

# Fisheries Research

## Octopus fisheries in Europe: socioeconomic importance and management

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<b>Abstract:</b>	<p>The European Union (EU) is one of the most important markets for cephalopods in the world. Currently, small-scale fisheries targeting octopus in the EU are of considerable social and economic importance, especially in southern European waters where more octopus are consumed as part of the traditional diet. Octopus in Europe are excluded from quota regulations under the Common Fisheries Policy, and Member States manage their fisheries employing different input and output control measures, especially in small-scale fisheries targeting octopus. The level of participation of the fishing industry in the management of their activity varies amongst member states and some management arrangements in place are tailored at the local level. This manuscript focuses on four European countries with important small-scale artisanal octopus fisheries (Portugal, Spain, Italy and Greece). It describes and compares the current status of small-scale octopus fisheries in each country, their socioeconomic importance, the management arrangements in place, and the opportunities and challenges for their future. Despite the increasing importance of octopus fisheries in southern Europe, few countries have collected detailed data on the socioeconomic importance and management of these fisheries. The information provided contributes to increase the knowledge about the human dimensions of octopus fisheries in Europe.</p>
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**Fisheries Research**  
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Dr. Angel González and Dr. Graham Pierce  
Guest editors Special Issue Cephalopod fisheries and ecosystems

Dear Dr. Angel González and Dr. Graham Pierce,

We hereby submit the manuscript entitled “**Octopus fisheries in Europe: socioeconomic importance and management**”, authored by Cristina Pita, Katina Roubledakis, Teresa Fonseca, Fábio L. Matos, João Pereira, Sebastián Villasante, Pablo Pita, José Maria Bellido, Angel F. Gonzalez, Manuel García-Tasende, Evgenia Lefkaditou, Aggeliki Adamidou, Danila Cuccu, Paola Belcari, Ana Moreno and Graham J. Pierce for consideration for publication in Fisheries Research as part of the special issue *Cephalopod fisheries and ecosystems*.

The manuscript focuses on important small-scale artisanal octopus fisheries in four European countries (Portugal, Spain, Italy and Greece). We describe and compare the current status of small-scale octopus fisheries in each country, their socioeconomic importance, the management arrangements in place, and the opportunities and challenges for their future. As such, we believe this manuscript would be an important contribution to the Special Issue.

The manuscript has not been published previously, nor has it been submitted for publication in other journals. Also, to the best of our knowledge, there are no financial or personal relationships with other people or organizations that could inappropriately influence (bias) this work. All sources of financing (which included grants for several people) have been identified and acknowledged in the acknowledgments.

Thank you for considering publishing our work and we look forward to your review.  
Sincerely,



Cristina Pita, PhD

Corresponding author (on behalf of all authors)

# 1 **Octopus fisheries in Europe: socioeconomic importance and management**

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31 **Abstract**

32 The European Union (EU) is one of the most important markets for cephalopods in the world.  
33 Currently, small-scale fisheries targeting octopus in the EU are of considerable social and economic  
34 importance, especially in southern European waters where more octopus are consumed as part of the  
35 traditional diet. Octopus in Europe are excluded from quota regulations under the Common Fisheries  
36 Policy, and Member States manage their fisheries employing different input and output control  
37 measures, especially in small-scale fisheries targeting octopus. The level of participation of the  
38 fishing industry in the management of their activity varies amongst member states and some  
39 management arrangements in place are tailored at the local level. This manuscript focuses on four  
40 European countries with important small-scale artisanal octopus fisheries (Portugal, Spain, Italy and  
41 Greece). It describes and compares the current status of small-scale octopus fisheries in each country,  
42 their socioeconomic importance, the management arrangements in place, and the opportunities and  
43 challenges for their future. Despite the increasing importance of octopus fisheries in southern Europe,  
44 few countries have collected detailed data on the socioeconomic importance and management of these  
45 fisheries. The information provided contributes to increase the knowledge about the human  
46 dimensions of octopus fisheries in Europe.

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49 **Keywords:** Governance; Management; *Octopus vulgaris*; small-scale fisheries; artisanal fisheries.

## 50 **1. Introduction**

51

52 The global overexploitation and depletion of many finfish species over the last few decades (FAO,  
53 2018) has led to an increase in the commercial importance of other marine resources, such as  
54 cephalopods (i.e., squids, cuttlefishes and octopuses) (Pierce and Portela, 2014; Pierce et al., 2010).  
55 Forty years ago, the Japanese fishery for *Todarodes pacificus* was the only significant cephalopod  
56 fishery in the world (Pierce and Portela, 2014). Cephalopods were exploited only in a few ocean  
57 regions, such as the northwest and central Pacific, the northwest African coasts, the northwest and  
58 southwest Atlantic, and the Mediterranean Sea (Villasante et al., 2014; Caddy, 1983). In the beginning  
59 of the 1980s, Caddy (1983) predicted that cephalopods were a resource with potential to support a  
60 high level of local exploitation in the near future. This prediction did indeed materialize, and  
61 cephalopods are now highly valuable commercial fishery resources, with world cephalopod landings  
62 having risen eight-fold from 1950 to 2014, the year landings peaked at 4.86 million tons. Following  
63 which landing have been steadily decreasing, accounting for 3.64 million ton in 2018, according to  
64 FAO statistics.

65 Cephalopods are typically caught by both industrial trawlers and jiggers and small-scale  
66 artisanal fleets worldwide. An important aspect of cephalopod fishing in many parts of the world is  
67 the high importance of these resources for small-scale artisanal fisheries (Pita et al., 2015; Pierce et  
68 al., 2010). This is the case in southern European waters, where small-scale directed coastal fisheries  
69 for octopus, cuttlefish and squid have increased in the last decades (Sauer et al., 2019). In Portugal,  
70 Spain, Italy and Greece, cephalopods have long been important target species for fishers using a  
71 variety of artisanal gears (Pierce et al., 2010) and are nowadays increasingly important fishery  
72 resources in terms of quantities landed and particularly in terms of commercial value. According to  
73 EUROSTAT statistics, these four countries together account for an average of 77% of the value of  
74 all cephalopods landed in the European Union (EU) (Table 1). To add to this, cephalopods are

75 traditionally consumed in southern European countries, with Spain and Italy (together with Japan and  
76 the United States), being the most important consumer markets worldwide (FAO, 2018).

77 The common octopus (*Octopus vulgaris*) is the most important commercially harvested  
78 octopus species in the EU. This species is fished at depths between 20-200 m in both the northeast  
79 Atlantic and the Mediterranean Sea mainly by small-scale coastal fleets using hand-jigs, pots, traps,  
80 fyke-nets and trammel nets, but also by trawlers specially in deeper waters (Sauer et al., 2019; Silva  
81 et al., 2019; Sonderblohm et al., 2017; Pita et al., 2015; Pierce and Portela, 2014; Pierce et al., 2010;  
82 Tsangridis et al., 2002; Lefkaditou et al., 2002). Other octopus species caught in Europe include the  
83 horned and musky octopuses (*Eledone cirrhosa* and *Eledone moschata*, respectively). They are  
84 important commercial species in some parts of Europe, such as the Mediterranean Sea (Sauer et al.,  
85 2019; Sartor et al., 1998), while in other parts, such as in the northeast Atlantic, they tend to be  
86 routinely discarded, with a small amount being landed by trawling fleets (Sauer et al., 2019).

87 Inshore local small-scale fishing fleets targeting the common octopus in Portugal, Spain, Italy  
88 and Greece are of considerable socio-economic importance in terms of providing employment and  
89 income in coastal fishing communities. The importance of octopus fisheries is higher than can be  
90 estimated looking at official landings as these are not well-documented and are often underreported,  
91 being probably underestimated in the official statistics (Bañón et al., 2018; Villasante et al. 2016; Pita  
92 et al., 2015). Nevertheless, octopus fisheries are often quite variable, with a strong seasonal  
93 dependence and marked variation in landings between years, reflecting a strong influence of  
94 environmental conditions (Pierce et al., 2008). This affects octopus' availability and market values,  
95 with obvious economic and social impacts.

96 Despite the increasing economic importance of octopus fisheries in the EU, these species have  
97 long been considered of minor commercial importance and information about this resource, especially  
98 its human dimensions (social, economic, cultural and institutional aspects) is scarce. As identified a  
99 decade ago by Pierce et al. (2010), in a review of cephalopods fisheries in Europe, there was (and still

100 is) an urgent need for a detailed analysis of the economic and social importance of these fisheries at  
101 the local and national levels, as well as an evaluation of the systems of governance.

102 This manuscript focuses on some of the most important fisheries targeting the common  
103 octopus in Europe: Algarve (Portugal), Andalucía and Galicia (Spain), Sardinia (Italy) and Thracian  
104 Sea (Greece) (Figure 1). It describes the current status of these fisheries, covering their socioeconomic  
105 importance, management arrangements and governance systems and discusses the opportunities and  
106 challenges for their future.

107

108 *[TABLE 1 ABOUT HERE]*

109 *[FIGURE 1 ABOUT HERE]*

110

## 111 **2. Important octopus fisheries in Europe**

### 112 ***2.1. Algarve, Portugal***

113 In Portuguese waters, fishing for octopus is a traditional activity which dates as far back as the 15<sup>th</sup>  
114 century, with reports of octopus caught and exported from the Algarve region, south of Portugal  
115 (Godinho, 1963). Nowadays, the common octopus is one of the most important fishery resources in  
116 Portugal, being consistently one of the most valuable species at first sale (Pita et al., 2015). In 2019,  
117 octopus was the most important species landed, representing 12% of the official first sale revenue of  
118 all Portuguese fisheries (INE, 2020). In the Algarve, octopus accounted for 28% (€17.2 million) of  
119 the total regional landings (INE, 2020). The common octopus is mostly captured with pots  
120 (“*alcatruzes*”) and traps (“*covos*”) by the local fleet (small-size boats, length overall (LOA) not  
121 exceeding 9 m) and the coastal fleet (comprised of vessels generally ranging in LOA from 9-15 m),  
122 with these two gears accounting in general for around 90% of octopus landings by weight (Pita and  
123 Gaspar, 2020; Sonderblohm et al., 2017; Pita et al., 2015; Moreno et al., 2014). In 2019, a total of  
124 358 vessels was licensed for traps or pots in the Algarve, employing a total of 1501 fishers in this  
125 directed fishery. Each vessel can carry more than one license, and the different gears can be operating



126 simultaneously. In 2019, 326 trap licenses and 189 pot licenses were issued, to give a total of 515  
127 units of octopus-directed gear in legal operation (DGRM official fisheries statistics data).

128         The exploitation of the common octopus in Portugal has more than doubled over the last 30  
129 years. However, octopus landings in the Algarve have been decreasing over the last few years and  
130 have remained below the historical mean since 2014. Despite this, there is an increasing economic  
131 dependence among the Portuguese small-scale sector on this species, especially in the Algarve, where  
132 the economic dependence of coastal fishing communities on octopus for their livelihood has been  
133 increasing over the last few decades (Pita and Gaspar, 2020; Pita et al., 2015; Pilar-Fonseca et al.,  
134 2014), with several coastal communities highly dependent on this resource. For instance, official  
135 fisheries statistics show that octopuses represented 80% and 92%, in weight and value, of the total  
136 landings in 2017 in the fishing community of Fuzeta (Algarve). The dependence is even higher in the  
137 fishing community of Santa Lúzia (Algarve), where octopus represent, in general, 99% in both weight  
138 and value of landings yearly.

## 139 ***2.2. Galicia and Andalucía, Spain***

140 Spain is one of the countries of the world with the highest demand for octopus (FAO, 2018) and it is  
141 also one of the main contributors to European landings of cephalopods, reaching 35,785 t in 2017  
142 (MAGRAMA, 2018). To meet the strong internal demand, several coastal regions support a large  
143 fishing fleet that exerts a significant fishing effort, especially in Andalucía, in the south (del Corral,  
144 2008), and Galicia, in the north (Pascual Fernández et al., 2020; Pita et al., 2016).

145         In Galicia, octopus was probably already consumed before the Roman period. In the 16<sup>th</sup>  
146 century a powerful fishing industry was already operating in Galicia, which marketed fresh octopus  
147 locally, and dry and cured octopus in inland markets. In the 19<sup>th</sup> century, octopus began to be exported  
148 from Galicia (Bañón et al., 2018). Thus, the Galician octopus fishery and the traditional consumption  
149 of octopus at local festivals throughout its territory have deep cultural roots that go beyond  
150 gastronomy (Pita et al., 2016).

151           Nowadays, the common octopus is fished along the entire Galician coast, even though the  
152 Rias Baixas area has traditionally had the largest catches. It is caught by the small-scale fleet mainly  
153 with octopus traps (called “*nasa de polbo*”), which are responsible for 80-90% of the total catches in  
154 weight of the small-scale fleet (Bañón et al, 2018). According to official statistics, landings have been  
155 decreasing in recent years, with a drop from 4.1 thousand tons in 2010 to 2.1 thousand in 2019. This  
156 decrease is explained by the environmental variation in the Galician estuaries (rías) combined with  
157 pollution, overfishing, and ineffective monitoring and control (Pascual Fernández et al., 2020). In  
158 2019, 33% (1217 vessels) of all small-scale vessels in Galicia were authorized to fish with octopus  
159 traps (Xunta de Galicia, 2020), and the common octopus accounted for 17% (2129 tons) in weight  
160 and 20% in value (€16.09 million) of all the catches from Galician waters. There is no information  
161 on the number of fishers directly involved in the octopus fishery, although the average number of  
162 crew per vessel is between 2 and 3 (the range is 1-6 crew per boat), which would mean an estimated  
163 2400 to 3600 fishers directly involved in this fishery in the region.

164           Andalucía is the largest southern region in Spain, with coasts both in the Atlantic and  
165 Mediterranean, and it retains an important local fishery tradition. Bernal Casasola (2009) dated the  
166 origins of fishing in western Andalucía to prehistoric times, including cephalopod fisheries. Similar  
167 to what was observed in Galicia, ancient cultures established in Andalucía (like the Phoenicians and  
168 Romans) used to consume octopus. Although many fishers and catches were historically linked to the  
169 Sahara and Morocco fisheries, current landings come almost entirely from national fishing grounds.  
170 According the official fisheries statistics, the common octopus is one of the most important fishery  
171 resources in Andalucía, being the fifth species in landings (2107 tons in 2018, accounting for 4.3%  
172 of the total catches) and the second in value (€15.4 million in 2018, 10% of the total value)  
173 (Estadísticas Pesqueras Junta de Andalucía, 2018). Octopus is caught by coastal trawlers and small-  
174 scale fisheries using traps (“*alcatruces*”, a fishing gear particularly designed to catch octopus).  
175 Octopus fishing has gained relevance since the early 2000s and is perceived by fishers as a cost-  
176 effective fishery that provides reasonable profits (del Corral, 2008).

177 **2.3. Sardinia, Italy**

178 In Italy there is no fishing fleet dedicated exclusively to octopuses (*O. vulgaris*, *E. cirrhosa* and *E.*  
179 *moschata*) or any other cephalopod species, although cephalopods may be among the targets of multi-  
180 species artisanal fisheries (e.g., in the Aeolian Islands) (Battaglia et al., 2010). Octopus species are  
181 mainly caught as a by-catch of bottom trawls, but a substantial fraction of the captures of the common  
182 octopus depends on small-scale fisheries. Both segments of the fleet (trawl and artisanal) employ an  
183 important number of local fishers in many small coastal communities along the Italian coast.

184 The Italian small-scale fishing fleet accounts for 2/3 of the entire fleet (8507 vessels) in  
185 number (but only 10% of the total tonnage). The fleet is composed mostly of vessels with LOA not  
186 exceeding 12 m and 2 GT, using mainly passive gear, such as set nets, long lines, pots and traps. The  
187 small-scale fishing activity is usually conducted as a family business, and exhibits marked differences  
188 in terms of specialization, productivity and profitability in different geographic areas. Temporal  
189 analysis (from 2004 to 2019) of Italian production of common octopus showed significant  
190 fluctuations, with a negative trend overall, from a maximum of 5495 tons in 2004 to a minimum of  
191 1898 tons in 2017. In 2019, national landings of the common octopus amounted to 3800 tons and  
192 €33.8 million, the small-scale fishery being responsible for 55% of the landings (IREPA, 2012;  
193 Mably, 2019). Sardinia accounted for a significant part of the production (1186 tons, €9.35 million),  
194 of which over 70% is landed by the artisanal fleet (Mably, 2019).

195 The Sardinian artisanal octopus fishery involves over 1200 vessels, using traps and set nets.  
196 Traps are the most suitable for catching the common octopus, particularly in spring and summer,  
197 when they are used in waters of up to 50 m depth, and have a very low by-catch of other species  
198 (Cuccu et al. 1999). Fishing with traps started about two centuries ago, and was introduced by fishing  
199 families from other parts of Italy, mainly from Campania. These traps used to be built using natural  
200 materials and lasted 4-6 months. Nowadays the most common traps have a cylindrical shape and are  
201 made of iron wire, the lateral surface encased in rigid plastic and the bases wrapped in soft nylon.  
202 They are baited mainly with crabs.

203 **2.4. Thracian Sea, Greece**

204 The common octopus has been fished in Greece since antiquity (Apel, 2004), when it was also known  
205 for its therapeutic properties (Voultsiadou, 2010). In 1982, official Hellenic Fisheries Statistics started  
206 to report the landings of mixed octopod species, split into *Octopus vulgaris* and Eledonid landings,  
207 and provide landings by month for the 16 divisions of the Hellenic waters and by 4 fishing gear types  
208 (bottom trawl, purse seine, boat seine, other small scale métiers). Small-scale and bottom trawl  
209 fisheries used to contribute approximately equally to total Greek octopus landings from 1982-1988  
210 (Lefkaditou et al., 2002), with annual average landings of 470 tons. A sharp increase of common  
211 octopus landings followed, leading to a peak of about 3500 tons in landing in 1992. This increase,  
212 and the subsequent yearly variation in total landings were mainly due to catches in the northeast  
213 Aegean, which contributes from 32% to 65% of the total catches in the Hellenic Seas (with the  
214 exception of 2011, when remarkably low octopus landings were reported in this area by the Hellenic  
215 Statistical Authority). Small-scale fisheries have been responsible for the largest amount of catches  
216 in the northeast Aegean since 1993 (Hellenic Statistical Authority data). The depletion of commercial  
217 demersal fish species in the heavily exploited north Aegean ecosystem (Tsangarakis et al., 2010),  
218 may have resulted in increases in abundance of the common octopus, and in the increased interest  
219 towards this resource.

220 Since 1982 major developments have occurred in small-scale fisheries targeting the common  
221 octopus, particularly in the northeastern Aegean Sea, with the introduction of fyke-nets in 1982,  
222 followed by the introduction of plastic pots in 1992 (Lefkaditou, 2007). Lefkaditou et al. (2004) and  
223 Kallianiotis and Koutrakis (1999), reported that the use of the octopus trap métier has varied  
224 considerably between fishing ports since 1997, with some ports having 30% of their small-scale fleets  
225 involved in this fishery and others 97%. The systematic and exclusive targeting of the common  
226 octopus by fyke-nets has been shown to be a feasible activity for a small fishing vessel, as it can  
227 ensure an adequate monthly income for two people (Lefkaditou et al. 2003).

228

### 229 **3. Management and governance of octopus fisheries in Europe**

#### 230 **3.1. Fisheries management**

231 Cephalopods fisheries in Europe are excluded from TAC and quota regulations under the scope of  
232 the Common Fisheries Policy (CFP). The existing management arrangements for the various fisheries  
233 across the EU have evolved under the tutelage of national and/or local governments. Southern  
234 European countries are the ones that more actively manage their cephalopod fisheries, possibly a  
235 reflection of the antiquity of the exploitation and the economic importance of these resources (Pierce  
236 et al., 2010) but also reflecting the fact that, in the north, most cephalopods are taken (frequently as a  
237 bycatch) by trawlers in the large-scale fleet, the activity of which is largely dependent on CFP  
238 regulations for quota species, whereas in the south, directed artisanal fisheries in coastal waters  
239 predominate – and these fall under regional or national jurisdiction.

240 Octopus fisheries in Greece, Italy, Portugal and Spain are all subject to a range of fishery  
241 legislation. Table 2 summarizes the current management measures in place for the octopus fisheries  
242 in the various regions under analysis. The management regimes in all locations involve both input  
243 and output control measures, as well a suit of other technical measures. Input controls consist mostly  
244 of setting gear limitations (e.g., number of traps/pots nets deployed, gear design) and limiting the  
245 number of licenses. Output controls consist mostly of limiting the weight of the octopus specimens  
246 landed, varying between 300g (Italy) and 1000g (Spain). Galicia is an exception, with several other  
247 output controls in place. All countries also have several other technical measures in place, some of  
248 which are common to the several case regions and some specific. Some management arrangements  
249 in place are tailored at the local level and, in some locations, fishers actively participate in the  
250 management of their activity, e.g., in Andalucía and Galicia.

251 The management of the octopus fishery in Galicia is the most comprehensive of all cases in  
252 this analysis, despite the fact that fisheries management in this region is shared by two  
253 administrations, the Galician Autonomous Government (Xunta de Galicia) and the National  
254 Government. The former is responsible for the management, monitoring and control of fisheries in

255 Galician inshore waters (Bañón et al., 2018), while the latter regulates offshore waters. There is a  
256 specific legal corpus for fisheries in Galician inshore waters with several regulations in force for the  
257 octopus fishery, setting rules about the gear which can be deployed, operating procedures, area of  
258 operation for different types of octopus traps, maximum amount of traps per vessel, the minimum  
259 landing weight, and the annual management plans for the octopus fishery. The management plan is  
260 established by fishing season (from June to May of the following year) and is usually implemented  
261 differently along the coast, allowing for modifications or complementing the general basic rules,  
262 according to the status of the resource, in co-management with the local fishers (Bañón et al., 2018;  
263 Pita et al., 2016; Villasante et al., 2016). The most recent management plan<sup>1</sup> established the rules for  
264 the octopus fishery for the 2020-2021 season, and includes, amongst other measures, closed seasons  
265 (from May 29<sup>th</sup> to July 1<sup>st</sup>, 2020), minimum weight of catches (currently 1 kg), maximum daily  
266 catches taking into account the number of crew members onboard of the vessel, and the number of  
267 traps per working hour at sea. Despite the management in place, a decline in octopus landings has  
268 been observed over recent years in Galicia. According to Pascual Fernández et al. (2020), this decline  
269 is partly due to overfishing and ineffective control of rules and regulations. There is a substantial  
270 amount of illegal commercial catch, which has been estimated to range between 20-50% of the total  
271 reported catches in 2010, and there is also a substantial number of recreational fishers selling octopus  
272 directly to restaurants, illegally (Villasante et al., 2016). However, better control and monitoring  
273 programs appear to have contributed to a substantial reduction of illegal practices over the last few  
274 years (Pascual Fernández et al., 2020; Villasante et al., 2016). In addition, advances in co-  
275 management processes in recent years have reduced social conflicts, and consequently increased  
276 compliance with regulations (Pita et al., 2016).

277         The management of octopus fisheries in Andalucía is also quite comprehensive and shared  
278 between the national and autonomous administrations, and a number of national and regional laws  
279 exist for the octopus fishery in both the Atlantic (Gulf of Cadiz) and Mediterranean coasts. National

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<sup>1</sup> Resolution of May 27th, 2020 approving the pilot plan for the management of octopus (*Octopus vulgaris*) with pots for the 2020–2021 campaign.

280 laws enforce Fisheries Management Plans in both coasts and three specific national laws are  
281 particularly important for the octopus fisheries<sup>2</sup>: the Management Plan for the octopus fisheries in the  
282 Gulf of Cadiz, the regulation of small-scale fisheries in offshore waters of the Gulf of Cadiz and the  
283 regulation for small-scale fisheries in Mediterranean offshore waters. To add to these, there is also an  
284 extensive corpus of regulation set by the autonomous region. The small-scale fisheries targeting  
285 octopus are so important in the region that autonomous regional competence extends offshore, with  
286 three recent regulations for the management of octopus small-scale fisheries in the Gulf of Cadiz and  
287 the Mediterranean. These new regulations are necessary due to the progressive increase in fishing  
288 effort exerted on octopus stocks by the small-scale fleet. It also harmonizes the regulations applicable  
289 to the fishery regardless of the waters in which it is carried out and establishes limits in fishing effort,  
290 regulates the amount of gear permitted per fishing line and per vessels and the way gear must be  
291 deployed, establishes spatio-temporal fishing closures, sets depth restrictions for fishing in certain  
292 areas and prohibits recreational fishing of octopus in Andalucía.

293         Andalucía has in place annual inspection plans; the most important controls for small scale  
294 fisheries are those related to illegal fishing, Marine Protected Areas, fishing hours, days and gear  
295 changes. Additionally, a location and tracking system (known as the green box) is mandatory for all  
296 fishing vessels in Andalucía. As well as serving for control purposes, it also provides the fishing  
297 sector with new communication technologies (such as the Auxiliary Alarm Center) and a Web Viewer  
298 for consulting technical services in coastal provinces.

299         In Portugal, octopus fisheries management derives from a combination of EU and national  
300 general and specific legislation. Specific management measures for octopus fishing consist essentially  
301 of the definition of a minimum landing weight (currently 750 g), regulating the gear in use (legally  
302 determined dimensions of traps, mesh size and the maximum number allowed per vessel), setting  
303 spatial-temporal constraints on the fishery and establishing the minimum distance from shore at which  
304 the gear can be deployed. Due to the importance of the octopus fishery in the Algarve, this region has

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<sup>2</sup> Orden APM/664/2017, of 12 July; Real Decreto 1428/1997 of 15 December; Orden AAA/2794/2012, of 21 December

305 some extra measures in place which only apply to this region. The use of live bait (common green  
306 crab, *Carcinus maenas*) is forbidden in traps, and during the weekend no fishing or landings are  
307 permitted by the small-scale octopus-directed fisheries and no landing is allowed by the trawl fleet.  
308 Compliance with rules and regulations in the Algarve is low and the effectiveness of the monitoring  
309 and control system at sea and on land is very limited, which results in the number of traps deployed  
310 being effectively under no control and reducing the efficacy of the minimum landing weight  
311 legislation (Pita and Gaspar, 2020; Sonderblohm et al., 2017; Pita et al., 2015).

312 In Italy, there are no management measures in place for octopus fisheries at the national level.  
313 However, this species is affected by the European Mediterranean Regulation for bottom trawling<sup>3</sup>,  
314 which regulates the mesh size allowed and forbids fishing within 3 miles from the coast or in waters  
315 of less than 50 m depth. Sardinia, as a devolved region, and due to being the region accounting for  
316 the highest octopus production in Italy, has in place some measures to regulate the common octopus  
317 fishery. The management consists mainly of establishing a minimum landing weight of 300 g and  
318 limiting the number of traps depending on the tonnage of the vessel and of the number of fishers  
319 allowed onboard. In some years, regional fishing bans of 45 days have been enforced (both for  
320 trawlers and artisanal gear), usually starting at the end of summer. In some locations, for example the  
321 Gulf of Oristano, specific bans directed at the octopus trap fishery have been put in place in some  
322 years, in order to protect recruitment. In the absence of a fishery ban, when facing continuous catch  
323 of undersized octopuses, fishers themselves tend to divert effort towards other species at the end of  
324 summer. Despite the legislation in force, illegal captures and selling of undersized octopus still occur.  
325 In response to the decline in landings, in an area of central western Sardinia, a Collaborative Fisheries  
326 Research (CFR) project has been carried out in order to evaluate the effectiveness of an experimental  
327 management regime based on different measures to be implemented simultaneously, such as a  
328 temporary fishing ban, stock enhancement in specific areas and the creation of artificial dens for  
329 spawning (Mereu et al, 2018). Positive results of the effectiveness of artificial dens as a temporary

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<sup>3</sup> EC n°1967/2006



330 and/or safe site for the spawning of the common octopus have recently led other fishers from different  
331 Sardinian areas to adopt the same measures, considering artificial dens an integrative tool for the  
332 management of this species.

333 In Greece, the continuous expansion of the coastal trap fishery for octopus led to the  
334 implementation of specific precautionary management measures in 2004<sup>4</sup>. These measures defined  
335 the gear allowed (octopus can be targeted with fyke-nets and pots), fishing gear characteristics and  
336 amount of gear units per vessel. In addition to these measures, there is a closed season from July to  
337 the end of September (spawning peak for the common octopus in the north Aegean), a restriction of  
338 the use of traps in shallow waters (less than 10 m), and a minimum individual landing weight of 500  
339 g. These measures aim to achieve the sustainable management of the common octopus fishery and to  
340 decrease conflicts between different gear users. The aforementioned legislation covers all Greek  
341 territory and no specific legislation has been issued for the Thracian Sea. Compliance with regulation  
342 was high for some years after the legislation was put in place but has been reduced in recent years.  
343 Data collected for the National Fisheries Data Collection Program showed landings from pots and  
344 traps during the closed season over the last three years, especially in the ports of the Thracian Sea,  
345 mainly coming from coastal vessels that make use of special licenses for fishing in international  
346 waters. Due to the extensive continental shelf in the region of the Thracian Sea, international waters  
347 cover a large part of the fishing grounds with depths less than 50 metres. This situation raises concerns  
348 about the potential impact on the octopus stock, which is exploited during its reproduction period.

349

350 *[TABLE 2 ABOUT HERE]*

351

### 352 **3. 2. Participation of fishers in the management of their activity**

353 The involvement of resource-users in the management of their activity is usually considered as a  
354 means to increase the efficiency of management measures, guarantee buy-in of resource users to

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<sup>4</sup> Presidential Decree 157/9-7-2004

355 support management decisions and increase compliance with rules and regulations (Pita et al., 2020;  
356 Leite and Pita, 2016).

357 In Galicia, the octopus fishery, as well as other fisheries, is managed under a co-management  
358 system (Macho et al., 2013), with the annual management plans being decided by the local authorities  
359 together with local fishers' organizations. In Andalucía, over the years, there have been routine  
360 stakeholders' committees and official meetings with the participation of national and autonomous  
361 administrations, representatives of the fishing sector and scientists. Additionally, the Fisheries Local  
362 Action Groups (FLAGs), developed under the European Fisheries Fund, plan to start a Participatory  
363 Local Development Strategy (EDLP), with the aim of achieving integrated local development  
364 accounting for all economic sectors in the territory.

365 In Sardinia, fishers have also been historically involved in the management of their fishery  
366 and they greatly contribute to the changes of the fishery legislation through their representatives. In  
367 particular, some measures, like bans directed at the octopus trap fishery, were put in place following  
368 fishers' recommendations. A request by some fishers to increase the minimum catch size from 300  
369 to 400g is currently being evaluated.

370 The management of the Portuguese octopus fishery is traditionally top-down with sporadic  
371 participation from octopus fishers, which has been increasing rapidly in recent years (Pita and Gaspar,  
372 2020; Pita et al., 2015). Despite the top-down system, most changes of legislation over time have  
373 occurred due to pressure from fishers (Pita et al., 2015). Recently, several fisher associations in the  
374 Algarve region have been attempting to achieve greater and more effective involvement in the  
375 management of the octopus fishery (Rangel et al., 2019; Silva et al., 2019; Pita et al., 2015). The last  
376 management measure implemented, the closure of octopus fisheries in the Algarve over the weekend<sup>5</sup>,  
377 was developed with the involvement of various fishers' associations after participatory workshops,  
378 which brought together leaders of the several associations involved in the octopus fishery in the  
379 Algarve, academia and management to discuss the issues afflicting the fishery over a two-year period.

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<sup>5</sup> established in 2019 by Order 1127-B/2019

380 Recently, a co-management project has been financed under the coordination of an NGO, and with  
381 fishers' support, and may contribute to change fishers' participation in management in the near future.

382 In Greece, the management system is also top-down with low participation of octopus fishers  
383 in the decision-making process. A general lack of internal consensus among the members of fishers'  
384 associations prevents them from exerting their influence effectively. However, recently, the Thracian  
385 Sea Fisheries Associations have begun to play a more active role and, in collaboration with the  
386 scientific community, have made proposals to amend existing legislation in order to protect the  
387 octopus stock from overfishing and illegal fishing. They also proposed the development of a targeted  
388 management plan for a sustainable octopus fishery in the Thracian Sea.

389

390 *[FIGURE 2 ABOUT HERE]*

391

#### 392 **4. Markets and trade of octopus in Europe**

393

394 Octopus is a global traded commodity and the EU plays an important role in global octopus seafood  
395 markets, with Spain currently a key actor, being a major global supplier of octopus (Villasante et al.  
396 2019) (Figure 2a). Demand for octopus is also strong in the EU, as well as in Japan, and continues to  
397 grow in the USA (FAO, 2019), making these markets the most important importers of octopus  
398 globally. Most of the octopus imported into the EU goes to the Spanish, Italian and Portuguese  
399 markets.

400 Despite the high consumer demand for octopus in Spain over the years, in the past the species  
401 did not reach high prices at first auction, perhaps due to its (past) relative abundance but also the  
402 influence of very substantial octopus landings from fishing by Spanish vessels in Mauritanian and  
403 Moroccan waters, which have traditionally been an important source of octopus to Spanish markets.  
404 However, prices at first sale of octopus caught by the artisanal fleets rising in recent years. In 2018,  
405 the average price of octopus was 7.5 €/kg in Galicia and 7.30€/kg in Andalucía (Xunta de Galicia,

406 2020; Estadísticas Pesqueras Junta de Andalucía, 2018). The international demand for Spanish  
407 common octopus, especially from Galicia, which has a reputation for quality in international markets,  
408 has resulted in a substantial increase in demand for the common octopus, and nowadays demand in  
409 Galicia has led to a ten-fold increase in octopus imports, namely from Morocco, Mauritania and  
410 Portugal (FAO, 2019; Villasante et al., 2019) (Figure 2b).

411 In Portugal, the average price of octopus at auction has been steadily increasing in recent years  
412 and in 2018 was 7.10€/kg (INE, 2020), making it a high value species for the small-scale fisheries  
413 sector. A large proportion of the catch tended to be exported, especially to Spain and Italy, where  
414 octopus was then processed (Pita et al., 2015). Currently, the demand for octopus is increasing  
415 nationally and Portugal has become an important market for octopus (FAO, 2019). Portugal continues  
416 to export octopus, especially to Spain and the USA (Figure 2a) and also imports a substantial amount  
417 of processed octopus from Spain (Figure 2b).

418 In Italy, the demand for the common octopus is growing and imports have been increasing  
419 since the early 2000s, mainly from Spain and Morocco, but also from a multitude of other locations  
420 (Figure 2b). In Sardinia, octopus is sold exclusively at the local level and it is common to find  
421 imported octopuses in the market.

422 In Greece, demand for octopus is high, particularly during the summer touristic period, as  
423 octopus is considered a famous traditional delicacy. Octopus landings from the Thracian Sea are  
424 marketed through auctions taking place in the major local fishing ports of Alexandroupolis and  
425 Kavala, but some are transferred to the Thessaloniki fish auction (the second biggest in the country)  
426 in order to get better prices. A large amount of fresh octopus, mainly the smaller individuals, is sold  
427 to the processing industry for freezing or canning (Lefkadiou et al., 2015).

428 Recent developments related to the marketing of octopus fisheries, with several initiatives in  
429 place, have contributed to add value to local octopus catches. For example, in Galicia, *Polbo das Rias*  
430 represents the first collective certification of origin for octopus captured by the small-scale fishing  
431 industry. In 2016, the octopus trap fishery operated by *cofradias* (local fisher organizations) in

432 western Asturias (northwest Spain) became the first octopus fishery in the world to obtain the Marine  
433 Stewardship Council (MSC) label.

434

## 435 **5. Challenges for the future of European octopus fisheries**

436

437 The main challenges for the common octopus fisheries in Portugal, Spain, Italy and Greece are quite  
438 similar, and all orbit around the correct management of the fishery so as to avoid overfishing. Current  
439 issues with octopus fisheries in the several countries include excessive effort, illegal fishing,  
440 exploitation of undersized octopus, and lack of effective monitoring and control of the fishing  
441 activity. There are also problems which are inherent to the biology of the species and its sensitivity  
442 to environmental influences, such as the (unpredictable) inter-annual and (predictable) seasonal  
443 variability in abundance, as well as the species' life cycle, the strong dependence of stock size on  
444 recruitment strength (due to the short-lifespan) and the long spawning season. Some other problems  
445 are specific to certain locations, such as overfishing, reduced fishing grounds, conflicts between  
446 commercial and recreational fishers (often selling octopus illegally) and competition for market share  
447 with imported octopus (Table 3). Another problem in the four countries concerns the lack of  
448 standardized data collection on small-scale octopus fisheries, especially socioeconomic information,  
449 a problem that is inherent to small-scale fisheries in general (Pita et al., 2019).

450 As mentioned, one of the most important challenges for the management of cephalopod  
451 fisheries relates to stock assessment. Under the EU-CFP, there is still no requirement for assessment  
452 of cephalopod stocks or regulation of cephalopod catches (there are no quotas for octopus) and,  
453 consequently, there is no routine assessment of octopus stocks in European waters. One of the barriers  
454 is that many traditional methods of fish stock assessment are unsuitable for assessing octopus, mostly  
455 due to the biology and population dynamics of this species (Sonderblohm et al., 2014), specifically  
456 the short life cycle and lack of stock-recruitment relationships (Pierce et al., 2010), which makes it  
457 difficult to assess and regulate these stocks. The strong yearly fluctuation in landings also make the

458 management of the fishery more challenging, although Sobrino et al. (2020) recently demonstrated  
459 the feasibility of forecasting *Octopus* abundance in the Gulf of Cadiz (based on environmental  
460 relationships and a recruitment index from a trawl survey). Since octopus is mostly landed by small-  
461 scale fisheries, the activity is mainly regulated at the member-state level, and different countries take  
462 different approaches to management. A possible solution for the directed fisheries of this short-lived  
463 species includes forecasting, real-time assessment and management, in direct collaboration with the  
464 fishing sector.

465

466 *[TABLE 3 ABOUT HERE]*

467

## 468 **6. Conclusions and recommendations**

469

470 The increased market demand for cephalopods and growing interest in targeting octopus in southern  
471 Europe means that even small-scale coastal fisheries can no longer be assumed to be sustainable. The  
472 expansion of small-scale octopus fisheries reflects a change in coastal fisheries due, partly, to the  
473 depletion of finfish resources and the rise in price per unit of octopus due to the increased market  
474 interest for this species. There are many small-scale directed octopus fisheries in European waters,  
475 using a range of artisanal gears, and these are becoming increasingly economically important for  
476 southern European coastal communities.

477 There are clear differences in the management of octopus fisheries in the four countries. For  
478 instance, minimum landing weight is highly variable, suggesting a lack of consistency when defining  
479 these measures - although geographic variation in biological characteristics of the species is also  
480 relevant.

481 Bio-socio-economic studies of local octopus small-scale fisheries, examining the implications  
482 of alternative management strategies, are essential to produce management advice and improve  
483 current management measures. The future of the octopus fishery in Portugal, Spain, Italy and Greece

484 depends on the successful implementation of management measures to fight illegal fishing, improving  
485 control and enforcement of rules and regulations, and increasing the minimum landings sizes - which  
486 are below optimum. For instance, the optimum size in Portugal appears to be 1100g/individual, based  
487 on information on natural mortality and growth patterns (IPMA, unpublished data), but this is likely  
488 to differ markedly across the distribution area, since population biology differs even over relatively  
489 short distances (Lourenço et al., 2012). In Italy, the definition and implementation of a national  
490 regulation would be very beneficial. Improvement of the existing regulations, when present, is highly  
491 desirable. A minimum requirement could be an increase in the minimum landing size, which would  
492 avoid the landings of a relatively large fraction of the mature population (see Canali et al., 2011;  
493 Cuccu et al., 2013a, 2013b), besides avoiding captures of immature animals. In Greece, smaller  
494 management areas might be more appropriate, to produce a framework for local implementation of  
495 management measures for small-scale inshore fisheries.

496         A better organization of fishers and co-management initiatives could be particularly beneficial  
497 for the management of octopus fisheries by small-scale fishing communities, as several authors  
498 suggest that octopus should be managed at the local level (Lourenço et al., 2012; Pierce et al., 2010;  
499 Pita et al., 2016). This belief that octopus fisheries, in part due to their small-scale nature, would be  
500 better managed at a regional/local level, has partly contributed to the lack of desire for a standardized  
501 European level management approach. The active participation of the fishing community in the  
502 management of their fishery should theoretically lead to an increased sense of ownership and thus  
503 improved compliance with rules and regulations - so a co-management system has the potential to  
504 be successful managing this species. However, it is important to understand whether fishers targeting  
505 octopus are ready for co-management. The common octopus has a peculiar biology, being a terminal  
506 spawner with a short life cycle (12–14 months) and a reproduction cycle highly influenced by  
507 environmental factors (Pierce et al., 2010; Sobrino et al., 2002). A study in Portugal noted that not all  
508 fishers targeting octopus are knowledgeable about the biological characteristics of this resource (Silva  
509 et al., 2019).

510           The future economic viability of the octopus fishery is highly dependent on improving  
511 sustainability and markets for the octopus fishery, e.g., seeking to increase the added-value of the  
512 product. Labelling initiatives, such as ecolabels and certifications of origin, can be important to add  
513 value to octopus fisheries and several such initiatives already exist, especially in Spain, and have been  
514 successful in increasing the visibility and value of octopus.

515

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## Legend of Figures and Tables

**Figure 1.** Location of important octopus fisheries in Europe, Algarve (Portugal), Andalucía (Spain), Galicia (Spain), Sardinia (Italy), Thracian Sea (Greece).

**Figure 2.** Sankey diagrams representing the global trade of octopus commodities for 2017 based on the UN COMTRADE data. Trade flows divided by exports (A) and imports (B) from and to Italy, Portugal, Spain, Greece and the other EU countries (aggregated data). The size of the bars is proportional to the total weight of all octopus commodities traded while the size of the flow indicates the proportion of the total weight traded between countries. The flow is colour encoded according to the importing and exporting country: Italy (red), Portugal (green), Spain (orange), and other EU (blue). To ensure a proper visualisation of the results, only the most representative countries in terms of trade of the octopus commodities are identified.

**Table 1.** Landings (total, cephalopods, octopuses) in quantity and value of fresh products in Greece, Italy, Portugal and Spain. The values are an average per year for the period between 2013 and 2017.

**Table 2.** Management measures for selected octopus fisheries in Europe.

**Table 3.** Main challenges in selected important octopus fisheries in Europe.



**Table 1.** Landings (total, cephalopods, octopuses) in quantity and value of fresh products in Greece, Italy, Portugal and Spain. The values are an average per year for the period between 2013 and 2017.

	Greece	Italy	Portugal	Spain	% four countries in EU-28
<b>Total landings of marine fish</b>					
Quantity (thousand tonnes)	55.6	123.2	107.1	371.9	11
Value (€ million)	194.0	466.1	193.3	809.3	31
Average price (€/kg)	3.5	3.8	1.8	2.2	–
<b>Total landings cephalopods (squids, cuttlefishes and octopuses)</b>					
Quantity (thousand tonnes)	5.9	17.6	8.7	16.4	63
Value (€ million)	29.7	133.6	38.9	73.4	70
Average price (€/kg)	5.0	7.6	4.5	4.5	–
<b>Total landings octopuses</b>					
Quantity (thousand tonnes)	2.6	7.2	7.2	8.5	90
Value (€ million)	14.6	47.4	30.6	36.7	93
Average price (€/kg)	5.6	6.6	4.3	4.3	–
<b>% cephalopods / total landings (quantity)</b>	10.6	14.3	8.1	4.4	–
<b>% cephalopods / total landings (value)</b>	15.3	28.7	20.1	9.1	–

Source: EUROSTAT Database (2020).

**Table 2.** Management measures for selected octopus fisheries in Europe.

Management measures	Octopus fishery				
	Algarve (Portugal)	Andalucía (Spain)	Galicia (Spain)	Sardinia (Italy)	Thracian Sea (Greece)
<b>Input (effort) controls</b>					
Number of licenses allowed	✓	✓	✓	∅	✓
Number of traps per boat	✓	✓	✓	✓	✓
Gear design (length, diameter, size of opening, mesh size)	✓	✓	✓	✓	✓
Limitation on soak time	∅	∅	✓	∅	∅
<b>Output (catch) controls</b>					
Minimum landing weight (MLW)	✓	✓	✓	✓	✓
Maximum fishing quota per vessel	∅	∅	✓	∅	∅
Limits on daily landings	∅	∅	✓	∅	∅
<b>Other technical measures</b>					
Weekend closures (captures)	✓	✓	✓	∅	∅
Weekend closures (sales)	✓	✓	✓	∅	∅
Closed season	∅	✓	✓	✓	✓
Closed areas	∅	✓	✓	✓	∅
Restrictions of fishing depth	∅	✓	∅	✓	✓
Restrictions of distance from the coast	✓	∅	∅	✓	∅
Restrictions on the bait allowed on traps	✓	∅	∅	∅	∅

**Main legislation:**

**Portugal** - Minimum landing size for *Octopus vulgaris* (Ordinance 27/2001); Regulation for fisheries using traps (Decree Law 43/87 and Ordinance 1102-D/2000, emended by Ordinance 447/2009, altered by Ordinance 774/2009, 193/2010, 1054/2010, 132/2011, 97A/2012 and 230/2012); Interdiction of using live bait in traps (Ordinance 230/2012); Weekend closure in the Algarve (Order 1127-B/2019).

**Andalucía (Spain)** - Common Fisheries Policy (Regulation (EU) No 1380/2013); Regulation for a Management Plan for the vessels registered in the census of the National Fishing Ground of the Gulf of Cádiz (Order AAA / 1406/2016); Regulation of fixed gears and small scale gears in the offshore waters of the

Mediterranean ( Order AAA / 2794/2012); Regulation establishing a management plan for the conservation of demersal fishery resources in the Mediterranean Sea (Order APA / 423/2020); Regulation for the capture of octopus, which establishes a Management Plan for vessels of the censuses of the National Fishing Ground of the Gulf of Cádiz (Order APM / 664/2017); Andalucía Law regulating the trap gear for the capture of octopus (*Octopus vulgaris*) on the Mediterranean coast of Andalucía and creating the census of boats authorized for this activity (Order of February 19, 2016, BOJA 41 of March 2 2016, 35-46.); Andalucía Law establishing measures for the conservation of octopus (*O. vulgaris*) in the inland waters of the Mediterranean coast of Andalucía (Order of February 24, 2016,BOJA 41 of March 2, 2016, 56-57.); Andalucía Law regulating the capture of octopus (*O. vulgaris*) with specific gear in the national fishing ground of the Gulf of Cádiz and Census of vessels authorized for this activity (Order of April 25, 2017,BOJA 80 of April 28, 2017, 14-35).

**Galicia (Spain)** - Regulation for fisheries in Galician inshore waters (Law 11/2008); Regulation defining fishing gear characteristics and use, and annual management plan (Decree 15/2011); Minimum landing size for octopus (Order of 27<sup>th</sup> July of 2012); Annual management plan for octopus fishery (Resolution of 27 May 2020).

**Italy** - Regulation for octopus fishery in Sardinia (Regional Decree 22/2002); Regulation for fishing ban (e.g. Decree n° A/68 2067/2008, Decree n° A/87 2067/2009). Regional decree N.669/DecA/18); Regulation for closing areas for experimental management of *O.vulgaris* fishery; EC Mediterranean regulation for mesh size for bottom trawling (EC n°1967/2006).

**Greece** - Regulation defining the technical characteristics of all the type of pots and traps used in Greece, the way that gears should be used, and the closed season for each type of traps/pots (Presidential Decree 157/9-7 2004).

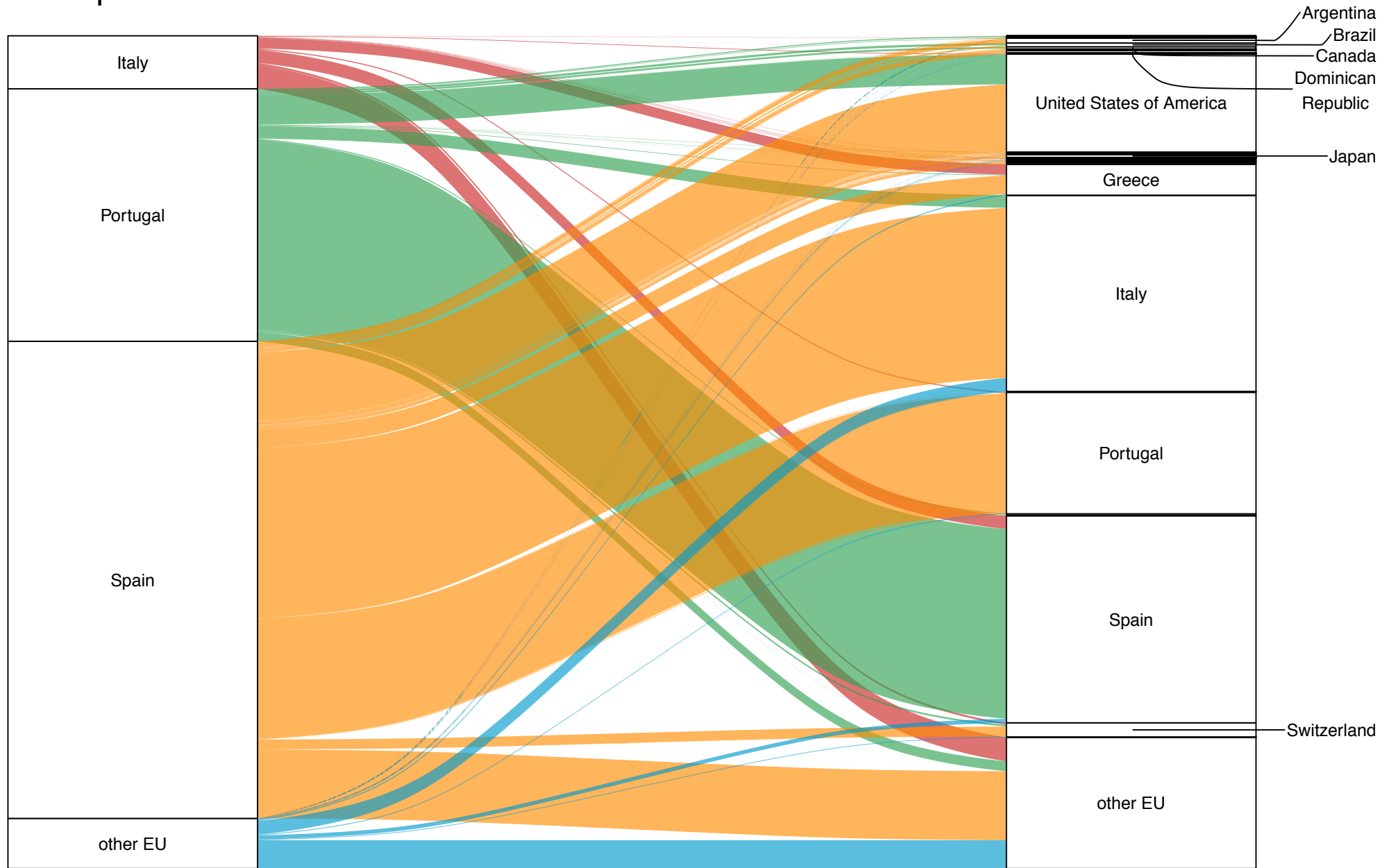
**Table 3.** Main challenges in selected important octopus fisheries in Europe.

Main challenges	Octopus fishery				
	Algarve (Portugal)	Andalucía (Spain)	Galicia (Spain)	Sardinia (Italy)	Thracian Sea (Greece)
Great inter-annual and seasonal variability and abundance	✓	✓	✓	✓	✓
Overfishing	✓	∅	✓	∅	∅
Unregulated fishery	∅	∅	∅	∅	∅
Illegal fishing	✓	∅	✓	✓	✓
Illegal selling of undersized specimens	✓	∅	✓	✓	∅
Reduced average price	∅	∅	∅	✓	∅
Competition with product from other markets	∅	✓	∅	∅	∅
Reduced fishing grounds	✓	✓	∅	∅	∅
Conflicts with recreational fishers	✓	∅	∅	∅	∅
Conflicts between different gear users	∅	∅	∅	∅	✓



Figure 2A

# A. Exports

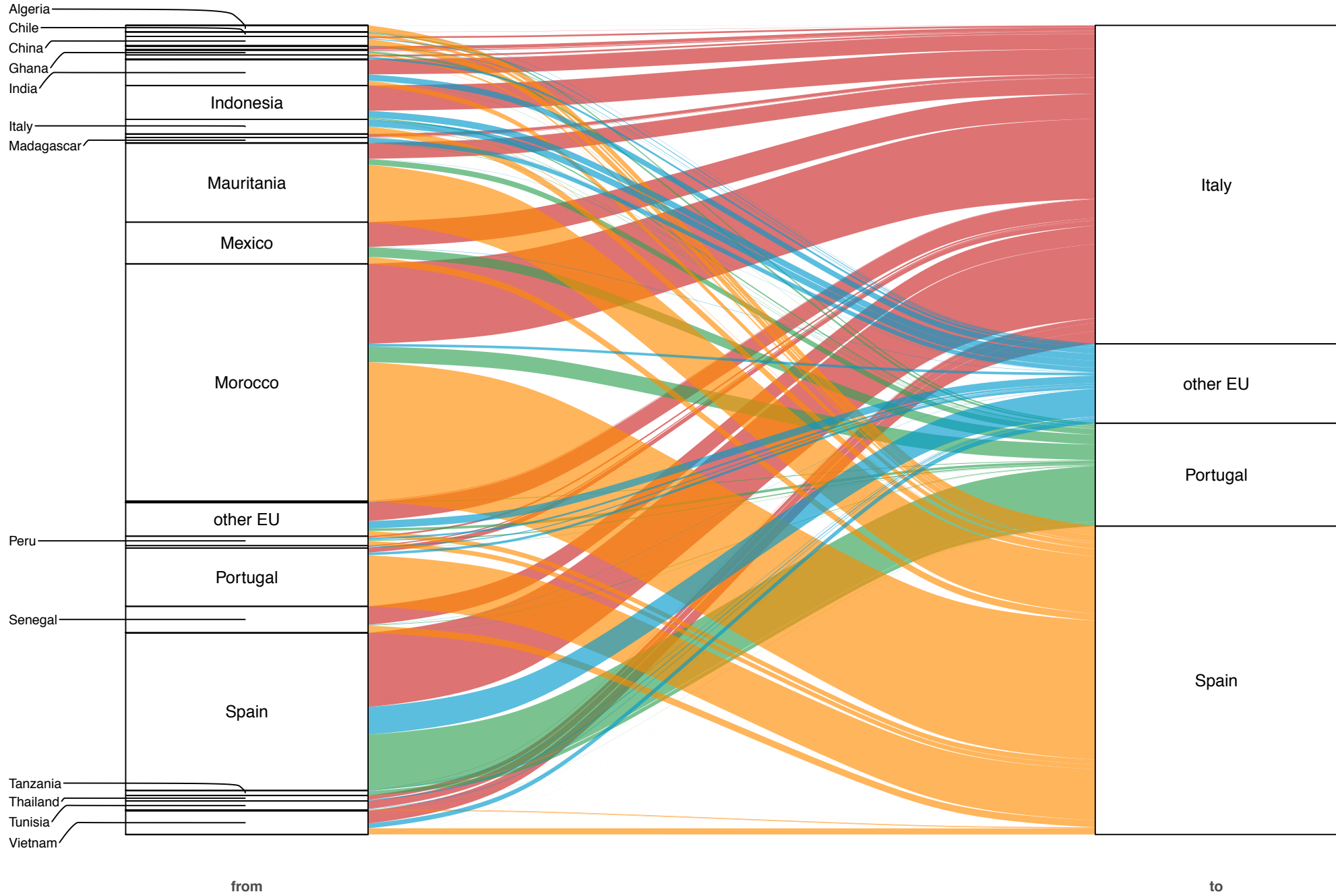


from

to

Figure 2B

# B. Imports



**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Aveiro, 20 July 2020



(Dr. Cristina Pita)