

1 **Common octopus' fisheries in Europe: socioeconomic importance and**
2 **management**
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26 **Abstract**

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

43

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

45 **1. Introduction**

46

47 The global overexploitation and depletion of many finfish species over the last few decades (FAO,
48 2018) has led to an increase in the commercial importance of other marine resources, such as
49 cephalopods (i.e., squids, cuttlefishes and octopuses) (Pierce and Portela, 2014; Hunsicker et al.,
50 2010; Pierce et al., 2010; Caddy and Rodhouse, 1998). Forty years ago, the Japanese fishery for
51 *Todarodes pacificus* was the only significant cephalopod fishery in the world (Pierce and Portela,
52 2014). Cephalopods were exploited only in a few ocean regions, such as the northwest and central
53 Pacific, the northwest African coasts, the northwest and southwest Atlantic, and the Mediterranean
54 Sea (Villasante et al., 2014; Caddy, 1983). In the beginning of the 1980s, Caddy (1983) predicted
55 cephalopods to be a resource with potential to support a high level of local exploitation in the near
56 future. This prediction did indeed materialize, and cephalopods are now highly valuable commercial
57 fishery resources, with world cephalopod landings having risen eight-fold from 1950 to 2014, the
58 year landings peaked at 4.86 million tons. However, have since decreased, accounting for 3.64 million
59 ton in 2018, according to FAO statistics.

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

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

72 The common octopus (*Octopus vulgaris*) is the most important commercially harvested
73 octopus species in the EU. It is widely distributed in European continental shelf waters and is tolerant
74 of a wide range of water temperatures and salinities, although the probability of occurrence of the
75 species varies with sea bottom temperature, sea bottom salinity, surface dissolved oxygen and sea
76 surface chlorophyll-a and it seems to prefer coarse sediments providing shelter. Spawners prefer areas
77 of moderate depth with hard bottom substrate (Guerra et al., 2015; Jereb et al., 2015; Moreno et al.,
78 2014; Hermosilla et al., 2011). 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, especially 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 Bañón et al., 2007; Tsangridis et al., 2002; Lefkaditou et al., 2002). Other octopus species caught in
83 Europe include the horned and musky octopuses (*Eledone cirrhosa* and *Eledone moschata*,
84 respectively). They are important commercial species in some parts of Europe, such as the
85 Mediterranean Sea and Galicia (Sauer et al., 2019; Regueira et al., 2014; Sartor et al., 1998), while in
86 other parts they tend to be routinely discarded, with a small amount being landed by trawling fleets
87 (Sauer et al., 2019).

88 Inshore local small-scale fishing fleets targeting the common octopus in Portugal, Spain, Italy
89 and Greece are of considerable socio-economic importance in terms of providing employment and
90 income in coastal fishing communities. The importance of the common octopus fisheries is higher
91 than can be estimated looking at official landings, in part because these are not well-documented and
92 are often underreported, being probably underestimated in the official statistics (Bañón et al., 2018;
93 Villasante et al. 2016; Pita et al., 2015; Otero et al., 2005). Nevertheless, common octopus fisheries
94 are often quite variable, with a strong seasonal dependence and marked variation in landings between

95 years, reflecting a strong influence of environmental conditions (Pierce et al., 2008). This affects
96 octopus' availability and market values, with obvious economic and social impacts.

97 Despite the increasing economic importance of octopus fisheries in the EU, these species have
98 long been considered of minor commercial importance and information about this resource, especially
99 its human dimensions (social, economic, cultural and institutional aspects) is scarce. As identified a
100 decade ago by Pierce et al. (2010), in a review of cephalopods fisheries in Europe, there was (and still
101 is) an urgent need for a detailed analysis of the economic and social importance of these fisheries at
102 the local and national levels, as well as an evaluation of the systems of governance.

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

108

109 *[TABLE 1 ABOUT HERE]*

110 *[FIGURE 1 ABOUT HERE]*

111

112 **2. Important common octopus fisheries in Europe**

113 ***2.1. Algarve, Portugal***

114 In Portuguese waters, fishing for the common octopus is a traditional activity which dates as far back
115 as the 15th century, with reports of octopus caught and exported from the Algarve region, south of
116 Portugal (Godinho, 1963). Nowadays, the common octopus is one of the most important fishery
117 resources in Portugal, being consistently one of the most valuable species at first sale (Pita et al.,
118 2015). In 2019, octopus was the most important species landed, representing 12% of the official first
119 sale revenue of all Portuguese fisheries (INE, 2020). In the Algarve, octopus accounted for 28%

120 (€17.2 million) of the total regional landings (INE, 2020). The common octopus is mostly captured
121 with pots (“*alcatruzes*”) and traps (“*covos*”) by the local fleet (small-size boats, length overall (LOA)
122 not exceeding 9 m) and the coastal fleet (comprised of vessels generally ranging in LOA from 9-15
123 m), with these two gears in general accounting for around 90% of octopus landings by weight (Pita
124 and Gaspar, 2020; Sonderblohm et al., 2017; Pita et al., 2015; Moreno et al., 2014). In 2019, a total
125 of 358 vessels was licensed for traps or pots in the Algarve, employing a total of 1501 fishers in this
126 directed fishery. Each vessel can carry more than one license, and the different gears can be operating
127 simultaneously. In 2019, 326 trap licenses and 189 pot licenses were issued, to give a total of 515
128 units of octopus-directed gear in legal operation (DGRM official fisheries statistics data).

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

140 ***2.2. Galicia and Andalucía, Spain***

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

146 In Galicia, octopus was probably already consumed before the Roman period (Bañón, 2014).
147 In the 16th century a powerful fishing industry was already operating in Galicia, which marketed fresh
148 octopus locally, and dry and cured octopus in inland markets. In the 19th century, octopus began to
149 be exported from Galicia (Bañón et al., 2018). Thus, the Galician octopus fishery and the traditional
150 consumption of octopus at local festivals throughout its territory have deep cultural roots that go
151 beyond gastronomy (Pita et al., 2016).

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

167 Andalucía is the largest southern region in Spain, with coasts both in the Atlantic and
168 Mediterranean, and it retains an important local fishery tradition. Bernal Casasola (2009) dated the
169 origins of fishing in western Andalucía to prehistoric times, including cephalopod fisheries. Similar
170 to what was observed in Galicia, ancient cultures established in Andalucía (like the Phoenicians and
171 Romans) used to consume octopus. Although many fishers and catches were historically linked to the

172 Sahara and Morocco fisheries, current landings come almost entirely from national fishing grounds.
173 According the official fisheries statistics, the common octopus is one of the most important fishery
174 resources in Andalucía, being the fifth most important species in landings (2107 tons in 2018,
175 accounting for 4.3% of the total catches) and the second in value (€15.4 million in 2018, 10% of the
176 total value) (Estadísticas Pesqueras Junta de Andalucía, 2018). Octopus is caught by coastal trawlers
177 and small-scale fisheries using traps (“*alcatruces*”) which are specifically designed to catch octopus.
178 Octopus fishing has gained relevance since the early 2000s and is perceived by fishers as cost-
179 effective and a fishing that provides reasonable profits (Florido del Corral, 2008).

180 **2.3. Sardinia, Italy**

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

188 The Italian small-scale fishing fleet accounts for 2/3 of the entire fleet (8507 vessels) in
189 number (but only 10% of the total tonnage). The fleet is composed mostly of vessels with LOA not
190 exceeding 12 m and 2 GT, using mainly passive gear, such as set nets, long lines, pots and traps. The
191 small-scale fishing activity is usually conducted as a family business, and exhibits marked differences
192 in terms of specialization, productivity and profitability in different geographic areas. Temporal
193 analysis (from 2004 to 2019) of Italian production of common octopus showed significant
194 fluctuations, with a negative trend overall, from a maximum of 5495 tons in 2004 to a minimum of
195 1898 tons in 2017. In 2019, national landings of the common octopus amounted to 3800 tons and
196 €33.8 million, the small-scale fishery being responsible for 55% of the landings (Mably, 2019).

197 Sardinia accounted for a significant part of the production (1186 tons, €9.35 million), of which over
198 70% is landed by the artisanal fleet (Mably, 2019).

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

207 ***2.4. Thracian Sea, Greece***

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

222 may have resulted in increases in abundance of the common octopus, and in the increased interest
223 towards this resource.

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

232

233 **3. Management and governance of the common octopus fisheries in Europe**

234 **3.1. Fisheries management**

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

244 Common octopus fisheries in Greece, Italy, Portugal and Spain are all subject to a range of
245 fishery legislation. Table 2 summarizes the current management measures in place for the common
246 octopus fisheries in the various regions under analysis. The management regimes in all locations

247 involve both input and output control measures, as well a suite of other technical measures. Input
248 controls consist mostly of setting gear limitations (e.g., number of traps/pots nets deployed, gear
249 design) and limiting the number of licenses. Output controls consist mostly of limiting the weight of
250 the octopus specimens landed, varying between 300g (Italy) and 1000g (Spain). Galicia is an
251 exception, with several other output controls in place. All countries also have several other technical
252 measures in place, some of which are common to the several case regions and some specific. Some
253 management arrangements in place are tailored at the local level and, in some locations, fishers
254 actively participate in the management of their activity, e.g., in Andalucía and Galicia.

255 The management of the octopus fishery in Galicia is the most comprehensive of all cases in
256 this review, despite the fact that fisheries management in this region is shared by two administrations,
257 the Galician Autonomous Government (Xunta de Galicia) and the National Government. The former
258 is responsible for the management, monitoring and control of fisheries in Galician inshore waters
259 (Bañón et al., 2018), while the latter regulates offshore waters. There is a specific legal corpus for
260 fisheries in Galician inshore waters with several regulations in force for the octopus fishery, setting
261 rules about the gear which can be deployed, operating procedures, area of operation for different types
262 of octopus traps, maximum amount of traps per vessel, the minimum landing weight, and the annual
263 management plans for the octopus fishery. The management plan is established by fishing season
264 (from June to May of the following year) and is usually implemented differently along the coast,
265 allowing for modifications or complementing the general basic rules, according to the status of the
266 resource, in co-management with the local fishers (Bañón et al., 2018; Pita et al., 2016; Villasante et
267 al., 2016). The most recent management plan (see Table 2 for details) established the rules for the
268 octopus fishery for the 2020-2021 season, and includes, amongst other measures, closed seasons
269 (from May 29th to July 1st, 2020), minimum weight of catches (currently 1 kg), maximum daily
270 catches taking into account the number of crew members onboard of the vessel, and the number of
271 traps per working hour at sea. Despite the management in place, a decline in octopus landings has
272 been observed over recent years in Galicia. According to Pascual-Fernández et al. (2020), this decline

273 is partly due to overfishing and ineffective control of rules and regulations. There is a substantial
274 amount of illegal commercial catch, which has been estimated to range between 20-50% of the total
275 reported catches in 2010, and there is also a substantial number of recreational fishers selling octopus
276 directly to restaurants, illegally (Villasante et al., 2016). This was also observed by Otero et al. (2005),
277 who noted a discrepancy of 30% in catches between 1998 and 2000, which can be due to misreporting
278 or illegal selling (out the official auctions). However, better control and monitoring programs appear
279 to have contributed to a substantial reduction of illegal practices over the last few years (Pascual-
280 Fernández et al., 2020; Villasante et al., 2016). In addition, advances in co-management processes in
281 recent years have reduced social conflicts, and consequently increased compliance with regulations
282 (Pita et al., 2016).

283 The management of the common octopus fisheries in Andalucía is also quite comprehensive
284 and shared between the national and autonomous administrations, and a number of national and
285 regional laws exist for the octopus fishery in both the Atlantic (Gulf of Cadiz) and Mediterranean
286 coasts. National laws enforce Fisheries Management Plans in both coasts and three specific laws are
287 particularly important for the octopus fisheries: the Management Plan for the octopus fisheries in the
288 Gulf of Cadiz, the regulation of small-scale fisheries in offshore waters of the Gulf of Cadiz and the
289 regulation for small-scale fisheries in Mediterranean offshore waters (see legislation in Table 2). To
290 add to these, there is also an extensive corpus of regulation set by the autonomous region. The small-
291 scale fisheries targeting octopus are so important in the region that autonomous regional competence
292 extends offshore, with three recent regulations for the management of octopus small-scale fisheries
293 in the Gulf of Cadiz and the Mediterranean (see Table 2). These new regulations are necessary due
294 to the progressive increase in fishing effort exerted on octopus stocks by the small-scale fleet. They
295 also harmonizes the regulations applicable to the fishery regardless of the waters in which it is carried
296 out and establishes limits in fishing effort, regulates the amount of gear permitted per fishing line and
297 per vessels and the way gear must be deployed, establishes spatio-temporal fishing closures, sets

298 depth restrictions for fishing in certain areas, and prohibits recreational fishing of octopus in
299 Andalucía.

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

306 In Portugal, octopus fisheries management derives from a combination of EU and national
307 general and specific legislation. Specific management measures for octopus fishing consist essentially
308 of the definition of a minimum landing weight (currently 750 g), regulating the gear in use (legally
309 determined dimensions of traps, mesh size and the maximum number allowed per vessel), setting
310 spatial-temporal constraints on the fishery and establishing the minimum distance from shore at which
311 the gear can be deployed. Due to the importance of the octopus fishery in the Algarve, this region has
312 some extra measures in place which only apply to this region. The use of live bait (common green
313 crab, *Carcinus maenas*) is forbidden in traps, and during the weekend no fishing or landings are
314 permitted by the small-scale octopus-directed fisheries and no landing is allowed by the trawl fleet.
315 Compliance with rules and regulations in the Algarve is low and the effectiveness of the monitoring
316 and control system at sea and on land is very limited, which results in the number of traps deployed
317 being effectively under no control and reducing the efficacy of the minimum landing weight
318 legislation (Pita and Gaspar, 2020; Sonderblohm et al., 2017; Pita et al., 2015).

319 In Italy, there are no management measures in place for octopus fisheries at the national level.
320 However, this species is affected by the European Mediterranean Regulation for bottom trawling (see
321 legislation in Table 2), which regulates the mesh size allowed and forbids fishing within 3 miles from
322 the coast or in waters of less than 50 m depth. Sardinia, as a devolved region, and due to being the
323 region with the highest octopus production in Italy, has in place some regional measures to regulate

324 the common octopus fishery. The management consists mainly of establishing a minimum landing
325 weight of 300 g and limiting the number of traps depending on the tonnage of the vessel and of the
326 number of fishers allowed onboard. In some years, regional fishing bans of 45 days have been
327 enforced (both for trawlers and artisanal gear), usually starting at the end of summer. In some
328 locations, for example the Gulf of Oristano, specific bans directed at the octopus trap fishery have
329 been put in place in some years, in order to protect recruitment. In the absence of a fishery ban, when
330 facing continuous catch of undersized octopuses, fishers themselves tend to divert effort towards
331 other species at the end of summer. Despite the legislation in force, illegal captures and selling of
332 undersized octopus still occur. In response to the decline in landings, in an area of central western
333 Sardinia, a Collaborative Fisheries Research (CFR) project has been carried out in order to evaluate
334 the effectiveness of an experimental management regime based on different measures to be
335 implemented simultaneously, such as a temporary fishing ban, stock enhancement in specific areas
336 and the creation of artificial dens for spawning (Mereu et al, 2018). Positive results of the
337 effectiveness of artificial dens as a temporary and/or safe site for the spawning of the common
338 octopus have recently led other fishers from different Sardinian areas to adopt the same measures,
339 considering artificial dens an integrative tool for the management of this species.

340 In Greece, the continuous expansion of the coastal trap fishery for octopus led to the
341 implementation of specific precautionary management measures in 2004 (see Table 2). These
342 measures defined the gear allowed and its characteristics (octopus can be targeted with fyke-nets and
343 pots) and the amount of gear units per vessel. In addition to these measures, there is a closed season
344 from July to the end of September (spawning peak for the common octopus in the north Aegean), a
345 restriction of the use of traps in shallow waters (less than 10 m), and a minimum individual landing
346 weight of 500g. These measures aim to achieve the sustainable management of the common octopus
347 fishery and to decrease conflicts between different gear users. The aforementioned legislation covers
348 all Greek territory and no specific legislation has been issued for the Thracian Sea. Compliance with
349 regulation was high for some years after the legislation was put in place but has been reduced in

350 recent years. Data collected for the National Fisheries Data Collection Program showed landings from
351 pots and traps during the closed season over the last three years, especially in the ports of the Thracian
352 Sea, mainly coming from coastal vessels that make use of special licenses for fishing in international
353 waters. Due to the extensive continental shelf in the region of the Thracian Sea, international waters
354 cover a large part of the fishing grounds with depths less than 50 metres. This situation raises concerns
355 about the potential impact on the octopus stock, which is exploited during its reproduction period.
356 Concerns with abundance of this resource led Katsanevakis and Verriopoulos (2006) to develop a
357 model, based on several life cycle parameters, useful for developing conservation policies.

358 A common feature of the management measures in place is that while they may be adjusted
359 from year to year according to perceived stock status, in reality the lack of formal stock assessment
360 means that stock abundance is unknown (and, indeed, stocks are usually not formally defined). It
361 should be noted that the management of the only MSC-certified octopus fishery in Europe, in
362 Asturias, is supported by formal stock assessment.

363 The option of spatial or temporal closures is often used, and in principle could protect new
364 recruits and/or spawning/post-spawning animals (e.g. females guarding their eggs), thus enhancing
365 sustainability. Limited seasonal migrations between shallow and deeper waters have been described
366 in this species and habitat preferences vary according to life stage (see Jereb et al., 2015; Guerra et
367 al., 2015; Moreno et al., 2014), suggesting that spatial closure could be designed to protect particular
368 life stages. However, it is not clear whether all existing closures afford such protection. While the
369 seasonality of the life cycle implies that seasonal closure could also be beneficial, the timing of the
370 life cycle of the common octopus shows substantial region variation (e.g. Jereb et al., 2015) and is
371 also likely to vary to some extent from year to year due to variation in environmental conditions.

372 Another relevant consideration is the degree of compliance with fishery management
373 measures. For example, as noted above, a substantial proportion of landings do not pass through fish
374 markets (and are hence illegal) and there is evidence that in some location the number of octopus pots
375 in the water far exceeds what is legally permissible.

376 Despite the general lack of routine stock assessment, the plethora of management measures
377 applied to octopus fishing in southern Europe coupled with fisher participation in decision-making
378 (see below) is likely to help limit overexploitation. Nevertheless, evidence of sustained declines in
379 landings over several years, beyond what would be expected due to natural environmental variation,
380 should be treated as a warning. The introduction of routine stock assessment (and a formal definition
381 of the stocks) is probably the highest priority at present, while routine monitoring of the size
382 composition and maturity state of landed octopus could allow redistribution of fishing effort to
383 account for variation in the timing of the life cycle.

384

385 *[TABLE 2 ABOUT HERE]*

386

387 **3. 2. Participation of fishers in the management of their activity**

388 The involvement of resource-users in the management of their activity is usually considered as a
389 means to increase the efficiency of management measures, guarantee buy-in by resource users to
390 support management decisions and increase compliance with rules and regulations (Pita et al., 2020;
391 Leite and Pita, 2016).

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

400 In Sardinia, fishers have also been historically involved in the management of their fishery
401 and they greatly contribute to the changes of the fishery legislation through their representatives. In

402 particular, some measures, like bans directed at the octopus trap fishery, were put in place following
403 fishers' recommendations. A request by some fishers to increase the minimum catch size from 300
404 to 400g is currently being evaluated.

405 The management of the Portuguese octopus fishery is traditionally top-down with sporadic
406 participation from octopus fishers, which has been increasing rapidly in recent years (Pita and Gaspar,
407 2020; Pita et al., 2015). Despite the top-down system, most changes of legislation over time have
408 occurred due to pressure from fishers (Pita et al., 2015). Recently, several fisher associations in the
409 Algarve region have been attempting to achieve greater and more effective involvement in the
410 management of the octopus fishery (Rangel et al., 2019; Silva et al., 2019; Pita et al., 2015). The last
411 management measure implemented, the closure of octopus fisheries in the Algarve over the weekend,
412 was developed with the involvement of various fishers' associations after participatory workshops,
413 which brought together leaders of the several associations involved in the octopus fishery in the
414 Algarve, academia and management to discuss the issues afflicting the fishery over a two-year period.
415 Recently, a co-management project has been financed under the coordination of an NGO, and with
416 fishers' support, and may contribute to change fishers' participation in management in the near future.

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

424

425 *[FIGURE 2 ABOUT HERE]*

426

427 **4. Markets and trade of common octopus in Europe**

428

429 Octopus is a global traded commodity and the EU plays an important role in global octopus seafood
430 markets, with Spain currently a key actor, being a major global supplier of octopus (Villasante et al.
431 2019) (Figure 2a). Demand for octopus is also strong in the EU, as well as in Japan, and continues to
432 grow in the USA (FAO, 2019), making these markets the most important importers of octopus
433 globally. Most of the octopus imported into the EU goes to the Spanish, Italian and Portuguese
434 markets.

435 Despite the high consumer demand for octopus in Spain over the years, in the past the species
436 did not reach high prices at first auction, perhaps due to its (past) relative abundance but also the
437 influence of very substantial octopus landings from fishing by Spanish vessels in Mauritanian and
438 Moroccan waters, which have traditionally been an important source of octopus to Spanish markets.
439 However, prices at first sale of octopus caught by the artisanal fleets have been rising in recent years.
440 In 2018, the average price of the common octopus was 7.5 €/kg in Galicia and 7.30€/kg in Andalucía
441 (Xunta de Galicia, 2020; Estadísticas Pesqueras Junta de Andalucía, 2018). The international demand
442 for Spanish common octopus, especially from Galicia, which has a reputation for quality in
443 international markets, has resulted in a substantial increase in demand for the common octopus, and
444 nowadays demand in Galicia has led to a ten-fold increase in octopus imports, namely from Morocco,
445 Mauritania and Portugal (FAO, 2019; Villasante et al., 2019) (Figure 2b).

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

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

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

463 Recent developments related to the marketing of octopus fisheries, with several initiatives in
464 place, have contributed to add value to local octopus catches. For example, in Galicia, *Polbo das Rias*
465 represents the first collective certification of origin for octopus captured by the small-scale fishing
466 industry. In 2016, the octopus trap fishery operated by *cofradías* (local fisher organizations) in
467 western Asturias (northwest Spain) became the first octopus fishery in the world to obtain the Marine
468 Stewardship Council (MSC) label.

469

470 **5. Challenges for the future of European common octopus fisheries**

471

472 The main challenges for the common octopus fisheries in Portugal, Spain, Italy and Greece are quite
473 similar, and all orbit around the correct management of the fishery so as to avoid overfishing. Current
474 issues with the common octopus fisheries in the several countries include excessive effort, illegal
475 fishing, exploitation of undersized octopus, and lack of effective surveillance and monitoring and
476 control of the fishing activity, as well as the general lack of routine assessment of stock status. There
477 is a lack of standardized data collection on small-scale octopus fisheries, especially socioeconomic
478 information in all four countries studied here, a problem that is inherent to small-scale fisheries in

479 general (Pita et al., 2019). Sustainability of fishing could also be improved by better aligning spatial
480 and temporal fishery closures with protection of key habitats and life-cycle stages (e.g. to protect new
481 recruits and spawners).

482 There are also problems which are inherent to the biology of the species and its sensitivity to
483 environmental influences, such as the (unpredictable) inter-annual and (predictable) seasonal
484 variability in abundance, as well as the species' life cycle, the strong dependence of stock size on
485 recruitment strength (due to the short-lifespan) and the long spawning season. Some other problems
486 are specific to certain locations, such as overfishing, reduced fishing grounds, conflicts between
487 commercial and recreational fishers (often selling octopus illegally) and competition for market share
488 with imported octopus (Table 3). Palas et al. (2017) point to the existence of an important recreational
489 fishery targeting octopus in Galicia, and Pita et al. (2017) note some conflicts between recreational
490 and commercial fisheries (although not specifically focused on octopus). Actually, bag limits for
491 octopus imposed for recreational fisheries in Galicia was based on concerns about the status of stock
492 and on the existent recreational fishing pressure (Pita and Villasante, 2019).

493 As mentioned, one of the most important challenges for the management of cephalopod
494 fisheries relates to stock assessment. Under the EU-CFP, there is still no requirement for assessment
495 of cephalopod stocks or regulation of cephalopod catches (there are no quotas for octopus) and,
496 consequently, there is no routine assessment of octopus stocks in European waters. One of the barriers
497 is that many traditional methods of fish stock assessment are unsuitable for assessing octopus (Pierce
498 and Guerra, 1994), mostly due to the biology and population dynamics of this species (Sonderblohm
499 et al., 2014), specifically the short life cycle and lack of stock-recruitment relationships (Pierce et al.,
500 2010), which makes it difficult to assess and regulate these stocks. The strong yearly fluctuation in
501 landings also make the management of the fishery more challenging, although Sobrino et al. (2020)
502 recently demonstrated the feasibility of forecasting *Octopus* abundance in the Gulf of Cadiz (based
503 on environmental relationships and a recruitment index from a trawl survey). Since the common
504 octopus is mostly landed by small-scale fisheries, the activity is mainly regulated at the member-state

505 level, and different countries take different approaches to management. Possible solutions for the
506 management of the directed fisheries of this short-lived species include real-time assessment (e.g.
507 using depletion models, which can also be used retrospectively) and management. Many studies also
508 show that management strategies based on protecting octopus' preferential spawning habitats should
509 be considered (Guerra et al., 2015; Guerra et al., 2014). Such approaches will be most successful if
510 introduced in direct collaboration with the fishing sector.

511

512 *[TABLE 3 ABOUT HERE]*

513

514 **6. Conclusions and recommendations**

515

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

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

527 Bio-socio-economic studies of local octopus small-scale fisheries, examining the implications
528 of alternative management strategies, are essential to produce management advice and improve
529 current management measures. The future of the octopus fishery in Portugal, Spain, Italy and Greece
530 depends on the successful implementation of management measures to fight illegal fishing, improving

531 control and enforcement of rules and regulations, and increasing the minimum landings sizes - which
532 are below optimum. For instance, the optimum size in Portugal appears to be 1100g/individual, based
533 on information on natural mortality and growth patterns (IPMA, unpublished data), but this is likely
534 to differ markedly across the distribution area, since population biology differs even over relatively
535 short distances (Lourenço et al., 2012). In Italy, the definition and implementation of a national
536 regulation would be very beneficial. Improvement of the existing regulations, when present, is highly
537 desirable. A minimum requirement could be an increase in the minimum landing size, which would
538 avoid the landings of a relatively large fraction of the mature population (see Canali et al., 2011;
539 Cuccu et al., 2013a, 2013b), besides avoiding captures of immature animals. In Greece, smaller
540 management areas might be more appropriate, to produce a framework for local implementation of
541 management measures for small-scale inshore fisheries. In addition, development of fishery
542 forecasting and routine stock assessment could help align fishing effort with stock status and reduce
543 the likelihood of overfishing.

544 A better organization of fishers and co-management initiatives could be particularly beneficial
545 for the management of octopus fisheries by small-scale fishing communities, as several authors
546 suggest that octopus should be managed at the local level (Lourenço et al., 2012; Pierce et al., 2010;
547 Pita et al., 2016). This belief that octopus fisheries, in part due to their small-scale nature, would be
548 better managed at a regional/local level, has partly contributed to the lack of desire for a standardized
549 European level management approach. The active participation of the fishing community in the
550 management of their fishery should theoretically lead to an increased sense of ownership and thus
551 improved compliance with rules and regulations - so a co-management system has the potential to
552 be successful managing this species. This approach could avoid the need to increase surveillance.
553 However, it is important to understand whether fishers targeting octopus are ready for co-
554 management. The common octopus has a peculiar biology, being a terminal spawner with a short life
555 cycle (12–14 months) and a reproduction cycle highly influenced by environmental factors (Pierce et

556 al., 2010; Sobrino et al., 2002). A study in Portugal noted that not all fishers targeting octopus are
557 knowledgeable about the biological characteristics of this resource (Silva et al., 2019).

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

563

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Legend of Figures and Tables

Figure 1. Location of important common 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. The UN COMTRADE is a free access repository with detailed data on global trade statistics accessible through <https://comtrade.un.org>. The trade flows are 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 common octopus fisheries in Europe.

Table 3. Main challenges in selected important common 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
Total landings of marine fish					
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	–
Total landings cephalopods (squids, cuttlefishes and octopuses)					
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	–
Total landings octopuses					
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	–
% cephalopods / total landings (quantity)	10.6	14.3	8.1	4.4	–
% cephalopods / total landings (value)	15.3	28.7	20.1	9.1	–

Source: EUROSTAT Database (2020).

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

Management measures	Common octopus fishery				
	Algarve (Portugal)	Andalucía (Spain)	Galicia (Spain)	Sardinia (Italy)	Thracian Sea (Greece)
Input (effort) controls					
Number of licenses allowed	✓	✓	✓	∅	✓
Number of traps per boat	✓	✓	✓	✓	✓
Gear design (length, diameter, size of opening, mesh size)	✓	✓	✓	✓	✓
Limitation on soak time	∅	∅	✓	∅	∅
Output (catch) controls					
Minimum landing weight (MLW)	✓	✓	✓	✓	✓
Maximum fishing quota per vessel	∅	∅	✓	∅	∅
Limits on daily landings	∅	∅	✓	∅	∅
Other technical measures					
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); Regulation of small-scale fisheries in offshore waters of the Gulf of Cadiz (Royal Decree 1428/1997 of 15 December); 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 27th 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 (Council Regulation (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).

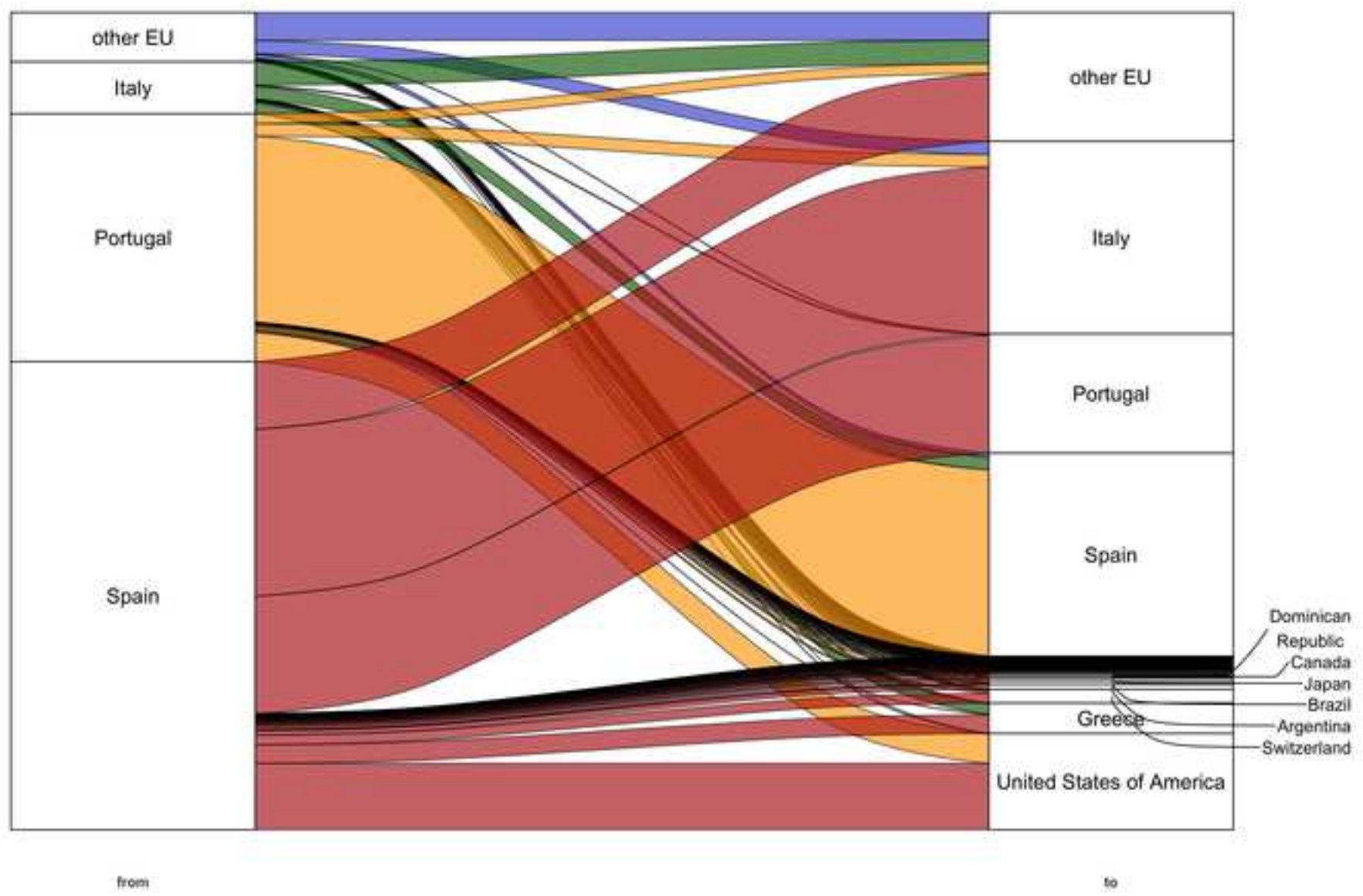
Table 3. Main challenges in selected important common octopus fisheries in Europe.

Main challenges	Common octopus fishery				
	Algarve (Portugal)	Andalucía (Spain)	Galicia (Spain)	Sardinia (Italy)	Thracian Sea (Greece)
Great inter-annual and seasonal variability and abundance	✓	✓	✓	✓	✓
Heavily fished	✓	∅	✓	∅	∅
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	∅	∅	∅	∅	✓

Note: Author's own elaboration.



A. Exports



B. Imports

