PLASMAR

Bases para la planificación sostenible de áreas marinas en la Macaronesia

Protocol for the development of Ecopath models in Macaronesia

ACT. 2.3.1

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I. Introduction

To analyze the structure and functioning of the marine ecosystem on Macaronesian region, the software Ecopath with Ecosim will be used. The parameterization to create the ecosystem models is based on satisfying two master equations. The first one describes how the production term for each functional group can be divided: catch (i) + predation (i) + net migration (i) + biomass accumulation (i) + other mortalities (i). The second equation describes the energy balance of each group and is based in the principle of conservation of matter within a group, given by the form: Consumption (Qi) = production (Pi) + respiration (Ri) +unassimilated food (Ui). Each functional group is represented by one balanced equation and four input parameters: biomass, production/biomass (P/B), consumption/biomass (Q/B) and ecotrophic efficiency (EE). Information about catches and diets is also mandatary.

Many variables can be collected through more than one method and in different places. When possible, data should be collected from several sources in order to be able to check for errors. Also, it is important to evaluate the degree of precision of each variable since it is necessary for the construction of the models and will determine if they are valid or not for subsequent publication in scientific journals.

The first requirement when modeling an ecosystem with Ecopath is to establish limits that are consistent with the theoretical basis of the model, that is, with mass balance. Therefore, the total flows within the ecosystem to be modeled must be equal to or greater than those that can exist between that ecosystem and the adjacent ecosystems. This means that it is not only necessary to identify the main species that are found in the marine ecosystem, but also that all the trophic levels must be represented in the chosen study area.

Once we have all the information available from each of the marine ecosystems, we must analyze it to be able to determine the area of study for each of the archipelagos. For this, the following considerations will be taken:

- Within this area must live representative species of all trophic levels. All species included in the model have to live in that area, including ancillary species that are part of the diets of certain species.

- If there are migratory species (turtles, tunas, cetaceans, etc.) should be indicated and the time spent in the study area must be estimated. For this it is necessary to know the number of months per year that reside in that area.

- The study area must include all the areas where fishing is done. To simplify the model it is better to focus on the fishing areas close to the islands.

II. Methodology: obtaining data

1. Canary Islands

1.1 Catches and effort data

It is necessary the construction of a time series with catch data (Fig. 1) obtained from detailed records of first sale. In case of not having this information, available data provided by official organisms (National Institute of Statistics, for example) will be needed. This information is very important since it can also be used as an approximation to abundance for the fishing species. Should also be identified the main fishing gears and the species caught with them. At this point, the best option is to use information already published. In case it was doubtful or incomplete, it will be necessary to conduct surveys (Fig.2). In this case, surveys designed for the Canary Archipelago could be used or adapted if it was necessary.

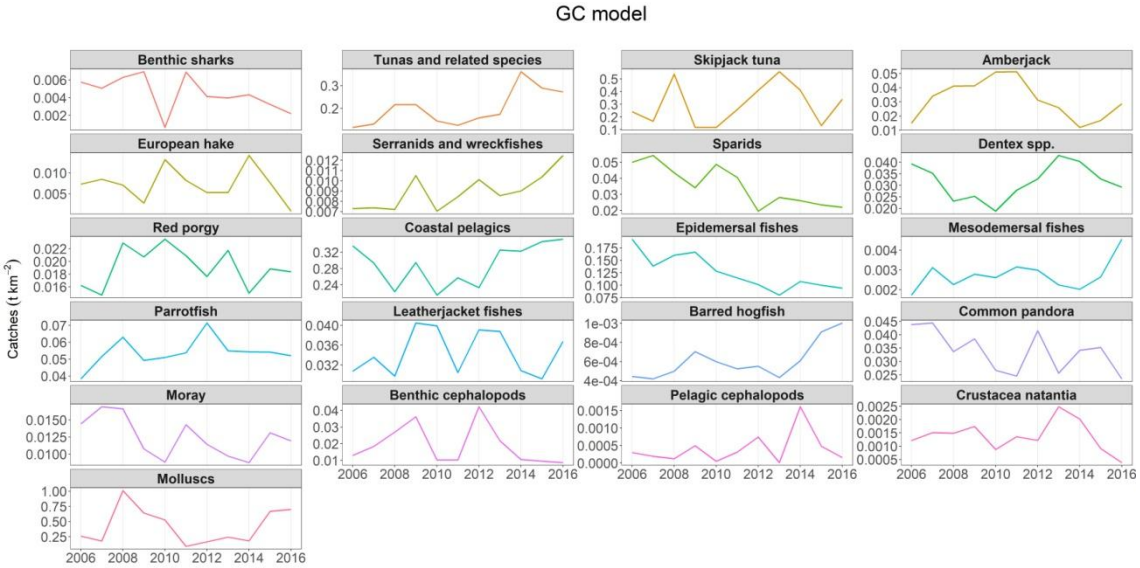


Figure 1. Example of a time series of catches of the main commercially exploited groups on the island of Gran Canaria

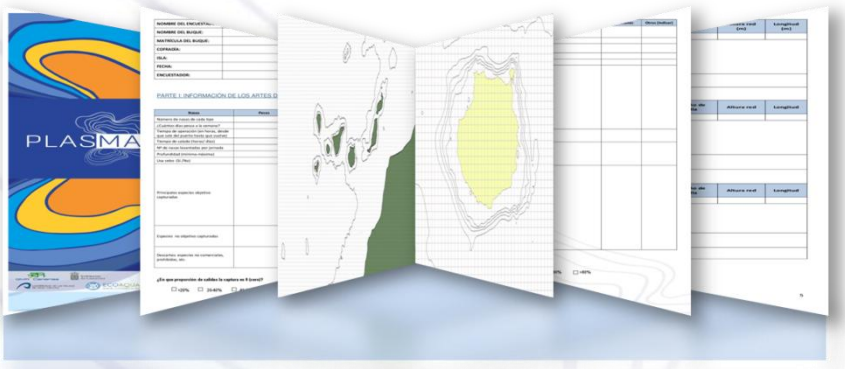


Figure 2. Survey to collect fishing data to fill the gaps.

1.2 Functional groups

Usually comprise multiple species, so to be able to define them properly is necessary information about the habitats, feeding preferences, and other taxonomic similarities. Without carrying out a previous bibliographic review it is difficult, if not impossible, to know which species should be included in the model. In broad terms, and taking as a reference the similarities within the Macaronesia region, the following groups of species have to be represented in the model: marine mammals, elasmobranchs, seabirds, turtles, fish groups (pelagic, benthic, demersal), cephalopods, invertebrate groups (crustaceans, shellfish, urchins, benthos, jellyfish, etc.), zooplankton group (includes gelatinous, small and large zooplankton), primary producers (phytoplankton and algae), and detritus. If exists in the study areas a deep scattering layer (DSL) and the species feed on it, it is necessary to include the DSL as a group in the model.

Defining the functional groups is the first step for the construction of the model, and the rest of the variables that will be detailed below (biomass, production, consumption and diets) must collect information about all the functional groups described.

1.3 Biomass

Biomass or abundance data must come from works realized in the study area, values from other regions cannot be used as a reference. The data of scientific campaigns and published studies will be valid. The model can estimate biomass values of some groups, but never of detritus, phytoplankton, zooplankton and species that are at the highest trophic levels (cetaceans, sharks, turtles, tunas, large fishes, etc.). Detritus represents a pool of dead organic material, including particulate and dissolved organic matter and its biomass can be estimated as a function of primary production and euphotic depth, so we need this information. All information must be presented in a table indicating the scientific name of each species, the value as well as its units of measurement (tons per km^2, for example) and the bibliographic reference where the source of the data is indicated.

1.4 Production

A bibliographical review of the area of study will be carried out to obtain an approximation of this parameter from works already published. Finally, when finding information on the study area was not possible, the values of P/B for these groups will be taken from estimates made for the same trophic groups in similar models. Under steady-state conditions, production per biomass ratio for fish groups is equal to the total mortality Z, where Z is the sum of natural (M) and fishing (F) mortality rates. Fishing mortality (F) can be calculated as the ratio between catches (Y) and biomass (B), and natural mortality can be estimated with many models.

All information must be presented in a table indicating the scientific name of each species, the value as well as its units of measurement ($year^{-1}$) and the bibliographic reference where the source of the data is indicated

1.5 Consumption

It is also necessary to perform a bibliographic revision to obtain this parameter and if necessary, values estimated in similar models will be used. For each functional fish group will be use the empirical relationship of Palomares and Pauly (1998):

$$\log\frac{Q}{B} = 7.964 - 0.204\log W_{\infty} .965T' + 0.083A + 0. - 1532h + 0.398d$$

where W_∞ is the asymptotic weight calculated from L_∞ and length–weight relationships (Froese and Pauly, 2014); T´ is water temperature expressed as 1000/(T (◦C) + 273.15); A is the aspect ratio of the caudal fin and h and d are dummy variables indicating the feeding category of the species (herbivore, detritivore, carnivore, or omnivore). For cetaceans (toothed whales and dolphins) will be necessary to use the empirical equation developed by Hunt et al. (2000), and modified by Piroddi (2008):

$$\frac{Q}{B} = \frac{365 \cdot 317 \bar{W}^{0.714}}{\bar{W} \cdot 1207}$$

where $\bar{W}$ indicates average individual weight (kg).

All information must be presented in a table indicating the scientific name of each species, the value as well as its units of measurement (year^{-1}) and the bibliographic reference where the source of the data is indicated.

1.6 Diets

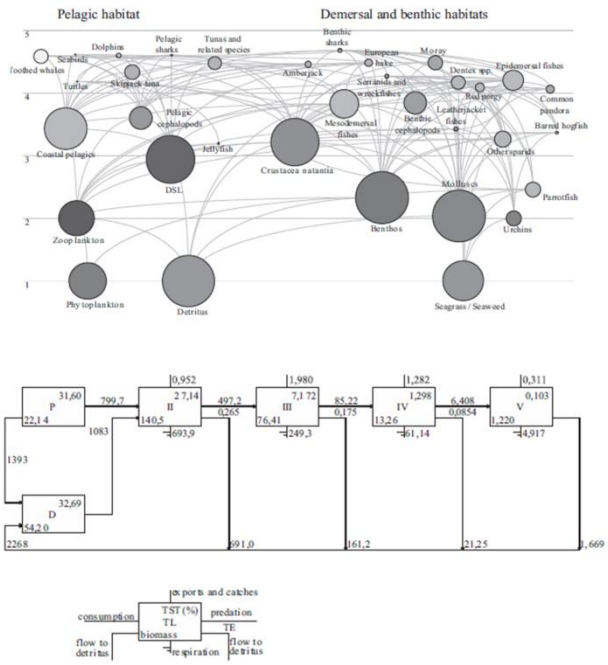
The diet composition matrix necessary for the model will be assembled after a comprehensive literature review in the study area as well as in similar areas. In groups including multiple species, information about the feeding habits of the most representative species will be necessary. The matrix of diets is very important for the adjustment of the model and the groups will be modified until finding the combination of species more coherent and logical. Therefore, for this variable, it will suffice to construct a table indicating the species and the name of the scientific article where the information is published.

In case of using unpublished information, the species, the percentage of each organism or group within the diet (% zooplankton,% shellfish, etc.) and the origin of the data should be indicated.

1.7 Expected results

Although the Canary archipelago comprises seven islands, five models will be developed since Lanzarote and Fuerteventura share the same insular shelf and fishermen from both islands can fish interchangeably in one or the other, and something similar happens with the islands of Tenerife and La Gomera. In addition, there are also species that inhabit and move in the channels between these islands, making it impossible to assign what proportion of that biomass and catches belongs to one island or another.

Once the models have been properly adjusted, it will be possible to analyse ecosystem structure and ecosystem impacts of fishing based on trophic flows analysis, thermodynamic concepts, information theory and other indicators (Fig. 3).



Statistics and flows	Value	Units
Total system throughput (TST)	7151.932	t km^{-2} year^{-1}
Sum of all consumptions (TQ)	2684.883	t km^{-2} year^{-1}
Sum of all exports (TE)	1189.410	t km^{-2} year^{-1}
Sum of all respiratory flows (TR)	1009.388	t km^{-2} year^{-1}
Sum of all flows into detritus (TFD)	2268.251	t km^{-2} year^{-1}
Sum of all production (TP)	3052.556	t km^{-2} year^{-1}
Calculated total net primary production (NPP)	2192.650	t km^{-2} year^{-1}
Total primary production/Total respiration (TPP/TR)	2.172	
Net system production (TPP-TR)	1183.262	t km^{-2} year^{-1}
Total primary production/Total biomass (TPP/TB)	8.647	
Total biomass/Total throughput (TB/TST)	0.035	year^{-1}
Total biomass (excluding detritus)	253.566	t km^{-2} year^{-1}
Mean transfer efficiency (TTE)	15.8	%
Ecopath Pedigree index	0.638	
Fishery indices		
Total catches	4.545	t km^{-2} year^{-1}
Mean trophic level of the catch (TLc)	3.433	
Primary production required to sustain the fishery (PPR, from p.p.)	21.22	%
Primary production required to sustain the fishery (PPR, from p.p. + det)	46.92	%
Gross efficiency (GE, Catches/Net p.p.)	0.002	
Network flow indices		
Throughput cycled (excluding detritus)	206.46	t km^{-2} year^{-1}
Predatory cycling index (PCI, of throughput without detritus)	7.89	%
Throughput cycled (including detritus)	900.91	t km^{-2} year^{-1}
Finn's cycling index (of total throughput) (FCI)	12.60	%
Finn's mean path length (MPL)	3.253	
Connectance index (CI)	0.152	
System omnivory index (SOI)	0.340	
Information indices		
Ascendency (A)	25.5	%
Overhead (O)	74.5	%
Capacity (C)	31637.9	Flowbits

Figure 3. Results obtained in the ecopath model of the Gran Canaria (Couce-Montero *et al.*, 2015). Figure includes flow diagram (top left), Lindeman spine (down left) and table with ecological indicators and summary statistics (right).

2. Azores and Madeira

The PLASMAR project contemplates coordination and cooperation between the participating Macaronesian regions to develop methodologies adapted to their characteristics, according to the DMEM. At the beginning of PLASMAR, a team of researchers from Azores, led by Telmo Morato published a model of the entire exclusive economic zone of that archipelago (Morato *et al.*, 2016) For this reason, a new Azores model was ruled out due to this recent publication and it was agreed to contact with its developers in the future to cooperate in the evaluation of the Descriptor 4 (D4) of the Marine Strategy Framework Directive (MSFD, Commission Decision 2010/477/EU) for the Macaronesian region. In the case of Madeira, by the time the project developed this action it was impossible to obtain organized data that would allow the development of an ecosystem model, despite all the attempts made by the project partners in that region. Finally, only the models of the Canary archipelago could be developed.

Parallel to the PLASMAR project, the MISTIC SEAS III project began, whose objective is the evaluation of D4 in Azores, Madeira and the Canary Islands. Some partners from Azores involved in PLASMAR also participate in Mistic Seas 3, and they suggested to the coordinators of this project contacting the researchers in charge of D4 in the PLASMAR project to join efforts, which they did.

Currently, Dr. José Juan Castro Hernández and Dr. Lorena Couce Montero cooperate with the Mistic Seas 3 project as advisory members, contributing their knowledge on marine ecosystems as well as the results obtained with the models developed in the Canary archipelago. This collaboration aims to achieve the assessment of the good environmental status of the marine ecosystems of the Macaronesian region under the same methodology, filling the gaps found in the Plasmar Project.

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