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# Ecosystem modelling in the Northwestern Mediterranean Sea: structure and functioning of a complex system

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## ABSTRACT

Ecopath mass-balanced models are widely-used tools to address various challenges in the understanding and protection of ecosystems. To track the continuing improvements in data and the evolving environment (climate change, anthropic pressure), new models are regularly being developed. In this study, we built a Gulf of Lion Ecopath model, focused on the continental shelf, featuring enhanced representation of benthic invertebrates and a realistic assessment of catches, and which takes into account the significant changes observed after 2008 – 2009 in the trophic structure of this ecosystem as well as related changes in fisheries activities. The model is composed of 68 functional groups, including 6 primary producers, discards and detritus, 27 invertebrate groups, 31 fish groups, dolphins and seabirds. New datasets were taken into account for biomasses, as well as for diets. P/B and Q/B parameters were calculated to include the most recent and geographically closest data. Model results highlight a food web diagram, ranging over 5 trophic levels and placing *Prionace glauca*, *Squalus acanthias* and dolphins as top predators. The mixed trophic impact analysis showed that the groups with the highest accumulated negative impacts are, in decreasing order, benthic trawls, nets and carnivorous echinoderms. The groups with the highest accumulated positive impacts are, in decreasing order, detritus, microphytoplankton and nanoplankton. The flux analysis shows that a major part of the flows occurs at trophic level 2 with 35.1% of the model total throughput and 43.8% of the total biomass. The catches have a mean trophic level of 3.47, higher than in previous studies, reflecting the evolution of changes the fisheries activities.

**Keywords:** Ecopath; Trophic structure; Modelling; Mediterranean; Gulf of Lion

## 1. INTRODUCTION

In the current context of climatic change and ever-growing anthropic pressure, it is essential to understand the structure and the functioning of marine ecosystems in order to predict how they will react to ongoing disturbances.

As both a hotspot of biodiversity, with 17 000 species (Coll *et al.*, 2010) and a center of human activities for centuries (*Large Marine Ecosystems Hub*, [www.lmehub.net](http://www.lmehub.net)), the Mediterranean Sea is a place of

44 particular interest for such studies. Many of its ecosystems are already impacted (Calvo *et al.*, 2011;  
45 Durrieu de Madron *et al.*, 2011; Micheli *et al.*, 2013; Fortibuoni, 2017) and the Gulf of Lion (GoL), in  
46 the Northwestern Mediterranean Sea, is no exception. A regime shift has been observed in its ecosystem  
47 since 2008, resulting mainly in important changes of condition and individual sizes of small  
48 planktivorous fishes (Van Beveren *et al.*, 2014; Saraux *et al.*, 2019; Feuilleley *et al.*, 2020) and most  
49 demersal fishes (Bensebaini *et al.*, 2022).

50 Historically-used single-species models have proven insufficient to accurately explain the processes  
51 influencing the biomass of a species (Cochrane, 2002). Ecosystem-based modelling is a response to this  
52 complexity and has been increasingly developed over the past decades. Ecopath with Ecosim (EwE,  
53 Ecopath.org) is today among the most widely-used software in this field. Since its introduction, it has  
54 been continuously improved, starting from a static ecosystem snapshot to become a dynamic and  
55 spatialized simulation (Polovina, 1984; Christensen and Pauly, 1992; Walters, Christensen and Pauly,  
56 1997; Walters, Pauly and Christensen, 1999; Heymans *et al.*, 2016). Its many uses include studies on  
57 the impact of fishing and fisheries management, the effectiveness of MPAs, habitat loss and degradation,  
58 understanding food webs and the dissemination of pollution (Coll and Libralato, 2012). Regarding this  
59 last aspect, the representation of biological groups interacting strongly with sediment is of paramount  
60 importance for the comprehension of some continental shelf marine areas (Cresson *et al.*, 2020) as well  
61 as for the modeling of the fate of contaminants in food webs (Hammerschmidt *et al.*, 2004; Ono *et al.*,  
62 2015; Tateda *et al.*, 2020).

63 Bănaru *et al.* (2013) developed an Ecopath model for the Gulf of Lion (NW Mediterranean Sea) and  
64 pointed out the lack of data for benthic invertebrate groups, the need for improved diet and biomass data  
65 and catch estimates. Their model covered the period 2000 - 2009; however an important shift in the GoL  
66 species composition and size occurred at the end of this period (Van Beveren *et al.*, 2014; Saraux *et al.*,  
67 2019) and may have led to changes in the structure and functioning of this system as well as fishing  
68 activities.

69 The aim of the present work is to investigate the current trophic functioning of the GoL after the changes  
70 observed from 2008 by developing a new Ecopath model that also includes the most accurate  
71 representation of sediment-dependent biological groups.

## 72 **2. MATERIALS AND METHODS**

### 73 **2.1. Study area**

74

75 The GOLEM (Gulf of Lion Ecopath Model) model area is located in the Gulf of Lion (GoL) between 0  
76 to 200 m depth, for a total area of 12172 km<sup>2</sup>. The 200 m isobath is located at the limit between the  
77 continental shelf and the canyons of the continental slope (**Fig. 1**). This model represents an average of  
78 the ecosystem situation between 2010 and 2014. The main environmental phenomena in this area are  
79 strong continental winds from the north-west (Tramontane) and north (Mistral) producing coastal  
80 upwellings (Millot, 1999; Agostini and Bakun, 2002), the mesoscale circulation of the western  
81 Mediterranean and the freshwater input from the Rhone River, which is the largest source of freshwater  
82 in the Mediterranean Sea (Margat, 1992; Petrenko *et al.*, 2005). The Rhone River is an important source  
83 of dissolved and particulate organic carbon (Lefevre *et al.*, 1997; Gaudy *et al.*, 2003; Harmelin-Vivien  
84 *et al.*, 2008). These phenomena lead to high primary and secondary production that supports a major  
85 part of the food web flows (Bănaru *et al.*, 2013, 2019; Cresson *et al.*, 2014). The sea floor features sandy  
86 and muddy substrates (Durrieu De Madron *et al.*, 2000) and few *Posidonia oceanica* meadows (Telesca  
87 *et al.*, 2015).

88

## 89 2.2. Ecopath software and balancing

90

91 The Ecopath software version 6.6.5 has been used to build the GOLEM model and ensure its mass and  
92 energy balance (Christensen *et al.*, 2008; Christensen and Walters, 2004; www.ecopath.org). The main  
93 equation driving Ecopath models is:

$$94 P_i = \sum B_j * M2_{ij} + Y_i + E_i + BA_i + P_i * (1 - EE_i)$$

95 with P the production of the functional group i,  $M2_{ij}$  the predation caused on i by a predator j and  $B_j$  its  
96 associated biomass, Y and E the export terms, the first for the fisheries and the latter for the other types  
97 of export, BA the biomass accumulation in the system and EE the ecotrophic efficiency (i. e. the  
98 proportion of the production of group i that is explained by the model, either by its exports or its  
99 predation). Thus,  $(1 - EE_i)$  represents other mortality, or mortality not explained in the system.

100 The first equation can be re-expressed as follows:

$$101 B_i * (P/B)_i = \sum B_j * (Q/B)_j * DC_{ij} + Y_i + E_i + BA_i + B_i * (P/B)_i + (1 - EE_i)$$

102 where  $(P/B)_i$  represents the production per biomass unit and, under steady state, is equivalent to Z, the  
103 total mortality (Allen, 1971),  $(Q/B)_j$  is the consumption per biomass unit and  $DC_{ij}$  is the portion of i in  
104 the diet of predator j (in weight or volume units).

105 For each functional group, Ecopath requires three among the following parameters: B, P/B, Q/B and  
106 EE. It also takes as input the diet of each group, their captures and discards, the assimilation rate (ratio  
107 of unassimilated/consumed food) and net migration rate (here considered as an 'import' part of the diet).

108 After all the input data were entered in the Ecopath software, but prior to balancing the model, special  
109 attention was paid to the P/Q ratio, as expected values range from 0.1 to 0.3 (Darwall *et al.*, 2010;  
110 Heymans *et al.*, 2016). Groups with too high P/Q values were corrected by recalculating the most  
111 uncertain between the P/B and Q/B. This was done by varying the parameters used to estimate P/B and  
112 Q/B (see section 2.4.3) within the range given by the literature.

113 When balancing the model, to adjust the values, the Automatic Mass Balance Procedure (Kavanagh *et al.*,  
114 2004) was used by removing the P/B or biomass (preferably the P/B, considered the most uncertain)  
115 data and setting the EE to 0.95, except for *Prionace glauca*, as a top predator, with  $EE = 0.1$  and  
116 planktonic groups, with  $EE = 0.99$ .

117 The model was considered balanced when all the EE, respiration/assimilation and net efficiency were  
118 less than 1 and the respiration/biomass was within expected values (Heymans *et al.*, 2016).

119

## 120 2.3. Functional groups

121

122 The species to be included in the model were selected mainly from the MEDITS database (Jadaud and  
123 Certain, 1994) in order to represent 99% of their estimated biomass indices. Then, others were included  
124 due to the large volume of capture in the area (total number of species representing 97% of the cumulated  
125 captures recorded in the SIH (Halieutics Information System, <http://sih.ifremer.fr>) fisheries database).  
126 Finally, some essential groups not represented in these data sets have been added, such as the planktonic  
127 and benthic groups, Posidonia and macrophytes. Then the diet for each species was completed from the  
128 literature (details below).

129 To form the functional groups, the species were grouped in two ways: the invertebrates were grouped  
130 according to the major taxa (brachyurids, echinids, etc.) with subdivisions based on the diet (e.g.  
131 carnivorous and detritivorous worms). Vertebrates (except birds and marine mammals) were grouped  
132 using hierarchical clustering based on their diet (**Appendix 1**). This clustering was carried out with  
133 STATISTICA software (version 12, Dell Inc.) using Ward's method and Euclidian distances.

134 This approach led to the constitution of 68 functional pelagic, demersal and benthic groups, the species  
135 composition of which is detailed in **Table 1**. They include 31 groups of fishes, 27 invertebrates, 6  
136 primary producers, a group of sea birds and a group of dolphins. Among them, 19 have been kept  
137 monospecific, either for commercial reasons (*Homarus gammarus*, *Mullus barbatus*) or for conservation  
138 interest (sharks and rays).

## 139 **2.4. Data sources and processing**

140

### 141 **2.4.1. Biomasses**

142 The main source of information on fish and invertebrates biomass used in this work comes from the  
143 MEDITS set of annual scientific bottom trawling campaigns (Jadaud and Certain, 1994) (**Appendix 2**).  
144 Their sampling scope has broadened over the years and includes all captured supra- and epibenthic  
145 invertebrate species since 2012.

146 The MEDITS data set has been processed to produce an average estimate of biomass (in t.km<sup>-2</sup>) for the  
147 period 2010-2014 and between 0 and 200 m depth while keeping information about the spatial  
148 heterogeneity of the species. The calculations were first carried out according to three depth strata (10-  
149 50 m, 50-100 m, 100-200 m) before being rescaled to the entire area. Given the geomorphology of the  
150 gulf (influence of the Rhône River in the east, mesoscale gyre in the west), it was decided to apply a  
151 correction factor to render the horizontal heterogeneity of the species distribution. For each species, its  
152 longitudinal extent was calculated and if it was less than 1.2° (over the 2.035° extent of the GoL), the  
153 biomass was corrected by the ratio of the longitudinal extent of the species to the longitudinal extent of  
154 the GoL. The value of 1.2° was considered suitable because species below this threshold would either  
155 be rare or restricted to part of the gulf, so their total weight value had to be lowered to avoid  
156 overestimation by multiplication by the area of the depth strata. No correction was applied to species  
157 present at a single station as it was impossible to determine whether it was highly localized, particularly  
158 rare or difficult to sample. The groups that contain at least one species concerned by this correction are  
159 the following: cnidarians, depositivorous molluscs, filter feeder molluscs, pagurids, *Homarus*  
160 *gammarus*, filter feeder echinoderms, holothurians, invertivorous fishes, wormivorous fishes, mullet  
161 and piscivorous flat fishes.

162 For *Engraulis encrasicolus*, *Sardina pilchardus*, *Sprattus sprattus*, *Trachurus Trachurus*, *T.*  
163 *mediterraneus*, *Scomber scomber* and *S. colias*, the datasets from the annual Mediterranean acoustic  
164 survey PELMED (Bourdeix and Hattab, (1985) were used. The GFCM (General Fisheries Commission  
165 for the Mediterranean) biomass data estimated by the stock assessment committees for this area were  
166 used for *Merluccius merluccius* and *Mullus barbatus*. In order to obtain densities per km<sup>2</sup>, the PELMED  
167 data, delivered in total weight, were divided by the surface surveyed by the GFCM, i.e. 11400 km<sup>2</sup>

168 Benthic endofauna data were provided by Labrune (pers. comm.) and estimated from Bonifácio *et al.*,  
169 (2018). They are based on REDIT2010 and APPEALMED cruises (Labrune and Amouroux, 2010;  
170 Labrune, 2018). These data were used for the following groups: cnidarians, sessile suspension feeders,  
171 depositivorous molluscs, filter feeder molluscs, carnivorous molluscs, depositivorous worms, filter  
172 feeder worms, carnivorous worms, sipuncula, suprabenthic and benthic invertebrates, pagurids and  
173 carnivorous echinoderms.

174 Among the species included to reach 97% of the total captures, some lacked biomass estimates. These  
175 missing values were completed from the literature (see **Appendix 2**).

176 To estimate the biomass of the detritus group, the particulate organic carbon (POC) inventory from  
177 Many *et al.* (2021) was used (average between 2011 and 2014, in t C). Their value was converted to wet  
178 weight (ww) with a 10x factor (Dalsgaard and Pauly, 1997) and divided by the GoL area.

179 The import term was calculated using data from the Rhone sediment observatory (Thollet *et al.*, 2018).  
180 The daily liquid discharge and daily concentration of particulate organic carbon (POC) from 2010 to  
181 2014 were used to determine an average annual import of POC (t C) from the Rhone River to the GoL.  
182 According to Many *et al.* (2021), the Rhone river accounted for 97% of the POC riverine input in the  
183 GoL over the period 2011 to 2014 (consistent with the 97.4% calculated from Higuera *et al.* (2014),  
184 over 2008-2009). In order to account for the inputs of the other rivers, an increase corresponding to 3%  
185 was applied. Again, a factor of 10 was applied to convert the carbon mass to wet weight, for a final POC  
186 import of 98.05 t/km<sup>2</sup>/y.

187

## 188 **2.4.2. Catches**

189 The landings data recorded from the GoL were provided by the Halieutics Information System (SIH).  
190 The raw data were averaged over 2010-2014, by species and fishing gear type, and over the entire GoL  
191 fishing area. Gear types were then regrouped into: benthic trawls, pelagic trawls, nets, seines, long lines,  
192 recreational fishing and other. The 2010-2014 averages of the reported Spanish catches  
193 (<https://www.fao.org/faostat>) in the study area were added. As the gear used were not specified, they  
194 were distributed by species in the 7 functional fleet groups according their relative importance in the  
195 French catches.

196 The organization of fisheries in the GoL, with a high proportion of small boats (< 10 m) and a small  
197 number of auction sale halls, makes it difficult to accurately assess the catches, as part of them are sold  
198 directly in small harbours, fish markets and/or are undeclared (CRPMEM PACA, 2016). To account for  
199 that, a correction factor was applied, based on the R3 report of SIH (Demaneche *et al.*, 2009) for the  
200 available species.

201 To improve the representativeness of the catches, discards and recreational fishing were considered.  
202 Discards were taken into account only for *Merluccius merluccius*, *Sardina pilchardus* and *Trachurus*  
203 *mediterraneus*, based on estimates by OBSMER (2009) and Bourjea *et al.* (2019). Recreational fishing  
204 is widespread in this region and SIH data probably represents only a small fraction of this activity. It  
205 was estimated by Levrel (2012) to amount to 4814 tonnes of fish for the Mediterranean French coast. In  
206 this work, we added together both sources raising this estimate to 4855 tonnes. This value was split  
207 between the species pointed out by Font and Lloret, (2014); Kayal *et al.* (2020); Lloret and Font (2013)  
208 according to their relative weight per unit effort. Some adjustments have been made to represent the  
209 environmental characteristics of the GoL. Several of these surveys took place in the rocky western part  
210 of the GoL whereas sandy coasts are the main type of substrate in the study area, which leads to  
211 unrealistic catch values. Levrel, (2012) also estimated recreational captures of the cephalopods for  
212 France at 704 t. It was decided, for lack of a better estimator, to attribute 33.2% to the French  
213 Mediterranean coast (the same proportion as for fish). The 233.7 t were then divided between octopus  
214 and squid, proportionally to their respective biomasses.

215

## 216 **2.4.3. Production/biomass (P/B) and consumption/biomass (Q/B) ratios**

217 These two ratios (in y<sup>-1</sup>) were calculated for each species using different methods depending on whether  
218 they belonged to the invertebrates or vertebrates, according to the indications of Heymans *et al.* (2016).

219 For invertebrates, the artificial neural network model of Brey (2001, 2012) was used to determine the  
220 P/B. For each taxon, it takes as inputs the body mass (J), the depth (here, we have chosen the maximum  
221 depth from MEDITS data), the temperature (set at 13.5°C, the annual average at 50 m depth estimated  
222 from SOMLIT (Service d'Observation en Milieu Littoral, www.somlit.fr) time series in the GoL) and  
223 five other parameters depending on the mobility, life style and diet of the species.

224 In order to obtain the body mass in joules for each species, the average body mass in grams was  
225 calculated from the entire MEDITS data sets (1994-2019), then converted using Brey's conversion  
226 factor calculator (Brey, 2010). The most accurate taxon for the given species was selected among those  
227 available and only marine species were included in the computation. For gastropods and bivalvia, the  
228 'with shell' conversion factor was chosen, to remain consistent with the MEDITS data.

229 The Q/B ratio of invertebrates was calculated based on the following empirical relation (Cammen, 1979;  
230 Brey, 2001):

$$231 \text{Log (Q)} = -0.42 + 0.742 * \text{log (BM)}$$

232 where BM is the body mass (mg DW) and Q the consumption (mg DW d<sup>-1</sup>). The average dry weight of  
233 each species was obtained as explained above, from the MEDITS dataset and the Brey conversion factor  
234 calculator.

235 For vertebrates, the P/B was estimated as follows:

$$236 \text{P/B} = \text{Z} = \text{F} + \text{M}$$

237 with Z the total mortality (y<sup>-1</sup>), F the fisheries mortality (y<sup>-1</sup>) and M the natural mortality (y<sup>-1</sup>). F is the  
238 ratio between the catches of a species and its biomass. M was calculated using Pauly's empirical  
239 equation (Pauly, 1980):

$$240 \text{Log (M)} = -0.0066 - 0.279 * \text{log (L}\infty) + 0.6543 * \text{log (K)} + 0.4634 * \text{log (T)}$$

241 with L $\infty$  the length at infinity (cm), K the von Bertalanffy growth parameter (y<sup>-1</sup>) and T the mean annual  
242 temperature (°C), in this case 15.7°C (from SOMLIT, surface temperature). K and L $\infty$  were found in  
243 the literature (see **Appendix 2**).

244 Similarly, vertebrates Q/B was estimated using the Palomares and Pauly (1998) empirical equation:

$$245 \text{Log (Q/B)} = 7.964 - 0.204 * \text{log (W}\infty) - 1.1965 * \text{T}' + 0.083 * \text{A} + 0.532 * \text{h} + 0.398 * \text{d}$$

246 with W $\infty$  the weight at infinity (g), T' expressed as 1000/(T + 273.1), A the aspect ratio of the tail (from  
247 www.fishbase.org) and h and d the herbivory and detritivory parameters, respectively. The latter were  
248 set to 1 if the species had the corresponding feeding habit and 0 otherwise. W $\infty$  was calculated using the  
249 weight/length relation provided on www.fishbase.org and L $\infty$ .

250

#### 251 **2.4.4. Diet and data quality**

252 The diet for each species was obtained from the literature (see **Table 3 and Appendix 2**). When multiple  
253 data sources were found, the closest geographically was chosen. For multispecies groups, the diets were  
254 calculated in proportion to the biomass of each species making up the group.

255 As advised by Heymans (2016), the integrated pedigree routine was used to assess the input data and  
256 the overall model quality. For each input parameter (biomass, P/B, Q/B, diet and catches), a score was  
257 assigned to the source according to the Ecopath default rating scale. The routine is then able to produce  
258 an overall score for the model, ranging from 0 to 1, with 1 being the best quality.

259

## 260 2.5. Network analysis

261 As indicated by Heymans *et al.* (2016), to compare this model with the model of Bănaru *et al.* (2013)  
262 and other models, we used the four indices below, as they are less sensitive to differences in the model  
263 construction. These indices are: the Total System Throughput (TST, t/km<sup>2</sup>/y), the total net primary  
264 production on the TST (PP/TST), the sum of all consumptions on the TST (Q/TST) and the sum of all  
265 exports on the TST (Ex/TST) (**Table 6**).

266 The following indicators are used to describe the modelled ecosystem. The Trophic Level (TL), for each  
267 group, represents the weighted average of the trophic level of its preys, with the primary producers and  
268 detritus TL set to 1.

$$269 TL_i = 1 + \sum_{j=1} DC_{ij} TL_j$$

270 with  $DC_{ij}$  the fraction of prey  $j$  in the diet of  $i$  and  $TL_j$ , the trophic level of prey  $j$ .

271 The Omnivory Index (OI) gives an indication on the specialization of a predator's diet, tending towards  
272 zero when the group feeds on a single trophic level and higher when the group is unspecialized (Pauly  
273 *et al.*, 1993). It is calculated as follows:

$$274 OI_i = \sum_{j=1} (TL_j - (TL_i - 1))^2 \cdot DC_{ij}$$

275 The Mixed Trophic Impact (MTI), as adapted by Ulanowicz and Puccia, (1990), is the representation of  
276 the theoretical impact, positive or negative, of a small variation in the biomass of one group on all the  
277 others in the modelled ecosystem. It accounts both for direct (predation) and indirect (competition)  
278 interaction.

279 Valls *et al.* (2015) define a keystone species as “a predator species which disproportionately influences  
280 the food-web structure of its community”. The Keystoness (KS) of each group was calculated following  
281 their method:

$$282 KS_i = \varepsilon_i \times \text{drank}(B_i) \quad \varepsilon_i = \sqrt{\sum_{j=1} m_{ij}^2}$$

283 with  $\text{drank}(B_i)$  the rank in a decreasing ranking of the biomass of group  $i$ ,  $\varepsilon_i$  the overall trophic impact  
284 of  $i$  and  $m_{ij}$  the net MTI. The Valls *et al.* (2015) method was preferred to the other two available in the  
285 Network Analysis plugin (Power *et al.*, 1996; Libralato, Christensen and Pauly, 2006) because it gives  
286 balanced weighting to trophic impact and biomass in the calculation of the KS, unlike the others. The  
287 fluxes and biomasses of each discrete trophic level can be summarized in a ‘Lindeman spine plot’, a  
288 diagram presenting the food chain in a linear form, consisting of TL boxes and fluxes entering or leaving  
289 each of them. This plot also includes transfer efficiency, total throughput and flux to detritus for each  
290 TL.

291

## 292 3. RESULTS

293

### 294 3.1. General outputs

295 The output parameters of the model are presented in **Table 4**. Invertebrates represent 68.2% of the total  
296 biomass (detritus groups excluded) against 23.4% for vertebrates. The most important group in term of  
297 biomass is the mesozooplankton with 8.7%, the three small pelagics together account for 10.9% (S.



298 *pilchardus*, *S. sprattus* and *E. encrasicolus*) while dolphins and sea birds represent only a minute part  
299 of the biomass (< 0.01% ).

300 The highest Omnivory Indexes (OI) are found, in decreasing order, for sea birds (1.55), *Dicentrarchus*  
301 *labrax* (1.13) and *Homarus gammarus* (0.88). The lowest non-zero OI values concern filter feeder  
302 worms and depositivorous molluscs. The overall omnivory of the system is low, at 0.21, and only eight  
303 groups are above 0.5, indicating that the groups have a rather selective diet towards a limited range of  
304 trophic levels.

305 Eighteen groups show a higher fishing mortality than predation mortality (e.g. octopus, crustivorous  
306 fishes 2, *Scomber scombrus*, etc.) (**Table 4**). The 3 most fished groups are *Sparus aurata*, *Merluccius*  
307 *merluccius*, and *Engraulis encrasicolus*. Despite its importance in the catches, *E. encrasicolus* has  
308 fishing mortality that is lower than its predation mortality.

309 For *Sardina pilchardus* and *Engraulis encrasicolus*, the main consumers were squid and tuna,  
310 respectively.

311 The most consumed groups are nanoplankton, detritus, picoplankton, microphytoplankton and  
312 mesozooplankton, with 32.8, 19.8, 16, 7.3 and 5.7% of the total consumption, respectively.  
313 Consumption of vertebrates represents only 0.63% of the total consumption. Among fishes,  
314 wormivorous fishes are the most consumed, with 26.2%, followed by *E. encrasicolus*, *S. pilchardus* and  
315 *S. sprattus* with 17.2, 16.9 and 16.7%, respectively. On the consumer side, zooplankton groups are  
316 responsible for 54.5% of the total consumption, other invertebrates 38.4% and the vertebrates 7%.

317 The model has an overall pedigree of 0.631 (1 being the best quality possible), which places it at the  
318 high end of the range given in the review by Coll  ter *et al.* (2015) who carried out a survey of 433 EwE  
319 models of which only 34 provided a pedigree, the latter ranging from 0.137 to 0.743.

320

## 321 **3.2. Network analysis and flows**

322 The balanced model includes five trophic levels (**Table 4**), with *Prionace glauca*, *Squalus acanthias*  
323 and dolphin exhibiting the highest trophic levels i.e. 5.2, 5.0 and 5.0, respectively. Thirteen other groups  
324 have TL > 4, including anglerfish, rays and *Conger conger*. The resulting trophic network diagram is  
325 shown in **Figure 2**.

326 The Lindeman spine plot (**Figure 3**) shows that the majority of the fluxes towards detritus, from lower  
327 TL and respiration occurs in TL II. It hosts 35.1% of the total system throughput and 43.8% of the total  
328 biomass (excluding detritus). However, this is not the case for the export and catches flow, dominated  
329 by fisheries, which is greater for TL III and IV, showing a preference in catches for intermediate TL. It  
330 is confirmed by the mean trophic level of the catches of 3.47 (**Table 5**). The total transfer efficiency  
331 reaches 18.2%, which is higher than the average of 10% proposed by Pauly & Christensen (1995) for  
332 aquatic systems, or the 15.7% reported by Tecchio *et al.* (2013), but slightly lower than the value of  
333 19.7% mentioned by B  naru *et al.* (2013).

334

## 335 **3.3. Trophic impact and keystone**

336 The mixed trophic impact matrix (**Figure 4**) shows that the mesozooplankton group plays an important  
337 role in the food web, with a relatively high direct negative impact on its prey (pico, nano and  
338 microzooplankton) and on itself (through competition) and a positive impact on its predators (4 groups  
339 of small pelagic planktonophagous fishes). It also has multiple smaller impacts throughout the food  
340 chain. Both suprabenthic/benthic invertebrates and decapod groups have a widespread impact, being

341 preyed upon by many higher TL groups. This also applies to the four groups of small pelagic fishes, but  
342 with a more limited impact on other vertebrates, since few invertebrates feed on them (except  
343 cephalopods). One can note the negative indirect impact of *E. encrasicolus* on *M. barbatus*, via  
344 promotion of *M. merluccius*, which is a predator of *M. barbatus*. In the same way, detritus has a negative  
345 impact on the microphytobenthos by favoring the sipuncula and the depositivorous molluscs.  
346 Crustivorous fishes 2 have a strong direct negative impact on jellyfish, of which they are the only  
347 predator in this model. Finally, fisheries have a strong negative impact on many fishes at high and  
348 intermediate TL. The highest negative impact is exerted by benthic trawls on *Squalus acanthias*,  
349 *Scyliorhinus canicula* and anglerfish, by nets on *Palinurus elephas* and by long lines on *Prionace*  
350 *glauca*. Overall, the groups with the highest negative impact (summed MTIs) are, in decreasing order,  
351 benthic trawls (-4.1), nets (-2.8) and carnivorous equinoderms (-1.6). On the other hand, the three groups  
352 with the highest accumulated positive impacts are, in decreasing order, detritus (4.7),  
353 microphytoplankton (2.3) and nanoplankton (2.1).

354 Regarding the Valls keystone index (Valls *et al.*, 2015), the three groups with the highest keystone index are  
355 the crustivorous fishes 2, squid and *Conger conger* (**Figure 5**). The plot of the keystone index according  
356 to Power *et al.* (1996) against the relative total impact is also given to allow comparison with the work  
357 of Bănaru *et al.* (2013). This index gives a higher value to species with low biomass. In this case, the  
358 three keystone groups are marine birds, dolphin and *C. conger*.

359

## 360 4. DISCUSSION

### 361 4.1. Exploitation of the GoL

362 According to Patterson (1992), a value of the exploitation rate ( $E = F / Z$ ) greater than 0.4 leads to a  
363 decline of the stock, i. e. overexploitation. On this basis, according to the GOLEM indices (**Table 4**),  
364 10 groups suffer from overexploitation by fisheries: octopus, *Palinurus elephas*, crustivorous fishes 2,  
365 mullet, *Sparus aurata*, carnivorous demersal fishes, anglerfish, *Dicentrarchus labrax*, *Merluccius*  
366 *merluccius* and *Conger conger*.

367 According to the GFCM stock assessment data available for the period 2010 – 2014  
368 (<https://www.fao.org/gfcm/data/safs>), *M. merluccius* is indeed considered to be overfished. On the  
369 other hand, the low modelled exploitation rate of *Engraulis encrasicolus* and *Sardina pilchardus* (0.06  
370 and 0.03, respectively) is in agreement with the GFCM data which assessed their fishing mortality as  
371 low. This is most likely due to the ecosystem shift of 2008 that resulted in unfavorable environmental  
372 conditions for these two species, leading to low abundance of commercial size fish. This, coupled  
373 with an increase in the biomass of *Sprattus sprattus*, which has a low commercial interest and which  
374 is captured along with *E. encrasicolus* and *S. pilchardus*, has led to a reduction in fishing effort on the  
375 small pelagics. This has also led to the diversification of the fisheries activity towards demersal  
376 species (GFCM stock assessment report for *M. merluccius*, 2013), increasing the fishing mortality of  
377 *M. merluccius*.

378 Although no information is available for the period 2010 – 2014, recent observations (Certain, pers.  
379 comm.) have revealed that anglerfish are also overfished in the GoL area. Given the model results, it  
380 seems reasonable to assume that it was indeed the case during the modelled period and that it could  
381 be a consequence of the diversification of the fisheries activities, as for *M. merluccius*. Overall, these  
382 facts show the consistency of the GOLEM model with the functioning of the GoL ecosystem and its  
383 ability to reflect the consequences of the 2008 shift.

384

## 385 **4.2. Comparison between models**

386 Comparison of Ecopath models is often difficult as many of the indicators produced are structure-  
387 dependent (Pinnegar *et al.*, 2005) and it is rather rare that models share enough traits (especially for area  
388 and species aggregation) to overcome this. However, Heymans *et al.* (2014, 2016) proposed several  
389 indices normalized to the total system throughput (TST, sum of the flows in the system) that are more  
390 robust with regard to the system construction (**Table 5 and 6**). We proposed here a comparison between  
391 6 Ecopath models (Sánchez and Olaso, 2004 (F); Coll *et al.*, 2006 (A), 2007b (D); Tsagarakis *et al.*,  
392 2010 (E); Bănanu *et al.*, 2013 (C)), 5 in the Mediterranean and one from the Cantabrian Sea (N-E  
393 Atlantic).

394 Before dealing with the comparison of the output parameters of these 6 models, as two of them have  
395 been developed on the GoL, a presentation of the differences in the structure of these two models is first  
396 given.

### 397 **4.2.1. Differences between the two GoL models**

398 Bănanu *et al.* (2013) achieved a first representation of the ecosystem of the GoL, giving an overview of  
399 its functioning and the impact of the fisheries. However, the limited availability of the data at that time  
400 did not allow for a good description of certain groups, especially among the invertebrates. The increased  
401 research effort on these species over the last decade, notably in terms of biomass and diet, made possible  
402 the creation of a new model, with a better resolution of functional group, radically changing the structure  
403 of the trophic network.

404 Previously divided into 7 groups, the benthic invertebrates are represented by 22 groups in the present  
405 work. These improvements enable us to better characterize the interactions between important  
406 compartments, such as holothurians and detritivorous worms with detritus. The flows in the system were  
407 consequently impacted, as shown in the Lindeman diagram (**Figure 3**), with a flow from detritus to  
408 trophic level II 2.5 times greater in the present model (606 t km<sup>-2</sup> y<sup>-1</sup>) than in the previous one (265 t  
409 km<sup>-2</sup> y<sup>-1</sup>), the latter being probably underestimated (an influence from the modelled area is also  
410 possible). The additional sharpness in the trophic network description provides better insight into species  
411 interactions, as can be seen in the mixed trophic impact matrix (**Figure 4**). For example, one may note  
412 the strong negative impact exerted on sipuncula and echinids by carnivorous mollusks, not visible on  
413 Bănanu *et al.* (2013) matrix.

414 In addition to the use of recent data, the catches estimate has been improved by the addition of catches  
415 from recreational fishing. Far from being negligible, they represent about 16% of the total estimated  
416 catches, improving the representation of the fisheries activity and its impact on the GoL food web.

417

### 418 **4.2.2. Flow indices, pedigree and omnivory index**

419 One of the most noticeable differences between the GOLEM model and the C model is on the TST. The  
420 higher TST value in GOLEM can be explained by the fact that the model focuses on the continental  
421 shelf (from 0 to 200 m), where most of the biological activity occurs, whereas the Bănanu *et al.* (2013)  
422 model incorporated an additional area (from 0 to 2500 m), mainly characterized by greater depth and  
423 therefore lower biological activity. This results in a dilution of the flows by the modelled area. The larger  
424 number of functional groups in GOLEM may also influence the TST, making explicit the flows that  
425 occurred within previously larger functional groups.

426 The difference in total biomass is also explained by the “dilution” phenomenon. It is further supported  
427 by the fact that the total net primary production (PP) and consumption (Q) calculated by Bănanu *et al.*  
428 (2013) are lower (**Table 5**) while the PP/TST and Q/TST ratios (**Table 6**) are quite similar, highlighting  
429 similarities between the biologically active parts of these two systems.

430 By analyzing the PP/TST, it may be noted that the Mediterranean models have a rather narrow range  
431 of values, between 0.23 and 0.35, which are lower than the Atlantic model (F) (other authors found  
432 similar high values in the Atlantic: 0.41 for Araujo *et al.* (2005); 0.43 for Damsiri *et al.* (2022)). This  
433 range may be even narrower, since the lowest value of model A does not include the 0-50 m zone, where  
434 high primary production often occurs. This rather low range of values of PP/TST may be related to the  
435 oligotrophic nature of the Mediterranean, characterized by low primary production compared to the  
436 Atlantic Ocean (Liénart *et al.*, 2017).

437 Overall, the E model from the North Aegean Sea shows strong similarities with GOLEM for PP/TST,  
438 Q/TST and Ex/TST but lower values for TST and total biomass. This highlights the similarities between  
439 the two systems, although Tsagarakis *et al.* (2010) pointed out differences in productivity between the  
440 western and eastern Mediterranean systems. The low values of TST and total biomass in model E could  
441 be explain by a smaller number of functional groups (40) and the exclusion of the 0 – 20 m zone,  
442 respectively. It is supported by the presence of *Posidonia* meadows in the area, known to have a high  
443 biomass per area (Boudouresque *et al.*, 2006). This resemblance is consistent with the similar nature of  
444 the two modelled areas, i. e. Mediterranean oligotrophic coastal areas, with productivity supported by  
445 large continental shelves and riverine inputs (Tsagarakis *et al.*, 2010). Both areas show sandy to muddy  
446 sediments, however the North Aegean Sea shows more *Posidonia* meadows, their distribution being  
447 limited in the GoL by the freshwater inputs of the Rhone River.

448 The slightly lower pedigree of the GOLEM model compared to model C is likely due to the increased  
449 number of the invertebrate groups for which data on diet, P/B and Q/B are scarce compared to  
450 vertebrates. Yet, it should be kept in mind that the splitting of these groups is a major step towards a  
451 better representation of the GoL ecosystem, made possible by the recent efforts to study invertebrate  
452 biomass.

453 Despite the structural differences, the omnivory index of the GOLEM and Bănaru *et al.* (2013) system  
454 are equal (0.21). Models A, D and E show slightly smaller indexes, and model F shows a less specialized  
455 food web with 0.27. As for PP/TST, the Mediterranean models show a small range of values at rather  
456 low level, compared to the Atlantic one. This is probably related to the oligotrophy of the Mediterranean  
457 food webs.

458

### 459 **4.2.3. Trophic levels and captures**

460 The TLs from GOLEM are in relatively good agreement with the C model, except for a few groups  
461 including cephalopods, lobster, herbivorous fishes, *T. mediterraneus* and *C. conger*. Regarding  
462 herbivorous fishes, the species considered are not exactly the same. For the remaining groups, the main  
463 explanation is the better resolution in the constitution of the functional groups (especially for the  
464 invertebrates) allowing the TL to more accurately reflect the diet.

465 The average trophic level of catches in GOLEM (3.47) is higher than in model A and C (3.12 and 3.24  
466 or 3.35, depending on the fishery scenario, respectively). Even if the structure of the model might have  
467 impacted this value, it is very likely that it reflects the recent collapse in the GoL of sardine fishery (and  
468 anchovy to a lesser extent), species characterized by a low TL. Over the period 2007-2008, *S. pilchardus*  
469 represented 39% of the total catches (Bănaru *et al.*, 2013) against 4.6% over 2010 – 2014 (this study).  
470 Coll *et al.* (2006) reported a similar trend, with sardines being the largest part of the catches in 1994 and  
471 decreasing by 70% in 2003. In addition, concerning the other side of the TL spectra, this work attempted  
472 to achieve a better estimate of the fisheries by integrating corrections accounting for recreational fishing  
473 and IUUs (illegal, unreported and regulated catches). These catches concerned relatively high TL  
474 species (e.g. 3.08 for *S. aurata*, 3.97 for *S. scombrus*, 3.9 for *D. labrax*) which increased the average TL  
475 of the catches.

476 The exports and catches terms in the Lindeman diagrams also reflect these two facts: the sum, although  
477 comparable, is lower in Bănaru *et al.* (2013) (2.11 against 2.39 t km<sup>-2</sup> y<sup>-1</sup> in this study), explained by the  
478 addition of recreational catches and the decrease in landings of small pelagic fishes. It also appears in  
479 the distribution of exports and catches between trophic levels, with a lower value for TL III but higher  
480 for TL IV and V in the present study.

481 Bănaru *et al.* (2013) pointed out that while *E. encrasicaulus* and *S. pilchardus* were the most important  
482 landings, their mortality was mainly due to natural causes (predation and other causes). It seems that  
483 this is still the case in the current model, but their importance in the landings has strongly decreased (see  
484 **section 4.1**).

485 Compared with E model, the average TL of the catches are identical and the total catches are close (2.43  
486 t km<sup>-2</sup> y<sup>-1</sup> for GOLEM against 2.35 for the northern Aegean Sea), adding to the similarities between the  
487 two systems.

488

### 489 **4.3. System maturity and keystone**

490 Based on Christensen (1995) and the ecosystem maturity theory of Odum (1969), a comparison of  
491 attributes between the GOLEM model and the C model is proposed in **Table 7**. Odum defined two  
492 stages of ecosystem maturity: young, associated with high production, growth and quantity, and  
493 mature, characterized by stability and quality over quantity. Christensen retained 12 of the 24 Odum  
494 attributes and, for simplicity, we retained 7 of them, for which Christensen (1995) did not find a  
495 correlation with the number of groups in the models.

496 Five of them (in bold, **Table 7**) indicate the C model is the most mature ecosystem, according to  
497 Odum's theory. As the latter was qualified by Bănaru *et al.* (2013) as "at a rather low development  
498 stage", the current GoL ecosystem appears at an even lower stage. The difference in the modelled  
499 domains (down to 2500 m depth; GOLEM: 200 m depth) seems an unlikely explanation as the  
500 majority of the biological activity occurs on the continental shelf (0-200 m). This decrease in the  
501 maturity of the ecosystem could be explained by a general degradation of the system and/or as one of  
502 the consequences of the 2008 shift. For example, the B/P attribute is an index for the average size of  
503 the organisms and a decrease in the size of sardine, anchovy and sprat has been indeed noted in the  
504 GoL during this period (Van Beveren *et al.*, 2014; Saraux *et al.*, 2019).

505 The 3 species/groups with the highest KS, according to the Valls index are, in decreasing order, squids,  
506 *C. conger* and cuttlefish. Crustivorous fishes 2 are in the top 3 keystone species with the index of Valls  
507 *et al.* (2015) and are in fourth position with the index of Power *et al.* (1995), its mixed trophic impact  
508 (MTI) being high enough to compensate for the advantage given to low biomass by the Power index.  
509 **Figure 4** shows, that this group MTI comes mainly from its impact on jellyfish, which have a very low  
510 biomass and of which crustivorous fishes 2 are the only predators. Thus, the MTI of this group is  
511 probably overestimated.

512

## 513 **5. CONCLUSION**

514

515 Ecopath models are a widely-used solution to address various challenges such as fisheries management  
516 or ecosystem characterization. Nevertheless, in order to track the ongoing evolution of the environment  
517 (climate change, anthropic pressures, etc.) and to better face these challenges, they should be regularly  
518 enhanced.

519 In this work, we built a new model of the GoL based on the most recent data for diet, biomass  
520 (integrating the shift observed in the GoL around 2008), P/B and Q/B, improved resolution of functional  
521 groups and fisheries corrections. This represents a new step towards a better representation and  
522 understanding of the GoL ecosystem.

523 Key results include:

524 - a diagram of the trophic network on five trophic levels, with *Prionace glauca*, dolphin and *Squalus*  
525 *acanthias* the 3 top predators. They differ from earlier studies because *P. glauca* and *S. acanthias* were  
526 not included previously.

527 - various functional traits of the trophic network, such as the most consumed and the most consuming  
528 groups, the omnivory index of the system and the distribution of fluxes between trophic levels. Squid,  
529 *C. conger* and cuttlefish are given as keystone species according to the most recent index.

530 - a mixed trophic impact matrix allowing to understand the impact of each group on the rest of the  
531 network and highlighting the negative impact of fisheries on fished groups, in particular benthic trawls  
532 on *S. acanthias*, *S. canicula* and anglerfish, nets on *P. elephas* and long lines on *P. glauca*.

533 Despite the existing difficulties to compare models with different structures, the comparison between  
534 different Mediterranean models #highlights some similarities, such as the narrow range of PP/TST or  
535 the omnivory index. The North Aegean Sea model and GOLEM seem to have strong similarities,  
536 explained by the resemblance between their modelled areas and ecosystems.

537 Finally, this study provides both insights for a better understanding of the local ecosystem and a basic  
538 tool for potential management initiatives.

539 The project of which the present work is a part aims to take advantage of this new Ecopath model, in  
540 particular the representation of invertebrates and their interaction with the detritus compartment, in order  
541 to build a complete spatialized and dynamic model able to track the fate of radionuclides and other  
542 contaminants in the environment.

543

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563

## 564 **7. REFERENCES**

565

566 Agostini, V.N. and Bakun, A. (2002) ‘Ocean triads’ in the Mediterranean Sea: physical mechanisms  
567 potentially structuring reproductive habitat suitability (with example application to European  
568 anchovy, *Engraulis encrasicolus*)’, *Fisheries Oceanography*, 11(3), pp. 129–142. Available at:  
569 <https://doi.org/10.1046/j.1365-2419.2002.00201.x>.

570 Allen, K.R. (1971) ‘Relation Between Production and Biomass’, *Journal of the Fisheries Research*  
571 *Board of Canada*, 28(10), pp. 1573–1581. Available at: <https://doi.org/10.1139/f71-236>.

572 Araujo, J.N. *et al.* (2005) ‘An Ecopath model of the Western English Channel ecosystem with an  
573 exploration of its dynamic properties’, *Science Series Technical report*, (125), p. 45.

574 Bănar, D. *et al.* (2013) ‘Trophic structure in the Gulf of Lions marine ecosystem (north-western  
575 Mediterranean Sea) and fishing impacts’, *Journal of Marine Systems*, 111–112, pp. 45–68. Available  
576 at: <https://doi.org/10.1016/j.jmarsys.2012.09.010>.

577 Bănar, D. *et al.* (2019) ‘Implementation of an end-to-end model of the Gulf of Lions ecosystem (NW  
578 Mediterranean Sea). I. Parameterization, calibration and evaluation’, *Ecological Modelling*, 401, pp.  
579 1–19. Available at: <https://doi.org/10.1016/j.ecolmodel.2019.03.005>.

580 Bensebaini, C.M. *et al.* (2022) ‘Interactions between demersal fish body condition and density during  
581 the regime shift of the Gulf of Lions’, *ICES Journal of Marine Science*. Edited by M. Hunsicker, 79(6),  
582 pp. 1765–1776. Available at: <https://doi.org/10.1093/icesjms/fsac106>.

583 Bonifácio, P. *et al.* (2018) ‘Long-term (1998 vs. 2010) large-scale comparison of soft-bottom benthic  
584 macrofauna composition in the Gulf of Lions, NW Mediterranean Sea’, *Journal of Sea Research*, 131,  
585 pp. 32–45. Available at: <https://doi.org/10.1016/j.seares.2017.08.013>.

586 Boudouresque, C.F., Mayot, N. and Pergent, G. (2006) ‘The outstanding traits of the functioning of  
587 the *Posidonia oceanica* seagrass ecosystem’, *Biol. Mar. Medit.*, 4, pp. 109–113.

588 Bourdeix, J.-H. and Hattab, T. (1985) ‘PELMED - Pélagique Méditerranée’. Available at:  
589 <https://doi.org/10.18142/19>.

590 Bourjea, J. *et al.* (2019) *Identification d’une fermeture spatio-temporelle en Méditerranée*  
591 *continentale française (GSA7) ayant pour objectif une diminution de 20% des captures de juvéniles de*  
592 *Merlu (Merluccius merluccius)*. Ifremer, p. 19.

593 Brey, T. (2001) ‘Population dynamics in benthic invertebrates. A virtual handbook.’ Available at:  
594 <http://www.thomas-brey.de/science/virtualhandbook/>.

595 Brey, T. (2010) ‘An empirical model for estimating aquatic invertebrate respiration: *Aquatic*  
596 *invertebrate respiration*’, *Methods in Ecology and Evolution*, 1(1), pp. 92–101. Available at:  
597 <https://doi.org/10.1111/j.2041-210X.2009.00008.x>.

598 Brey, T. (2012) 'A multi-parameter artificial neural network model to estimate macrobenthic  
599 invertebrate productivity and production: Macrobenthic production model', *Limnology and*  
600 *Oceanography: Methods*, 10(8), pp. 581–589. Available at: <https://doi.org/10.4319/lom.2012.10.581>.

601 Calvo, E. *et al.* (2011) 'Effects of climate change on Mediterranean marine ecosystems: the case of  
602 the Catalan Sea', *Climate Research*, p. 29.

603 Cammen, L.M. (1979) 'Ingestion rate: An empirical model for aquatic deposit feeders and  
604 detritivores', *Oecologia*, 44(3), pp. 303–310. Available at: <https://doi.org/10.1007/BF00545232>.

605 Christensen, V. (1995) 'Ecosystem maturity — towards quantification', *Ecological Modelling*, 77(1),  
606 pp. 3–32. Available at: [https://doi.org/10.1016/0304-3800\(93\)E0073-C](https://doi.org/10.1016/0304-3800(93)E0073-C).

607 Christensen, V. *et al.* (2008) 'Ecopath with Ecosim version 6 user guide', *Lenfest Ocean Futures*  
608 *Project*, 235.

609 Christensen, V. and Pauly, D. (1992) 'ECOPATH II - a software for balancing steady-state ecosystem  
610 models and calculating network characteristics', *Ecological Modelling*, 61, pp. 169–185. Available at:  
611 [https://doi.org/10.1016/0304-3800\(92\)90016-8](https://doi.org/10.1016/0304-3800(92)90016-8).

612 Christensen, V. and Walters, C.J. (2004) 'Ecopath with Ecosim: methods, capabilities and limitations',  
613 *Ecological Modelling*, 172(2–4), pp. 109–139. Available at:  
614 <https://doi.org/10.1016/j.ecolmodel.2003.09.003>.

615 Cochrane, K. (2002) 'The Use of Ecosystem Models to Investigate Multispecies Management  
616 Strategies for Capture Fisheries', *Fisheries Centre Research Reports*. Edited by K. Cochrane and T.  
617 Pitcher, 10(2), p. 156.

618 Coll, M. *et al.* (2006) 'Trophic flows, ecosystem structure and fishing impacts in the South Catalan  
619 Sea, Northwestern Mediterranean', *Journal of Marine Systems*, 59(1–2), pp. 63–96. Available at:  
620 <https://doi.org/10.1016/j.jmarsys.2005.09.001>.

621 Coll, M. *et al.* (2007) 'An ecological model of the Northern and Central Adriatic Sea: Analysis of  
622 ecosystem structure and fishing impacts', *Journal of Marine Systems*, 67(1–2), pp. 119–154. Available  
623 at: <https://doi.org/10.1016/j.jmarsys.2006.10.002>.

624 Coll, M. *et al.* (2010) 'The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats',  
625 *PLoS ONE*. Edited by S.J. Bograd, 5(8), p. e11842. Available at:  
626 <https://doi.org/10.1371/journal.pone.0011842>.

627 Coll, M. and Libralato, S. (2012) 'Contributions of food web modelling to the ecosystem approach to  
628 marine resource management in the Mediterranean Sea: Ecosystem approach in the Mediterranean  
629 Sea', *Fish and Fisheries*, 13(1), pp. 60–88. Available at: [https://doi.org/10.1111/j.1467-](https://doi.org/10.1111/j.1467-2979.2011.00420.x)  
630 [2979.2011.00420.x](https://doi.org/10.1111/j.1467-2979.2011.00420.x).

631 Colléter, M. *et al.* (2015) 'Global overview of the applications of the Ecopath with Ecosim modeling  
632 approach using the EcoBase models repository', *Ecological Modelling*, 302, pp. 42–53. Available at:  
633 <https://doi.org/10.1016/j.ecolmodel.2015.01.025>.

634 Cresson, P. *et al.* (2014) 'Contrasting perception of fish trophic level from stomach content and stable  
635 isotope analyses: A Mediterranean artificial reef experience', *Journal of Experimental Marine Biology*  
636 *and Ecology*, 452, pp. 54–62. Available at: <https://doi.org/10.1016/j.jembe.2013.11.014>.



- 637 Cresson, P. *et al.* (2020) 'Primary production and depth drive different trophic structure and  
638 functioning of fish assemblages in French marine ecosystems', *Progress in Oceanography*, 186, p.  
639 102343. Available at: <https://doi.org/10.1016/j.pocean.2020.102343>.
- 640 CRPMEM PACA (2016) *Etat des lieux et caractérisation de la pêche maritime professionnelle et des*  
641 *élevages marins en PACA*. CRPMEM PACA.
- 642 Dalsgaard, J. and Pauly, D. (1997) 'Preliminary Mass-Balance Model of Prince William Sound, Alaska,  
643 for the Pre-Spill Period, 1980-1989', *Fisheries Centre Research Reports*, 5(2), p. 43.
- 644 Damsiri, Z. *et al.* (2022) 'An ecopath model for fisheries management in the Mogador marine  
645 protected area (Moroccan, Atlantic)', *Community Ecology*, 23(1), pp. 13–26. Available at:  
646 <https://doi.org/10.1007/s42974-021-00069-0>.
- 647 Darwall, W.R.T. *et al.* (2010) 'Lake of flies, or lake of fish? A trophic model of Lake Malawi', *Ecological*  
648 *Modelling*, 221(4), pp. 713–727. Available at: <https://doi.org/10.1016/j.ecolmodel.2009.11.001>.
- 649 Demaneche, S. *et al.* (2009) *Rapport R3 Méditerranée continentale, échantillonnage des marées au*  
650 *débarquement*. Ifremer.
- 651 Durrieu De Madron, X. *et al.* (2000) 'Particulate matter and organic carbon budgets for the Gulf of  
652 Lions (NW Mediterranean)', *Oceanologica Acta*, 23(6), pp. 717–730. Available at:  
653 [https://doi.org/10.1016/S0399-1784\(00\)00119-5](https://doi.org/10.1016/S0399-1784(00)00119-5).
- 654 Durrieu de Madron, X. *et al.* (2011) 'Marine ecosystems' responses to climatic and anthropogenic  
655 forcings in the Mediterranean', *Progress in Oceanography*, 91(2), pp. 97–166. Available at:  
656 <https://doi.org/10.1016/j.pocean.2011.02.003>.
- 657 Feuilleley, G. *et al.* (2020) 'Concomitant changes in the environment and small pelagic fish  
658 community of the Gulf of Lions', *Progress in Oceanography*, 186, p. 12.
- 659 Font, T. and Lloret, J. (2014) 'Biological and Ecological Impacts Derived from Recreational Fishing in  
660 Mediterranean Coastal Areas', *Reviews in Fisheries Science & Aquaculture*, 22(1), pp. 73–85. Available  
661 at: <https://doi.org/10.1080/10641262.2013.823907>.
- 662 Fortibuoni, T. (2017) 'Analysis of Long-Term Changes in a Mediterranean Marine Ecosystem Based on  
663 Fishery Landings', *Frontiers in Marine Science*, 4, p. 16.
- 664 Gaudy, R. *et al.* (2003) 'Biomass, metabolism and nutrition of zooplankton in the Gulf of Lions (NW  
665 Mediterranean)', *Oceanologica Acta*, 26(4), pp. 357–372. Available at:  
666 [https://doi.org/10.1016/S0399-1784\(03\)00016-1](https://doi.org/10.1016/S0399-1784(03)00016-1).
- 667 Hammerschmidt, C.R. *et al.* (2004) 'Biogeochemistry of methylmercury in sediments of Long Island  
668 Sound', *Marine Chemistry*, 90(1–4), pp. 31–52. Available at:  
669 <https://doi.org/10.1016/j.marchem.2004.02.024>.
- 670 Harmelin-Vivien, M. *et al.* (2008) 'Comparison of C and N stable isotope ratios between surface  
671 particulate organic matter and microphytoplankton in the Gulf of Lions (NW Mediterranean)',  
672 *Continental Shelf Research*, 28(15), pp. 1911–1919. Available at:  
673 <https://doi.org/10.1016/j.csr.2008.03.002>.
- 674 Heymans, J.J. *et al.* (2014) 'Global Patterns in Ecological Indicators of Marine Food Webs: A Modelling  
675 Approach', *PLOS ONE*, 9(4). Available at: <https://doi.org/10.1371/journal.pone.0095845>.

676 Heymans, J.J. *et al.* (2016) 'Best practice in Ecopath with Ecosim food-web models for ecosystem-  
677 based management', *Ecological Modelling*, 331, pp. 173–184. Available at:  
678 <https://doi.org/10.1016/j.ecolmodel.2015.12.007>.

679 Higuera, M. *et al.* (2014) 'Biogeochemical characterization of the riverine particulate organic matter  
680 transferred to the NW Mediterranean Sea', *Biogeosciences*, 11(1), pp. 157–172. Available at:  
681 <https://doi.org/10.5194/bg-11-157-2014>.

682 Jadaud, A. and Certain, G. (1994) 'MEDITS - MEDiterranean Trawl Survey'. Available at:  
683 <https://doi.org/10.18142/7>.

684 Kavanagh, P. *et al.* (2004) 'Automated parameter optimization for Ecopath ecosystem models',  
685 *Ecological Modelling*, 172(2–4), pp. 141–149. Available at:  
686 <https://doi.org/10.1016/j.ecolmodel.2003.09.004>.

687 Kayal, M. *et al.* (2020) 'Marine reserve benefits and recreational fishing yields: The winners and the  
688 losers', *PLOS ONE*. Edited by A. Belgrano, 15(12), p. e0237685. Available at:  
689 <https://doi.org/10.1371/journal.pone.0237685>.

690 Labrune, C. (2018) 'APPEAL MED 2018', RV Téthys II. Available at:  
691 <https://doi.org/https://doi.org/10.17600/18000598>.

692 Labrune, C. and Amouroux, J.-M. (2010) 'REDIT2010 cruise', RV Téthys II. Available at:  
693 <https://doi.org/10.17600/10450130>.

694 *Large Marine Ecosystems Hub* (no date). Available at: <https://www.lmehub.net/#mediterranean-sea>  
695 (Accessed: 27 April 2022).

696 Lefevre, D. *et al.* (1997) 'Review of gross community production, primary production, net community  
697 production and dark community respiration in the Gulf of Lions', *Deep Sea Research Part II: Topical  
698 Studies in Oceanography*, 44(3), pp. 801–832. Available at: [https://doi.org/10.1016/S0967-  
699 0645\(96\)00091-4](https://doi.org/10.1016/S0967-0645(96)00091-4).

700 Levrel, H. (2012) *Analyse économique et sociale de l'utilisation de nos eaux marines et du coût de la  
701 dégradation du milieu marin*. Ifremer.

702 Libralato, S., Christensen, V. and Pauly, D. (2006) 'A method for identifying keystone species in food  
703 web models', *Ecological Modelling*, 195(3–4), pp. 153–171. Available at:  
704 <https://doi.org/10.1016/j.ecolmodel.2005.11.029>.

705 Liénart, C. *et al.* (2017) 'Dynamics of particulate organic matter composition in coastal systems: A  
706 spatio-temporal study at multi-systems scale', *Progress in Oceanography*, 156, pp. 221–239.  
707 Available at: <https://doi.org/10.1016/j.pocean.2017.03.001>.

708 Lloret, J. and Font, T. (2013) 'A comparative analysis between recreational and artisanal fisheries in a  
709 Mediterranean coastal area', *Fisheries Management and Ecology*, 20(2–3), pp. 148–160. Available at:  
710 <https://doi.org/10.1111/j.1365-2400.2012.00868.x>.

711 Many, G. *et al.* (2021) 'Particulate organic carbon dynamics in the Gulf of Lion shelf (NW  
712 Mediterranean) using a coupled hydrodynamic–biogeochemical model', *Biogeosciences*, 18(19), pp.  
713 5513–5538. Available at: <https://doi.org/10.5194/bg-18-5513-2021>.

714 Margat, J. (1992) 'L'eau dans le bassin méditerranéen', *Aménagement et nature* [Preprint].

- 715 Micheli, F. *et al.* (2013) 'Cumulative Human Impacts on Mediterranean and Black Sea Marine  
716 Ecosystems: Assessing Current Pressures and Opportunities', *PLoS ONE*. Edited by J.P. Meador, 8(12),  
717 p. e79889. Available at: <https://doi.org/10.1371/journal.pone.0079889>.
- 718 Millot, C. (1999) 'Circulation in the Western Mediterranean Sea', *Journal of Marine Systems*, 20(1–4),  
719 pp. 423–442. Available at: [https://doi.org/10.1016/S0924-7963\(98\)00078-5](https://doi.org/10.1016/S0924-7963(98)00078-5).
- 720 *OBSMER report* (2009). OBSMER. Ifremer.
- 721 Odum, E.P. (1969) 'The Strategy of Ecosystem Development', *Science*, 164, p. 10.
- 722 Ono, T. *et al.* (2015) 'Concentration of  $^{134}\text{Cs}$  +  $^{137}\text{Cs}$  bonded to the organic fraction of sediments  
723 offshore Fukushima, Japan', *Geochemical Journal*, 49(2), pp. 219–227. Available at:  
724 <https://doi.org/10.2343/geochemj.2.0351>.
- 725 Otosaka, S. and Kobayashi, T. (2013) 'Sedimentation and remobilization of radiocesium in the coastal  
726 area of Ibaraki, 70 km south of the Fukushima Dai-ichi Nuclear Power Plant', *Environmental*  
727 *Monitoring and Assessment*, 185(7), pp. 5419–5433. Available at: [https://doi.org/10.1007/s10661-](https://doi.org/10.1007/s10661-012-2956-7)  
728 [012-2956-7](https://doi.org/10.1007/s10661-012-2956-7).
- 729 Palomares, M.L.D. and Pauly, D. (1998) 'Predicting food consumption of fish populations as functions  
730 of mortality, food type, morphometrics, temperature and salinity', *Marine and Freshwater Research*,  
731 49(5), p. 447. Available at: <https://doi.org/10.1071/MF98015>.
- 732 Patterson, K. (1992) 'Fisheries for small pelagic species: an empirical approach to management  
733 targets', *Reviews in Fish Biology and Fisheries*, 2(4), pp. 321–338. Available at:  
734 <https://doi.org/10.1007/BF00043521>.
- 735 Pauly, D. (1980) 'On the interrelationships between natural mortality, growth parameters, and mean  
736 environmental temperature in 175 fish stocks', *ICES Journal of Marine Science*, 39(2), pp. 175–192.  
737 Available at: <https://doi.org/10.1093/icesjms/39.2.175>.
- 738 Pauly, D. and Christensen, V. (1995) 'Primary production required to sustain global fisheries', *Letters*  
739 *to Nature*, 374, p. 3.
- 740 Pauly, D., Soriano-Bartz, M.L. and Palomares, M.L.D. (1993) 'Improved Construction, Parametrization  
741 and Interpretation of Steady-State Ecosystem Models', V. Christensen and D. Pauly (eds.), *Trophic*  
742 *models of aquatic ecosystems.*, pp. 1–13.
- 743 Petrenko, A., Leredde, Y. and Marsaleix, P. (2005) 'Circulation in a stratified and wind-forced Gulf of  
744 Lions, NW Mediterranean Sea: in situ and modeling data', *Continental Shelf Research*, 25(1), pp. 7–  
745 27. Available at: <https://doi.org/10.1016/j.csr.2004.09.004>.
- 746 Pinnegar, J.K. *et al.* (2005) 'Aggregation and removal of weak-links in food-web models: system  
747 stability and recovery from disturbance', *Ecological Modelling*, 184(2–4), pp. 229–248. Available at:  
748 <https://doi.org/10.1016/j.ecolmodel.2004.09.003>.
- 749 Polovina, J. (1984) 'Model of a Coral Reef Ecosystem I. The Ecopath Model and its application to  
750 French Frigate Shoals', *Coral Reefs*, 3, pp. 1–11.
- 751 Power, M.E. *et al.* (1996) 'Challenges in the Quest for Keystones', *BioScience*, 46(8), pp. 609–620.

752 Sánchez, F. and Olaso, I. (2004) 'Effects of fisheries on the Cantabrian Sea shelf ecosystem',  
753 *Ecological Modelling*, 172(2–4), pp. 151–174. Available at:  
754 <https://doi.org/10.1016/j.ecolmodel.2003.09.005>.

755 Saraux, C. *et al.* (2019) 'Small pelagic fish dynamics: A review of mechanisms in the Gulf of Lions',  
756 *Drivers of dynamics of small pelagic fish resources: environmental control of long-term changes*, 159,  
757 pp. 52–61. Available at: <https://doi.org/10.1016/j.dsr2.2018.02.010>.

758 Shigenobu, Y. *et al.* (2015) 'Investigation of Radiocesium Translation from Contaminated Sediment to  
759 Benthic Organisms', in *Impacts of the Fukushima Nuclear Accident on Fish and Fishing Grounds*.  
760 Tokyo: Springer Japan.

761 Tateda, Y. *et al.* (2020) 'Reconstruction of radiocesium levels in sediment off Fukushima: Simulation  
762 analysis of bioavailability using parameters derived from observed <sup>137</sup>Cs concentrations', *Journal of*  
763 *Environmental Radioactivity*, 214–215, p. 106172. Available at:  
764 <https://doi.org/10.1016/j.jenvrad.2020.106172>.

765 Tecchio, S. *et al.* (2013) 'Food web structure and vulnerability of a deep-sea ecosystem in the NW  
766 Mediterranean Sea', *Deep Sea Research Part I: Oceanographic Research Papers*, 75, pp. 1–15.  
767 Available at: <https://doi.org/10.1016/j.dsr.2013.01.003>.

768 Telesca, L. *et al.* (2015) 'Seagrass meadows (*Posidonia oceanica*) distribution and trajectories of  
769 change', *Scientific Reports*, 5(1), p. 12505. Available at: <https://doi.org/10.1038/srep12505>.

770 Thollet, F. *et al.* (2018) 'Observatoire des Sédiments du Rhône'. Irstea. Available at:  
771 <https://doi.org/10.17180/OBS.OSR>.

772 Tsagarakis, K. *et al.* (2010) 'Food-web traits of the North Aegean Sea ecosystem (Eastern  
773 Mediterranean) and comparison with other Mediterranean ecosystems', *Estuarine, Coastal and Shelf*  
774 *Science*, 88(2), pp. 233–248. Available at: <https://doi.org/10.1016/j.ecss.2010.04.007>.

775 Ulanowicz, R.E. and Puccia, C.J. (1990) 'Mixed trophic impacts in ecosystems', *Coenoses*, 5(1), pp. 7–  
776 16.

777 Valls, A., Coll, M. and Christensen, V. (2015) 'Keystone species: toward an operational concept for  
778 marine biodiversity conservation', *Ecological Monographs*, 85(1), pp. 29–47. Available at:  
779 <https://doi.org/10.1890/14-0306.1>.

780 Van Beveren, E. *et al.* (2014) 'Rapid changes in growth, condition, size and age of small pelagic fish in  
781 the Mediterranean', *Marine Biology*, 161(8), pp. 1809–1822. Available at:  
782 <https://doi.org/10.1007/s00227-014-2463-1>.

783 Walters, C., Christensen, V. and Pauly, D. (1997) 'Structuring dynamic models of exploited  
784 ecosystems from trophic mass-balance assessments', *Reviews in Fish Biology and Fisheries*, 7, pp.  
785 139–172.

786 Walters, C., Pauly, D. and Christensen, V. (1999) 'Ecospace: Prediction of Mesoscale Spatial Patterns  
787 in Trophic Relationships of Exploited Ecosystems, with Emphasis on the Impacts of Marine Protected  
788 Areas', *Ecosystems*, 2, pp. 539–554.

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## Table des figures et tableaux

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- 794 • **Figure 1** Location and bathymetry of the study area in the Gulf of Lion north-western  
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- 796 • **Table 1** Description of the functional groups of GOLEM model.
- 797 • **Table 2** Input parameters of the GOLEM model by functional group:  $B_i$  = initial estimated  
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- 800 • **Table 3** Diet composition matrix of the GOLEM model.
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802 the model are indicated in bold. TL = trophic level,  $B_f$  = final biomass ( $t\ km^{-2}$ ),  $EE$  =  
803 ecotrophic efficiency,  $F$  = fishing mortality ( $y^{-1}$ ),  $M_2$  = predation mortality ( $y^{-1}$ ),  $M_0$  =  
804 natural mortality ( $y^{-1}$ ),  $F/Z$  = exploitation rate,  $Q$  = consumption ( $t\ km^{-2}\ y^{-1}$ ),  $FD$  = flow to  
805 detritus ( $t\ km^{-2}\ y^{-1}$ ),  $P/Q$  = production/consumption,  $NE$  = net efficiency,  $OI$  = Omnivory  
806 Index.
- 807 • **Figure 2** Trophic diagram of the GOLEM model. The ordinate axis represents the trophic  
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- 821 • **Table 7** Odum's attributes (1969) as calculated by Christensen (1995). For each attribute,  
822 values in bold indicate the most mature model.  $PP/R$  = total primary production/total  
823 respiration,  $PP/B$  = total primary production/total biomass (\*excluding detritus),  $B/TST$  =  
824 biomass (\*)/total throughput, total respiration/total biomass(\*),  $B/P$  = total biomass(\*)/ total  
825 production,  $B/(R+Exp)$  = total biomass/(total respiration+total export)

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**Table 1** Description of the functional groups GOLEM model.

Functional group	Species/groups included
1 Picoplankton	Cyanobacteria, autotrophic and heterotrophic pico-eucaryotes
2 Nanoplankton	Bacteria, protist, autotrophic and heterotrophic nano-eucaryotes
3 Microphytoplankton	Diatoms, dinobionts
4 Microphytobenthos	spp.
5 Posidonia	<i>Posidonia oceanica</i>
6 Benthic macrophytes and epibionts	spp.
7 Microzooplankton	Eggs and nauplii of copepods, small cladocerans, pteropods, euphausiids, and mysids
8 Mesozooplankton	Copepods, cladocerans, pteropods, euphausiids, mysids, amphipods, ostracods, fish and invertebrate eggs and larvae
9 Macrozooplankton	Krill, fish and invertebrate eggs and larvae, pteropods, euphausiids, mysids, amphipods and non-jellyfish gelatinous zooplankton
10 Jellyfishes	35.9% <i>Pelgia noctiluca</i> , 64.4% <i>Rhizostoma pulmo</i>
11 Cnidarians	13.6% <i>Pteroeides spinosum</i> , 34.9% <i>Veretillum</i> spp, 6.3% <i>Funiculina quadrangularis</i> , 31% Alcyoniidae, 2.3% <i>Nemertesia antennina</i> , 4.5% <i>Nemertesia ramosa</i> , 7.3% Actinaria ( <i>Adamsia palliata</i> , <i>Calliactis parasitica</i> )
12 Sessile suspension feeders	Bryozoa, Tunicata and Porifera
13 Depositivorous molluscs	<i>Cerastoderma edule</i> , <i>Ruditapes</i> spp, <i>Calliostoma granulatum</i> , <i>Littorina littorea</i> , <i>Tritia mutabilis</i> , <i>Turritella communis</i>
14 Filter feeder molluscs	<i>Atrina pectinata</i> , <i>Acanthocardia echinata</i> , <i>Glossus humanus</i> , <i>Mytilus galloprovincialis</i> , Ostreidae, <i>Tellina</i> spp
15 Carnivorous Molluscs	<i>Bolinus brandaris</i> , <i>Buccinum undatum</i> , <i>Galeodea echinophora</i> , <i>Galeodea rugosa</i> , <i>Scaphander lignarius</i>
16 Octopuses	51.3% <i>Octopus vulgaris</i> , 2.2% <i>Octopus salutii</i> , 35.4% <i>Eledone cirrhosa</i> , 11.1% <i>Eledone moschata</i>
17 Cuttlefishes	32.6% <i>Sepia officinalis</i> , 8.3% <i>Sepia elegans</i> , 50.3% <i>Sepia orbignyana</i> , 8.8% <i>Sepietta oweniana</i>
18 Squids	10.3% <i>Alloteuthis</i> spp, 58.3% <i>Illex coindetii</i> , 20.5% <i>Loligo</i> spp, 10.9% <i>Todaropsis eblanae</i>
19 Detritivorous worms	Maldanidae, enteropneusta
20 Filter feeding worms	<i>Serpula</i> spp.
21 Carnivorous worms	<i>Aphrodita aculeata</i> , nemerteans
22 Sipuncula	spp.
23 Suprabenthic and benthic crustaceans	Mysids, amphipods, isopods, cumaceans, benthic copepods, euphausiids,
24 Pagurids	10.5% <i>Pagurus excavatus</i> , 71.3% <i>Pagurus prideaux</i> , 18.2% <i>Dardanus arrosor</i>
25 Shrimps - decapods	<i>Natantia</i> , <i>Palaemon serratus</i> , <i>Parapenaeus longirostris</i>
26 Other Malacostraca	46.6% <i>Squilla mantis</i> , 53.4% <i>Nephrops norvegicus</i>
27 Brachyurids	<i>Carcinus aestuarii</i> , <i>Liocarcinus depurator</i> , <i>Macropipus tuberculatus</i> , <i>Medorippe lanata</i> , <i>Necora puber</i>
28 Palinurus elephas	
29 Homarus gammarus	
30 Filter feeder echinoderms	<1% <i>Ophiolithrix</i> spp, 7.7% <i>Antedon</i> spp, 88.6% <i>Leptometra</i> spp, 3.7% <i>Ocnus planci</i>
31 Carnivorous echinoderms	38.4% <i>Anseropoda placenta</i> , 39.2% <i>Astropecten irregularis pentacanthus</i> , 16.4% <i>Echinaster sepositus</i> , 5.9% <i>Ophiura ophiura</i>
32 Holothurians	18.8% <i>Leptopentacta elongata</i> , 81.2% <i>Parastichopus regalis</i>
33 Echinids	<1% <i>Brissopsis lyrifera</i> , 7.1% <i>Cidaris cidaris</i> , 9.8% <i>Gracilechinus acutus</i> , 81.3% <i>Paracentrotus lividus</i> , 1.7% <i>Spatangus purpureus</i>
34 Herbivorous fishes	99% <i>Sarpa salpa</i> , 1% <i>Diplodus annularis</i>
35 Sardina pilchardus	
36 Engraulis encrasicolus	
37 Sprattus sprattus	
38 Planctonophagous pelagic	63.4% <i>Sardinella aurita</i> , 3.2% <i>Spicara smari</i> , 33.3% Atherinidae
39 Planctonophagous demersal	1.7% <i>Spicara flexuosa</i> , 5.2% <i>Cepala macrophtalma</i> , 21.3% <i>Boops boop</i> , 1.2% <i>Argentina sphyraena</i> , 1.7% <i>Micromesistius poutassou</i> , 68.9% <i>Scomber colias</i>
40 Invertivorous fishes	42.3% <i>Trisopterus capelanus</i> , <1% <i>Trisopterus luscus</i> , 1.4% <i>Gobius niger</i> , 36.1% <i>Diplodus cervinus</i> , <1% <i>Blennius ocellaris</i> , 5.8% <i>Lepidotrigla cavillone</i> , 1.6% <i>Lepidotrigla dieuzeidei</i> , 1% <i>Scorpeana notata</i> , 4.1% <i>Lepidorhombus boscii</i> , 7% <i>Serranus hepatus</i>
41 Crustivorous fishes 1	7.2% <i>Chelidonichthys lucerna</i> , 8.5% <i>Trachinus draco</i> , 67.6% <i>Eutrigla gurnadus</i> , 16.8% <i>Serranus cabrilla</i>
42 Crustivorous fishes 2	8.6% <i>Trigla lyra</i> , 12.7% <i>Mullus surmuletus</i> , 21.8% <i>Chelidonichthys cuculus</i> , 2% <i>Phycis blennoides</i> , 27.2% <i>Pagellus acarne</i> , 17.9% <i>Pagellus erythrinus</i> , 4.4% <i>Spondyliosoma cantharus</i> , 3.8% <i>Capros aper</i> , 1.5% <i>Macroramphosus scolopax</i>
43 Wormivorous fishes	1% <i>Deltentosteus quadrimaculatus</i> , <1% <i>Lesueurigobius friesii</i> , <1% <i>Callionymus maculatus</i> , 98.6% <i>Diplodus sargus</i>
44 Mulets	25% <i>Mugil cephalus</i> , <1% <i>Liza aurata</i> , <1% <i>Liza ramda</i> , <1% <i>Oedalechilus labeo</i> , 74.8% <i>Chelon labrosus</i>
45 Lagoon flat fish	13.4% <i>Microchirus variegatus</i> , 53.2% <i>Solea solea</i> , 33.3% <i>Pegusa lascaris</i>
46 Scomber scombrus	
47 Trachurus mediterraneus	
48 Trachurus trachurus	
49 Mullus barbatus	
50 Sparus aurata	
51 Diplodus vulgaris	
52 Coris julis	
53 Carnivorous demersal fishes 1	6.25% <i>Seriola dumerili</i> , <1% <i>Dentex dentex</i> , 4.9% <i>Scorpeana scrofa</i> , 2.5% <i>Scorpeana elongata</i> , 8.7% <i>Uranoscopus scaber</i> , 3% <i>Torpedo marmorata</i> , 14.9% <i>Torpedo nobiliana</i> , 6.25% Muraenidae, 6.7% <i>Pagellus bogaraveo</i> , 1.6% <i>Pagrus pagrus</i> , 6.25% <i>Limanda limanda</i> , 6.25% <i>Lithognathus mormyrus</i> , 8.4% <i>Scopthalmus maximus</i> , 3.8% <i>Scopthalmus rhombus</i> , 13.8% <i>Zeus faber</i> , 6.25% <i>Sarda sarda</i>
54 Piscivorous flat fishes	2% <i>Lepidorhombus whiffiagonis</i> , 26.8% <i>Arnoglossus laterna</i> , 71.2% <i>Citharus linguatula</i>
55 Piscivorous fishes	<i>Sphyraena</i> spp., <i>Xiphias gladius</i> , <i>Lepidopus caudatus</i>
56 Thunas	<i>Thunnus thynnus</i> , <i>Thunnus alalunga</i> , <i>Katsuwonus pelamis</i>
57 Anglerfish	64.3% <i>Lophius budegassa</i> , 35.7% <i>Lophius piscatorius</i>
58 Dicentrarchus labrax	
59 Merluccius merluccius	
60 Conger conger	
61 Squalus acanthias	
62 Scyliorhinus canicula	
63 Prionace glauca	
64 Rays	16.7% <i>Leucoraja naevus</i> , 29.6% <i>Pteroplatytrigon violacea</i> , 8% <i>Raja asterias</i> , 26.4% <i>Raja clavata</i> , 2.6% <i>Raja montagui</i> , 16.7% <i>Rostroraja alba</i>
65 Dolphins	<i>Tursiops truncatus</i>
66 Sea birds	<i>Larus michaellis</i> , <i>Calonectris diomedea diomedea</i> , <i>Puffinus yelkouan yelkouan</i> , <i>Puffinus yelkouan mauretanicus</i> , <i>Sterna hirundo</i> , <i>Morus bassanus</i>

830 Table 2 Input parameters of the GOLEM model by functional group:  $B_i$  =initial estimated biomass,  $P/B$   
831 = production/biomass,  $Q/B$  = consumption/biomass,  $EE$  = ecotrophic efficiency,  $U/Q$  = unassimilated  
832 food/consumption.



	Functionnal groups	Bi (t km-2)	(t P/B (y-1)	Q/B (y-1)	EE	U/Q	Total landings (t km-1 y-1)
1	Picoplankton	3,537	200			0	0
2	Nanoplankton	6,026	97,29			0	0
3	Microphytoplankton	3,537	84,29			0	0
4	Microphytobenthos	0,742	100			0	0
5	Posidonia	4,819	1,18			0	0
6	Benthic macrophytes and epibionts	3,24	12,46			0	0
7	Microzooplankton	0,76	120	145,00		0,4	0
8	Mesozooplankton	9,07	39	80,00		0,4	0
9	Macrozooplankton	2,25	18	38,00		0,2	0
10	Jellyfishes	0,0002	14,6	50,48		0,2	0
11	Cnidarians	1,966	0,13	15,37		0,2	0
12	Sessile suspension feeders	0,048	3,20	3,80		0,2	9,34E-04
13	Depositivorous molluscs	0,851	7,00	31,28		0,2	0,03
14	Filter feeder molluscs	3,103	7,90	16,74		0,4	0,16
15	Carnivorous Molluscs	0,24	5,30	19,21		0,2	0,02
16	Octopuses	0,083	2,01	8,07		0,2	0,18
17	Cuttlefishes	0,011	2,70	13,21		0,2	0,01
18	Squids	0,032	2,96	14,20		0,2	0,04
19	Detritivorous worms	7,519	10,83	18,75		0,4	3,91E-05
20	Filter feeding worms	0,873	35,99	32,52		0,3	4,50E-06
21	Carnivorous worms	2,865	3,85	14,20		0,2	1,49E-05
22	Sipuncula	1,136	0,13	4,30		0,6	0
23	Suprabenthic and benthic crustaceans	1,559	11	25,00		0,3	0
24	Pagurids	0,061	1,82	16,09		0,3	2,51E-04
25	Shrimps - decapods	0,001	9,80	11,00		0,2	7,89E-04
26	Other Malacostraca	0,005	2,92	12,18		0,3	5,23E-03
27	Brachyurids	0,008	2,87	16,59		0,3	2,62E-03
28	Palinurus elephas	0,001	1,79	6,31		0,2	6,99E-04
29	Homarus gammarus	0,001	1,78	5,70		0,2	3,74E-04
30	Filter feeder echinoderms	0,304	3,69	28,06		0,2	0
31	Carnivorous echinoderms	0,515	3,18	18,04		0,2	0
32	Holothurians	0,139	1,58	15,61		0,3	4,33E-05
33	Echinids	1,906	2,40	11,80		0,2	2,23E-02
34	Herbivorous fishes	0,262	1,45	22,14		0,3	0,08
35	Sardina pilchardus	5,039	0,95	9,94		0,3	0,12
36	Engraulis encrasicolus	2,724	1,12	8,24		0,3	0,20
37	Sprattus sprattus	3,578	0,68	11,88		0,3	1,19E-06
38	Planctonophagous pelagic fishes	0,029	0,95	7,41		0,3	0,01
39	Planctonophagous demersal fishes	0,219	0,94	6,09		0,3	0,10
40	Invertivorous fishes	0,146	0,91	8,03		0,2	0,16
41	Crustivorous fishes 1	0,049	0,53	5,33		0,2	0,03
42	Crustivorous fishes 2	0,117	1,16	6,52		0,2	0,11
43	Wormivorous fishes	0,042	1,05	11,05		0,2	0,03
44	Mulets	0,278	0,50	3,68		0,2	0,16
45	Lagoon flat fish	0,057	1,04	5,29		0,2	0,06
46	Scomber scombrus	0,227	1,29	7,29		0,2	0,16
47	Trachurus mediterraneus	0,531	0,64	6,24		0,2	0,00
48	Trachurus trachurus	0,698	0,55	7,37		0,2	0,05
49	Mullus barbatus	0,095	0,98	5,89		0,2	0,03
50	Sparus aurata	0,169	1,00	4,90		0,2	0,39
51	Diplodus vulgaris	0,008	1,16	11,00		0,2	0,01
52	Coris julis	0,101	0,40	6,58		0,2	0,01
53	Carnivorous demersal fishes	0,095	0,59	3,50		0,2	0,09
54	Piscivorous flat fishes	0,013	0,49	6,68		0,2	0,01
55	Piscivorous fishes	0,324	0,27	3,49		0,2	0,01
56	Thunas	0,657	0,17	3,27		0,2	0,02
57	Anglerfish	0,070	0,69	5,70		0,2	0,07
58	Dicentrachus labrax	0,118	1,13	3,54		0,2	0,21
59	Merluccius merluccius	0,376	0,94	3,07		0,2	0,21
60	Conger conger	0,007	0,91	4,15		0,2	0,04
61	Squalus acanthias	0,006	0,25	2,88		0,2	9,65E-05
62	Scyliorhinus canicula	0,045	0,46	3,87		0,2	2,64E-03
63	Prionace glauca		0,30	2,80	0,1	0,2	6,22E-04
64	Rays	0,140	0,48	3,12		0,2	0,01
65	Dolphins	0,008	0,02	6,12		0,2	0
66	Marine birds	0,003	0,60	66,00		0,2	0
67	Discards	0,298				0,2	0
68	Detritus	64,700				0	0



836 Table 4 Main output parameters of the GOLEM model. Biomass parameters estimated by the model  
837 are indicated by bold characters. TL = trophic level, Bf = final biomass (t km<sup>-2</sup>), EE = ecotrophic  
838 efficiency, F = fishing mortality (y<sup>-1</sup>), M2 = predation mortality (y<sup>-1</sup>), M0 = natural mortality (y<sup>-1</sup>),  
839 F/Z = exploitation rate, Q = consumption (t km<sup>-2</sup> y<sup>-1</sup>), FD = flow to detritus (t km<sup>-2</sup> y<sup>-1</sup>), P/Q =  
840 production/consumption, NE = net efficiency, OI = Omnivory Index.

Functional group	TL	Bf	Bf/B0	EE	F	M2	M0	F/Z	Q	FD	P/Q	NE	OI
1 Picoplankton	1,00	3,54	1,00	0,70	0	139,08	60,92	0,00		215,48			0
2 Nanoplankton	1,00	6,03	1,00	0,99	0	166,85	1,69	0,00		10,16			0
3 Microphytoplankton	1,00	3,54	1,00	0,76	0	63,669	20,62	0,00		72,94			0
4 Microphytobenthos	1,00	0,74	1,00	0,88	0	87,931	12,07	0,00		8,96			0
5 Posidonia	1,00	4,82	1,00	0,89	0	1,046	0,13	0,00		0,65			0
6 Benthic macrophytes and	1,00	3,24	1,00	0,99	0	12,294	0,17	0,00		0,54			0
7 Microzooplankton	2,00	<b>0,90</b>	1,18	0,99	0,00	118,84	1,16	0,00	359,60	141,29	0,30	0,49	0
8 Mesozooplankton	2,05	9,07	1,00	0,50	0,00	19,41	19,59	0,00	1179,10	637,55	0,30	0,49	0,05
9 Macrozooplankton	2,72	2,25	1,00	0,46	0,00	8,26	9,74	0,00	135,00	48,91	0,30	0,38	0,22
10 Jellyfishes	2,82	0,00	1,00	0,30	0,00	4,41	10,19	0,00	0,01	0,00	0,29	0,36	0,53
11 Cnidarians	2,45	2,49	1,26	1,00	0,00	4,50	0,00	0,00	38,19	7,65	0,29	0,37	0,28
12 Sessile suspension feeders	2,05	<b>3,64</b>	75,77	0,98	0,00	3,12	0,08	0,00	38,92	8,07	0,30	0,37	0,04
13 Depositivorous molluscs	2,00	<b>5,08</b>	5,97	0,95	0,01	6,65	0,35	0,00	158,91	33,56	0,22	0,28	0,00
14 Filter feeder molluscs	2,05	<b>3,42</b>	1,10	1,00	0,05	7,83	0,02	0,01	90,50	36,28	0,30	0,50	0,05
15 Carnivorous Molluscs	3,02	<b>1,69</b>	7,02	0,99	0,01	5,23	0,05	0,00	32,38	6,56	0,28	0,34	0,18
16 Octopuses	4,22	<b>0,15</b>	1,85	1,00	1,17	0,84	0,00	0,58	1,24	0,25	0,25	0,31	0,10
17 Cuttlefishes	4,22	<b>0,30</b>	26,04	1,00	0,04	3,74	0,02	0,01	3,95	0,79	0,29	0,36	0,16
18 Squids	4,29	<b>0,24</b>	7,63	1,00	0,15	2,80	0,01	0,05	3,46	0,69	0,21	0,26	0,18
19 Detritivorous worms	2,00	7,52	1,00	0,78	0,00	8,44	2,39	0,00	270,68	123,52	0,30	0,49	0,00
20 Filter feeding worms	2,00	0,87	1,00	0,55	0,00	5,54	4,46	0,00	29,68	12,79	0,29	0,42	0,00
21 Carnivorous worms	3,11	2,87	1,00	1,00	0,00	5,55	0,01	0,00	54,45	10,92	0,29	0,37	0,09
22 Sipuncula	2,00	1,14	1,00	0,95	0,00	0,45	0,02	0,00	4,88	2,96	0,11	0,27	0,00
23 Suprabenthic and benthic c	2,06	<b>4,63</b>	2,97	0,97	0,00	14,62	0,38	0,00	236,27	72,63	0,29	0,42	0,08
24 Pagurids	2,90	0,06	1,00	0,98	0,00	4,89	0,11	0,00	1,04	0,32	0,29	0,42	0,33
25 Shrimps - decapods	3,20	2,27	2493,39	1,00	0,00	9,79	0,01	0,00	74,94	15,00	0,30	0,37	0,27
26 Other Malacostraca	3,63	<b>0,05</b>	9,51	0,97	0,11	2,71	0,10	0,04	0,60	0,18	0,24	0,34	0,78
27 Brachyurids	3,32	<b>2,12</b>	271,77	1,00	0,00	4,20	0,00	0,00	35,16	10,55	0,25	0,36	0,59
28 Palinurus elephas	3,22	0,00	1,00	0,56	1,00	0,00	0,79	0,56	0,00	0,00	0,28	0,36	0,35
29 Homarus gammarus	3,13	0,00	1,00	0,27	0,44	0,05	1,30	0,25	0,00	0,00	0,30	0,37	0,88
30 Filter feeder echinoderms	2,02	0,30	1,00	0,95	0,00	4,71	0,25	0,00	8,52	1,78	0,18	0,22	0,02
31 Carnivorous echinoderms	3,26	<b>2,47</b>	4,80	1,00	0,00	5,30	0,00	0,00	44,62	8,93	0,29	0,37	0,26
32 Holothurians	2,00	0,14	1,00	0,73	0,00	1,16	0,42	0,00	2,17	0,71	0,10	0,14	0,00
33 Echinids	2,07	<b>4,21</b>	2,21	1,00	0,01	3,53	0,00	0,00	49,62	9,93	0,30	0,38	0,09
34 Herbivorous fishes	2,00	0,26	1,00	0,19	0,20	0,08	1,17	0,14	5,79	2,04	0,07	0,09	0,00
35 Sardina pilchardus	2,95	5,04	1,00	0,71	0,03	0,65	0,28	0,03	50,08	16,43	0,10	0,14	0,11
36 Engraulis encrasicolus	3,15	2,72	1,00	0,95	0,08	1,22	0,06845116	0,06	22,43	6,92	0,17	0,24	0,06
37 Sprattus sprattus	3,10	3,58	1,00	0,95	0,00	0,90	0,05	0,00	42,51	12,92	0,08	0,11	0,03
38 Planctonophagous pelagic	3,08	<b>0,33</b>	11,42	0,95	0,04	0,86	0,05	0,04	2,44	0,75	0,13	0,18	0,09
39 Planctonophagous dermers	3,61	<b>0,87</b>	3,96	0,98	0,08	0,83	0,02	0,09	5,29	1,61	0,15	0,22	0,37
40 Invertivorous fishes	3,97	<b>1,96</b>	13,46	1,00	0,05	0,86	0,00	0,05	15,75	3,15	0,11	0,14	0,41
41 Crustivorous fishes 1	4,13	<b>0,45</b>	9,27	0,99	0,01	0,68	0,00	0,02	2,41	0,48	0,13	0,16	0,46
42 Crustivorous fishes 2	3,38	0,12	1,00	0,95	0,73	0,71	0,08	0,48	0,76	0,16	0,23	0,29	0,32
43 Wormivorous fishes	3,19	<b>3,58</b>	85,57	0,95	0,01	1,42	0,07	0,01	39,54	8,18	0,14	0,17	0,29
44 Mulets	2,50	0,28	1,00	0,88	0,38	0,06	0,06	0,76	1,02	0,22	0,14	0,17	0,42
45 Lagoon flat fish	3,29	<b>0,15</b>	2,60	0,95	0,38	0,61	0,05	0,36	0,78	0,16	0,20	0,25	0,77
46 Scomber scombrus	3,97	<b>0,23</b>	1,00	0,52	0,49	0,19	0,62	0,38	1,65	0,47	0,18	0,22	0,05
47 Trachurus mediterraneus	3,68	0,53	1,00	0,08	0,00	0,05	0,59	0,00	3,31	0,97	0,10	0,13	0,25
48 Trachurus trachurus	3,83	0,70	1,00	0,73	0,07	0,33	0,15	0,13	5,14	1,13	0,07	0,09	0,05
49 Mullus barbatus	3,57	0,10	1,00	0,95	0,36	1,15	0,08	0,23	0,56	0,12	0,27	0,34	0,37
50 Sparus aurta	3,08	<b>0,33</b>	1,92	0,95	0,94	0,01	0,05	0,94	1,59	0,33	0,20	0,26	0,56
51 Diplodus vulgaris	3,21	<b>0,03</b>	3,87	0,96	0,15	0,96	0,04	0,13	0,35	0,07	0,11	0,13	0,10
52 Coris julis	3,58	0,10	1,00	0,96	0,08	0,31	0,02	0,19	0,66	0,13	0,06	0,08	0,23
53 Carnivorous demersal fishe	4,32	<b>0,12</b>	1,29	0,95	0,60	0,40	0,05	0,57	0,43	0,09	0,30	0,37	0,44
54 Piscivorous flat fishes	4,33	<b>1,02</b>	75,88	0,84	0,01	0,54	0,10	0,01	6,79	1,46	0,10	0,12	0,12
55 Piscivorous fishes	4,28	0,32	1,00	0,36	0,02	0,07	0,17	0,09	1,13	0,28	0,08	0,10	0,24
56 Thunas	4,19	0,66	1,00	0,18	0,03	0,00	0,14	0,18	2,15	0,52	0,05	0,06	0,29
57 Anglerfish	4,77	0,07	1,00	0,95	1,07	0,00	0,06	0,95	0,40	0,08	0,20	0,25	0,19
58 Dicentrachus labrax	3,91	<b>0,14</b>	1,15	0,95	1,08	0,01	0,05	0,95	0,53	0,11	0,29	0,36	1,13
59 Merluccius merluccius	4,19	0,38	1,00	0,89	0,55	0,28	0,11	0,59	1,18	0,28	0,30	0,37	0,05
60 Conger conger	4,42	<b>0,08</b>	11,78	0,96	0,50	0,38	0,04	0,55	0,33	0,07	0,22	0,27	0,32
61 Squalus acanthias	4,95	0,01	1,00	0,19	0,05	0,00	0,20	0,19	0,02	0,00	0,09	0,11	0,14
62 Scyliorhinus canicula	4,34	0,04	1,00	0,13	0,06	0,00	0,40	0,13	0,17	0,05	0,12	0,15	0,07
63 Prionace glauca	5,19	0,02	NA	0,10	0,03	0,00	0,27	0,10	0,06	0,02	0,11	0,13	0,09
64 Rays	4,43	0,14	1,00	0,14	0,07	0,00	0,41	0,14	0,44	0,14	0,15	0,19	0,31
65 Dolphins	4,95	0,01	1,00	0,00	0,00	0,00	0,02	0,00	0,05	0,01	0,00	0,00	0,19
66 Sea birds	3,84	0,00	1,00	0,00	0,00	0,00	0,60	0,00	0,20	0,04	0,01	0,01	1,55
67 Discards	1,00	0,30	1,00	0,98					0	0,00		0	0
68 Detritus	1,00	64,70	1,00	0,37					1559,99	0,00		0	0,32

841

842 Table 5 Ecological indicators related to community energetics, structure, flows and information  
 843 theory.

	Value	Units
<i>Statistics and flows</i>		
Sum of all consumption	3069,81	t km <sup>-2</sup> y <sup>-1</sup>
Sum of all exports	1053,91	t km <sup>-2</sup> y <sup>-1</sup>
Sum of all respiratory flows	1187,96	t km <sup>-2</sup> y <sup>-1</sup>
Sum of all flows into detritus	1658,06	t km <sup>-2</sup> y <sup>-1</sup>
Total system throughput	6969,74	t km <sup>-2</sup> y <sup>-1</sup>
Sum of all production	3002,08	t km <sup>-2</sup> y <sup>-1</sup>
Mean trophic level of the catch	3,47	
Gross efficiency (catch/net p.p.)	0,001	
Calculated total net primary production	2141,38	t km <sup>-2</sup> y <sup>-1</sup>
Total primary production/total respiration	1,80	
Net system production	953,42	t km <sup>-2</sup> y <sup>-1</sup>
Total primary production/total biomass	20,57	
Total biomass/total throughput	0,01	t km <sup>-2</sup> y <sup>-1</sup>
Total biomass (excluding detritus)	104,11	t km <sup>-2</sup>
Total catch	2,43	t km <sup>-2</sup> y <sup>-1</sup>
Connectance Index	0,16	
System Omnivory Index	0,21	
Ecopath pedigree	0,64	
Measure of fit. t*	6,63	
Shannon diversity index	3,46	
<i>Network flow indices</i>		
Throughput cycled (excluding detritus)	15,8	t km <sup>-2</sup> y <sup>-1</sup>
Predatory cycling index	0,432	% of throughput without detritus
Throughput cycled (including detritus)	312,4	t km <sup>-2</sup> y <sup>-1</sup>
Finn's cycling index	4,48	% of total throughput
Finn's mean path length	3,11	
<i>Information indices</i>		
Ascendency	28,79	%
Overhead	71,21	%
Capacity (total)	38073	Flowbits

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847 Table 6 Comparison between GOLEM model and models from the literature based on total  
 848 throughput (TST) normalized parameters (Heymans, 2014) and three other useful indices. PP =  
 849 primary production, Q = consumption

	Area	modelled period	n° of functional groups	PP / TST	Q / TST	Export / TST	TST (t/Km <sup>2</sup> /y)	Total biomass (excluding detritus, t/Km <sup>2</sup> )	Modelled area (Km <sup>2</sup> )	Depth range (m)	Omnivory index	Reference
A	Catalan Sea (N-W Mediterranean)	1994	40	0,23	0,51	0,04	1657	58,99	4500	50 - 400	0,19	Coll et al (2006)
B	Gulf of Lion	2010-2014	68	0,31	0,44	0,15	6969,74	104,11	12172	0 - 200	0,21	GOLEM
C	Gulf of Lion	2000-2009	40	0,35	0,49	0,08	2995	68,9	20403	0 - 2500	0,21	Banaru (2013)
D	Adriatic Sea (central Mediterranean)	1990s	40	0,3	0,34	0,19	3844	130,3	55500	10 - 230	0,19	Coll et al (2007)
E	Aegean Sea (N-E Mediterranean)	2003-2006	40	0,27	0,44	0,14	1976	33,04	8374	20 - 300	0,18	Tsagarakis et al (2010)
F	Cantabrian Sea (N-E Atlantic)	1994	28	0,48	0,24	0,31	10143	174,86	16000	NS	0,27	Sanchez & Olaso (2004)

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852 Table 7 Odum's attributes (1969) as calculated by Christensen (1995). For each attribute, values in  
 853 bold indicate the most mature model. PP/R = total primary production/total respiration, PP/B = total  
 854 primary production/total biomass (\*excluding detritus), B/TST = biomass (\*)/total throughput, total  
 855 respiration/total biomass(\*), B/P = total biomass(\*)/ total production, B/(R+Exp) = total  
 856 biomass/(total respiration+total export)

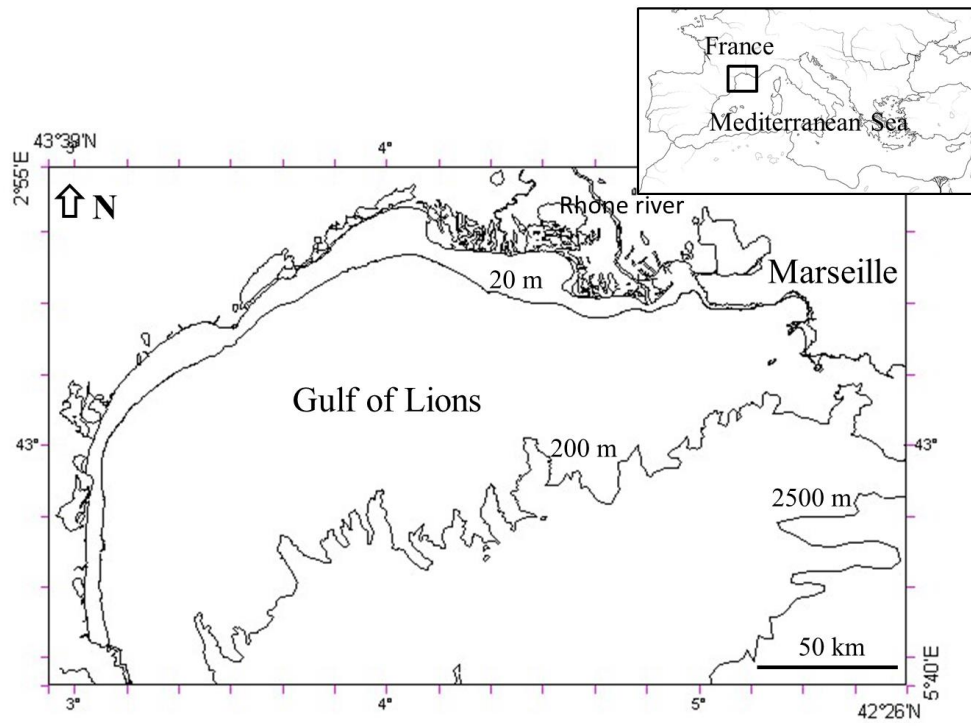
	PP/R	PP/B	B/TST	R/B	B/P	Residence time of energy B/(R+Exp)	Finn's mean path length	Connectance Index	System Omnivory Index
GOLEM	<b>1,8</b>	20,57	0,015	<b>11,41</b>	0,035	0,046	3,11	0,16	0,21
Banaru (2013)	2,09	<b>15,1</b>	<b>0,023</b>	7,24	<b>0,044</b>	<b>0,092</b>	<b>3,99</b>	0,15	0,21

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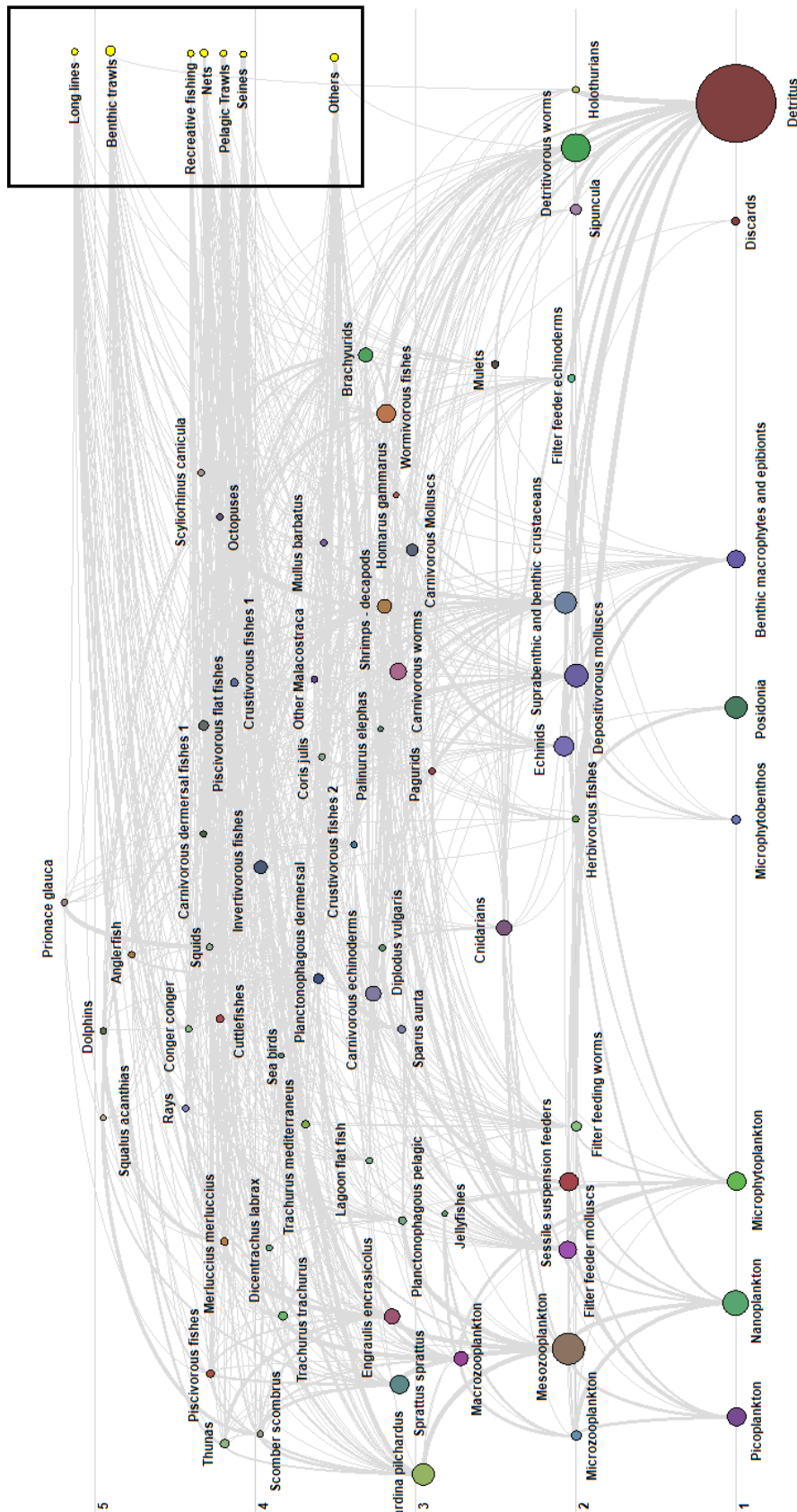
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862 **Figure 1** Location and bathymetry of the study area in the Gulf of Lion north-western Mediterranean  
863 Sea.

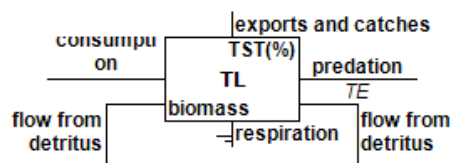
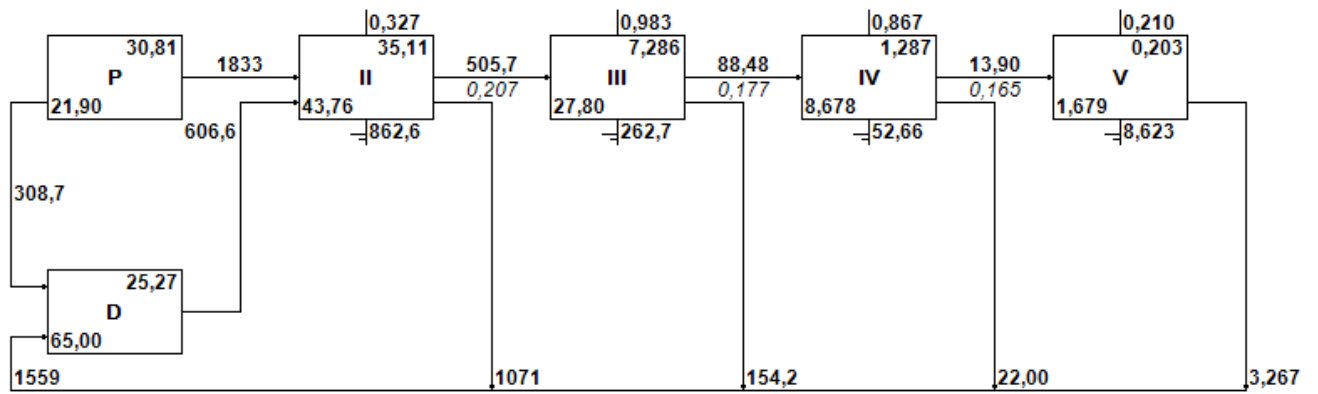
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866 **Figure 2** Trophic diagram of the GOLEM model. The ordinate axis represents the trophic level. Black  
 867 rectangle highlights the fisheries. The dot size is proportional to the group biomass and the link  
 868 width to flow between the two groups.

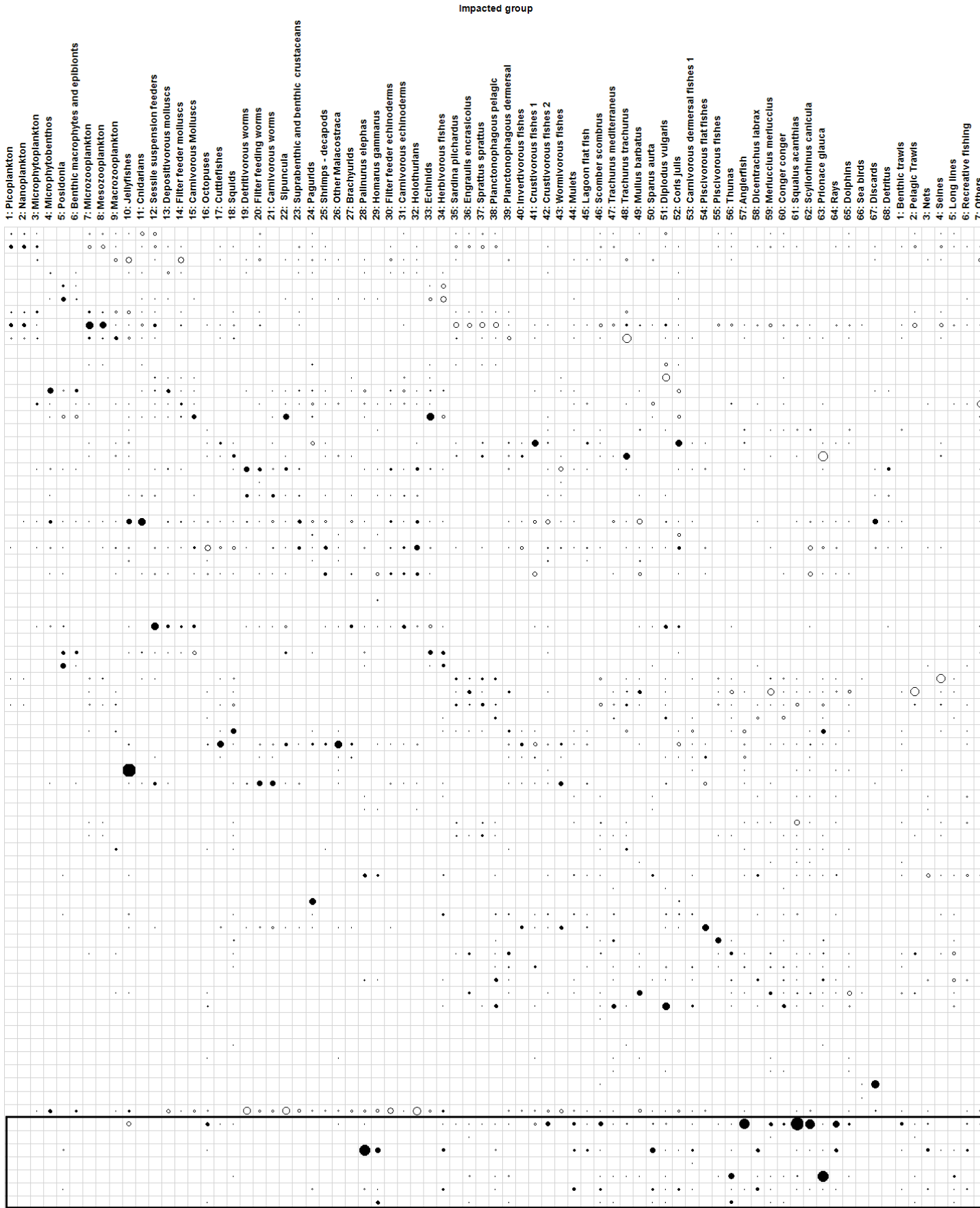




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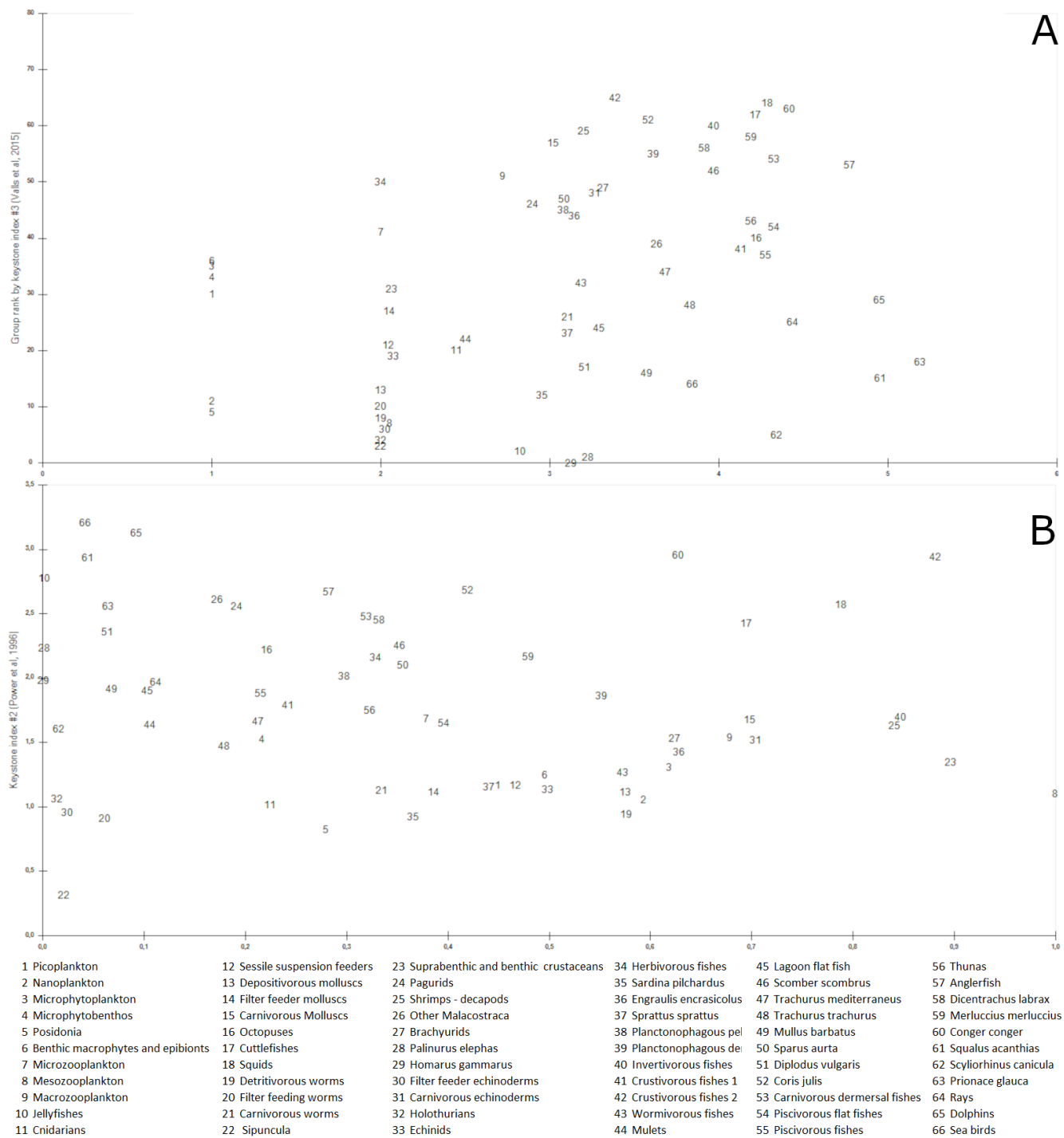
870 **Figure 3** Lindeman spine diagram of GOLEM model: P: primary producers, D: detritus, TST: total  
 871 system throughput and TE: trophic efficiency

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874 **Figure 4** Mixed trophic impact matrix. Black rectangle highlights the fisheries impact on other groups.

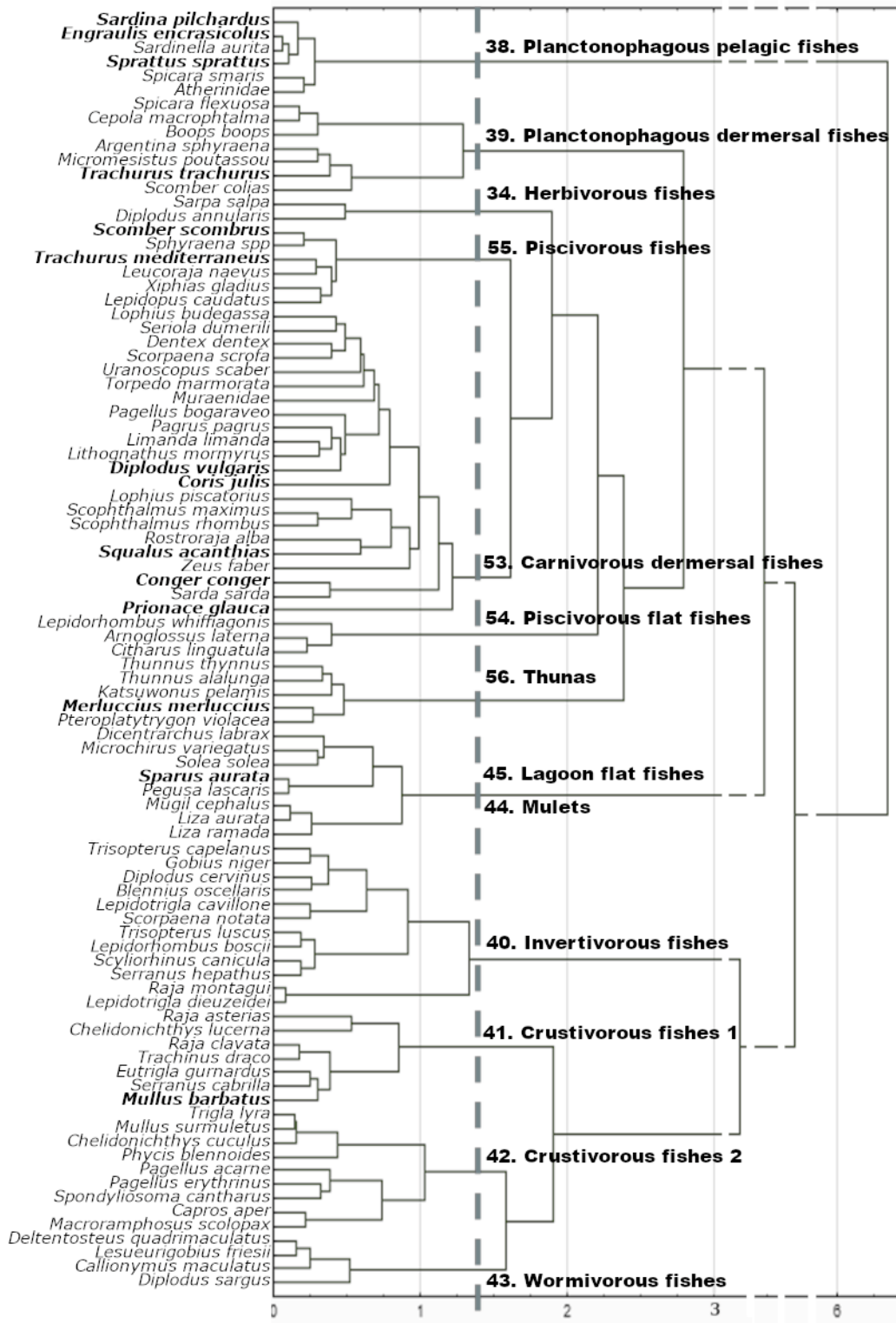


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876 **Figure 5** Keystoness plots. A) Valls keystone index against trophic levels. B) Power keystone index  
877 against the relative total impact.

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881 **Appendix 1** Cluster analysis using Ward method and mean distance between classes, representing  
 882 the diet similarity between the 91 analyzed fish species. The number and the name of the groups in  
 883 the model were indicated and species represented separately were indicated in bold characters.

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• Functional group	• Data sources and references
•	•
• 1. Picozooplankton	•
• Biomass	• Hunt et al., 2017; Lefevre et al., 1997; Marty et al., 2008
• P/B	• Landry et al., 2021; Lefevre et al., 1997; Schwinghamer et al., 1986
•	•
• 2. Nanozooplankton	•
• Biomass	• Christaki et al., 2009; Hunt et al., 2017; Lefevre et al., 1997; Marty et al., 2008
• P/B	• Gaudy et al., 2003; Lefevre et al., 1997
•	•
• 3. Microphytoplankton	•
• Biomass	• Christaki et al., 2009; Harmelin-Vivien et al., 2008; Hunt et al., 2017; Lefevre et al., 1997; Marty et al., 2008
• P/B	• Gaudy et al., 2003; Lefevre et al., 1997
•	•
• 4. Microphytobenthos	•
• Biomass	• Plante-Cuny & Bodoy, 1987; Riaux-Gobin et al., 1998
• P/B	• Plante-Cuny & Bodoy, 1987; Schwinghamer et al., 1986; van der Heijden et al., 2020
•	•
• 5. Posidonie	•
• Biomass, P/B	• Boudouresque et al., 2006
•	•
• 6. Benthic macrophytes + epibiontes	•
• Biomass	• Bănaru et al., 2013
• P/B	•
•	•
• 7. Microzooplankton	•

- Biomass
- P/B, Q/B
- Diet
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- 8. Mesozooplankton
- Biomass
- P/B, Q/B
- Diet
- 
- 9. Macrozooplankton
- Biomass
- P/B, Q/B
- Diet
- 
- 10. Jellyfishes
- Biomass
- P/B, Q/B
- Diet
- 
- 11. Cnidarians (benthic)
- Biomass
- P/B
- Diet
- 
- 12. Sessile Suspension Feeders
- Biomass
- P/B, Q/B
- Diet
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- www.somlit.fr ; Carlotti, pers. comm. ; Christaki et al., 2009; Gaudy et al., 2003; Vaqué et al., 1997
- Gaudy et al., 2003; Le Borgne, 1982; Pinnegar, 2000; Plounevez & Champalbert, 2000
- Chen, 2019
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- www.somlit.fr, Carlotti, pers. comm.
- Gaudy et al., 2003; Pinnegar, 2000; Plounevez & Champalbert, 2000
- C.-T. Chen, 2019
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- www.somlit.fr, Carlotti, pers. comm.
- Labat & Cuzin-Roudy, 1996; Pinnegar, 2000; Velsch, 1997
- C.-T. Chen, 2019
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- Medits
- Coll et al., 2007
- Pérez-Ruzafa et al., 2002; Tilves et al., 2018
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- C. Labrune pers. comm., Bonifácio et al., 2018
- Munari et al., 2013
- Coma et al., 1995; Sebens & Koehl, 1984
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- C. Labrune pers. comm., Bonifácio et al., 2018
- Ortiz et al., 2013; Wong et al., 2011
- Cook et al., 2018; Petersen, 2007; Ribes et al., 1999
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- 13. Depositivorous Molluscs
- Biomass
- P/B, Q/B
- Diet
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- 14. Filter Feeder Molluscs
- Biomass
- P/B
- Q/B
- Diet
- 
- 15. Carnivorous Molluscs
- Biomass
- P/B, Q/B
- Diet
- 
- 16. Octopuses
- Biomass
- P/B, Q/B
- Diet
- 
- 17. Cuttlefishes
- Biomass
- P/B, Q/B
- Diet
- 
- 18. Squids
- Biomass
- P/B, Q/B
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Doris.fffesm.fr T. mutabilis, Ferro & Cretella, 1993; Imrie et al., 1990; Kang et al., 1999; Watanabe et al., 2009; Yonge, 1946
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- C. Labrune pers. comm., Bonifácio et al., 2018
- Loo & Rosenberg, 1996
- T. Brey see Materials & methods
- Dupuy et al., 2000; Gosling, 2003; Prato et al., 2010
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Eilertsen & Malaquias, 2013; Himmelman & Hamel, 1993; Hughes, 1986; Riedel, 1995; Scolding et al., 2007; Vasconcelos et al., 2012
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- Medits
- T. Brey see Materials & methods
- Kaci, 2012; Quetglas et al., 2005
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- Medits
- T. Brey see Materials & methods
- Alves et al., 2006; Bergström, 1985; Kaci, 2012
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- Medits
- T. Brey see Materials & methods

- Diet
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- 19. Detritivorous worms
- Biomass
- P/B, Q/B
- Diet
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- 20. Filter feeders worms
- Biomass
- P/B, Q/B
- Diet
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- 21. Carnivorous worms
- Biomass
- P/B, Q/B
- Diet
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- 22. Sipuncula
- Biomass
- P/B
- Q/B
- Diet
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- 23. Suprabenthic and benthic invertebrates
- Biomass
- P/B, Q/B
- Diet
- 
- 24. Pagurids
- Biomass
- P/B, Q/B
- Diet
- Coelho et al., 1997; Hastie et al., 2013; Kaci, 2012; Roscian, 2016
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Jumars et al., 2015
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Jumars et al., 2015
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Jumars et al., 2015; Mettam, 1980
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- C. Labrune pers. comm., Bonifácio et al., 2018
- Han, 2019
- Lovvorn et al., 2015
- Cutler, 1994
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Arrontes, 1990; Bozzano, 2002; Domingues et al., 2000
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Kunze & Anderson, 1979; Ramsay et al., 1996



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- 25. Decapods
- Biomass
- P/B, Q/B
- Diet
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- 26. Other Malacostracas
- Biomass
- P/B, Q/B
- Diet
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- 27. Brachyurids
- Biomass
- P/B, Q/B
- Diet
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- 28. Palinurus elephas
- Biomass
- P/B, Q/B
- Diet
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- 29. Homarus gammarus
- Biomass
- P/B, Q/B
- Diet
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- 30. Filter Feeder Echinoderms
- Biomass
- P/B, Q/B
- Diet
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- Medits
- Viegas et al., 2007
- Cartes, 1995; Guerao & Ribera, 1996
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- Medits
- T. Brey see Materials & methods
- Baden et al., 1990; Mili et al., 2013
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- Medits
- T. Brey see Materials & methods
- Abello, 1989; R. B. Chen et al., 2004; Freire, 1996
- doris.ffessm.fr N. puber
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- Medits
- T. Brey see Materials & methods
- Goñi et al., 2001
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- Medits
- T. Brey see Materials & methods
- Sainte-Marie & Chabot, 2002
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- Medits
- T. Brey see Materials & methods
- La Touche & West, 1980; Massin, 1982; Warner, 1982
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- 31. Carnivorous Echinoderms
- Biomass
- P/B, Q/B
- Diet
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- 32. Holothurians
- Biomass
- P/B, Q/B
- Diet
- 
- 33. Echinids
- Biomass
- P/B, Q/B
- Diet
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- 34. Herbivorous fishes
- Biomass
- K and L<sub>∞</sub>
- Diet
- 
- 35. *Sardina pilchardus*
- Biomass
- K and L<sub>∞</sub>
- Diet
- 
- 36. *Engraulis encrasicolus*
- Biomass
- K and L<sub>∞</sub>
- Diet
- 
- 37. *Sprattus sprattus*
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- C. Labrune pers. comm., Bonifácio et al., 2018
- T. Brey see Materials & methods
- Baeta & Ramón, 2013; Guillou, 1987; Vasserot, 1961; Warner, 1982
- 
- Medits
- T. Brey see Materials & methods
- Fankboner, 1981; Ramón et al., 2019
- 
- Medits
- T. Brey see Materials & methods
- doris.ffessm.fr C. cidaris, Bay-Nouailhat 2008, web voir file, Barberá et al., 2011; Hollertz & Duchêne, 2001; Verlaque & Nédelec, 1983
- 
- 
- Dufour et al., 1995, Fishbase.org, Medits
- Campillo, 1992; Criscoli et al., 2006
- Cresson et al., 2014; Havelange et al., 1997
- 
- PELMED
- Van Beveren et al., 2014
- C.-T. Chen, 2019
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- PELMED
- Bigot et al., 2014
- C.-T. Chen, 2019
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- Biomass
- K and  $L_{\infty}$
- Diet
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- 38. Pelagic planktonophagous fishes
- Biomass
- K and  $L_{\infty}$
- Diet
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- 39. Demersal planktonophagous fishes
- Biomass
- K and  $L_{\infty}$
- Diet
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- 40. Invertivorous
- Biomass
- K and  $L_{\infty}$
- Diet
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- 41. Crustivorous fishes 1
- Biomass
- K and  $L_{\infty}$
- PELMED
- Kasapoğlu, 2018
- C.-T. Chen, 2019
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- Medits, PELMED 2009
- Delaunay, 2017; Dulčić et al., 2003; Tsikliras et al., 2005
- C.-T. Chen, 2019; Cresson et al., 2014; Danilova, 1991
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- 
- Medits, PELMED 2009
- Campillo, 1992; Çiçek et al., 2007; Dulčić et al., 2008; Ferri et al., 2017; Velasco et al., 2011
- Bourgogne, 2014; C.-T. Chen, 2019; Le Luherne, 2012; Sever, 2019; Sever et al., 2013
- 
- 
- Dufour et al., 1995, Medits
- Baştusta et al., 2017; Campillo, 1992; Delaunay, 2017; Derbal & Kara, 2013; Dulčić et al., 2007; Filiz, 2009; Merayo & Villegas, 1994; Ragonese & Bianchini, 1998; Scarcella et al., 2011
- Bilecenoglu, 2009; Cresson et al., 2014; Derbal & Kara, 2006; Dobroslavić, 2015; Joyeux et al., 1991; Kabasakal, 1999; Labarta, 1976; Labropoulou & Machias, 1998; Labropoulou & Papadopoulou-Smith, 1999; M. S. Morte et al., 2001; S. Morte et al., 1999
- 
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- Medits
- Buz & Baştusta, 2015; Ismen et al., 2004; McCarthy et al., 2018; Rachedi & Tania Dahel, 2019

- Diet
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- 42. Crustivorous fishes 2
- Biomass
- K and L<sub>∞</sub>
- Diet
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- 43. Wormivorous fishes
- Biomass
- K and L<sub>∞</sub>
- Diet
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- 44. Mulets
- Biomass
- K and L<sub>∞</sub>
- Diet
- 
- 45. Lagoon flat fishes
- Biomass
- K and L<sub>∞</sub>
- Diet
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- 46. Scomber scombrus
- Biomass
- K and L<sub>∞</sub>
- Diet
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- 47. Trachurus mediterraneus
- Castriota et al., 2012; Cresson et al., 2014; Montanini et al., 2010; Šantić et al., 2016
- 
- 
- Medits
- Borges, 2000; Boughamou et al., 2015; Busalacchi et al., 2014; Campillo, 1992; Vagenas et al., 2020
- Bautista-Vega, 2007; Caragitsou & Papaconstantinou, 1994; Carpentieri et al., 2016; Cresson et al., 2014; Dulčić et al., 2006; Macpherson, 1978; Montanini et al., 2017
- 
- 
- Medits, Dufour et al., 1995
- Erguden et al., 2016; Hussein et al., 2011; Metin et al., 2011; Nash, 1982
- Bell & Harmelin-Vivien, 1983; Cresson et al., 2014; Gibson & Ezzi, 1979, 1987
- 
- 
- Dufour et al., 1995, Fishbase.org, Medits
- Campillo, 1992; Matić-Skoko et al., 2012
- S. Blanco et al., 2003
- 
- 
- Medits
- Campillo, 1992; Félix et al., 2011
- Cresson et al., 2014; Darnaude, 2005
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- PELMED 2009
- Campillo, 1992
- Le Luherne, 2012
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- Biomass
- K and  $L_{\infty}$
- Diet
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- 48. *Trachurus trachurus*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 49. *Mullus barbatus*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 50. *Sparus aurata*
- Biomass
- P/B, Q/B
- Diet
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- 51. *Diplodus vulgaris*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 52. *Coris julis*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 53. Demersal carnivorous fishes
- Biomass
- K and  $L_{\infty}$
- PELMED 2009
- Karlou-Riga, 2000
- Le Luherne, 2012
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- PELMED 2009
- Campillo, 1992
- Le Luherne, 2012
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- Jadaud et al., 2018 average 2010-2014, calculated from weight at age and abundance at age
- Jadaud et al., 2018
- Bautista-Vega, 2007
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- 
- Vaudo, 2002
- Palomares et al., 1993
- Rosecchi, 1987
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- Medits
- Campillo, 1992
- Cresson et al., 2014; Sala & Ballesteros, 1997
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- Francour, 1997
- Gordo et al., 2000
- Sinopoli et al., 2017
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- 
- Medits
- Akyol, 2001; Boufersaoui et al., 2018; Campillo, 1992; Duman & Basusta, 2013; Félix et al.,

- 2011; Kaya & Bařusta, 2016; Kozul et al., 2001; Matić-Skoko et al., 2011; Morales-Nin & Moranta, 1997; S. I. Rizkalla & Bakhoun, 2009; Valeiras, Macías, et al., 2008; Vassilopoulou & Papaconstantinou, 1992
- Diet
  - Abdel-Aziz, 1994; Campo et al., 2006; Capapé et al., 2007; Capezzuto et al., 2021; Cresson et al., 2014; Matallanas et al., 1995; Morales-Nin & Moranta, 1997; Morato et al., 2001; Papaconstantinou & Caragitsou, 1989; S. Rizkalla & Philips, 2008; Sallami, 2014; Šantić et al., 2010; Schückel et al., 2012; Stergiou & Fourtouni, 1991; Vinagre et al., 2011
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- 54. Piscivorous flat fishes
  - Biomass
  - K and  $L_{\infty}$
  - Diet
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  - 55. Piscivorous fishes
    - Biomass
    - K and  $L_{\infty}$
    - Diet
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    - 
    - 56. Thunas
      - Biomass
      - K and  $L_{\infty}$
      - Diet
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      - 57. Anglerfishes
        - Biomass
        - K and  $L_{\infty}$
        - Diet
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- Medits
- Félix et al., 2011; Teixeira et al., 2010; Tičina & Matić-Skoko, 2012
- de Juan et al., 2007; Fanelli et al., 2009; S. Morte et al., 1999
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- Medits, Tserpes, 2010
- Demestre et al., 1993; Rim et al., 2009; Valeiras, de la Serna, et al., 2008
- Cresson et al., 2014; Demestre et al., 1993; Romeo et al., 2009; Salman, 2004; Torre et al., 2019
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- Estimate
- Campillo, 1992
- Imbert et al., 2007; Van Beveren et al., 2017; Varela et al., 2019
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- Medits
- García-Rodríguez et al., 2005; Landa et al., 2001
- N. López et al., 2016; N. L. López, 2014

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- 58. *Dicentrarchus labrax*
- Biomass
- K and  $L_{\infty}$
- Diet
- 
- 59. *Merluccius merluccius*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 60. *Conger conger*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 61. *Squalus acanthias*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 62. *Scyliorhinus canicula*
- Biomass
- K and  $L_{\infty}$
- Diet
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- 63. *Prionace glauca*
- P/B, Q/B
- Diet
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- 64. Rays
- Biomass
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- 
- Vaudo, 2002
- R. López et al., 2015
- Cresson et al., 2014; Pasquaud et al., 2008
- 
- 
- Jadaud et al., 2011
- Jadaud et al., 2011
- Merquiol, 2015
- 
- 
- Medits
- Matić-Skoko et al., 2012
- Sallami et al., 2015
- 
- 
- Medits
- Avsar, 2001
- Henderson et al., 2002
- 
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- Medits
- Ozcan & Basusta, 2018
- Mialet et al., 2017
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- Kitchell et al., 2002
- Clarke et al., 1996
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- Medits





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- 945
- 946
- 947
- 948
- 949
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- 952
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- 955
- 956
- Baden, S., Pihl, L. and Rosenberg, R. (1990) 'Effects of oxygen depletion on the ecology, blood physiology and fishery of the Norway lobster *Nephrops norvegicus*', *Marine Ecology Progress Series*, 67, pp. 141–155. Available at: <https://doi.org/10.3354/meps067141>.
  - Baeta, M. and Ramón, M. (2013) 'Feeding ecology of three species of *Astropecten* (Asteroidea) coexisting on shallow sandy bottoms of the northwestern Mediterranean Sea', *Marine Biology*, 160(11), pp. 2781–2795. Available at: <https://doi.org/10.1007/s00227-013-2270-0>.
  - Bănanu, D. *et al.* (2013) 'Trophic structure in the Gulf of Lions marine ecosystem (northwestern Mediterranean Sea) and fishing impacts', *Journal of Marine Systems*, 111–112, pp. 45–68. Available at: <https://doi.org/10.1016/j.jmarsys.2012.09.010>.
  - Barberá, C. *et al.* (2011) 'Trophic ecology of the sea urchin *Spatangus purpureus* elucidated from gonad fatty acids composition analysis', *Marine Environmental Research*, 71(4), pp. 235–246. Available at: <https://doi.org/10.1016/j.marenvres.2011.01.008>.
  - Barría, C., Coll, M. and Navarro, J. (2015) 'Unravelling the ecological role and trophic relationships of uncommon and threatened elasmobranchs in the western Mediterranean Sea', *Marine Ecology Progress Series*, 539, pp. 225–240. Available at: <https://doi.org/10.3354/meps11494>.
  - Baştusta, A. *et al.* (2017) 'A study on age and growth characteristics of spiny gurnard (*Lepidotrigla dieuzeidei* Blanc & Hureau, 1973), northeastern Mediterranean Sea', *Journal of Applied Ichthyology*, 33(5), pp. 966–970. Available at: <https://doi.org/10.1111/jai.13384>.
  - Bautista-Vega, V. (2007) *Etude des réseaux trophiques abouissant aux rougets méditerranéens (*Mullus barbatus* et *M. surmuletus*) par l'utilisation des isotopes stables*. Thèse de doctorat Sciences de l'Environnement marin. Université de la Méditerranée Aix-Marseille II.
  - Bell, J.D. and Harmelin-Vivien, M. (1983) 'Fish fauna of French Mediterranean *Posidonia oceanica* seagrass meadows. 2. Feeding habits', *Tethys*, 11(1), pp. 1–14.
  - Bergström, B.I. (1985) 'Aspects of natural foraging by *Sepietta oweniana* (Mollusca, Cephalopoda)', *Ophelia*, 24(1), pp. 65–74. Available at: <https://doi.org/10.1080/00785236.1985.10426620>.
  - Bigot, J.-L., Bourdeix, J.-H. and Saraux, C. (2014) *Stock Assessment Form: Small Pelagics*. GFCM.
  - Bilecenoglu, M. (2009) 'Growth and feeding habits of the brown comber, *Serranus hepatus* (Linnaeus, 1758) in Izmir Bay, Aegean Sea', *ACTA ADRIATICA*, 50(1), pp. 105–110.
  - Blanco, C., Salomón, O. and Raga, J.A. (2001) 'Diet of the bottlenose dolphin (*Tursiops truncatus*) in the western Mediterranean Sea', *Journal of the Marine Biological Association of the United Kingdom*, 81(6), pp. 1053–1058. Available at: <https://doi.org/10.1017/S0025315401005057>.
  - Blanco, S. *et al.* (2003) 'Fish communities and food web interactions in some shallow Mediterranean lakes', *Hydrobiologia*, 506–509(1–3), pp. 473–480. Available at: <https://doi.org/10.1023/B:HYDR.0000008583.05327.da>.
  - Bonifácio, P. *et al.* (2018) 'Long-term (1998 vs. 2010) large-scale comparison of soft-bottom benthic macrofauna composition in the Gulf of Lions, NW Mediterranean Sea', *Journal of Sea Research*, 131, pp. 32–45. Available at: <https://doi.org/10.1016/j.seares.2017.08.013>.
  - Borges, L. (2000) 'Age and growth of the snipefish, *Macrorhamphosus* spp., in the Portuguese continental waters', *Journal of the Marine Biological Association of the United Kingdom*, 80(1), pp. 147–153. Available at: <https://doi.org/10.1017/S0025315499001666>.

- 957
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- 994
- 995
- 996
- 997
- 998
- 999
- 1000
- 1001
- 1002
- 1003
- 1004
- 1005
- Boudouresque, C.F., Mayot, N. and Pergent, G. (2006) 'The outstanding traits of the functioning of the *Posidonia oceanica* seagrass ecosystem', *Biol. Mar. Medit.*, 4, pp. 109–113.
  - Boufersaoui, S. *et al.* (2018) 'Age and growth of the striped seabream, *Lithognathus mormyrus* (Actinopterygii: Perciformes: Sparidae), in the central coast of Algeria, Mediterranean Sea', *Acta Ichthyologica et Piscatoria*, 48(4), pp. 319–328. Available at: <https://doi.org/10.3750/AIEP/02485>.
  - Boughamou, N., Derbal, F. and Kara, M.H. (2015) 'Age, growth and reproduction of the black sea bream *Spondylisoma cantharus* (Linnaeus, ) (Sparidae) in the Gulf of Annaba (Algeria)', *Journal of Applied Ichthyology*, 31(4), pp. 773–779. Available at: <https://doi.org/10.1111/jai.12714>.
  - Bourgogne, H. (2014) *Etude de la stratégie alimentaire du Micromesistius poutassou (Risso, 1827) dans le Golfe du Lion (France)*. Rapport de stage de Master Océanographie 1ere année. Aix-Marseille Université.
  - Bozzano, A. (2002) 'Fishery discard consumption rate and scavenging activity in the northwestern Mediterranean Sea', *ICES Journal of Marine Science*, 59(1), pp. 15–28. Available at: <https://doi.org/10.1006/jmsc.2001.1142>.
  - Busalacchi, B. *et al.* (2014) 'Distribution and biological features of the common pandora, *Pagellus erythrinus* (Linnaeus, 1758), in the southern Tyrrhenian Sea (Central Mediterranean)', p. 11.
  - Buz, K. and Başusta, N. (2015) 'Age and growth of the greater weever, *Trachinus draco* (Linnaeus, 1758) inhabiting Iskenderun Bay, North-eastern Mediterranean Sea', *Cah. Biol. Mar.*, 56, pp. 289–295.
  - Campillo, A. (1992) *Les pêcheries françaises de Méditerranée: synthèse des connaissances*. Ifremer.
  - Campo, D. *et al.* (2006) 'Feeding habits of the Atlantic bonito, *Sarda sarda* (Bloch, 1793) in the southern Tyrrhenian sea', *Fisheries Research*, 81(2–3), pp. 169–175. Available at: <https://doi.org/10.1016/j.fishres.2006.07.006>.
  - Capapé, C. *et al.* (2007) 'Diet of the marbled electric ray *Torpedo marmorata* (chondrichthyes: torpedinidae) off the Languedocian coast (southern France, Northern Mediterranean)', *Annales - Ser. Hist. Nat.*, 17(1), pp. 17–22.
  - Capezzuto, F. *et al.* (2021) 'Comparison of trophic spectrum in the blackspot seabream, *Pagellus bogaraveo* (Brünnich, 1768), between cold-water coral habitats and muddy bottoms in the central Mediterranean', *Deep Sea Research Part I: Oceanographic Research Papers*, 169, p. 103474. Available at: <https://doi.org/10.1016/j.dsr.2021.103474>.
  - Caragitsou, E. and Papaconstantinou, C. (1994) 'Feeding habits of piper (*Trigla lyra*) in the Saronikos Gulf (Greece)', *Journal of Applied Ichthyology*, 10(2–3), pp. 104–113. Available at: <https://doi.org/10.1111/j.1439-0426.1994.tb00149.x>.
  - Carpentieri, P. *et al.* (2016) 'Food preferences and rhythms of feeding activity of two co-existing demersal fish, the longspine snipefish, *Macroramphosus scolopax* (Linnaeus, 1758), and the boarfish *Capros aper* (Linnaeus, 1758), on the Mediterranean deep shelf', *Marine Ecology*, 37(1), pp. 106–118. Available at: <https://doi.org/10.1111/maec.12265>.
  - Cartes, J. (1995) 'Diets of, and trophic resources exploited by, bathyal penaeoidean shrimps from the western Mediterranean', *Marine and Freshwater Research*, 46(6), p. 889. Available at: <https://doi.org/10.1071/MF9950889>.
  - Castriota, L. *et al.* (2012) 'Trophic relationships among scorpaeniform fishes associated with gas platforms', *Helgoland Marine Research*, 66(3), pp. 401–411. Available at: <https://doi.org/10.1007/s10152-011-0281-0>.

- 1006
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- 1050
- 1051
- 1052
- Chen, C.-T. (2019) *Alimentation des poissons planctonophages de la région marseillaise (Nord-Ouest de la Méditerranée Occidentale)*. Aix-Marseille Université. Available at: <https://hal-amu.archives-ouvertes.fr/hal-03241573> (Accessed: 13 October 2021).
  - Chen, R.B., Watanabe, S. and Yokota, M. (2004) 'Feeding habits of an exotic species, the Mediterranean green crab *Carcinus aestuarii*, in Tokyo Bay', *Fisheries Science*, 70(3), pp. 430–435. Available at: <https://doi.org/10.1111/j.1444-2906.2004.00822.x>.
  - Christaki, U. *et al.* (2009) 'Community structure and trophic role of ciliates and heterotrophic nanoflagellates in Rhone River diluted mesoscale structures (NW Mediterranean Sea)', *Aquatic Microbial Ecology*, 57, pp. 263–277. Available at: <https://doi.org/10.3354/ame01339>.
  - Çiçek, E. *et al.* (2007) 'Population characteristics and growth of *Spicara maena* (Linnaeus, 1758) inhabiting in Babadillimani Bight (northeastern Mediterranean-Turkey)', *International Journal of Natural and Engineering Sciences*, 1, pp. 15–18.
  - Clarke, M.R. *et al.* (1996) 'The diet of the blue shark (*prionace glauca* L.) In azorean waters', *Life and Marine Sciences*, 14, pp. 41–56.
  - Coelho, M. *et al.* (1997) 'A comparative study of the diet of *Loligo vulgaris* (Lamarck, 1799) (Mollusca:Cephalopoda) from the south coast of Portugal and the Saharan Bank (Central-East Atlantic)', *Fisheries Research*, 29(3), pp. 245–255. Available at: [https://doi.org/10.1016/S0165-7836\(96\)00540-1](https://doi.org/10.1016/S0165-7836(96)00540-1).
  - Coll, M. *et al.* (2007) 'An ecological model of the Northern and Central Adriatic Sea: Analysis of ecosystem structure and fishing impacts', *Journal of Marine Systems*, 67(1–2), pp. 119–154. Available at: <https://doi.org/10.1016/j.jmarsys.2006.10.002>.
  - Coll, M., Navarro, J. and Palomera, I. (2013) 'Ecological role, fishing impact, and management options for the recovery of a Mediterranean endemic skate by means of food web models', *Biological Conservation*, 157, pp. 108–120. Available at: <https://doi.org/10.1016/j.biocon.2012.06.029>.
  - Coma, R., Gili, J.-M. and Zabala, M. (1995) 'Trophic ecology of a benthic marine hydroid, *Campanularia everta*', *Marine Ecology Progress Series*, 119, pp. 211–220.
  - Cook, P. *et al.* (2018) *Australian Bryozoa Volume 1: Biology, Ecology and Natural History*. CSIRO Publishing, Melbourne.
  - Cresson, P. *et al.* (2014) 'Contrasting perception of fish trophic level from stomach content and stable isotope analyses: A Mediterranean artificial reef experience', *Journal of Experimental Marine Biology and Ecology*, 452, pp. 54–62. Available at: <https://doi.org/10.1016/j.jembe.2013.11.014>.
  - Criscoli, A. *et al.* (2006) 'Observations on the reproductive cycle, age and growth of the salema, *Sarpa salpa* (Osteichthyes: Sparidae) along the western central coast of Italy', *Scientia Marina*, 70(1), pp. 131–138. Available at: <https://doi.org/10.3989/scimar.2006.70n1131>.
  - Cutler, E.B. (1994) *The Sipuncula: their systematics, biology, and evolution*. Ithaca: Comstock Pub. Associates.
  - Danilova, M.M. (1991) 'Diet of juvenile silversides, *Atherina boyeri*, from the Black Sea', *J. Ichthyol.*, 31(3), pp. 137–147.
  - Darnaude, A.M. (2005) 'Fish ecology and terrestrial carbon use in coastal areas: implications for marine fish production', *Journal of Animal Ecology*, 74(5), pp. 864–876. Available at: <https://doi.org/10.1111/j.1365-2656.2005.00978.x>.
  - Delaunay, D. (2017) *Sélection des espèces sensibles à la pression de pêche dans les sous-régions marines DCSMM*. Ifremer, p. 42.

- 1053       ▪ Demestre, M. *et al.* (1993) 'Life history and fishery of *Lepidopus caudatus* (Pisces:  
1054       Trichiuridae) in the Catalan Sea (Northwestern Mediterranean)', *Marine Biology*, 115(1),  
1055       pp. 23–32. Available at: <https://doi.org/10.1007/BF00349382>.
- 1056       ▪ Derbal, F. and Kara, M.H. (2006) 'Régime alimentaire du sar tambour, *Diplodus cervinus*  
1057       *cervinus* (Sparidae) des côtes de l'est algérien', p. 10.
- 1058       ▪ Derbal, F. and Kara, M.H. (2013) 'Âge, croissance et reproduction du sar tambour *Diplodus*  
1059       *cervinus cervinus* (Sparidae) des côtes de l'Est algérien', p. 8.
- 1060       ▪ Dobroslavić, T. (2015) *Biološko-ekološke karakteristike kokotića Lepidotrigla dieuzeidei*  
1061       *Blanc & Hureau, 1973 i kokotića oštruljića Lepidotrigla cavillone (Lacepede, 1801) na*  
1062       *području južnog Jadrana*. University of Split.
- 1063       ▪ Domingues, P.M. *et al.* (2000) 'Mysid culture: lowering costs with alternative diets',  
1064       *Aquaculture Research*, p. 10.
- 1065       ▪ Dufour, V., Jouvenel, J.-Y. and Galzin, R. (1995) 'Study of a Mediterranean reef fish  
1066       assemblage. Comparisons of population distributions between depths in protected and  
1067       unprotected areas over one decade', *Aquatic Living Resources*, 8(1), pp. 17–25. Available  
1068       at: <https://doi.org/10.1051/alr:1995002>.
- 1069       ▪ Dulčić, J. *et al.* (2003) 'Age, growth and mortality of picarel, *Spicara smaris* L. (Pisces:  
1070       Centranchidae), from the eastern Adriatic (Croatian coast): Age, growth and mortality  
1071       of picarel, *S. smaris* L.', *Journal of Applied Ichthyology*, 19(1), pp. 10–14. Available at:  
1072       <https://doi.org/10.1046/j.1439-0426.2003.00345.x>.
- 1073       ▪ Dulčić, J. *et al.* (2006) 'Diet of *Spondyliosoma cantharus* and *Diplodus puntazzo* (Sparidae)  
1074       in the Eastern Central Adriatic', p. 8.
- 1075       ▪ Dulčić, J. *et al.* (2007) 'Age, growth and mortality of brown comber, *Serranus hepatus*  
1076       (Linnaeus, 1758) (Pisces: Serranidae), in the eastern Adriatic (Croatian coast)', *Journal of*  
1077       *Applied Ichthyology*, 23(2), pp. 195–197. Available at: [https://doi.org/10.1111/j.1439-](https://doi.org/10.1111/j.1439-0426.2006.00840.x)  
1078       0426.2006.00840.x.
- 1079       ▪ Dulčić, J. *et al.* (2008) 'Age, growth and mortality of red bandfish, *Cepola macrophthalma*  
1080       (L.), in the eastern Adriatic Sea (Croatian coast)', *Journal of Applied Ichthyology*, 24(3), pp.  
1081       351–353. Available at: <https://doi.org/10.1111/j.1439-0426.2007.01047.x>.
- 1082       ▪ Duman, O.V. and Basusta, N. (2013) 'Age and Growth Characteristics of Marbled Electric  
1083       Ray *Torpedo marmorata* (Risso, 1810) Inhabiting Iskenderun Bay, North-eastern  
1084       Mediterranean Sea', *Turkish Journal of Fisheries and Aquatic Sciences*, 13(3). Available at:  
1085       [https://doi.org/10.4194/1303-2712-v13\\_3\\_19](https://doi.org/10.4194/1303-2712-v13_3_19).
- 1086       ▪ Dupuy, C. *et al.* (2000) 'Feeding rate of the oyster *Crassostrea gigas* in a natural planktonic  
1087       community of the Mediterranean Thau Lagoon', *Marine Ecology Progress Series*, 205, pp.  
1088       171–184. Available at: <https://doi.org/10.3354/meps205171>.
- 1089       ▪ Eilertsen, M.H. and Malaquias, M.A.E. (2013) 'Unique digestive system, trophic  
1090       specialization, and diversification in the deep-sea gastropod genus *Scaphander*: Trophic  
1091       Specialization in *Scaphander*', *Biological Journal of the Linnean Society*, 109(3), pp. 512–  
1092       525. Available at: <https://doi.org/10.1111/bij.12069>.
- 1093       ▪ Erguden, D., Erguden, S.A. and Ozdemir, O. (2016) 'Age, growth and mortality of the Red  
1094       Sea invasive blotchfin dragonet, *Callionymus filamentosus* Valenciennes, 1837 from the  
1095       Northeastern Mediterranean, Turkey', *Cah. Biol. Mar.*, 57, pp. 17–23.
- 1096       ▪ Fanelli, E. *et al.* (2009) 'Diet and trophic level of sculdfish *Arnoglossus laterna* in the  
1097       southern Tyrrhenian Sea (western Mediterranean): contrasting trawled versus untrawled  
1098       areas', *Journal of the Marine Biological Association of the United Kingdom*, 89(4), pp. 817–  
1099       828. Available at: <https://doi.org/10.1017/S0025315409000137>.

- 1100       ▪ Fankboner, P.V. (1981) 'A re-examination of mucus feeding by the sea cucumber  
1101       *Leptopentacta* (= *Cucumaria*) *elongata*', *Journal of the Marine Biological Association of*  
1102       *the United Kingdom*, 61(3), pp. 679–683. Available at:  
1103       <https://doi.org/10.1017/S0025315400048128>.
- 1104       ▪ Farias, I. *et al.* (2006) 'Diet comparison of four ray species ( *Raja clavata*, *Raja brachyura*,  
1105       *Raja montagui* and *Leucoraja naevus* ) caught along the Portuguese continental shelf',  
1106       *Aquatic Living Resources*, 19(2), pp. 105–114. Available at:  
1107       <https://doi.org/10.1051/alr:2006010>.
- 1108       ▪ Félix, P.M., Vinagre, C. and Cabral, H.N. (2011) 'Life-history traits of flatfish in the  
1109       Northeast Atlantic and Mediterranean Sea: Life-history traits of flatfish', *Journal of*  
1110       *Applied Ichthyology*, 27(1), pp. 100–111. Available at: [https://doi.org/10.1111/j.1439-](https://doi.org/10.1111/j.1439-0426.2010.01623.x)  
1111       0426.2010.01623.x.
- 1112       ▪ Ferri, J. *et al.* (2017) 'A preliminary study on the age and growth of the argentine,  
1113       Argentina sphyraena (Actinopterygii: Osmeriformes: Argentinidae) from the eastern  
1114       Adriatic Sea', *Acta Ichthyologica et Piscatoria*, 47(4), pp. 365–369. Available at:  
1115       <https://doi.org/10.3750/AIEP/02268>.
- 1116       ▪ Ferro, R. and Cretella, M. (1993) 'Osservazioni sulla biologia di *Calliostoma granulatum*  
1117       (born) (gastropoda: trochidae).', *Boll. Malacologico*, 29, pp. 49–56.
- 1118       ▪ Filiz, H. (2009) 'Age and growth, reproduction and diet of the black goby, (*Gobius niger*)  
1119       from Aegean Sea, Turkey', *Journal of FisheriesSciences.com* [Preprint]. Available at:  
1120       <https://doi.org/10.3153/jfsc.com.2009030>.
- 1121       ▪ Francour, P. (1997) 'Fish Assemblages of *Posidonia oceanica* Beds at Port-Cros (France,  
1122       NW Mediterranean): Assessment of Composition and Long-Term Fluctuations by Visual  
1123       Census', *Marine Ecology*, 18(2), pp. 157–173. Available at:  
1124       <https://doi.org/10.1111/j.1439-0485.1997.tb00434.x>.
- 1125       ▪ Freire, J. (1996) 'Feeding ecology of *Liocarcinus depurator* (Decapoda: Portunidae) in the  
1126       Ria de Arousa (Galicia, north-west Spain): effects of habitat, season and life history',  
1127       *Marine Biology*, 126(2), pp. 297–311. Available at: <https://doi.org/10.1007/BF00347454>.
- 1128       ▪ Gallagher, M.J., Nolan, C.P. and Jeal, F. (2004) 'Age, Growth and Maturity of the  
1129       Commercial Ray Species from the Irish Sea', *Journal of Northwest Atlantic Fishery Science*,  
1130       35, pp. 47–66. Available at: <https://doi.org/10.2960/J.v35.m527>.
- 1131       ▪ García-Rodríguez, M. *et al.* (2005) 'On the biology and growth of the anglerfish *Lophius*  
1132       *budegassa* Spinola, 1807 in the Spanish Mediterranean: a preliminary approach', *Fisheries*  
1133       *Research*, 71(2), pp. 197–208. Available at: <https://doi.org/10.1016/j.fishres.2004.08.033>.
- 1134       ▪ Gaudy, R. *et al.* (2003) 'Biomass, metabolism and nutrition of zooplankton in the Gulf of  
1135       Lions (NW Mediterranean)', *Oceanologica Acta*, 26(4), pp. 357–372. Available at:  
1136       [https://doi.org/10.1016/S0399-1784\(03\)00016-1](https://doi.org/10.1016/S0399-1784(03)00016-1).
- 1137       ▪ Gibson, R.N. and Ezzi, I.A. (1979) 'Aspects of the biology of the spotted dragonet  
1138       *Callionymus maculatus* Rafmesque-Schmaltz from the west coast of Scotland', *Journal of*  
1139       *Fish Biology*, 15(5), pp. 555–569. Available at: [https://doi.org/10.1111/j.1095-](https://doi.org/10.1111/j.1095-8649.1979.tb03646.x)  
1140       8649.1979.tb03646.x.
- 1141       ▪ Gibson, R.N. and Ezzi, I.A. (1987) 'Feeding relationships of a demersal fish assemblage on  
1142       the west coast of Scotland', *Journal of Fish Biology*, 31(1), pp. 55–69. Available at:  
1143       <https://doi.org/10.1111/j.1095-8649.1987.tb05214.x>.
- 1144       ▪ Goñi, R., Quetglas, A. and Reñones, O. (2001) 'Diet of the spiny lobster *Palinurus elephas*  
1145       (Decapoda: Palinuridea) from the Columbretes Islands Marine Reserve (north-western  
1146       Mediterranean)', *Journal of the Marine Biological Association of the United Kingdom*,  
1147       81(2), pp. 347–348. Available at: <https://doi.org/10.1017/S0025315401003861>.

- 1148
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- 1184
- 1185
- 1186
- 1187
- 1188
- 1189
- 1190
- 1191
- 1192
- 1193
- 1194
- 1195
- Gordoa, A., Molí, B. and Raventós, N. (2000) 'Growth performance of four wrasse species on the north-western Mediterranean coast', *Fisheries Research*, 45(1), pp. 43–50. Available at: [https://doi.org/10.1016/S0165-7836\(99\)00094-6](https://doi.org/10.1016/S0165-7836(99)00094-6).
  - Gosling, E.M. (2003) *Bivalve molluscs: biology, ecology, and culture*. Oxford ; Malden, MA: Fishing News Books.
  - Guerao, G. and Ribera, C. (1996) 'Locomotor Activity Patterns and Feeding Habits in the Prawn Palaemon Serratus (Pennant, 1777) (Decapoda, Palaemonidae) in the Alfacos Bay, Ebro Delta, Spain', *Crustaceana*, 69(1), pp. 101–112. Available at: <https://doi.org/10.1163/156854096X00132>.
  - Guillou, M. (1987) 'Etude du régime alimentaire d'Anseropoda placenta (Asteroidea: Echinodermata) en rade de Brest (Finistère, France)', *Bulletin de la Société des Sciences Naturelles de l'ouest de la France*, Suppl H.S.
  - Han, Q. (2019) 'Macrobenthic Biomass and Secondary Production in the Northern East China Sea and the Relative Importance of Environmental Variables1', *Pacific Science*, 73(2), p. 249. Available at: <https://doi.org/10.2984/73.2.6>.
  - Harmelin-Vivien, M. *et al.* (2008) 'Comparison of C and N stable isotope ratios between surface particulate organic matter and microphytoplankton in the Gulf of Lions (NW Mediterranean)', *Continental Shelf Research*, 28(15), pp. 1911–1919. Available at: <https://doi.org/10.1016/j.csr.2008.03.002>.
  - Hastie, L.C. *et al.* (2013) 'Alloteuthis subulata, European Common Squid.', *Advances in Squid Biology, Ecology and Fisheries*, pp. 109–122.
  - Havelange, S. *et al.* (1997) 'Feeding of the Sparid Fish *Sarpa salpa* in a Seagrass Ecosystem: Diet and Carbon Flux', *Marine Ecology*, 18(4), pp. 289–297. Available at: <https://doi.org/10.1111/j.1439-0485.1997.tb00443.x>.
  - van der Heijden, L.H. *et al.* (2020) 'Quantitative food web modeling unravels the importance of the microphytobenthos-meiofauna pathway for a high trophic transfer by meiofauna in soft-bottom intertidal food webs.', *Ecological Modelling*, 430. Available at: <https://doi.org/10.1016/j.ecolmodel.2020.109129>.
  - Henderson, A.C., Dunne, J. and Flannery, K. (2002) 'Stomach Contents of Spiny Dogfish *Squalus acanthias* L. off the West Coast of Ireland', *The Irish Naturalists' Journal*, 27(3), pp. 101–105.
  - Himmelman, J.H. and Hamel, J.-R. (1993) 'Diet, behaviour and reproduction of the whelk *Buccinum undatum* in the northern Gulf of St. Lawrence, eastern Canada', *Marine Biology*, 116(3), pp. 423–430. Available at: <https://doi.org/10.1007/BF00350059>.
  - Hollertz, K. and Duchêne, J.C. (2001) 'Burrowing behaviour and sediment reworking in the heart urchin *Brissopsis lyrifera* Forbes (Spatangoida)', *Marine Biology*, 139(5), pp. 951–957. Available at: <https://doi.org/10.1007/s002270100629>.
  - Hughes, R.N. (1986) 'Laboratory observations on the feeding behaviour, reproduction and morphology of *Galeodea echinophora* (Gastropoda: Cassidae)', *Zoological Journal of the Linnean Society*, 86(4), pp. 355–365. Available at: <https://doi.org/10.1111/j.1096-3642.1986.tb01815.x>.
  - Hunt, B.P.V. *et al.* (2017) 'Trophic pathways of phytoplankton size classes through the zooplankton food web over the spring transition period in the north-west Mediterranean Sea: Mediterranean zooplankton food web', *Journal of Geophysical Research: Oceans*, 122(8), pp. 6309–6324. Available at: <https://doi.org/10.1002/2016JC012658>.
  - Hussein, C. *et al.* (2011) 'Assessing the impact of artisanal and recreational fishing and protection on a white seabream (*Diplodus sargus sargus*) population in the north-western Mediterranean Sea using a simulation model. Part 1: Parameterization and simulations',

- 1196 *Fisheries Research*, 108(1), pp. 163–173. Available at:  
 1197 <https://doi.org/10.1016/j.fishres.2010.12.017>.
- 1198 ▪ Imbert, G. *et al.* (2007) *Prélèvement d'échantillons cytologiques et analyse de contenus*  
 1199 *stomacaux*. La thonaille ou courantille volante. Rapport final au Conseil Régional  
 1200 Provençes-Alpes-Côte d'Azur. Cannes, pp. 75–116.
  - 1201 ▪ Imrie, D.W., McCrohan, C.R. and Hawkins, S.J. (1990) 'Feeding behaviour in *Littorina*  
 1202 *littorea*: a study of the effects of ingestive conditioning and previous dietary history on  
 1203 food preference and rates of consumption', *Hydrobiologia*, 193, pp. 191–198.
  - 1204 ▪ Ismen, A., Ismen, P. and Basusta, N. (2004) 'Age, Growth and Reproduction of Tub Gurnard  
 1205 (*Chelidonichthys lucerna* L. 1758) in the Bay of Iskenderun in the Eastern Mediterranean',  
 1206 *Turk J Vet Anim Sci*, (28), pp. 289–295.
  - 1207 ▪ Jadaud, A. *et al.* (2011) *Stock Assessment Form: Merluccius merluccius*. GFCM, p. 378.
  - 1208 ▪ Jadaud, A. *et al.* (2018) *Stock Assessment Form Demersal species: Mullus barbatus*. GFCM,  
 1209 p. 29.
  - 1210 ▪ Joyeux, J.-C., Tomasini, J.-A. and Bouchereau, J.-L. (1991) 'Le régime alimentaire de *Gobius*  
 1211 *niger* Linné, 1758 (Teleostei, Gobiidae) dans la lagune de Mauguio - France', *Annales des*  
 1212 *Sciences Naturelles, Zoologie*, 12, pp. 57–69.
  - 1213 ▪ de Juan, S., Cartes, J.E. and Demestre, M. (2007) 'Effects of commercial trawling activities  
 1214 in the diet of the flat fish *Citharus linguatula* (Osteichthyes: Pleuronectiformes) and the  
 1215 starfish *Astropecten irregularis* (Echinodermata: Asteroidea)', *Journal of Experimental*  
 1216 *Marine Biology and Ecology*, 349(1), pp. 152–169. Available at:  
 1217 <https://doi.org/10.1016/j.jembe.2007.05.003>.
  - 1218 ▪ Jumars, P.A., Dorgan, K.M. and Lindsay, S.M. (2015) 'Diet of Worms Emended: An Update  
 1219 of Polychaete Feeding Guilds', *Annual Review of Marine Science*, 7(1), pp. 497–520.  
 1220 Available at: <https://doi.org/10.1146/annurev-marine-010814-020007>.
  - 1221 ▪ Kabasakal, H. (1999) 'A note on the diet of five deep-sea fishes from the North-eastern  
 1222 Aegean Sea', *BILJESKE - NOTES*, 82, p. 9.
  - 1223 ▪ Kaci, L. (2012) *Etude du régime alimentaire et de la forme des becs de céphalopodes dans*  
 1224 *le Golfe du Lion*. Rapport de stage de licence 3e année SVT parcours Mer. Aix-Marseille  
 1225 Université.
  - 1226 ▪ Kang, C.K. *et al.* (1999) 'Food sources of the infaunal suspension-feeding bivalve  
 1227 *Cerastoderma edule* in a muddy sandflat of Marennes-Olqon Bay, as determined by  
 1228 analyses of carbon and nitrogen stable isotopes', *Marine Ecology Progress Series*, 187, pp.  
 1229 147–158.
  - 1230 ▪ Karlou-Riga, C. (2000) 'Otolith morphology and age and growth of *Trachurus*  
 1231 *mediterraneus* (Steindachner) in the Eastern Mediterranean', *Fisheries Research*, 46(1–3),  
 1232 pp. 69–82. Available at: [https://doi.org/10.1016/S0165-7836\(00\)00134-X](https://doi.org/10.1016/S0165-7836(00)00134-X).
  - 1233 ▪ Kasapoğlu, N. (2018) 'Age, Growth, and Mortality of Exploited Stocks: Anchovy, Sprat,  
 1234 Mediterranean Horse Mackerel, Whiting, and Red Mullet in the Southeastern Black Sea',  
 1235 *Aquatic Sciences and Engineering*, pp. 39–49. Available at:  
 1236 <https://doi.org/10.18864/ase201807>.
  - 1237 ▪ Kaya, G. and Başusta, N. (2016) 'A study on age and growth of juvenile and semi adult  
 1238 *Torpedo nobiliana* Bonaparte, 1835 inhabiting Iskenderun Bay, northeastern  
 1239 Mediterranean Sea', p. 7.
  - 1240 ▪ Kitchell, J.F. *et al.* (2002) 'The Role of Sharks and Longline Fisheries in a Pelagic Ecosystem  
 1241 of the Central Pacific', *Ecosystems*, 5(2), pp. 202–216. Available at:  
 1242 <https://doi.org/10.1007/s10021-001-0065-5>.

- 1243           ▪ Kozul, V. *et al.* (2001) 'Age, growth and mortality of the Mediterranean amberjack *Seriola*  
1244 *dumerili* (Risso 1810) from the south-eastern Adriatic Sea', *J. Appl. Ichthyol.*, 17, pp. 134–  
1245 141.
- 1246           ▪ Kunze, J. and Anderson, D.T. (1979) 'Functional Morphology of the Mouthparts and  
1247 Gastric Mill in the Hermit Crabs *Clibanarius taeniatus* (Milne Edwards), *Clibanavius*  
1248 *virescens* (Krauss), *Paguvistes squamosus* McCulloch and *Dardanus setifev* (Milne-  
1249 Edwards)(Anomura: Paguridae)', *Aust. J. Mar. Freshwater Res.*, 30, pp. 683–722.
- 1250           ▪ La Touche, R.W. and West, A.B. (1980) 'Observations on the food of *Antedon bifida*  
1251 (Echinodermata: Crinoidea)', *Marine Biology*, 60(1), pp. 39–46. Available at:  
1252 <https://doi.org/10.1007/BF00395604>.
- 1253           ▪ Labarta, E. (1976) 'Aportacion al estudio del régimen alimentario y competencia  
1254 interespecifica de *Aspitrigla cuculus*, *Trisopterus luscus* y *Trisopterus minutus*, de las  
1255 costas de Galicia', *Invest. Pesqua*, 40(2), pp. 341–354.
- 1256           ▪ Labat, J.Ph. and Cuzin-Roudy, J. (1996) 'Population dynamics of the krill *Meganyctiphanes*  
1257 *norvegica* (M. Sars, 1857) (Crustacea: Euphausiacea) in the Ligurian Sea (NW  
1258 Mediterranean Sea). Size structure, growth and mortality modelling', *Journal of Plankton*  
1259 *Research*, 18(12), pp. 2295–2312. Available at:  
1260 <https://doi.org/10.1093/plankt/18.12.2295>.
- 1261           ▪ Labropoulou, M. and Machias, A. (1998) 'Effect of habitat selection on the dietary patterns  
1262 of two triglid species', *Marine Ecology Progress Series*, 173, pp. 275–288. Available at:  
1263 <https://doi.org/10.3354/meps173275>.
- 1264           ▪ Labropoulou, M. and Papadopoulou-Smith, K.-N. (1999) 'Foraging Behaviour Patterns of  
1265 Four Sympatric Demersal Fishes', *Estuarine, Coastal and Shelf Science*, 49, pp. 99–108.  
1266 Available at: [https://doi.org/10.1016/S0272-7714\(99\)80014-6](https://doi.org/10.1016/S0272-7714(99)80014-6).
- 1267           ▪ Landa, J. *et al.* (2001) 'Growth of anglerfish (*Lophius piscatorius* and *L. budegassa*) in  
1268 Atlantic Iberian waters', *Fisheries Research*, p. 14.
- 1269           ▪ Landry, M.R. *et al.* (2021) 'Low temperature sensitivity of picophytoplankton P : B ratios  
1270 and growth rates across a natural 10°C temperature gradient in the oligotrophic Indian  
1271 Ocean', *Limnology and Oceanography Letters*, p. 102224. Available at:  
1272 <https://doi.org/10.1002/lol2.10224>.
- 1273           ▪ Le Borgne, R. (1982) 'Zooplankton production in the eastern tropical Atlantic Ocean: Net  
1274 growth efficiency and P:B in terms of carbon, nitrogen, and phosphorus: Tropical  
1275 zooplankton production', *Limnology and Oceanography*, 27(4), pp. 681–698. Available at:  
1276 <https://doi.org/10.4319/lo.1982.27.4.0681>.
- 1277           ▪ Le Luherne, E. (2012) *Etude de l'alimentation des maquereaux et chinchard dans le Golfe*  
1278 *du Lion*. Rapport de stage de Master Océanographie 2e année. Aix-Marseille Université.
- 1279           ▪ Lefevre, D. *et al.* (1997) 'Review of gross community production, primary production, net  
1280 community production and dark community respiration in the Gulf of Lions', *Deep Sea*  
1281 *Research Part II: Topical Studies in Oceanography*, 44(3), pp. 801–832. Available at:  
1282 [https://doi.org/10.1016/S0967-0645\(96\)00091-4](https://doi.org/10.1016/S0967-0645(96)00091-4).
- 1283           ▪ Lipej, L. *et al.* (2013) 'Feeding habits of the pelagic stingray *Pteroplatytrygon violacea*  
1284 (Chondrichthyes: Dasyatidae) in the Adriatic Sea', *Journal of the Marine Biological*  
1285 *Association of the United Kingdom*, 93(2), pp. 285–290. Available at:  
1286 <https://doi.org/10.1017/S0025315412000197>.
- 1287           ▪ Loo, L.-O. and Rosenberg, R. (1996) 'Production and energy budget in marine suspension  
1288 feeding populations: *Mytilus edulis*, *Cerastoderma edule*, *Mya arenaria* and *Amphiura*  
1289 *filiformis*', *Journal of Sea Research*, 35(1–3), pp. 199–207.



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- 1328
- 1329
- 1330
- 1331
- 1332
- 1333
- 1334
- 1335
- 1336
- 1337
- López, N. *et al.* (2016) 'Feeding ecology of two demersal opportunistic predators coexisting in the northwestern Mediterranean Sea', *Estuarine, Coastal and Shelf Science*, 175, pp. 15–23. Available at: <https://doi.org/10.1016/j.ecss.2016.03.007>.
  - López, N.L. (2014) *Feeding ecology of a demersal predator, the black anglerfish (Lophius budegassa Spinola, 1807) in the northwestern Mediterranean Sea*. Institut de Ciències del Mar.
  - López, R. *et al.* (2015) 'What can exploratory modelling tell us about the ecobiology of European sea bass (*Dicentrarchus labrax*): a comprehensive overview', *Aquat. Living Resour.*, 28, pp. 61–79.
  - Lovvorn, J.R. *et al.* (2015) 'Modeling spatial patterns of limits to production of deposit-feeders and ectothermic predators in the northern Bering Sea', *Estuarine, Coastal and Shelf Science*, 154, pp. 19–29. Available at: <https://doi.org/10.1016/j.ecss.2014.12.020>.
  - Macpherson, E. (1978) 'Régimen alimentario de *Phycis blennoides* (Brünich) y *Antonogadus megalokynodon* (Kolombatovich) (Pisces: Gadidae) en el Mediterráneo occidental.', *Invest. Pesqua*, 42, pp. 455–466.
  - Marty, J.-C., Garcia, N. and Raimbault, P. (2008) 'Phytoplankton dynamics and primary production under late summer conditions in the NW Mediterranean Sea', *Deep Sea Research Part I: Oceanographic Research Papers*, 55(9), pp. 1131–1149. Available at: <https://doi.org/10.1016/j.dsr.2008.05.001>.
  - Massin, C. (1982) *Echinoderm nutrition*. Edited by M. Jangoux and J.M. Lawrence. Rotterdam : Salem, NH: Balkema ; Distributed in USA & Canada by MBS.
  - Matallanas, J. *et al.* (1995) 'The Food of *Seriola Dumerili* (Pisces: Carangidae) in the Catalan Sea (Western Mediterranean)', *Journal of the Marine Biological Association of the United Kingdom*, 75(1), pp. 257–260. Available at: <https://doi.org/10.1017/S0025315400015356>.
  - Matic-Skoko, S. *et al.* (2011) 'Mediterranean moray eel *Muraena helena* (Pisces: Muraenidae): biological indices for life history', *Aquatic Biology*, 13(3), pp. 275–284. Available at: <https://doi.org/10.3354/ab00373>.
  - Matic-Skoko, S. *et al.* (2012) 'The age, growth and feeding habits of the European conger eel, *Conger conger* (L.) in the Adriatic Sea', *Marine Biology Research*, 8(10), pp. 1012–1018. Available at: <https://doi.org/10.1080/17451000.2012.706307>.
  - McCarthy, I.D., Cant, J. and Marriott, A.L. (2018) 'Population biology of grey gurnard (*Eutrigla gurnardus* (L.); Triglidae) in the coastal waters of Northwest Wales', *Journal of Applied Ichthyology*, 34(4), pp. 896–905. Available at: <https://doi.org/10.1111/jai.13733>.
  - Merayo, C.R. and Villegas, M.L. (1994) 'Age and growth of *Trisopterus luscus* (Linnaeus, 1758) (Pisces, Gadidae) off the coast of Asturias', *Hydrobiologia*, 281(2), pp. 115–122. Available at: <https://doi.org/10.1007/BF00006440>.
  - Merquiol, L. (2015) *Alimentation et condition du merlu européen, *Merluccius merluccius* (L., 1758) dans le Nord-Ouest de la Méditerranée: une comparaison 2004-2015*. Rapport de stage de Master 1ere année SDUJEE/Océanographie et Environnements Marins. Université Pierre et Marie Curie.
  - Metin, G. *et al.* (2011) 'Age, growth and reproduction of four-spotted goby, *Deltentosteus quadrimaculatus* (Valenciennes, 1837), in İzmir Bay (central Aegean Sea)', *Turk. J. Zool.*, 35(5), pp. 711–716.
  - Mettam, C. (1980) 'On the feeding habits of *Aphrodita aculeata* and commensal polynoids', *J. mar. biol. Ass*, 60, p. 2.
  - Mialet, B. *et al.* (2017) *Bilan des essais et optimisation du suivi mutualisé « réseaux trophiques et contaminants » sur les campagnes halieutiques DCF 2014-2015*. Programmes de surveillance DCSMM, p. 108.

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- 1377
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- 1386
- Mili, S. *et al.* (2013) 'Food and biochemical composition of the spot-tail mantis shrimp *Squilla mantis* caught in three Tunisian Gulfs: Tunis, Hammamet and Gabes', *Cah. Biol. Mar.*, 54, pp. 271–280.
  - Montanini, S. *et al.* (2017) 'Feeding strategy and ontogenetic changes in diet of gurnards (Teleostea: Scorpaeniformes: Triglidae) from the Adriatic Sea', *The European Zoological Journal*, 84(1), pp. 356–367. Available at: <https://doi.org/10.1080/24750263.2017.1335357>.
  - Montanini, S., Stagioni, M. and Vallisneri, M. (2010) 'Diet of the grey gurnard, *Eutrigla gurnardus* in the Adriatic Sea, north-eastern Mediterranean', p. 6.
  - Morales-Nin, B. and Moranta, J. (1997) 'Life history and fishery of the common dentex (*Dentex dentex*) in Mallorca (Balearic Islands, western Mediterranean)', *Fisheries Research*, 30(1–2), pp. 67–76. Available at: [https://doi.org/10.1016/S0165-7836\(96\)00560-7](https://doi.org/10.1016/S0165-7836(96)00560-7).
  - Morato, T. *et al.* (2001) 'Feeding habits of two congener species of seabreams, *pagellus bogaraveo* and *pagellus acarne*, off the azores (northeastern atlantic) during spring of 1996 and 1997', *Bulletin of Marine Science*, 69(3), p. 15.
  - Morte, M.S., Redon, M.J. and Sanz-Brau, A. (2001) 'Feeding Habits of *Trisopterus minutus capelanus* (Gadidae) Off the Eastern Coast of Spain (Western Mediterranean)', *Marine Ecology*, 22(3), pp. 215–229. Available at: <https://doi.org/10.1046/j.1439-0485.2001.01731.x>.
  - Morte, S., Redón, M.J. and Sanz-Brau, A. (1999) 'Feeding ecology of two megrimms *Lepidorhombus boschii* and *Lepidorhombus whiffiagonis* in the western Mediterranean (Gulf of Valencia, Spain)', *Journal of the Marine Biological Association of the United Kingdom*, 79(1), pp. 161–169. Available at: <https://doi.org/10.1017/S0025315497000180>.
  - Munari, C., Serafin, G. and Mistri, M. (2013) 'Structure, growth and secondary production of two Tyrrhenian populations of the white gorgonian *Eunicella singularis* (Esper 1791)', *Estuarine, Coastal and Shelf Science*, 119, pp. 162–166. Available at: <https://doi.org/10.1016/j.ecss.2013.01.007>.
  - Nash, R.D.M. (1982) 'The biology of Fries' goby, *Lesueurigobius friesii* (Malm), in the Firth of Clyde, Scotland, and a comparison with other stocks', *Journal of Fish Biology*, 21(1), pp. 69–85. Available at: <https://doi.org/10.1111/j.1095-8649.1982.tb02825.x>.
  - Ortiz, M. *et al.* (2013) 'Network properties and keystone assessment in different intertidal communities dominated by two ecosystem engineer species (SE Pacific coast): A comparative analysis', *Ecological Modelling*, 250, pp. 307–318. Available at: <https://doi.org/10.1016/j.ecolmodel.2012.10.014>.
  - Ozcan, E.I. and Basusta, N. (2018) 'Some population parameters of *Scyliorhinus canicula* (Linnaeus, 1758) from the northeastern Mediterranean Sea', *J. Black Sea/Mediterranean Environment*, 24(1), pp. 51–64.
  - Palomares, M.L. *et al.* (1993) 'A trophic model of a Mediterranean lagoon, Etang de Thau, France', *Trophic models of aquatic ecosystems*, (26), p. 390.
  - Papaconstantinou, C. and Caragitsou, E. (1989) 'Feeding interaction between two sympatric species *Pagrus pagrus* and *Phycis phycis* around Kastellorizo Island (Dodecanese, Greece)', *Fisheries Research*, 7(4), pp. 329–342. Available at: [https://doi.org/10.1016/0165-7836\(89\)90065-9](https://doi.org/10.1016/0165-7836(89)90065-9).
  - Pasquaud, S. *et al.* (2008) 'A preliminary investigation of the fish food web in the Gironde estuary, France, using dietary and stable isotope analyses', *Estuarine, Coastal and Shelf Science*, 78(2), pp. 267–279. Available at: <https://doi.org/10.1016/j.ecss.2007.12.014>.
  - Pérez-Ruzafa, A. *et al.* (2002) 'Evidence of a planktonic food web response to changes in nutrient input dynamics in the Mar Menor coastal lagoon, Spain', in E. Orive, M. Elliott,

- 1387 and V.N. de Jonge (eds) *Nutrients and Eutrophication in Estuaries and Coastal Waters*.  
 1388 Dordrecht: Springer Netherlands, pp. 359–369. Available at: [https://doi.org/10.1007/978-](https://doi.org/10.1007/978-94-017-2464-7_26)  
 1389 [94-017-2464-7\\_26](https://doi.org/10.1007/978-94-017-2464-7_26).
- 1390 ▪ Petersen, J.K. (2007) 'Ascidian suspension feeding', *Journal of Experimental Marine*  
 1391 *Biology and Ecology*, 342(1), pp. 127–137. Available at:  
 1392 <https://doi.org/10.1016/j.jembe.2006.10.023>.
  - 1393 ▪ Pinnegar, J.K. (2000) *Planktivorous fishes : links between the Mediterranean littoral and*  
 1394 *pelagic*. Ph.D. University of Newcastle upon Tyne. Available at:  
 1395 <https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.311108> (Accessed: 13 October  
 1396 2021).
  - 1397 ▪ Plante-Cuny, M.-R. and Bodoy, A. (1987) 'Biomasse et production primaire du  
 1398 phytoplancton et du microphytobenthos de deux biotopes sableux (Golfe de Fos, France)',  
 1399 *Oceanologica Acta*, 10(2), pp. 223–237.
  - 1400 ▪ Plounevez, S. and Champalbert, G. (2000) 'Diet, feeding behaviour and trophic activity of  
 1401 the anchovy (*Engraulis encrasicolus* L.) in the Gulf of Lions (Mediterranean Sea)',  
 1402 *Oceanologica Acta*, 23(2), pp. 175–192. Available at: [https://doi.org/10.1016/S0399-](https://doi.org/10.1016/S0399-1784(00)00120-1)  
 1403 [1784\(00\)00120-1](https://doi.org/10.1016/S0399-1784(00)00120-1).
  - 1404 ▪ Prato, E. *et al.* (2010) 'Lipid and Fatty Acid Compositions of *Mytilus galloprovincialis*  
 1405 Cultured in the Mar Grande of Taranto (Southern Italy): Feeding Strategies and Trophic  
 1406 Relationships', *Zoological Studies*, p. 9.
  - 1407 ▪ Quetglas, A., Gonzalez, M. and Franco, I. (2005) 'Biology of the upper-slope cephalopod  
 1408 *Octopus salutii* from the western Mediterranean Sea', *Marine Biology*, 146(6), pp. 1131–  
 1409 1138. Available at: <https://doi.org/10.1007/s00227-004-1522-4>.
  - 1410 ▪ Rachedi, M. and Tania Dahel, A. (2019) 'Population Dynamic Parameters of the Comber  
 1411 *Serranus Cabrilla* (Teleostei, Serranidae) in Western Mediterranean (Eastern Coast of  
 1412 Algeria)', *Egyptian Journal of Aquatic Biology and Fisheries*, 23(5 (Special Issue)), pp. 31–  
 1413 42. Available at: <https://doi.org/10.21608/ejabf.2019.64840>.
  - 1414 ▪ Ragonese, S. and Bianchini, M.L. (1998) 'Growth, Mortality, and Yield-per-Recruit of the  
 1415 Poor Cod, *Trisopterus minutus capelanus*, from the Strait of Sicily', *Naga, the ICLARM*  
 1416 *Quarterly* [Preprint].
  - 1417 ▪ Ramón, M. *et al.* (2019) 'Evaluation of sediment particle size selection during feeding by  
 1418 the holothurian *Parastichopus regalis* (Cuvier, 1817)', *Regional Studies in Marine Science*,  
 1419 31, p. 100763. Available at: <https://doi.org/10.1016/j.rsma.2019.100763>.
  - 1420 ▪ Ramsay, K., Kaiser, M. and Hughes, R. (1996) 'Changes in hermit crab feeding patterns in  
 1421 response to trawling disturbance', *Marine Ecology Progress Series*, 144, pp. 63–72.  
 1422 Available at: <https://doi.org/10.3354/meps144063>.
  - 1423 ▪ Riaux-Gobin, C. *et al.* (1998) 'Microphytobenthos et phytoplancton en baie de Banyuls  
 1424 (Golfe du Lion): biomasses pigmentaires et facteurs hydroclimatiques', *Vie Milieu*, 48(1),  
 1425 pp. 1–13.
  - 1426 ▪ Ribes, M., Coma, R. and Gili, J. (1999) 'Natural diet and grazing rate of the temperate  
 1427 sponge *Dysidea avara* (Demospongiae, Dendroceratida) throughout an annual cycle',  
 1428 *Marine Ecology Progress Series*, 176, pp. 179–190. Available at:  
 1429 <https://doi.org/10.3354/meps176179>.
  - 1430 ▪ Riedel, F. (1995) 'An outline of cassoidean phylogeny (Mollusca, Gastropoda)', *Contr. Tert.*  
 1431 *Quatern. Geol.*, 32(4), pp. 97–132.
  - 1432 ▪ Rim, Z.-K., Mohamed-Nejmeddine, B. and Abderrahmen, B. (2009) 'Reproduction and  
 1433 Growth of the Yellowstripe Barracuda *Sphyræna chrysotaenia* Klunzinger, 1884, in  
 1434 Central Mediterranean', *Reviews in Fisheries Science*, 17(4), pp. 485–493. Available at:  
 1435 <https://doi.org/10.1080/10641260903082471>.

- 1436
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- 1471
- 1472
- 1473
- 1474
- 1475
- 1476
- 1477
- 1478
- 1479
- 1480
- 1481
- 1482
- Rizkalla, S. and Philips, A. (2008) 'Feeding habits of the Atlantic stargazer fish *Uranoscopus scaber* Linnaeus, 1758 (Family: Uranoscopidae) in Egyptian Mediterranean waters', *Egyptian Journal of Aquatic Biology and Fisheries*, 12(1), pp. 1–11. Available at: <https://doi.org/10.21608/ejabf.2008.1967>.
  - Rizkalla, S.I. and Bakhoum, S.A. (2009) 'Some Biological Aspects of Atlantic Stargazer *Uranoscopus scaber* Linnaeus, 1758 (Family: Uranoscopidae) in The Egyptian Mediterranean Water', p. 8.
  - Romeo, T. *et al.* (2009) 'An evaluation of resource partitioning between two billfish, *Tetrapturus belone* and *Xiphias gladius*, in the central Mediterranean Sea', *Journal of the Marine Biological Association of the United Kingdom*, 89(4), pp. 849–857. Available at: <https://doi.org/10.1017/S0025315408002087>.
  - Roscian, M. (2016) *Etude du régime alimentaire de Illex coindetii (Vérani, 1839) dans le Golfe du Lion*. Rapport de stage de Master Océanographie 1ere année. Aix-Marseille Université.
  - Rosecchi, E. (1987) 'L'alimentation de *Diplodus annularis*, *Diplodus sargus*, *Diplodus vulgaris* et *Sparus aurata* (pisces, sparidae) dans le golfe du lion et les lagunes littorales', *Rev. Trav. Inst. Pêches marit*, 49(3 et 4), pp. 125–141.
  - Sainte-Marie, B. and Chabot, D. (2002) 'Ontogenetic shifts in natural diet during benthic stages of American lobster (*Homarus americanus*), off the Magdalen Islands', *Fish. Bull*, 100(1), pp. 106–116.
  - Sala, E. and Ballesteros, E. (1997) 'Partitioning of space and food resources by three fish of the genus *Diplodus* (Sparidae) in a Mediterranean rocky infralittoral ecosystem', *Marine Ecology Progress Series*, 152, pp. 273–283. Available at: <https://doi.org/10.3354/meps152273>.
  - Sallami, B. (2014) 'Diet of Mediterranean moray, *Muraena helena* (Actinopterygii: Anguilliformes: Muraenidae), from the north-eastern Tunisian coast (central Mediterranean)', *Acta Ichthyologica et Piscatoria*, 44(4), pp. 273–283. Available at: <https://doi.org/10.3750/AIP2014.44.4.01>.
  - Sallami, B. *et al.* (2015) 'Diet of European conger eel *Conger conger* (Osteichthyes: Congridae) from the northeastern coast of Tunisia (central Mediterranean)', *Cah. Biol. Mar.*, 56, pp. 253–262.
  - Salman, A. (2004) 'The role of cephalopods in the diet of swordfish (*Xiphias gladius* linnaeus, 1758) in the aegean sea (eastern mediterranean)', *BULLETIN OF MARINE SCIENCE*, 74(1), p. 9.
  - Šantić, M. *et al.* (2016) 'Diet composition of greater weever, *Trachinus draco* (Linnaeus, 1758) captured in the eastern-central Adriatic Sea in relation to fish size, season and sampling area', *Journal of Applied Ichthyology*, 32(4), pp. 675–681. Available at: <https://doi.org/10.1111/jai.13081>.
  - Šantić, M., Paladin, A. and Elez, G. (2010) 'Diet of striped sea bream *Lithognathus mormyrus* (Sparidae) from eastern central Adriatic Sea', *Cybium*, 34(4), pp. 345–352.
  - Šantić, M., Rađa, B. and Pallaoro, A. (2012) 'Diet and feeding strategy of thornback ray *Raja clavata*', *Journal of Fish Biology*, 81(3), pp. 1070–1084. Available at: <https://doi.org/10.1111/j.1095-8649.2012.03382.x>.
  - Scarcella, G. *et al.* (2011) 'Comparison of growth rates estimated by otolith reading of *Scorpaena porcus* and *Scorpaena notata* caught on artificial and natural reefs of the northern Adriatic sea', *Brazilian Journal of Oceanography*, 59(spe1), pp. 33–42. Available at: <https://doi.org/10.1590/S1679-87592011000500006>.

- 1483       ▪ Schücker, S. *et al.* (2012) 'Diet overlap among flatfish species in the southern North Sea',  
1484       *Journal of Fish Biology*, 80(7), pp. 2571–2594. Available at:  
1485       <https://doi.org/10.1111/j.1095-8649.2012.03309.x>.
- 1486       ▪ Schwinghamer, P. *et al.* (1986) 'Partitioning of production and respiration among size  
1487       groups of organisms in an intertidal benthic community', *Marine Ecology Progress Series*,  
1488       31, pp. 131–142. Available at: <https://doi.org/10.3354/meps031131>.
- 1489       ▪ Scolding, J.W.S., Richardson, C.A. and Luckenbach, M.J. (2007) 'Predation of cockles  
1490       (*Cerastoderma edule*) by the whelk (*Buccinum undatum*) under laboratory conditions',  
1491       *Journal of Molluscan Studies*, 73(4), pp. 333–337. Available at:  
1492       <https://doi.org/10.1093/mollus/eym031>.
- 1493       ▪ Sebens, K.P. and Koehl, M.A.R. (1984) 'Predation on zooplankton by the benthic  
1494       anthozoans *Alcyonium siderium* (Alcyonacea) and *Metridium senile* (Actiniaria) in the  
1495       New England subtidal', *Marine Biology*, 81, pp. 255–271.
- 1496       ▪ Serra-Pereira, B. *et al.* (2005) 'Description of Portuguese mixed-fisheries with positive  
1497       landings of *Raja brachyura* Lafont, 1873 and *Raja montagui* Fowler, 1910', *Elasmobranch*  
1498       *Fisheries Science*, (18), p. 10.
- 1499       ▪ Sever, T.M. *et al.* (2013) 'Diet composition of the five deep sea fish from the Aegean Sea.',  
1500       *Ege Journal of Fisheries and Aquatic Sciences*, 30(2), pp. 61–67. Available at:  
1501       <https://doi.org/10.12714/egejfas.2013.30.2.03>.
- 1502       ▪ Sever, T.M. (2019) 'Diet Composition of the Blotched Picarel *Spicara flexuosa*', *Acta*  
1503       *Zoologica Bulgarica*, 71(4), pp. 581–588.
- 1504       ▪ Sinopoli, M. *et al.* (2017) 'Food resource partitioning between two sympatric temperate  
1505       wrasses', *Marine and Freshwater Research*, 68(12), p. 2324. Available at:  
1506       <https://doi.org/10.1071/MF16363>.
- 1507       ▪ Stergiou, K.I. and Fourtouni, H. (1991) 'Food habits, ontogenetic diet shift and selectivity  
1508       in *Zeus faber* Linnaeus, 1758', *Journal of Fish Biology*, 39(4), pp. 589–603. Available at:  
1509       <https://doi.org/10.1111/j.1095-8649.1991.tb04389.x>.
- 1510       ▪ Sviben, S. *et al.* (2019) 'Observations on the diet of the Starry skate, *Raja asterias*  
1511       Delaroche, 1809 (Elasmobranchii: Rajidae) in the Adriatic Sea', *Mediterranean Marine*  
1512       *Science*, 20(3), p. 577. Available at: <https://doi.org/10.12681/mms.19338>.
- 1513       ▪ Teixeira, C.M., Batista, M.I. and Cabral, H.N. (2010) 'Diet, growth and reproduction of four  
1514       flatfishes on the Portuguese coast', *Scientia Marina*, 74(2), pp. 223–233. Available at:  
1515       <https://doi.org/10.3989/scimar.2010.74n2223>.
- 1516       ▪ Tičina, V. and Matić-Skoko, S. (2012) 'Age, growth and mortality of scaldfish (*Arnoglossus*  
1517       *laterna* Walbaum, 1792) from the Adriatic Sea: Age, growth and mortality of *Arnoglossus*  
1518       *laterna*', *Journal of Applied Ichthyology*, 28(5), pp. 836–841. Available at:  
1519       <https://doi.org/10.1111/j.1439-0426.2012.01975.x>.
- 1520       ▪ Tilves, U. *et al.* (2018) 'Trophic interactions of the jellyfish *Pelagia noctiluca* in the NW  
1521       Mediterranean: evidence from stable isotope signatures and fatty acid composition',  
1522       *Marine Ecology Progress Series*, 591, pp. 101–116. Available at:  
1523       <https://doi.org/10.3354/meps12332>.
- 1524       ▪ Torre, M., Sicuro, B. and Kallianiotis, A. (2019) 'Diet of Silver scabbardfish *Lepidopus*  
1525       *caudatus* (Euphrasen, 1788) in the Northern Aegean Sea', *Cah. Biol. Mar.*, 60, pp. 31–40.  
1526       Available at: <https://doi.org/10.21411/CBM.A.4C45C5BD>.
- 1527       ▪ Tserpes, G. (2010) *Report of the 2010 ICCAT mediterranean swordfish stock assessment*  
1528       *meeting*. ICCAT.

- 1529
- 1530
- 1531
- 1532
- 1533
- 1534
- 1535
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- 1539
- 1540
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- 1565
- 1566
- 1567
- 1568
- 1569
- 1570
- 1571
- 1572
- 1573
- 1574
- 1575
- Tsikliras, A.C., Koutrakis, E.T. and Stergiou, K.I. (2005) 'Age and growth of round sardinella (*Sardinella aurita*) in the northeastern Mediterranean', *Scientia Marina*, 69(2), pp. 231–240. Available at: <https://doi.org/10.3989/scimar.2005.69n2231>.
  - Vagenas, G. *et al.* (2020) 'Age, growth and feeding habits of boarfish (*Capros aper*) in the Aegean and Ionian Seas (Greece)', *Marine Biology Research*, 16(8–9), pp. 585–592. Available at: <https://doi.org/10.1080/17451000.2020.1855657>.
  - Valeiras, X., Macías, D., *et al.* (2008) 'Age and growth of atlantic bonito (*Sarda sarda*) in western Mediterranean sea', *Collect. Vol. Sci. Pap. ICCAT*, 62(5), pp. 1649–1658.
  - Valeiras, X., de la Serna, J.M., *et al.* (2008) 'Age and growth of swordfish (*Xiphias gladius*) in the western Mediterranean sea', *Collect. Vol. Sci. Pap. ICCAT*, 62(2), pp. 1112–1121.
  - Valls, M. *et al.* (2011) 'Feeding ecology of demersal elasmobranchs from the shelf and slope off the Balearic Sea (western Mediterranean)', *Scientia Marina*, 75(4), pp. 633–639. Available at: <https://doi.org/10.3989/scimar.2011.75n4633>.
  - Van Beveren, E. *et al.* (2014) 'Rapid changes in growth, condition, size and age of small pelagic fish in the Mediterranean', *Marine Biology*, 161(8), pp. 1809–1822. Available at: <https://doi.org/10.1007/s00227-014-2463-1>.
  - Van Beveren, E. *et al.* (2017) 'Predator–prey interactions in the face of management regulations: changes in Mediterranean small pelagic species are not due to increased tuna predation', *Canadian Journal of Fisheries and Aquatic Sciences*, 74(9), pp. 1422–1430. Available at: <https://doi.org/10.1139/cjfas-2016-0152>.
  - Vaqué, D., Blough, H. and Duarte, C. (1997) 'Dynamics of ciliate abundance, biomass and community composition in an oligotrophic coastal environment (NW Mediterranean)', *Aquatic Microbial Ecology*, 12, pp. 71–83. Available at: <https://doi.org/10.3354/ame012071>.
  - Varela, J.L. *et al.* (2019) 'Inter-regional variation in feeding patterns of skipjack tuna (*Katsuwonus pelamis*) inferred from stomach content, stable isotope and fatty acid analyses', *Marine Environmental Research*, 152, p. 104821. Available at: <https://doi.org/10.1016/j.marenvres.2019.104821>.
  - Vasconcelos, P. *et al.* (2012) 'Growth of the purple dye murex, *Bolinus brandaris* (Gastropoda: Muricidae), marked and released in a semi-intensive fish culture earthen pond', *Scientia Marina*, 76(1), pp. 67–78. Available at: <https://doi.org/10.3989/scimar.03313.21B>.
  - Vasserot, J. (1961) 'Caractère hautement spécialisé du régime alimentaire chez les astérides *Echinaster sepositus* et *Henricia sanguinolenta*, prédateurs de spongiaires.'
  - Vassilopoulou, V. and Papaconstantinou, C. (1992) 'Age, growth and mortality of the red porgy, *Pagrus pagrus*, in the eastern Mediterranean sea (Dodecanese, Greece)', *Vie et Milieu*, pp. 51–55.
  - Vaudo, G. (2002) *Contribution à l'étude des pêcheries marines et lagunaires interactives du golfe du Lion*. Aix-Marseille III.
  - Velasco, E.M. *et al.* (2011) 'Age and growth of the Spanish chub mackerel *Scomber colias* off southern Spain: a comparison between samples from the NE Atlantic and the SW Mediterranean', *Revista de biología marina y oceanografía*, 46(1), pp. 27–34. Available at: <https://doi.org/10.4067/S0718-19572011000100004>.
  - Velsch, J.P. (1997) *Dynamique de population et migrations verticales journalières de *Meganycitphanes Norvegica* (Crustacés: Euphausiaces) en Méditerranée Nord-Occidentale*. These de doctorat. Aix-Marseille 2. Available at: <https://www.theses.fr/1997AIX22118> (Accessed: 13 October 2021).

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- 1596
- 1597
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- 1599
- 1600
- 1601
- 1602
- 1603
- 1604
- Verlaque, M. and Nédelec, H. (1983) 'Biologie de *Paracentrotus lividus* (Lamarck) sur substrat rocheux en corse (Méditerranée, France): alimentation des adultes - Biology of *Paracentrotus lividus* (Lamarck) on rocky bottoms in Corsica (Mediterranean, France): Diet of adults', *Vie et Milieu*, 33(3), pp. 191–201.
  - Viegas, I. *et al.* (2007) 'Population dynamics, distribution and secondary production of the brown shrimp *Crangon crangon* (L.) in a southern European estuary. Latitudinal variations', *Scientia Marina*, 71(3), pp. 451–460. Available at: <https://doi.org/10.3989/scimar.2007.71n3451>.
  - Vinagre, C. *et al.* (2011) 'Diet and niche overlap of southern populations of brill *Scophthalmus rhombus* and turbot *Scophthalmus maximus*', *Journal of Fish Biology*, 79(5), pp. 1383–1391. Available at: <https://doi.org/10.1111/j.1095-8649.2011.03116.x>.
  - Warner, G. (1982) *Echinoderm nutrition*. Edited by M. Jangoux and J.M. Lawrence. Rotterdam : Salem, NH: Balkema ; Distributed in USA & Canada by MBS.
  - Watanabe, S. *et al.* (2009) 'Small-scale variation in feeding environments for the Manila clam *Ruditapes philippinarum* in a tidal flat in Tokyo Bay', *Fisheries Science*, 75(4), pp. 937–945. Available at: <https://doi.org/10.1007/s12562-009-0113-1>.
  - Wong, M., Peterson, C. and Piehler, M. (2011) 'Evaluating estuarine habitats using secondary production as a proxy for food web support', *Marine Ecology Progress Series*, 440, pp. 11–25. Available at: <https://doi.org/10.3354/meps09323>.
  - Yigin, C. and Ismen, A. (2010) 'Age, growth, reproduction and feed of bottlenose skate, *Rostroraja alba* (Lacepède, 1803) in Saros Bay, the north Aegean Sea'. *Elasmobranch Fisheries: developments in stock assessment, technical mitigation and management measures*.
  - Yonge, C.M. (1946) 'On the Habits of *Turritella Communis* Risso', *Journal of the Marine Biological Association of the United Kingdom*, 26(3), pp. 377–380. Available at: <https://doi.org/10.1017/S0025315400012194>.