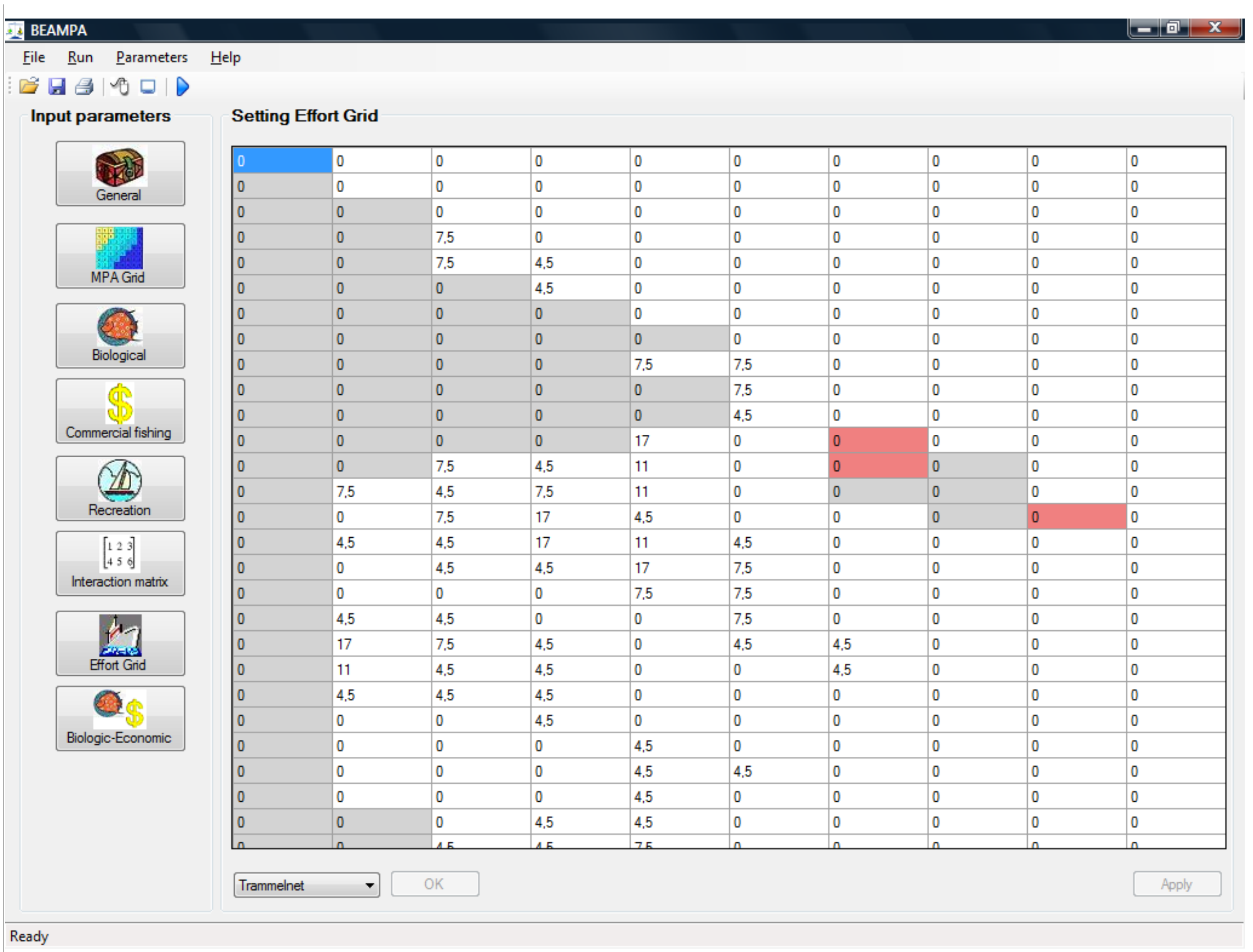
Fig. 6. Spatial distribution of total biomass per cell

3.1.4 Fishing effort

The effort of the trammel net and gillnet fleets was allocated per cell following a GIS analysis of the fishing effort during the sample programme and averaged for the 2003-2005 period, following the protocol in WP2 of EMPAFISH (Stelzenmüller et al., 2007). The resulting maps are shown in Fig. 7.



Effort distribution of gillnet



0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	7,5	0	0	0	0	0	0	0
0	0	7,5	4,5	0	0	0	0	0	0
0	0	0	4,5	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	7,5	7,5	0	0	0	0
0	0	0	0	0	7,5	0	0	0	0
0	0	0	0	0	4,5	0	0	0	0
0	0	0	0	17	0	0	0	0	0
0	0	7,5	4,5	11	0	0	0	0	0
0	7,5	4,5	7,5	11	0	0	0	0	0
0	0	7,5	17	4,5	0	0	0	0	0
0	4,5	4,5	17	11	4,5	0	0	0	0
0	0	4,5	4,5	17	7,5	0	0	0	0
0	0	0	0	7,5	7,5	0	0	0	0
0	4,5	4,5	0	0	7,5	0	0	0	0
0	17	7,5	4,5	0	4,5	4,5	0	0	0
0	11	4,5	4,5	0	0	4,5	0	0	0
0	4,5	4,5	4,5	0	0	0	0	0	0
0	0	0	4,5	0	0	0	0	0	0
0	0	0	0	4,5	0	0	0	0	0
0	0	0	0	4,5	4,5	0	0	0	0
0	0	0	0	4,5	0	0	0	0	0
0	0	0	4,5	4,5	0	0	0	0	0
0	0	4,5	4,5	7,5	0	0	0	0	0

Effort distribution of trammelnet

Fig. 7. Effort distribution of gillnet and trammelnet in number of fishing trips to each cell per year, averaged over the 2003-2005 study period. Total effort was 251.5 and 281 fishing trips per year for gillnetters and trammel netters respectively.

3.1.5 Economic parameters of the commercial fleets

The economic parameters of the two fleets are given in Tables 5 and 6.

	Gillnet	Trammelnet
Comm tax	0	0
fuel (€/d)	39.76	24.93
ice (€/d)	9.15	7.87
ODC (€/d)	32.21	22.57
share	0.5	0.5
NHD	12	12
NFD	251,5	381
Compulsory costs (€/yr)	4200	4400
Maintenance costs (€/yr)	5000	5550
effort proportion	1	1
crew size	1	1
capital (€)	95000	102000
Secondary species catches (kg)	2500	2300
Secondary species Price (€/kg)	20	25

Table 5: Economic parameters of the gillnet and trammel net fleets

	Gillnet	Trammel net
Merluccius merluccius	8.40	-
Pagellus erythrinus	9.72	-
Sparus aurata	19.05	-
Mullus surmuletus	-	9.97
Scorpaena porcus	-	20.40
Solea vulgaris	-	27.92

Table 6: Average prices (€/kg) of the target species of the gillnet and trammel net fleets

3.1.6 Fishing mortality

The fishing mortality exterted by each fleet on each target species was obtained from the Virtual Population Analysis and is shown in Table 7.

	Gillnet	Trammel net
Merluccius merluccius	0.682	-
Pagellus erythrinus	0.206	-
Sparus aurata	0.457	-
Mullus surmuletus	-	0.455
Scorpaena porcus	-	0.091
Solea vulgaris	-	0.049

Table 7: Fishing mortality of the target species for the gillnet and trammel net fleets

3.1.7 Recreational activities

The parameters of the recreational activities were computed from the field survey data (WP3, Alban et al., 2007) for the two main recreational activities in Medes Islands Marine Protected Area (glass-bottom boat tours and SCUBA diving). These parameters are summarized in Tables 8 and 9. The data for producers were aggregated to the level of two notional companies, one offering SCUBA diving activities ("Diving clubs") and the other offering glass-bottom boat tours ("Glass-bottom boats") because not all operators provided sufficient data to treat the them individually in the model.

	Glass- Bottom Boats	Scuba Diving
Quality of recreational activity (□)	1	1
Importance of ecosystem quality (□)	2	2
Importance of non-congestion (□)	1	1
Max. number of users	200000	65000
Frequentation	155000	61295
Average budget (€)	50	1100
Average unit price (€)	15	30

Table 8: Parameters of the consumers for the main recreational activities offered in Medes Islands MPA.

Name	Diving Clubs	Glass- Bottom Boats
Commercial tax	0.16	0.16
Daily cost of fuel (€/day)	1700	2400
Daily cost of labour (€/day)	1000	2000
Other daily costs (€/day)	500	300
Operating days (€/yr)	200	100
Compulsory costs (€/yr)	6000	4000
Maintenance costs (€/yr)	1800	2200
Capital (€)	2000000	1500000
Main activity	Scuba Diving	Glass-bottom tours

Table 9: Parameters of the producers for the main recreational activities offered in Medes Islands MPA

3.1.8 Specifications of Scenario 0

With the parameters given in the previous sections a base scenario ("Scenario 0") was set up and projected for 20 years. This simulation represents the likely evolution of the bio-economic situation of the Medes Islands case study under current management conditions and the following basic assumptions:

- Recruitment of each species is constant and randomly allocated in each cell at the start of the simulation
- Tradition is set to 1, *i.e.* effort is not redistributed in space
- adult biomass of each species is redistributed in space at the end of each iteration according to a density-dependent algorithm, specified in D20, and with the mobility parameters estimated above

- commercial fishing in the buffer area does not impact on the quality of habitat and, consequently there is no interaction between commercial fishing and recreational activities.

Alternative scenarios will be considered below (sections 4 and 5). To analyze the evolution of Scenario 0 the main indicators used will be: Total biomass of the target species; costs, revenues and profits of the 2 fleets; catches of the target species by the 2 fleets.

3.1.9 Results of Scenario 0

Fig. 8 shows the trajectories of biomass for each of the 6 target species in the model MPA, by zone and total. Under current exploitation conditions, an increase of biomass for the 6 species is expected because they are generally not heavily exploited (cf. Fig. 5). This result should be interpreted under the assumptions of constant fishing effort and catchability, which are likely, given the fisheries regime prevalent in the case study MPA (cf. 3.1), but also under the assumptions of constant recruitment implicit in Scenario 0. Depending on the life span and growth rate of each species, it is expected that between years 10 and 15 of the simulation all species will reach their carrying capacity level, which is 2 to 4 times the current levels of biomass (Table 10). Table 10 shows also the values of biomass for each species at years 0, 5 (shot-term) and 20 (long-term) of the simulation. It can be seen how most of the biomass increase is achieved during the first 5 years of the simulation (short-term) and that biomass increase is higher in the NTZ for all species, and usually lower in the Buffer zone. The relatively lower biomass increase in the Buffer zone can be explained in part by the concentration of fishing effort in this zone (cf. fig. 7). It should be noted also how the NTZ and Buffer zone comprise a small part of the total biomass for each species (10-15% at year 0), due to the small size of the protected zones.

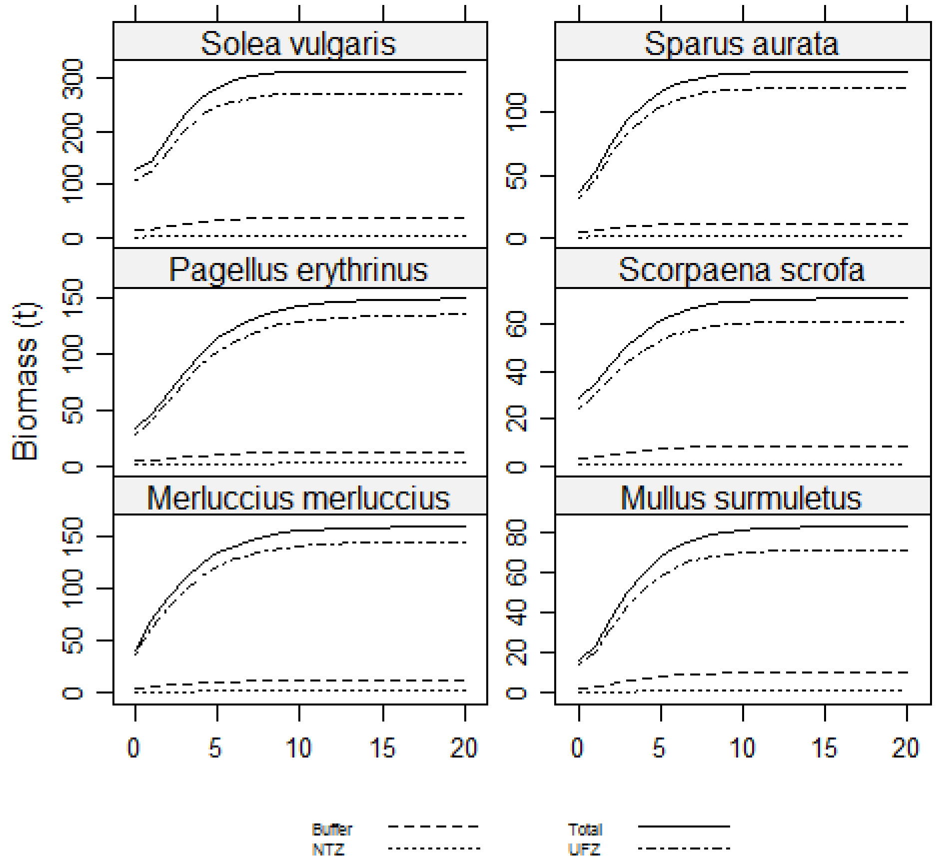


Fig. 8. Trajectories of biomass for the 6 selected species under Scenario 0 in each of the 3 spatial zones considered in the model (NTZ: No Take Zone; Buffer: Buffer zone; UFZ: unrestricted fishing zone) and total biomass over the entire model MPA.

	zone	*year 0*	*year 5*		*year 20*	
		t	*t*	*%*	*t*	*%*
Merluccius merluccius	*NTZ*	*0.573*	*2.130*	*372%*	*2.416*	*422%*
	Buffer	*4.965*	*10.501*	*211%*	*12.201*	*246%*
	UFZ	*36.474*	*121.960*	*334%*	*145.423*	*399%*
	Total	*42.012*	*134.590*	*320%*	*160.040*	*381%*
Pagellus erythrinus	*NTZ*	*0.451*	*1.851*	*410%*	*2.158*	*478%*
	Buffer	*3.911*	*9.746*	*249%*	*12.160*	*311%*

	UFZ	*28.732*	*102.051*	*355%*	*135.148*	*470%*
	Total	*33.094*	*113.647*	*343%*	*149.466*	*452%*
Sparus aurata	*NTZ*	*0.498*	*1.754*	*352%*	*1.967*	*395%*
	Buffer	*4.317*	*10.225*	*237%*	*11.405*	*264%*
	UFZ	*31.716*	*104.582*	*330%*	*119.831*	*378%*
	Total	*36.532*	*116.561*	*319%*	*133.203*	*365%*
Mullus surmuletus	*NTZ*	*0.219*	*1.028*	*470%*	*1.356*	*620%*
	Buffer	*1.896*	*8.250*	*435%*	*10.299*	*543%*
	UFZ	*13.927*	*58.401*	*419%*	*71.030*	*510%*
	Total	*16.042*	*67.680*	*422%*	*82.686*	*515%*
Scorpaena porcus	*NTZ*	*0.389*	*0.860*	*221%*	*0.997*	*256%*
	Buffer	*3.372*	*7.371*	*219%*	*8.512*	*252%*
	UFZ	*24.773*	*53.544*	*216%*	*61.643*	*249%*
	Total	*28.535*	*61.776*	*216%*	*71.153*	*249%*
Solea vulgaris	*NTZ*	*1.726*	*3.903*	*226%*	*4.455*	*258%*
	Buffer	*14.955*	*33.238*	*222%*	*37.038*	*248%*
	UFZ	*109.862*	*245.458*	*223%*	*270.782*	*246%*
	Total	*126.543*	*282.600*	*223%*	*312.276*	*247%*

Table 10: Biomass (t) of each target species at current levels (year 0), and projected short-term (year 5) and long-term (year 20) values, with percentage variation in comparison with current levels.

Fig. 9 shows the trajectories of total costs, revenues and profits for the two fleets in the model MPA. The 3 indicators increase up to year 5, approximately, and stabilize in the medium and long term. The increase in total revenues for the two fleets can be explained by increased catches (Fig. 10) of the target species, while the increasing costs can also be explained by the increased commercialization costs of increased catches. In the long term the profits would stabilize around 110 000 € for gillnet and 100 000 € for trammel net annually, increasing 145% and 171% respectively from current levels (Table 11).

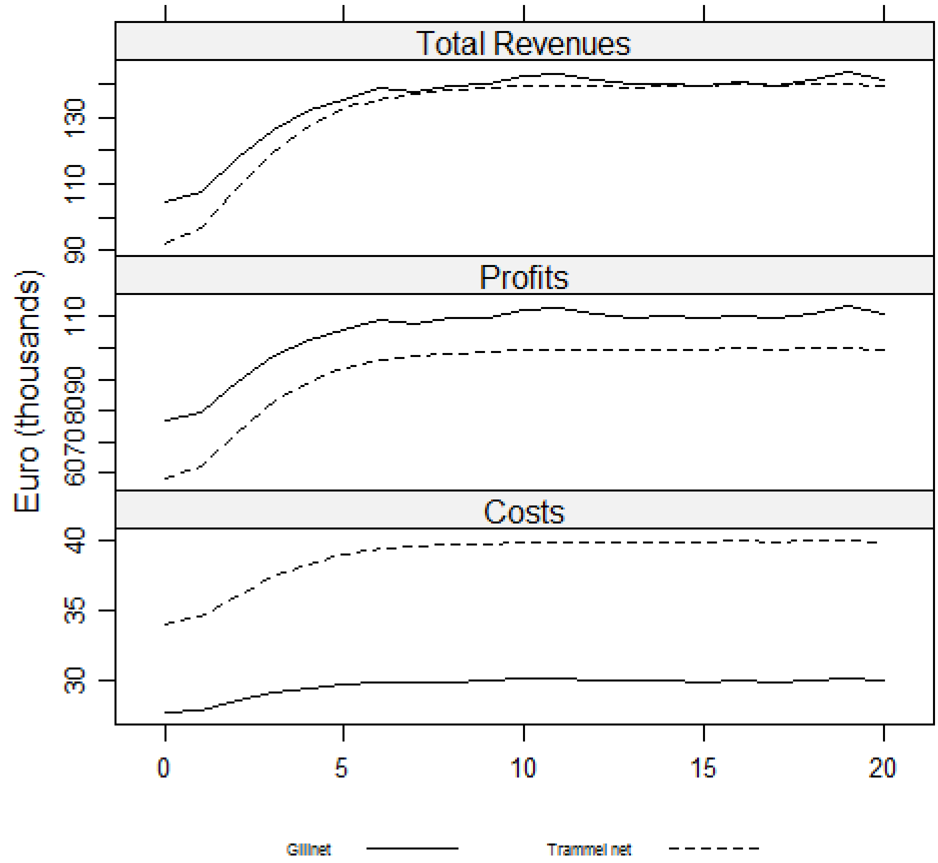


Fig. 9: Trajectories of total costs, total revenues and profits (net revenues) over the entire model MPA for gillnet and trammelnet, under Scenario 0.

	year 0	*year 5*		*year 20*	
	000 €	*000 €*	*%*	*000 €*	*%*
Total costs for Gillnet	*27.616*	*29.616*	*107%*	*29.984*	*109%*
Total costs for Trammelnet	*33.917*	*39.068*	*115%*	*39.919*	*118%*
Total revenues for Gillnet	*104.321*	*135.317*	*130%*	*141.031*	*135%*
Total revenues for Trammelnet	*92.163*	*132.810*	*144%*	*139.531*	*151%*
Profits for Gillnet	*76.705*	*105.702*	*138%*	*111.046*	*145%*
Profits for Trammelnet	*58.246*	*93.743*	*161%*	*99.611*	*171%*

Table 11: Costs, revenues and profits (000 €) of each fleet at current levels (year 0), and projected short-term (year 5) and long-term (year 20) values, with percentage variation in comparison with current levels.

Considering the increase in biomass predicted by the model (Fig. 8) and the low level of exploitation of the 6 target species, the increase in catches observed in Fig. 10 is not unexpected. Table 12 shows that predicted catches would increase rapidly in the short term (5 years) and then stabilize at 2-3 times the current levels, except for *Merluccius merluccius*.

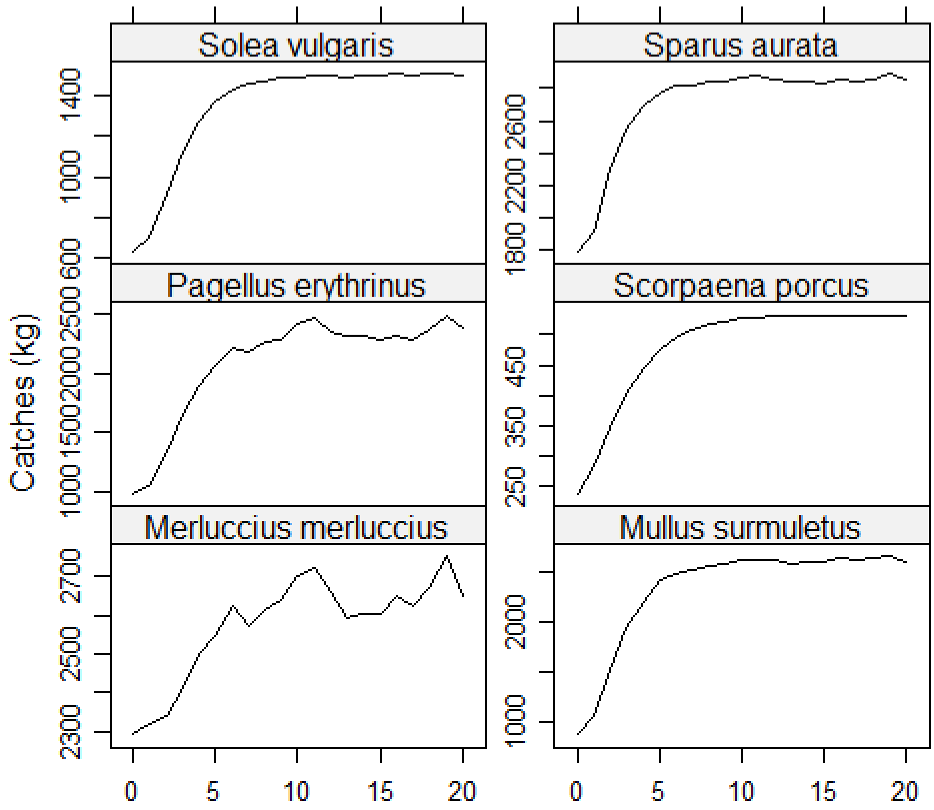


Fig. 10: Trajectories of the catches of the 6 target species over the entire model MPA, under Scenario 0.

	year 0	*year 5*		*year 20*	
	kg	*kg*	*%*	*kg*	*%*
Merluccius merluccius	*2292*	*2547*	*111%*	*2650*	*116%*
Pagellus erythrinus	*994*	*2056*	*207%*	*2379*	*239%*
Sparus aurata	*1791*	*2764*	*154%*	*2853*	*159%*
Mullus surmuletus	*884*	*2402*	*272%*	*2598*	*294%*
Scorpaena porcus	*239*	*474*	*198%*	*532*	*222%*
Solea vulgaris	*632*	*1374*	*217%*	*1503*	*238%*

Table 12: Catches (kg) of each target species at current levels (year 0), and projected short-term (year 5) and long-term (year 20) values, with percentage variation in comparison with current levels. *M. merluccius*, *P. erythrinus* and *S. aurata* are target species of fleet gillnet and *M. surmuletus*, *S. porcus* and *S. vulgaris* are target species of fleet trammelnet.

In summary, scenario 0, based on the projection of current bioeconomic conditions over a 20 year simulation horizon, allows to predict increasing biomass and economic benefits to the fishery even with the relatively small current protection configuration. These economic benefits to the fishery would result mainly from relatively sedentary species such as *Pagellus erythrinus*, *Mullus surmuletus* or *Solea vulgaris* which benefit from protection (see also Stelzenmüller et al., 2007).

The economic results for the recreational activities are summarized in Table 13. Considering that there is no feedback in Scenario 0 between commercial and recreational activities, the model output for the simulation horizon is constant.

	Operators of glass-bottom boats (€)	*Operators of SCUBA Diving (€)*
Revenues	*2,325,000*	*1,838,850*
Commercial costs	*372,000*	*294,216*
Daily costs	*470,000*	*640,000*
Fixed costs	*4,000*	*6,000*
Maintenance costs	*2,200*	*1,800*
Opportunity costs	*75,000*	*100,000*
Profits	*1,838,850*	*796,834*

Table 13: summary of the revenues, costs and profits of the 2 recreational activities considered in the model MPA. See Tables 8 and 9 for parameters.

4 *Cost-Benefit Analysis*

Considering the limited data available on costs and benefits of the case-study MPAs presented to EMPAFISH a fully developed Cost-Benefit Analysis cannot be performed. As a surrogate, we will consider the institutional costs of protection as costs and the profits of the commercial fishery as benefits. The institutional costs of protection were obtained during the economic field sampling of WP3.

The rationale of the analysis is the following:

1) compute the profits of commercial fisheries in the current situation (Scenario 0),
2) compute the profits of commercial fisheries in the absence of protection (Scenario 1),
3) the difference can be accounted for by the benefits of protection and deducted from the institutional costs of protection.

The variation in benefits due to non-extractive uses is considered under Scenario 2, by assuming that removing protection will impact negatively on ecosystem quality and therefore on the perception of the quality of the activity by recreational users.

4.1 The CBA in Medes islands MPA

The institutional costs of ensuring protection[5] in Medes Islands MPA are the following:

Management	**Nb of employees**	**4 (2.5 FTE[6])**
Enforcement	**Nb of employees**	**8 (4 FTE)**
Annual costs	**Labour**	**156 496 €**
	Running costs	**240 112 €**
	Total costs	**396 608 €**

Table 14: Institutional costs of protection in Medes Islands MPA.

It should be noted that this MPA is largely self-funded because it receives 3 € and 1.5 € as taxes from each individual dive and glass-bottom boat trip. Given the frequentation observed in 2005 (61 295 dives and 155 000 customers of glass-bottom boats), the amount perceived in taxes (183 885 € + 232 500 € = 416 385 €) covers institutional costs.

4.1.1 Scenario 1 – removing protection

Scenario 1 was constructed by removing all NTZ and Buffer cells from the model MPA (cf. Fig. 2) and allowing for a tradition coefficient of 0.5. This means that half of the effort in each cell can be randomly reallocated by the model to neighboring

[5] Note that these costs do not include the initial costs of setting up protection because this MPA is long-established (1983).
[6] FTE: Full-Time Equivalent

cells, based on their perceived profitability. Additional assumptions of Scenario1 are constant recruitment and constant input of revenues from secondary species, as in Scenario 0.
The projection of the 3 economic indicators (costs, revenues and profits of the commercial fleets) is shown in Fig. 11 in comparison with the same indicators for Scenario 0. Apparently, the benefits of protection are small, based on the profits of the commercial fishery (Table 15). In the absence of protection, profits would be 1% smaller than with the current configuration for both fleets at years 0 and 5; and up to 3% smaller for gillnets in the long term (year 20). Assuming that the costs of protection (396 608 €) do not increase with time, institutional costs would still be higher than the profits to the fishery under both Scenarios 0 and 1 in year 20 (net institutional cost of *ca.* 200 000 €). Naturally, this cost has to be reconsidered in terms of the other activities (non-extractive SCUBA diving and glass bottom boats) which produce profits of 1 magnitude higher than commercial fisheries (*ca.* 800 000 € and 1 400 000 €, respectively for SCUBA diving and glass-bottom boats, Table 13) and which ensure self-funding of the MPA. Catches (Fig. 12) would increase for the 3 species targeted by gillnet (*M. merluccius*, *P. erythrinus* and *S. aurata*) because the model allocates part of the effort to cells with higher biomass of these species. However, in the long-term (year 20) catches of these 3 species would be very similar to the catches predicted in Scenario 0. Catches of the 3 species targeted by trammel net (*M. surmuletus*, *S. porcus* and *S. vulgaris*) are expected to decrease after year 5, approximately, although to a level that is still higher than the level at year 0.

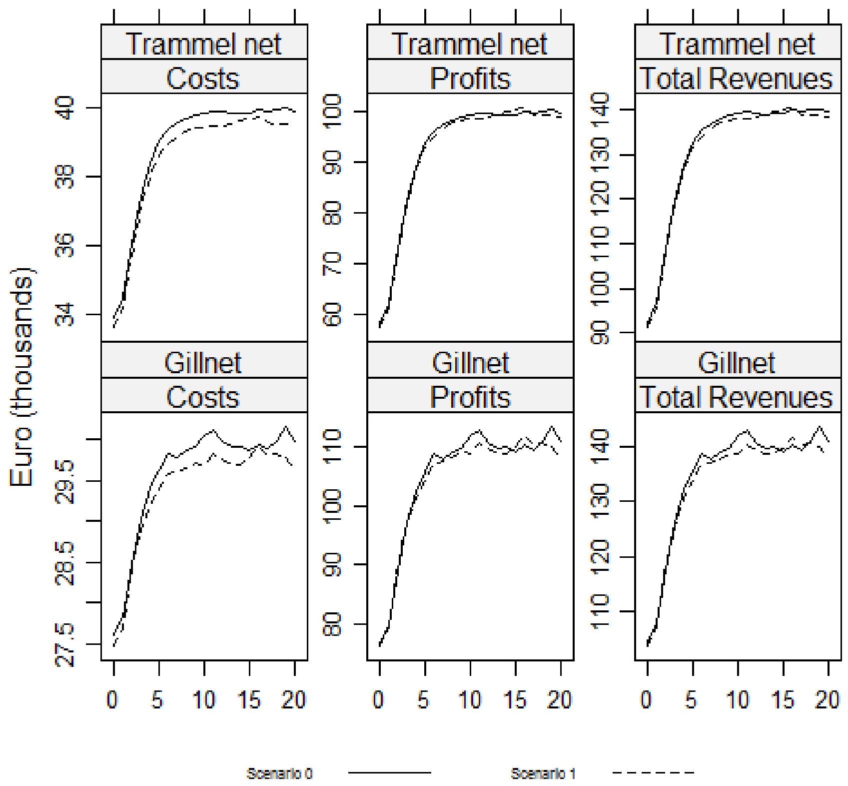


Fig. 11: Trajectories of total costs, total revenues and profits (net revenues) over the entire model MPA for gillnet and trammelnet, under Scenarios 0 and 1.

	year 0	*year 5*		*year 20*	
	(000 €)	*(000 €)*	*%*	*(000 €)*	*%*
Scenario 1					
Profits gillnet	*76*	*104*	*137%*	*108*	*142%*
Profits trammelnet	*58*	*93*	*161%*	*99*	*172%*
% over Scenario 0					
gillnet	*99%*	*99%*		*97%*	
trammelnet	*99%*	*99%*		*99%*	

Table 15: Comparison of profits by the two fleets at times 0, 5 and 20 yr of the simulation between Scenario 0 (current configuration) and Scenario 1 (removing protection).

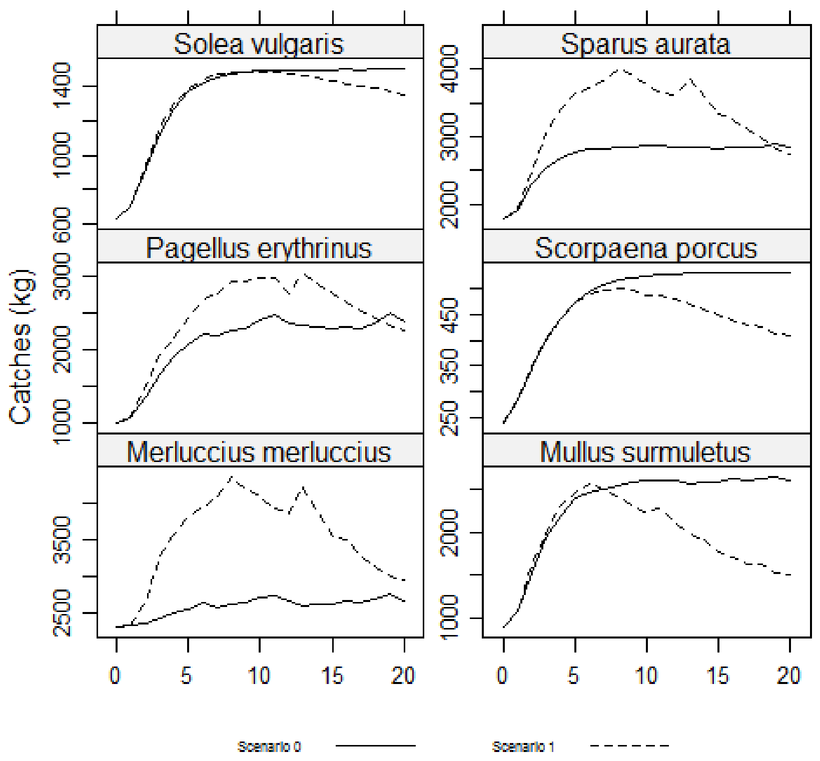


Fig. 12: Trajectories of the catches of the 6 target species over the entire model MPA, comparing Scenarios 0 and 1.

4.1.2 Scenario 2 – effects of habitat quality on recreational activities

To assess the impact of habitat quality on recreational activities, the model of frequentation in D20 was parameterized using the socio-economic data for SCUBA diving in Medes Islands MPA. The absence of data on user perception for the glass-bottom activity precluded further analysis. For SCUBA diving habitat quality was computed by assigning arbitrary values of 0 (offshore sandy bottoms), 1 (sandy bottoms near the MPA) and 2 (rocky bottoms around the MPA), based on the observation that divers rank rocky bottoms around the MPA as more desirable for diving. The average quality of the NTZ and Buffer zone, where organized SCUBA diving takes place, was 0.7091. Further, based on the responses of SCUBA diving users to the socio-economic questionnaires we estimated that for the current frequentation of 61 295 divers annually (2005) the parameter □ (quality of dive) is 1 and the parameter □ (importance of ecosystem quality) is 2, disregarding □ (importance of non-congestion, which apparently is not relevant for divers in Medes Islands). Under these conditions (current conditions of Scenario 0), the net profits of the organized diving activity would be 796 834 € (Table 16). The effects of decreasing the habitat quality by removing all protection are shown in Fig. 13 and summarized in Table 16: a reduction of habitat quality to 0.3 (42% of current value) would considerably reduce the frequentation and decrease profits to SCUBA diving operators to 52% of current profits.

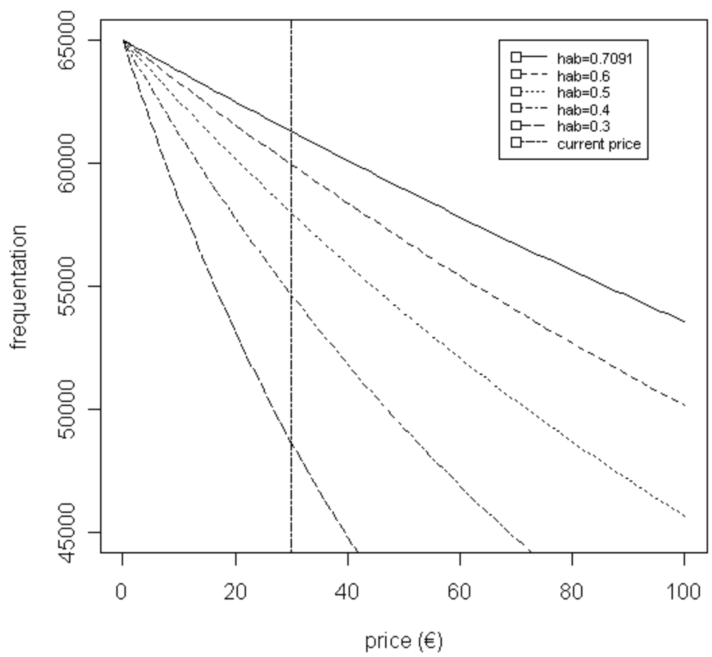


Fig. 13. Response of the recreational demand model for SCUBA divers (frequentation) with changing habitat quality. Current habitat quality is 0.7091 (continuous line) and the effect of progressive decrease is habitat quality is shown by broken lines. Carrying capacity (maximum annual permitted dives) is 65 000.

habitat quality	*number of dives*	*revenues (€)*	*% of current frequentation*	*profits (€)*[7]
0.7091	*61,295*	*1,838,850*	*100*	*796,834*
0.6	*59,943*	*1,798,290*	*97.8*	*762,490*
0.5	*57,964*	*1,738,920*	*94.6*	*703,120*
0.4	*54,651*	*1,639,530*	*89.2*	*603,730*
0.3	*48,663*	*1,459,890*	*79.4*	*424,090*

Table 16: Simulation of negative impact of commercial fishing on habitat quality and resulting decrease in frequentation and profits to operators of SCUBA diving clubs

[7] see Tables 8 and 9 for costs

5 Alternative management strategies

The bioeconomic model BEAMPA allows to evaluate alternative management strategies by changing the parameters or the configuration of the MPA. These strategies can be interesting from the scientific point of view, for example to assess the contribution of biomass spillover to fisheries yield, or from the point of view of policy measures, for example to assess the conservation and economic impacts of establishing new protection areas.

5.1 Medes islands MPA

5.1.1 Assessing biomass spillover to fisheries yield (Scenario 3)

In many scientific publications it is shown how establishing a No Take Zone can enhance fisheries yields in adjacent zones by a mechanism known as spillover of adult biomass (e.g. Murawski et al., 2004; other mechanisms such as larval export cannot be approached by the BEAMPA model). To assess to what extent the current configuration of the Medes islands MPA contributes to enhance the fisheries yields in the surrounding area, we built a simulation scenario consisting in eliminating completely fishing effort from the model MPA (Scenario 3). The rationale for this analysis is that in the absence of catches the biomass will buildup in the Buffer zone and the Unrestricted Fishing Zone and the density differences among the 3 zones will cancel in the long run. In the long run also total biomass will be larger than under Scenario 0 (fishery conditions).

As shown in Fig. 14, the trajectories of biomass for the 6 species in the NTZ are very similar for both Scenarios, as can be expected because there was no fishing effort in the base Scenario either. Fig. 15 shows how removing fishing effort from the Buffer zone results in increased biomass for all species, especially those targeted by gillnet and of high mobility (*M. merluccius*, *P. erythrinus* and *S. aurata*). Biomass of the 6 species in the UFZ would also increase, although in lower proportion (Fig. 16). Due to the large extent of the UFZ, the trends in total biomass (Fig. 17) are very similar.
Table 17 summarizes the biomass variations in absolute terms and percentage between Scenarios 0 and 3. For all species (except *S. porcus* with mobility set to 0) the biomass in the NTZ is lower under Scenario 3 than Scenario 0 (up to 16% in the case of *P. erythrinus*). This can be explained by the fact that as fisheries are removed from the adjacent areas, average density will tend to become equal between the NTZ and surrounding cells, by biomass export from the former. In the buffer area, biomass increases under Scenario 3 are important, especially for the highly mobile species: *M. merluccius* would increase by 68% in the short term and 71% in the long term; *P. erythrinus* and *S. aurata* around 50%. Species of low mobility such as *M. surmuletus*, *S. porcus* o *S. vulgaris* show low or moderate (1-10%) increases in the Buffer zone. This result highlights the importance of biomass spillover for fisheries yields in the case of moderately to highly mobile species and also shows how fisheries for species with low mobility obtain little benefit from protection.

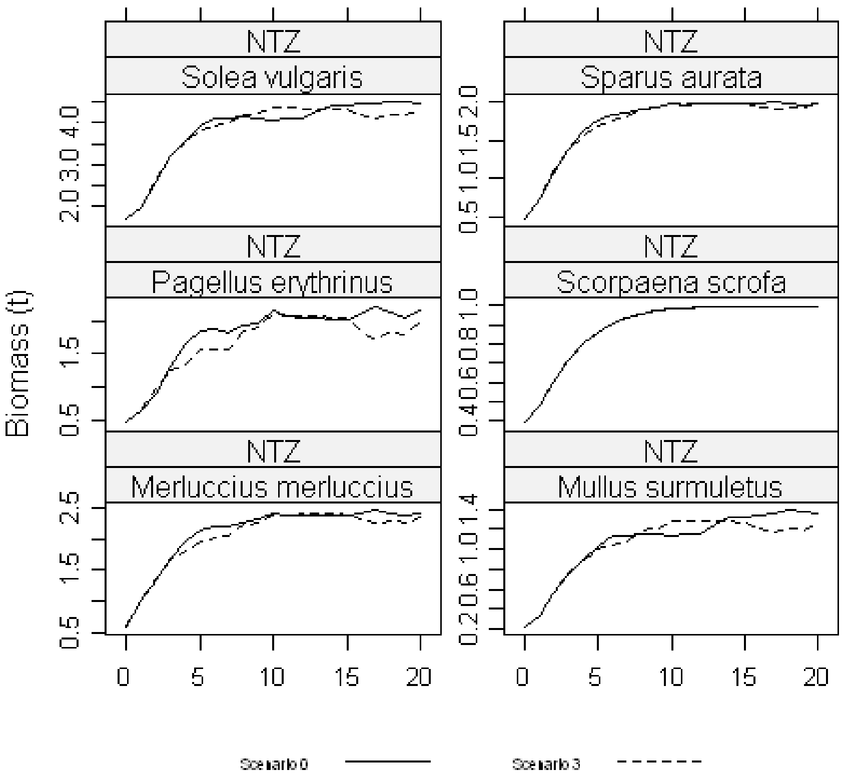


Fig. 14: Trajectories of biomass for the 6 selected species under Scenarios 0 and 3 in NTZ (No Take Zone) of the model MPA.

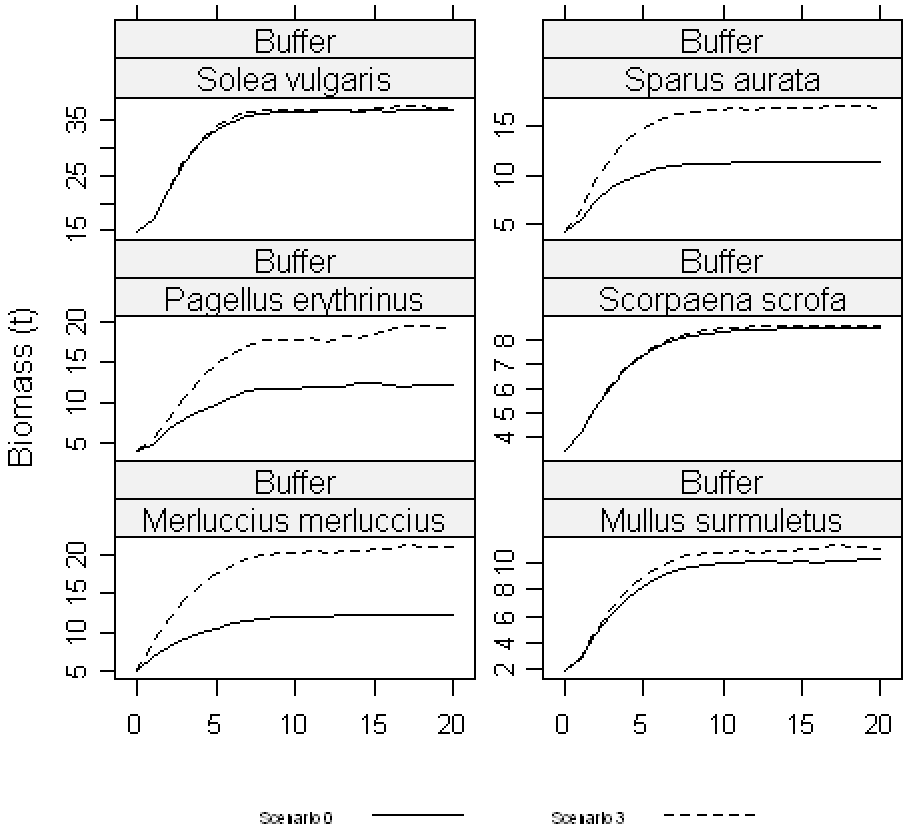


Fig. 15: Trajectories of biomass for the 6 selected species under Scenarios 0 and 3 in the Buffer zone of the model MPA.

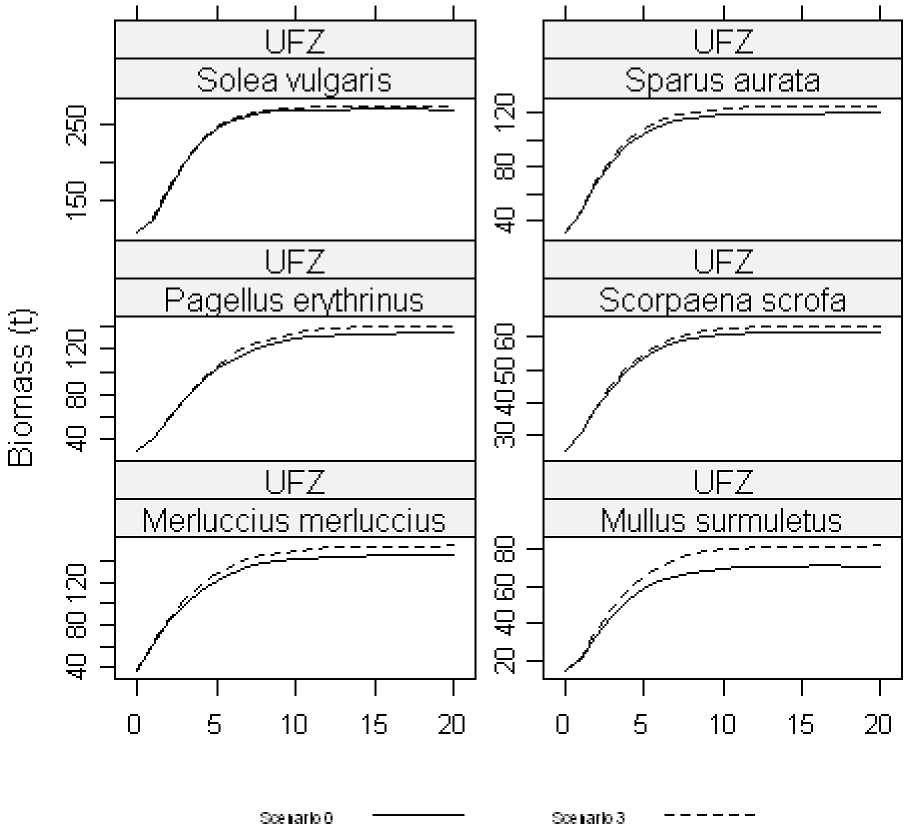


Fig. 16: Trajectories of biomass for the 6 selected species under Scenarios 0 and 3 in UFZ (Unrestricted Fishing Zone) of the model MPA

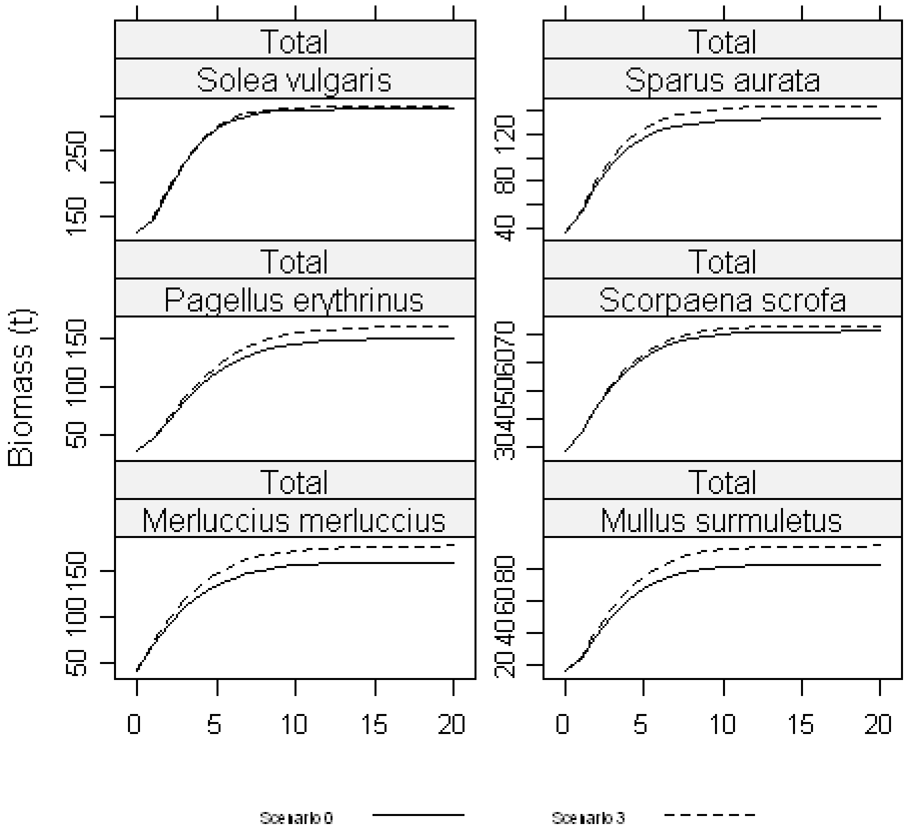


Fig. 17: Trajectories of total biomass for the 6 selected species under Scenarios 0 and 3 in the model MPA

		Biomass (t) year 5			*Biomass (t) year 20*		
		Scenario 0	*Scenario 3*	*%*	*Scenario 0*	*Scenario 3*	*%*
Merluccius merluccius	*NTZ*	*2.130*	*1.974*	*93%*	*2.4159*	*2.345*	*97%*
	Buffer	*10.501*	*17.654*	*168%*	*12.2013*	*20.910*	*171%*
	UFZ	*121.960*	*128.108*	*105%*	*145.4233*	*154.135*	*106%*
	Total	*134.590*	*147.735*	*110%*	*160.0405*	*177.390*	*111%*
Pagellus erythrinus	*NTZ*	*1.851*	*1.557*	*84%*	*2.1579*	*1.992*	*92%*
	Buffer	*9.746*	*14.653*	*150%*	*12.1603*	*18.913*	*156%*
	UFZ	*102.051*	*105.052*	*103%*	*135.1481*	*141.107*	*104%*
	Total	*113.647*	*121.263*	*107%*	*149.4664*	*162.012*	*108%*

Sparus aurata	*NTZ*	*1.754*	*1.686*	*96%*	*1.9671*	*1.947*	*99%*
	Buffer	*10.225*	*14.856*	*145%*	*11.4055*	*16.993*	*149%*
	UFZ	*104.582*	*108.462*	*104%*	*119.8306*	*125.045*	*104%*
	Total	*116.561*	*125.005*	*107%*	*133.2031*	*143.985*	*108%*
Mullus surmuletus	*NTZ*	*1.028*	*1.001*	*97%*	*1.3558*	*1.249*	*92%*
	Buffer	*8.250*	*9.027*	*109%*	*10.2994*	*11.108*	*108%*
	UFZ	*58.401*	*65.418*	*112%*	*71.0305*	*81.987*	*115%*
	Total	*67.680*	*75.447*	*111%*	*82.6857*	*94.344*	*114%*
Scorpaena porcus	*NTZ*	*0.860*	*0.860*	*100%*	*0.9967*	*0.997*	*100%*
	Buffer	*7.371*	*7.455*	*101%*	*8.5125*	*8.638*	*101%*
	UFZ	*53.544*	*54.768*	*102%*	*61.6433*	*63.460*	*103%*
	Total	*61.776*	*63.083*	*102%*	*71.1525*	*73.095*	*103%*
Solea vulgaris	*NTZ*	*3.903*	*3.840*	*98%*	*4.4551*	*4.277*	*96%*
	Buffer	*33.238*	*34.016*	*102%*	*37.0382*	*37.321*	*101%*
	UFZ	*245.458*	*247.883*	*101%*	*270.7823*	*274.863*	*102%*
	Total	*282.600*	*285.739*	*101%*	*312.2756*	*316.461*	*101%*

Table 17: Comparison of the trajectories of biomass for the 6 target species under Scenarios 0 (fishery conditions) and 3 (removal of fishery), for each zone in the short term (5 yr) and long-term.

5.1.2 Change of MPA configuration (Scenario 4)

A simulation scenario (Scenario 4), considering an enlargement of the protected area to the adjacent coast of Montgrí currently envisaged by the Department of Environment of Catalonia's Autonomous Government, was set up by adding 12 new NTZ cells and 8 new Buffer cells representing the likely projected enlargement of Medes islands MPA (Fig. 18). In addition to the assumptions specified in Scenario 0, this Scenario assumes that the fisheries regime in the new NTZ and Buffer cells will be the same as in the current configuration, *i.e.* no fishing in NTZ cells and artisanal fishing in Buffer cells. In practice Scenario 4 will represent a removal of 51 annual effort units for trammel net in the newly protected area, because gillnets do not usually operate on the Montgrí coast. These 51 effort units are allowed to reallocate in the model MPA by setting the Tradition parameter to 0.5, so that the total effort applied by trammel net does not decrease over the entire model MPA.

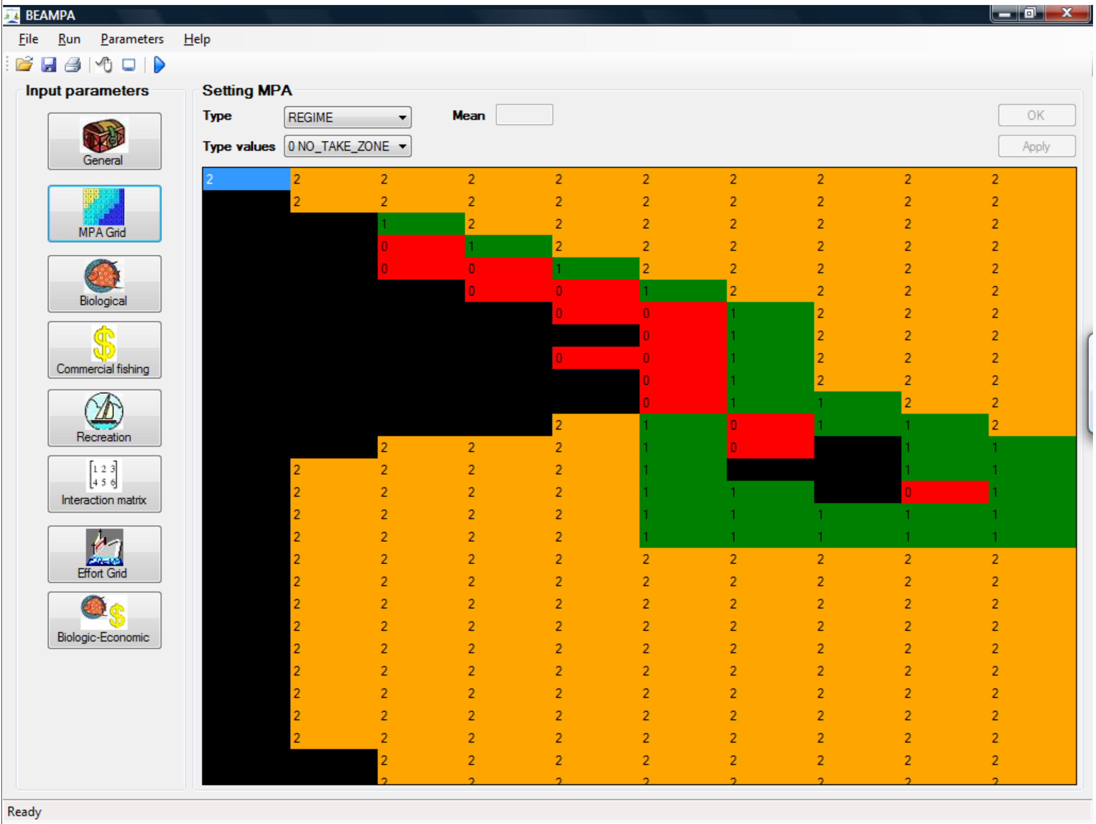


Fig. 18: Model MPA showing the projected enlargement of Medes islands MPA by the Autonomous government.

As shown in Fig. 19, the new MPA layout would represent moderate losses of catches for trammel net only, especially from *M. surmuletus* (13 % at year 20, table 18), and to a lesser extent from *S. porcus* and *S. vulgaris* (3 % at year 20, table 18). This loss in catches would represent 5% of lost profits from the trammel net fishery (table 19) or *ca.* 5 000 € annually. However, considering the institutional costs of implementing and running the MPA the costs to fisheries are negligible. The proposed enlargement would consist in effect of more than doubling the current protection regime in terms of surface and if institutional costs are proportional to surface protected, the added institutional costs would be of the order of 1 million € (cf. section 4.1).

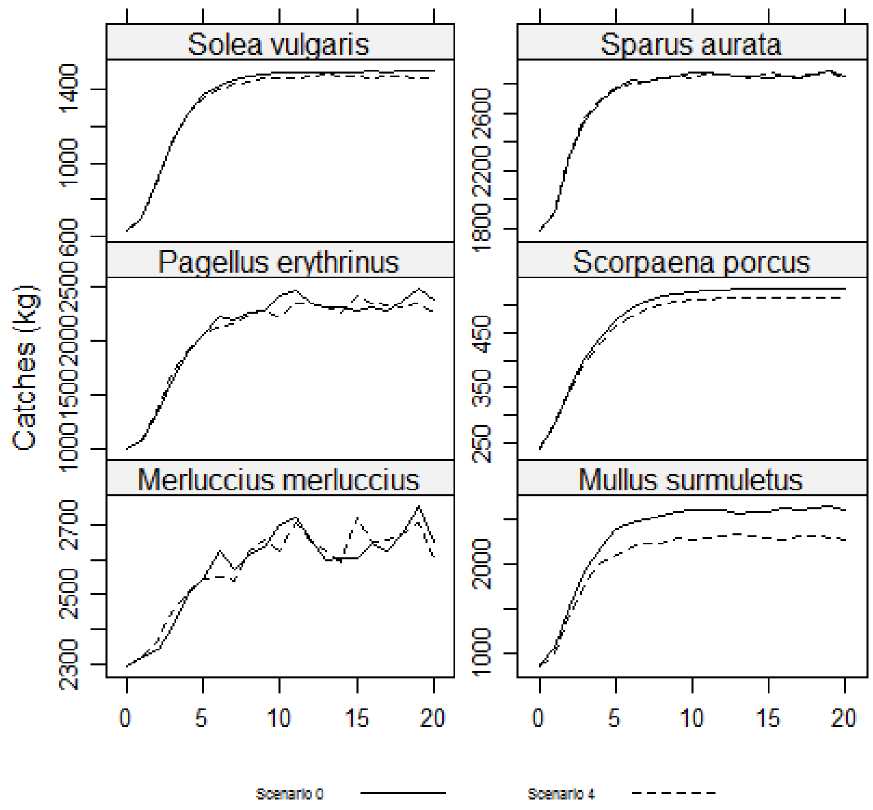
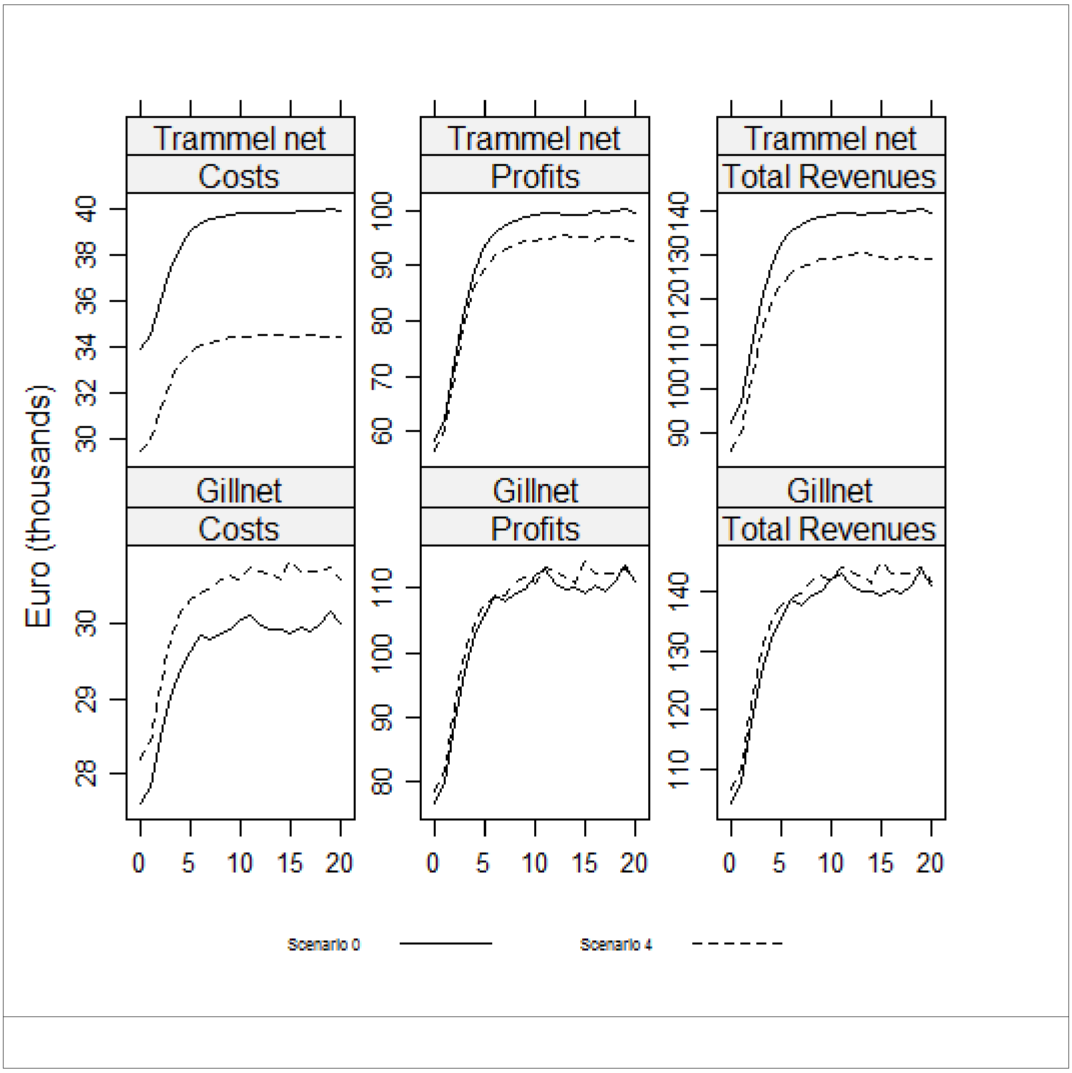


Fig. 19: Trajectories of catches (kg) of the 6 target species for Scenarios 0 and 4 in the model MPA.

	Catches (kg) year 5			*Catches (kg) year 20*		
	Scenario 0	*Scenario 4*	*%*	*Scenario 0*	*Scenario 4*	*%*
Merluccius merluccius	*2547*	*2545*	*100%*	*2650*	*2604*	*98%*
Pagellus erythrinus	*2056*	*2042*	*99%*	*2379*	*2262*	*95%*
Sparus aurata	*2764*	*2768*	*100%*	*2853*	*2835*	*99%*
Mullus surmuletus	*2402*	*2102*	*88%*	*2598*	*2267*	*87%*
Scorpaena porcus	*474*	*462*	*98%*	*532*	*516*	*97%*
Solea vulgaris	*1374*	*1352*	*98%*	*1503*	*1463*	*97%*

Table 18: Comparison of catches for the 6 target species under Scenarios 0 (current conditions) and 4 (enlargement of the protected area), for each zone in the short term (5 yr) and long-term (20 yr).



	(000 €) year 5			*(000 €) year 20*		
	Scenario 0	*Scenario 4*	*%*	*Scenario 0*	*Scenario 4*	*%*
Total costs for Gillnet	*30*	*30*	*102%*	*30*	*31*	*102%*
Total costs for Trammelnet	*39*	*34*	*86%*	*40*	*34*	*86%*
Total revenues for Gillnet	*135*	*138*	*102%*	*141*	*142*	*100%*
Total revenues for Trammelnet	*133*	*123*	*93%*	*140*	*129*	*92%*
Profits for Gillnet	*106*	*107*	*102%*	*111*	*111*	*100%*
Profits for Trammelnet	*94*	*89*	*95%*	*100*	*95*	*95%*

Table 19: Comparison of economic indicators for the 2 fleets under Scenarios 0 (current conditions) and 4 (enlargement of the protected area), for each zone in the short term (5 yr) and long-term (20 yr).

6 Conclusions

With the bioeconomic analysis performed here, based on different scenarios and realistic data obtained from biological and economic field sampling during the EMPAFISH project, we can conclude that in coastal MPAs where the main **extractive use** is small scale artisanal fisheries:

- The protection of a small portion of the coastal area (1% of the area as No Take Zone; 10% of the area as Buffer zone) produces low or barely detectable economic benefits. This is due to two factors: *i)* the relatively low fisheries impact of small scale coastal fishing, which ensures that stocks suffer low fishing pressure, and *ii*) the low spillover, in absolute terms, of biomass from the protected area, due to its small size.
- Fisheries yield in the area immediately adjacent to the no take area benefits from adult biomass spillover for moderately to highly mobile species.
- Due to the low profits, in absolute terms, of commercial fisheries the institutional costs of protection are high if only professional extractive uses are considered. When other non-extractive uses are added, the costs of protection become small, due to the higher economic importance of eco-tourism uses.
- Enlarging the protected area by effectively doubling its size would not impact excessively on the economy of commercial fisheries, but would considerably increase institutional costs of protection.
- The negative impact of commercial fisheries on habitats where ecotourism is a paramount activity can adversely affect recreational activities, both in terms of frequentation and economic profits. Because recreational activities have much higher economic and social relevance than small scale artisanal fisheries, it is recommended to clearly separate the areas where both types of activity take place in order to avoid reciprocal interferences.

7 References:

Alban, F., J. Person, N. Roncin and J. Boncoeur. 2007. Marine Protected Areas Socio-economic data. A review of EMPAFISH field survey results. *EMPAFISH Project, Deliverable nº 22*.

Gayanilo Jr., F. C., P. Sparre and D. Pauly. 2002. FAO-ICLARM Stock Assessment Tools (FiSAT). FAO, Rome.

Hilborn, R. and C. J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York. 570 p.

Lleonart, J. and J. Salat. 1997. VIT: Software for fishery analysis. User's manual. FAO Computerized Information Series (Fisheries). No. 11. Rome, FAO, 105 p.

Maynou, F. and J. Boncoeur. 2007. A bioeconomic model of Marine Protected Areas. *EMPAFISH Project, Deliverable nº 20.*

Planes, S., J. A. García Charton and A. Pérez Ruzafa (coord.). 2006. Ecological effects of Atlanto-Mediterranean Marine Protected Areas in the European Union. *EMPAFISH Project, Deliverable nº 3*.

Murawski, S., P. Rago and M. Fogarty. 2004. Spillover effects from temperate Marine Protected Areas. *Am. Fish. Soc. Symp.*, 42: 167-184.

Schnute, J. T. and L. J. Richards. 2002. Surplus production models. *In:* P. J. B. Hart and J. D. Reynolds (eds.) *Handbook of fish biology and fisheries*, pp. 105-126. Blackwell Publishing.

Stelzenmüller, V., F. Maynou and P. Martín. 2007. Spatial assessment of benefits of a coastal Mediterranean Marine Protected Area. *Biological Conservation*, 136: 571-583.

Vandeperre, F., R. Higgins, R. S. Santos and A. Pérez Ruzafa (coord.). 2006. Fishery regimes in Atlanto-Mediterranean European Marine Protected Areas. *EMPAFISH Project, Deliverable nº 4*.