Pots vs trammel nets: a catch comparison study in a Mediterranean small-scale fishery

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Passive bottom-set nets are the most widely used fishing gears in Mediterranean small-scale fisheries (SSFs). Trammel nets, in particular, have key advantages such as their ease of use and handling and high capture efficiency for numerous commercial species. However, they entail high discard rates (5-44% of the total catch) connected to high mortality, thus exerting an adverse impact on benthic communities, besides catching individuals of commercial species under the minimum conservation reference size (MCRS) and specimens of protected species. Fish pots are seen as alternative and a more sustainable gear type that allow reducing discards in SSFs. In this study, a collapsible pot was tested at three coastal sites in the north-western Adriatic Sea (GFCM GSA 17) to compare its catch efficiency with that of the local traditional trammel nets. Data analysis demonstrated a similar catch efficiency for the commercial species, both among sites and as a whole. Moreover, the trammel net caught a larger amount of discards, both in terms of species number and of CPUEw. The catch comparison study involved the two most abundant landed species, common cuttlefish *Sepia officinalis* and annular sea bream *Diplodus annularis*. The pots were more effective for *S. officinalis*, whereas the trammel net was more effective for the shorter length classes for *D. annularis*, which were mostly under the MCRS (12 cm). The innovative pots could provide a valuable alternative to the trammel nets traditionally used in the Adriatic Sea, at least in certain areas and periods. Their main advantages include that they do not require a different rigging and they can be used without bait, while their foldable design allows large numbers to be easily loaded on board SSF vessels. The results of this pilot study indicate that pots can achieve the objectives of reducing discards and bycatch in SSFs without penalizing the catch of commercial species.

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Abstract

Passive bottom-set nets are the most widely used fishing gears in Mediterranean small-scale fisheries (SSFs). Trammel nets, in particular, have key advantages such as their ease of use and handling and high capture efficiency for numerous commercial species. However, they entail high discard rates (5-44% of the total catch) connected to high mortality, thus exerting an adverse impact on benthic communities, besides catching individuals of commercial species under the minimum conservation reference size (MCRS) and specimens of protected species. Fish pots are seen as alternative and a more sustainable gear type that allow reducing discards in SSFs. In this study, a collapsible pot was tested at three coastal sites in the north-western Adriatic Sea (GFCM GSA 17) to compare its catch efficiency with that of the local traditional trammel nets. Data analysis demonstrated a similar catch efficiency for the commercial species, both among sites and as a whole. Moreover, the trammel net caught a larger amount of discards, both in terms of species number and of $CPUE_w$. The catch comparison study involved the two most abundant landed species, common cuttlefish *Sepia officinalis* and annular sea bream *Diplodus annularis*. The pots were more effective for *S. officinalis*, whereas the trammel net was more effective for the shorter length classes for *D. annularis*, which were mostly under the MCRS (12 cm). The innovative pots could provide a valuable alternative to the trammel nets traditionally used in the Adriatic Sea, at least in certain areas and periods. Their main advantages include that they do not require a different rigging and they can be used without bait, while their foldable design allows large numbers to be easily loaded on board SSF vessels. The results of this pilot study indicate that pots can achieve the objectives of reducing discards and bycatch in SSFs without penalizing the catch of commercial species.

Introduction

40

41 Gillnets and trammel nets (or set/passive nets) are the most widely used fishing gears in
42 Mediterranean small-scale fisheries (SSFs) (Lucchetti et al., 2015), which account for more than
43 70,000 vessels (FAO, 2018) and approximately 150,000 jobs. Set nets consist of netting panels
44 hanging in the water column, where they are held perpendicular to the bottom by floaters and
45 sinkers. Bottom-set fixed nets passively exploit the movements of target species (Gabriel et al.,
46 2005). The fish swimming into them are caught by being gilled, tangled or wedged in gillnets,
47 which are constituted of a single netting panel. On the contrary, the typical catching method of
48 trammel nets is trapping the fish in a pocket of netting thanks to three panels: an inner panel with
49 small mesh size and two outer panels with larger mesh size (Fabi et al., 2002). The success of the
50 passive nets is due to their ease of use and handling (especially on small boats) (Dinçer & Bahar,
51 2008), high selectivity (especially gillnets) (Holt, 1963; Fabi et al., 2002) and their high capture
52 efficiency for numerous commercial species (Amengual-Ramis et al., 2016). Their technical
53 parameters, e.g. mesh size, netting twine, hanging ratio and net drop, vary widely in relation to
54 the characteristics of target species and fishing areas (e.g. depth, seafloor), as do their selection
55 properties (Stergiou et al., 2006; Lucchetti et al., 2017a). Although passive nets are considered as
56 selective gears, they nonetheless produce a large amount of discards (Goncalves et al., 2007;
57 Tzanatos & Somarakis, 2007) that range from 5% to about 40% of the total biomass caught
58 (Tsagarakis, Palialexis & Vassilopoulou, 2014). SSFs discards consist of species with low
59 commercial value, individuals that are found in poor condition and specimens under the
60 Minimum Conservation Reference Size (MCRS; Regulation (EU), 2019/1241). The proportion
61 of undersized individuals in the catch is variable and for some commercial species it can be quite
62 high (20% for *Sparus aurata*, 28.2-74.8% for *Diplodus* spp., 93.8% for *Pagellus acarne* in the
63 eastern Mediterranean, Tzanatos et al., 2008; large numbers of *Diplodus bellottii*, *Argyrosomus*
64 *regius* in Cadiz and *Diplodus* spp., *Pagrus pagrus* in the Cyclades, Goncalves et al, 2007).
65 Notably, species that are caught in excessively small amounts for the fishers' target market may
66 also become discards (Goncalves et al., 2007). Moreover, set nets can be also responsible for the
67 incidental catch of protected species such as sea turtles (Lucchetti and Sala, 2010; Casale, 2011;
68 Lucchetti et al., 2017b) and elasmobranches with no economic value (Morey et al., 2006; Saidi et
69 al., 2016; Bradai, Saidi & Enajjar, 2018)
70 The reduction of discards and bycatch has become a priority for fisheries worldwide, by means
71 of measures to improve selectivity and to preserve the environment (FAO, 2011). The Common
72 Fishery Policy, through the article 15 of Regulation (EU), 2013/1380, calls for the development
73 of more selective technical solutions, to avoid the catch of unwanted species and sizes. Several
74 solutions are being tested in the Mediterranean. They include: i) gear modifications to improve
75 size and species selection (Lucchetti et al., 2015, 2017a); ii) time/area fishing closures to
76 minimize bycatch (Lucchetti, Vasapollo & Virgili, 2017a); iii) mitigation devices to avoid
77 catching some protected species (e.g. UV lights for sea turtles; Virgili et al., 2017); and iv)
78 alternative and more sustainable fishing gears (Amengual-Ramis et al., 2016).

79   As regards the latter point, experimental pots developed in the past few years in certain areas
80   have ensured catch efficiencies comparable to those of traditional set nets (Furevik & Hågensen,
81   1997; Iskandar et al., 2006; Furevik et al., 2008; Königson et al., 2015; Amengual-Ramis et al.,
82   2016). Pots are passive gears to which fish, crustaceans and molluscs are attracted by bait or
83   pasture, whereas cephalopods are caught because use them as a refuge or a site to spawn. Pots
84   have several appealing features – in particular a minimal habitat impact and low manufacturing
85   cost – which have led them to be classified as LIFE (low-impact fuel-efficient) gears (Suuronen
86   et al., 2012). Moreover, bycatch can be minimized by acting on bait, mesh size, materials, and
87   position/design of the entrance and the escape gap(s) (Furevik & Løkkeborg, 1994; Furevik &
88   Hågensen, 1997; Boutson et al., 2009).
89   In Mediterranean SSFs traditional pots are locally employed to target molluscs and crustaceans
90   (Grati et al., 2010; Amengueal-Ramis et al., 2016), ensuring high catch efficiency and low
91   discard rates (0.8-6.6%; Fabi et al., 2001). They are usually deployed in specific seasons (e.g. the
92   spawning period of *Sepia officinalis*, Melli et al., 2014), in circumscribed areas (e.g. north
93   western Adriatic Sea for *Squilla mantis*, Grati et al., 2018; Gulf of Càdiz (Spain), Thracian Sea
94   (Greece) and Gulf of Gabès (Tunisia) for *Octopus vulgaris*, Ezzeddine-Najai, 1992; Tsangridis,
95   Sánchez & Ioannidou, 2002; Sobrino et al., 2011), or in replacement of other gears (e.g. for
96   *Nephrops norvegicus* during trawl fishing closures in Croatian northern Adriatic waters, Brčić et
97   al., 2018). A major disadvantage of traditional pots is their large volume, which entails that
98   vessels can carry only a limited number of units per trip.
99   In the Mediterranean Sea, studies of alternative fishing gears such as innovative pots are still
100 limited (ICES SGPOT, 2008, 2009; Pol et al., 2010) and mainly regard those targeted to
101 cephalopods like *O. vulgaris* (Sbrana et al., 2008) and crustaceans such as *N. norvegicus*,
102 *Plesionika* spp. (Colloca, 2002; Sartor et al., 2006) and *Palinurus elephas* (Amengual-Ramis et
103 al., 2016).
104 Based on these considerations, a pilot study was devised to test a fully collapsible pot design and
105 to compare it to a traditional set net in commercial fishing conditions. The main goals of the
106 study were to evaluate the respective catch compositions and to assess the effectiveness of the
107 pots in terms of their use and handling, discards and bycatch reduction.
108
Materials & Methods
109
110 *Study area*
111 The pilot study was conducted in FAO Geographical Sub-Area 17 (north-western Adriatic Sea)
112 and involved three coastal areas (Marina di Ravenna, Portonovo and Senigallia), where depth
113 ranges from 5 to 19 m (Figure 1). Specifications of bottom type and average depth of the three
114 sites are listed in Table 1. In these areas, SSFs mostly employ gillnets and trammel nets to catch
115 cuttlefish (*S. officinalis*), various fish species (e.g. *Solea solea, Lithognathus mormyrus*,
116 *Diplodus* spp*., S. aurata, Sciaena umbra, Umbrina cirrhosa, Dicentrarchus labrax*) and
117 crustaceans (*S. mantis, Paeneus kerathurus*) (Fabi & Grati, 2005). Moreover, artisanal pots are
118 deployed in spring to specifically target cuttlefish.

119   *Fishing gears and experimental setup*

120   The trials were conducted on board local professional fishing vessels (Table 1). The

121   characteristics of the traditional trammel nets (GTRs) employed and the fishing grounds were

122   selected by the fishers, and similarly the fishing operations (e.g. fishing time) and the sorting of

123   the catch were carried out following the fishers' procedures, without interferences from the

124   scientists on board. Experiments to compare the GTRs and the foldable pots were carried out

125   from April to August, in 2016 and 2017, and involved a total number of 42 fishing trials: 20 at

126   Marina di Ravenna, 12 at Portonovo and 10 at Senigallia. To minimize differences due to patchy

127   species distribution, GTRs and pots were deployed close to each other (a few tens of metres).

128   The technical features of the GTRs are reported in Figure 2. The three netting panels were made

129   of transparent polyamide multifilament: 210/4 mm multifilament and 36 mm mesh bar for the

130   inner panel and 210/3 mm multifilament and 200 mm mesh bar for the outer panels. The net had

131   a nominal height of 2.5 m (35 meshes), although its effective vertical opening in the water was

132   around 1.5 m. The float line and lead line were in propylene (diameter, 8 and 10 mm,

133   respectively); the float line was reinforced with external oval-shaped floats (diameter, 8 cm); the

134   lead line weighed 120 g/m. The total length of the set nets used in each site was: 500 m at

135   Marina di Ravenna and Portonovo, 300 m at Senigallia (Table 1). The GTRs were set early in the

136   morning and hauled in the afternoon.

137   The pots (manufactured by Trapula[LTD], Croatia; Figure 3) have a stainless-steel bar frame with a

138   pentagonal shape and a single oval entrance. Two steel structures on the top and bottom allow

139   folding them. A propylene rope 5 mm in diameter was externally reinforced with a nylon net (32

140   mm square-mesh bar). Flexible steel bars 2 mm in diameter allow manual adjustment of the

141   opening. To establish whether catch efficiency was related to the volume of the chamber

142   (Furevik & Løkkeborg, 1994), two different pot sizes were tested: a smaller pot (SP) measuring

143   40 x 100 cm (height x width) and a larger pot (LP) measuring 60 x 140 cm. The pots were

144   attached to a main propylene line (namely a gang) 8 mm in diameter anchored to the seabed by 2

145   m plastic branch lines 5 mm in diameter, placed at 15 m intervals. The pots were set 15 m apart

146   according to the traditional rigging used by the local fishers (Fabi et al., 2001). The number of

147   pots of each type ranged from 9 to 20 per fishing trial. Soaking time (i.e. the period of time the

148   pots were left on the bottom) depended on weather conditions and fishers' tactics (Table 1). They

149   were commonly retrieved after 2-3 days, or more, in case of adverse weather conditions, to

150   attract a wider range of commercial species other than cuttlefish, for which traditional pots are

151   usually left 24 hours (Fabi, 2001). The pots were not baited, but several black plastic ribbons

152   were attached to the frame, to attract cuttlefish.

153   The GTR and pot hauls were paired: each haul consisted in setting and retrieving the GTR, the

154   gang with SPs and the gang with LPs.

155   *Data collection*

156   For each haul, the crew sorted onboard the catch, that was kept separate by gear (GTR, LP, SP).

157   The total catch for each gear was thus divided into a landed catch (species with commercial

158   value, not necessarily target species) and discards, i.e. species discarded for different reasons

159 (invertebrates and fish species with no commercial value, commercial individuals under the
160 MCRS or in poor conditions). All individuals were identified to the lowest taxonomic level
161 possible, counted, weighed to the lowest 0.1 g and measured to the nearest 0.5 cm for total length
162 (TL; fish) or mantle length (ML; cephalopods) and to the nearest 0.5 mm for carapace length
163 (CL; crustaceans).

164 ***Data analysis***

165 The catch per unit effort (CPUE) was calculated for GTRs and pots. The GTR catch was
166 standardized for the number of individuals (CPUE$_I$) and total catch weight (CPUE$_W$; in kg)
167 captured by 1000 m of net in 12 h, considering that fishers commonly set 3000 to 6000 m of net
168 and haul it up after about half a day. The pot catch was standardized for the CPUE$_I$ and CPUE$_W$
169 (in kg) captured by 66.6 pots (i.e., the number of pots corresponded to 1000 m of set net
170 considering 15 m distance between two subsequent pots, according to Fabi et al., 2001) in 24 h.
171 This duration corresponds to the commercial fishing time of the traditional pots used in the area
172 to target cuttlefish (Fabi, 2001). The Kruskal-Wallis H test (χ^2) was applied to seek differences
173 between the CPUE$_W$ of GTRs and pots. A non parametric test was adopted, because the data
174 distributions were not normal and extremely skewed, with wide tails. If differences did emerge, a
175 pairwise Wilcoxson's signed rank test based on Bonferroni correction for multiple comparisons
176 was applied to establish the levels showing significantly different median values.

177 Differences in the size of the individuals caught by the GTRs, LPs and SPs were explored by
178 analysing the length frequency distribution (LFD) of the landed species. The catch efficiency of
179 each pot type vs GTR was compared using generalized linear mixed models (GLMMs; Holst and
180 Revill, 2009). The probability for an individual to be retained in a pot follows from:

181
$$Pr\left\{ {}^{Pot}\big/(Pot + GTR)\right\} = 1\big/\left(1 + e^{-\left(\beta_0 + \beta_1 \times length + \beta_2 \times length^2 + \beta_3 \times length^3\right)}\right)$$

182 A binomial error distribution was used to calculate the probability of the number of fish caught
183 in a pot (CPUE$_I$) given that they were caught by both gears based on 1-cm size classes. A
184 probability value of 0.5 corresponds to equal catches in both gears. According to Holst and
185 Revill (2009), a 3rd order polynomial would be adequate for most cases, although in some
186 instances a 1st or 2nd order would be enough. The best binomial model was chosen based on the
187 lowest Akaike's Information Criterion (AIC) value. A random term was added to the models.
188 Since the GTR and pot hauls were paired, the catches for each site and for each gear were pooled
189 and the term 'site' was used as a random intercept.

190 The most abundantly caught species, *S. officinalis* and *Diplodus annularis*, were selected for the
191 catch comparison analysis. Since only SPs were set at Portonovo, the catch comparison of LPs
192 included only the Senigallia and Marina di Ravenna. The models are illustrated graphically with
193 a 95% confidence interval (CI) calculated with a bootstrap method using 999 simulations. The
194 free software R (R Core Team, 2018) and the R packages nlme (Pinheiro et al., 2018) and lme4
195 (Bates et al., 2014) were used for the analyses.

196

197 **Results**

198   Overall, the three gears caught 53 species, 38 of which belonged to the landed fraction
199   (GTRs=30, LPs=15, and SPs=22) and 28 to the discard species (GTRs=25, LPs=5, and SPs=5),
200   thus confirming that the pots were more species-selective than GTRs (Supplementary Tables 1
201   and 2).
202   As regards the landed species, cuttlefish (*S. officinalis*) was the most abundant in terms of
203   biomass at all 3 sites for all 3 gears. Two other abundant species caught by all 3 gears were
204   annular seabream (*D. annularis*), caught at Marina di Ravenna and Senigallia but not at
205   Portonovo, and striped seabream (*L. mormyrus*), caught at all 3 sites with greater abundance at
206   Senigallia and Portonovo. Additional landed species caught by GTRs were *S. solea*, *S. mantis*
207   and *S. umbra* at Marina di Ravenna; *Liza aurata*, *Sarda sarda* and *Scophthalmus rhombus* at
208   Senigallia; and *Mugil cephalus* at Portonovo. Other landed species caught by the pots were *S.
209   umbra* (LP, SP) and *Conger conger* (LP) at Marina di Ravenna and *Dentex dentex* (SP) at
210   Portonovo (Supplementary Table 1).
211   The mean biomass values (calculated as CPUEw) and 95% CIs of the landed catch are reported
212   in Table 2. The CI values of the three gears did overlap, indicating the lack of significant
213   differences among them, both at each site and as a whole. Standardization of the landed catch
214   weight failed to highlight significant differences in the medians among GTRs, LPs and SPs,
215   either within the 3 sites or as a whole (χ^2 = 2.59, df = 2, p = 0.274; Figure 4).
216   The discards of LPs and SPs were lower than those of the GTRs both in terms of species number
217   and of $CPUE_w$; in fact, they were close to zero both at Senigallia and at Portonovo
218   (Supplementary Table 2). The GTRs captured large amounts of *Alosa fallax* and
219   *Pteroplatytrygon violacea* at Marina di Ravenna; *A. fallax* and *Liocarcinus vernalis* at Senigallia
220   and *Eriphia verrucosa*, *Hexaplex trunculus* and *Maja crispata* at Portonovo (Supplementary
221   Table 2).
222   The CIs of the mean biomass values (CPUEw) of GTR discards did not overlap with those of
223   LPs and SPs, whereas those of LPs and SPs did (Table 2). The discards showed significant
224   differences in terms of standardized biomass (χ^2 = 11.34, df = 2, p = 0.004, Figure 4) and were
225   mostly caught by GTRs. Wilcoxson's pairwise test showed that the median differences between
226   gears were significant for GTRs vs LPs and for GTRs vs SPs (p = 0.011 and p = 0.016,
227   respectively), whereas the medians of LPs and SPs were not significantly different.
228   The LFD of *S. officinalis* and *D. annularis* at each site and as a whole is reported in Figure 5.
229   The lines of LPs and SPs were mostly above those of GTRs, indicating a greater catch efficiency.
230   The catch comparison curves (Figure 6 and Table 3) demonstrate that for *S. officinalis,* pots
231   (both dimensions) were more efficient than GTRs. SPs were more efficient than GTRs for most
232   *S. officinalis* sizes, except for the larger ones (above the 25 cm size class), for which the
233   efficiency of both gears were similar, as the lower CI exceeds the limit of 0.5 indicating equal
234   proportion of individual catches between both gears. In contrast, LPs showed the same efficiency
235   as GTRs for the smaller individuals (below the 11 cm size class) and were more efficient for the
236   larger individuals. LPs and SPs showed overlapping CIs from the 10 cm size class, i.e. a similar
237   catch efficiency. As regards *D. annularis*, the GTR reflected a greater efficiency than both LPs

238 and SPs at the smaller sizes, usually under the MCRS of the species (12 cm). As a result, the
239 percentage in number of undersized individuals of *D. annularis* caught by GTR was 15.1%
240 (7.1% for Marina di Ravenna; 16.4% for Senigallia), while it was lower for both pots: 7.3% for
241 SPs (3.3% for Marina di Ravenna; 8% for Senigallia) and 3.7% for LPs (3.3% for Marina di
242 Ravenna; 4.5% for Senigallia). Therefore, LPs and SPs both showed a high selectivity for larger
243 fish, although they also caught some undersized individuals. However, there were no differences
244 among the three gears in the catch efficiency for the larger *D. annularis* individuals.
245
Discussion
247 This study was aimed at testing the catching efficiency of an innovative pot design in the north-
248 western Adriatic Sea; in particular, it was evaluated the pot's ability to provide an alternative to
249 traditional trammel nets and to reduce discards in SSFs. The comparison implied a different
250 standardization (CPUE$_w$ at 12 hours for trammel nets and 24 hours for pots) that represented a
251 compromise to maintain the standardization unit as close as possible between the two gears,
252 taking into account that they operate in different ways and with a different fishing time. The
253 main finding, from the catch comparison analysis of the two most abundant species caught
254 (cuttlefish and annular sea bream), was that the catch rates of the two types of pot tested, which
255 differed only in dimensions, were comparable to those of the trammel nets. These data are in line
256 with the high efficiency of the experimental pots reported in the Barents Sea (Furevik et al.,
257 2008) and the Baltic Sea (Königson et al., 2015), where pots showed similar, if not higher, catch
258 rates than those of passive nets, at least in a period of the year. Interestingly, the innovative pots
259 caught a larger number of commercial species than the traditional ones used in the area by
260 artisanal fishers, which are not collapsible, with a different shape and entrance, and mainly target
261 cuttlefish (Fabi et al., 2001).
262 Regarding the annular sea bream, the poor selectivity of the trammel nets found for this species
263 has been previously reported for *Diplodus* spp. by Tzanatos et al. (2008), who estimated a
264 percentage (in weight) of the undersized individuals caught of 28.2% for *D. annularis* and 74.8%
265 for *D. sargus,* being even higher than the average percentage of this study (15%). In contrast,
266 pots seemed to be able to avoid *D. annularis* juveniles (average percentage of around 7%).
267 Unlike studies in other areas (Munro, 1974; Furevik & Løkkeborg, 1994; Hedgärde et al., 2016),
268 which concluded that larger pots are more effective than small ones, in this study, pot size
269 seemed not to affect catch efficiency. However, the number of pots that actually produced a
270 catch, ranged between 38.5 ± 3.3% for SPs to 42.5 ± 4.3% for LPs, stressing the need for
271 increasing catch efficiency by using attractive baits.
272 The cost of a collapsible pot as the one tested in this study ranges from €50 (SP) to €100 (LP),
273 whereas 100 m of the traditional trammel net used for the sea trials is around €200. Assumed that
274 100 m of nets would correspond to more than 6 pots (as stated in the Materials and Methods
275 section), the alternative gear is more expensive. Nevertheless, whereas the set nets usually last a
276 single season and are then too damaged to be repaired, these kind of pots last up to two years.
277 Another advantage of pots is that they afford a more limited access to the catch, making them

278 less subject to depredation by large predators than set nets (e.g. seal- and dolphin-safe fishing
279 gear; Königson, 2011; Königson et al., 2015). Moreover, they provide a greater catch quality,
280 because they generally do not damage the specimens caught (Suuronen et al., 2012; Olsen,
281 2014). In addition, even if trammel nets require a shorter fishing time than pots, fishers could set
282 different pots gangs in order to alternate the retrieve, and thus to haul them daily.
283 With reference to discards, the greater amount caught by the trammel nets clearly produces a
284 greater impact on the benthic community, since discard mortality is high (Suuronen et al., 2012).
285 Moreover, the cleaning of the trammel net implies an additional time and labour on deck for
286 fishers, since discards must be released or untangled manually (Sartor et al., 2018; Szynaka et al.,
287 2018). In contrast, the removal of discards from pots can be done without significantly reducing
288 fishing time and leaving high probability for the unwanted organisms to survive (Suuronen et al.,
289 2012). Discarding is a major issue for fisheries management worldwide (Tsagarakis, Palialexis &
290 Vassilopoulou, 2014). In the Mediterranean, the Common Fisheries Policy (CFP Regulation
291 (EU), 2013/1380) has introduced the obligation to land ('discard ban') all the individuals of the
292 species with minimum legal size (MCRS, e.g. those species reported in the Annex III of the
293 Council Regulation (EC) No 1967/2006), thus emphasizing the need to reduce discards
294 (Damalas, 2015). The landing obligation is a matter of concern among fishers, which are facing
295 difficulties related to storing and bringing to land the former discard, due to limited hold space,
296 and to sorting time or personnel increasing (Maynou et al., 2018). The introduction of a new and
297 alternative technology in a fishery, such as innovative pots, could help to achieve this goal of
298 discard reduction only if it is acceptable to both fishers and fishery policies. In this context, fish
299 collapsible pots are revealed to be: practical (i.e. involving no major changes to common fishers'
300 practices), cost-effective (i.e. easy to use and not expensive to maintain, no waste of time for
301 cleaning the gear), efficient (i.e. large spectrum of species caught) and enforceable (i.e. easy to
302 control by inspection authorities).
303 With reference to bycatch of sensitive and protected species, during our study the trammel nets
304 caught five specimens of the pelagic stingrays (*Pteroplatytrigon violacea*), a frequent event in
305 several Adriatic fisheries (Bonanomi et al., 2018). This Elasmobranch species, usually discarded
306 due to its scarce commercial value, is considered as a 'Least Concern' species in the IUCN red
307 list (Baum et al., 2016). Another bycatch species caught by the trammel nets was the twait shad
308 (*A. fallax*), listed in Annexes II and V of the Habitats Directive (European Commission, 1992) as
309 requiring close protection. In addition, the passive nets deployed in the central and northern
310 Adriatic are responsible for the bycatch – maybe as many as thousands individuals a year
311 (Lucchetti, Vasapollo & Virgili, 2017b) – of loggerhead sea turtles (*Caretta caretta*), which are
312 listed in Annex IV of the Habitats Directive. In contrast, the pots did not capture any of these
313 species, substantially due of the small size of the pot entrance compared with the larger size of
314 animals such as stingrays and sea turtles. As regards *A. fallax*, its absence in the pots catch may
315 depend on their position close to the bottom, whereas trammel nets can also intercept pelagic fish
316 species (*A. fallax*, *Sardina pilchardus*, *Engraulis encrasicolus*, *Scomber japonicus* etc.) which
317 for different reasons can be discarded (Goncalves et al., 2007).

318

Conclusions

319 The innovative pots tested in this study seem to provide a sound alternative to the traditional
320 trammel nets used in the Adriatic Sea, at least in spring and summer, as concerns the small-scale
321 fishery targeting common cuttlefish. These pots do not require a different vessel rigging nor
322 changes to the on board practices; moreover, they can be used without baits and their foldable
323 design involves that they can be easily stored on board the typical artisanal boats used in
324 Mediterranean SSFs. The findings of this pilot study, although not conclusive, clearly indicate
325 that these alternative gears go some way towards reducing bycatch and discards in SSFs while
326 maintaining the commercial catch. Similar tests should be extended to other areas and seasons,
327 also using baits, to provide a clearer assessment of their efficiency.

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340

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507

Summary of the fishing trials carried out at the three sites (Marina di Ravenna, Senigallia, Portonovo)

AVG: Average; SD: Standard Deviation; LOA: Length all out; GT: Gross tonnage; GTR: Trammel net; LP: Large pots; SP: Small pots.

1 **Table 1. Summary of the fishing trials carried out at the three sites (Marina di Ravenna, Senigallia, Portonovo).**

2   **AVG: Average; SD: Standard Deviation; LOA: Length all out; GT: Gross tonnage; GTR: Trammel net; LP: Large pots; SP:**
3 **Small pots.**

	Marina di Ravenna	Senigallia	Portonovo
Bottom type	sandy-mud with scattered rocky outcrops	sandy-mud	rocky
AVG depth [m] ± SD	9.9 ± 2.5	10.7 ± 0.43	6.0 ± 0.57
Vessel characteristics	LOA 12.4 m; 10 GT; 350 kW	LOA 12.4 m; 6 GT; 130 kW	LOA 6.6 m; 1 GT; 100 kW
Study period	April-July 2017	April-June 2016	May-August 2016
No. of trials	20	10	12
GTR length [m]	500	300	500
No. of LPs	20	9-10	0
No. of SPs	20	19-20	20
AVG GTR soak time [h] ± SD	19.9 ± 3.3	17.4 ± 2.0	17.2 ± 1.8
AVG LP soak time [h] ± SD	91.4 ± 28.7	73.9 ± 9.1	-
AVG SP soak time [h] ± SD	87.3 ± 25.6	76.6 ± 10.1	90.1 ± 21.3

1   **Table 2: Mean biomass values (*CPUE$_W$*) with standard errors and confidence intervals, in brackets, of the landed catch and of discards for**
2   **the three gears,**

3   **GTR (trammel net), LP (large pot) and SP (small pot), at each site (top) and as a whole (bottom). NA (not available).**

	Site	GTR CPUE$_W$	LP CPUE$_W$	SP CPUE$_W$
Landed catch	M. di Ravenna	5.41 ± 0.76 (3.92 - 6.89)	7.27 ± 1.77 (3.81 - 10.73)	3.72 ± 0.64 (2.48 - 4.97)
	Senigallia	4.34 ± 0.14 (2.16 - 6.52)	2.41 ± 0.35 (0.23 - 4.59)	3.08 ± 0.17 (2.20 - 3.97)
	Portonovo	2.90 ± 0.70 (1.53 - 4.27)	-	2.48 ± 0.59 (1.33 - 3.62)
Discards	M. di Ravenna	0.77 ± 0.20 (0.38 - 1.17)	0.14 ± 0.04 (0.07 - 0.21)	0.07 ± 0.05 (0.02 - 0.17)
	Senigallia	0.95 ± 0.57 (0.17 - 2.07)	-	0.04 ± 0.0 (NA)
	Portonovo	1.52 ± 0.79 (0.02 - 3.06)	-	0.06 ± 0.0 (NA)

	Gear	CPUE$_W$
Landed catch	GTR	4.35 ± 0.51 (3.35 - 5.34)
	LP	6.01 ± 1.39 (3.28 - 8.74)
	SP	3.21 ± 0.36 (2.49 - 3.93)
Discards	GTR	0.95 ± 0.23 (0.51 - 1.40)
	LP	0.14 ± 0.04 (0.06 - 0.21)
	SP	0.06 ± 0.03 (0.01 - 0.12)

Estimates of the parameters of the GLMM calculated for catch comparison

SE: standard error. GTR: Trammel net; LP: Large pots; SP: Small pots.

1 **Table 3. Estimates of the parameters of the GLMM calculated for catch comparison. SE:**
2 **standard error. GTR: Trammel net; LP: Large pots; SP: Small pots.**

Species	Model		Parameter	Estimate	SE	p
Sepia officinalis	Linear	LP vs GTR	β_0	-0.61	0.45	0.171
			β_1	0.08	0.03	0.009
	Quadratic	SP vs GTR	β_0	4.07	1.47	0.006
			β_1	-0.46	0.20	0.022
			β_2	0.01	0.01	0.038
Diplodus annularis	Quadratic	LP vs GTR	β_0	-27	5.62	<0.001
			β_1	3.33	0.71	<0.001
			β_2	-0.98	0.02	<0.001
	Quadratic	SP vs GTR	β_0	-11.39	4.24	0.007
			β_1	1.35	0.56	0.017
			β_2	-0.04	0.02	0.048

Figure 1

Map of the study area where the trials were performed in 2016 and 2017 (April-August).
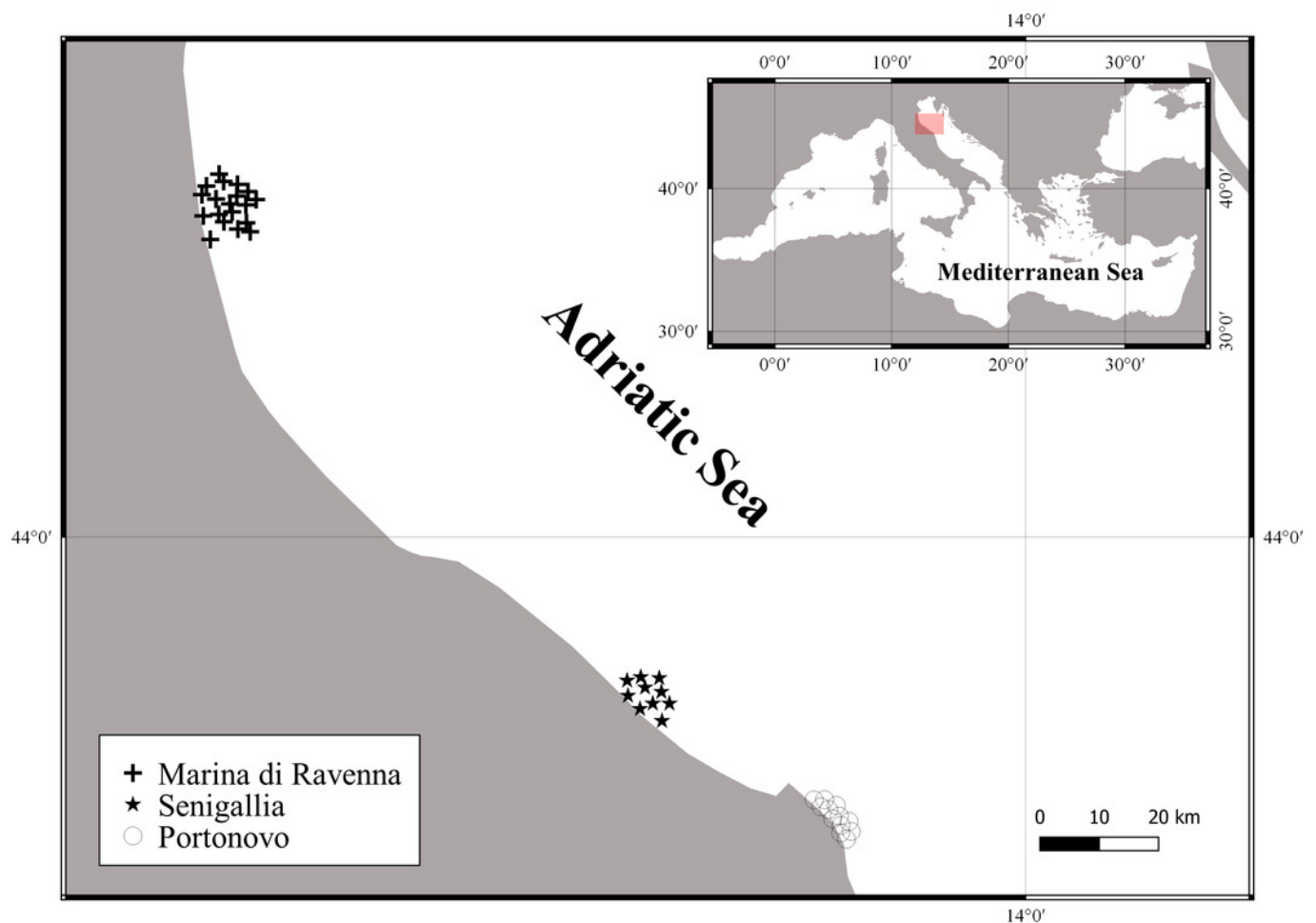
Figure 2

Scheme of the trammel net used in the study.

Inner panel: middle; outer panel: top and bottom. PA: polyamide; PP: propylene; ø: diameter;
E: hanging ratio.

50 m PP Ø 8			Ø 8 cm
7	PA Ø 210/3	263	E=0.47
35	PA Ø 210/4	1315	E=0.52 72 mm E=0.54
7	PA Ø 210/3	263	400 mm
50 m PP Ø 10			120g/m
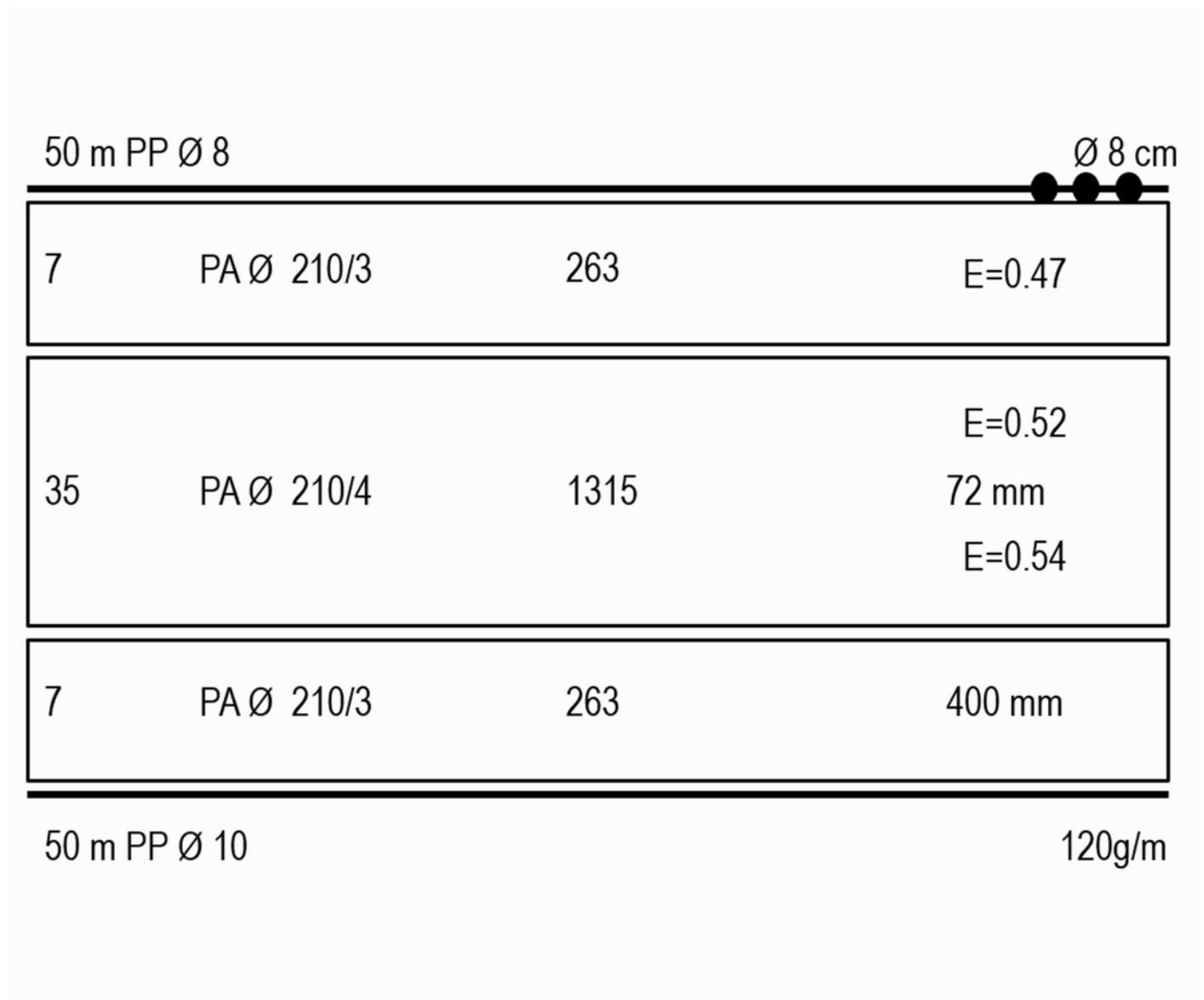
Figure 3

Picture of the 'Trapula' pots tested in the study. See text for dimensions.
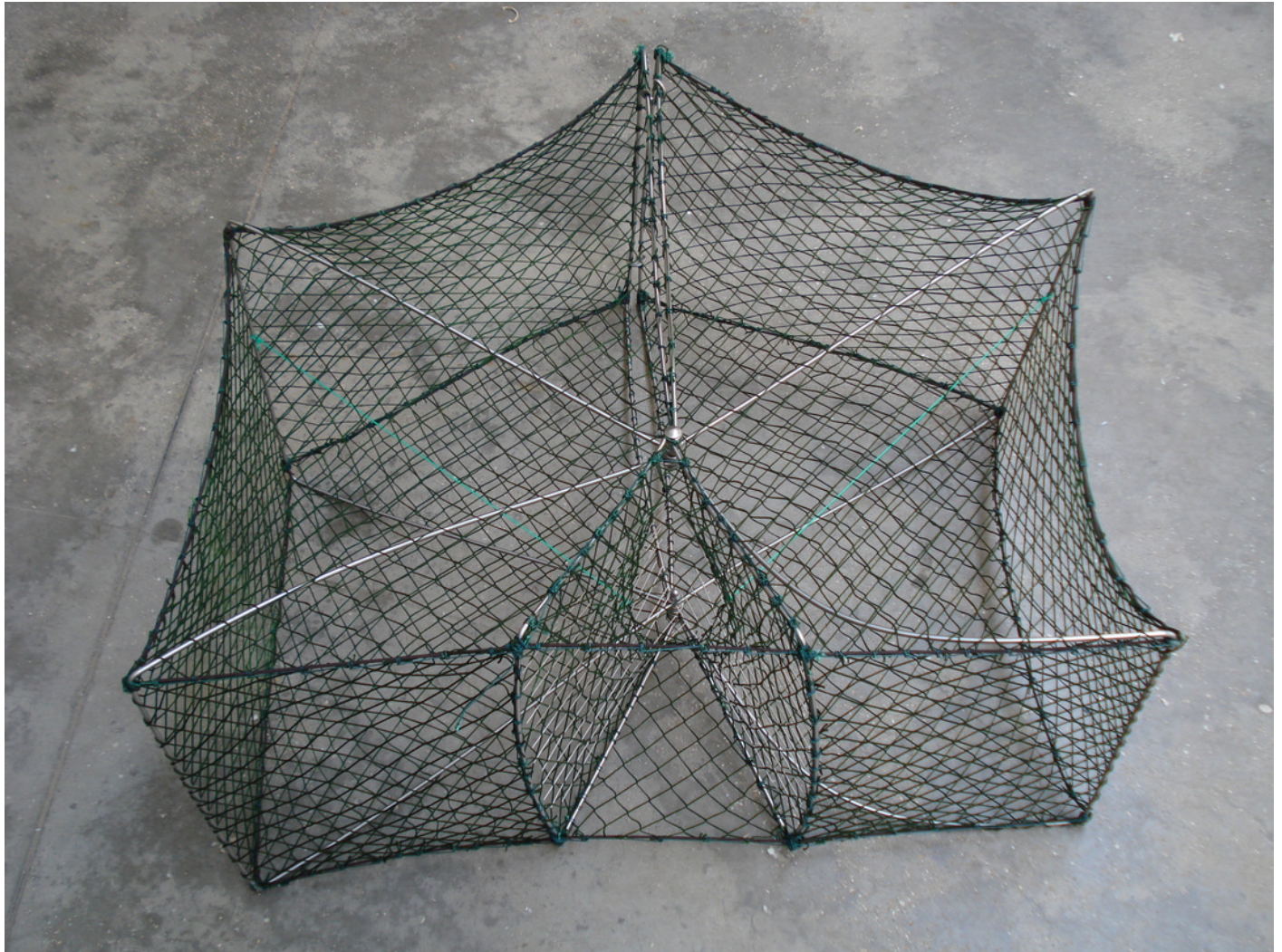
Figure 4

Overall CPUEw of landings and discards of the three gears tested in the study.

GTR: trammel nets; LP: large pots; SP: small pots. Red dots: mean $CPUE_w$; red bars:

confidence intervals (CIs). (A) Commercial; (B) Discard.
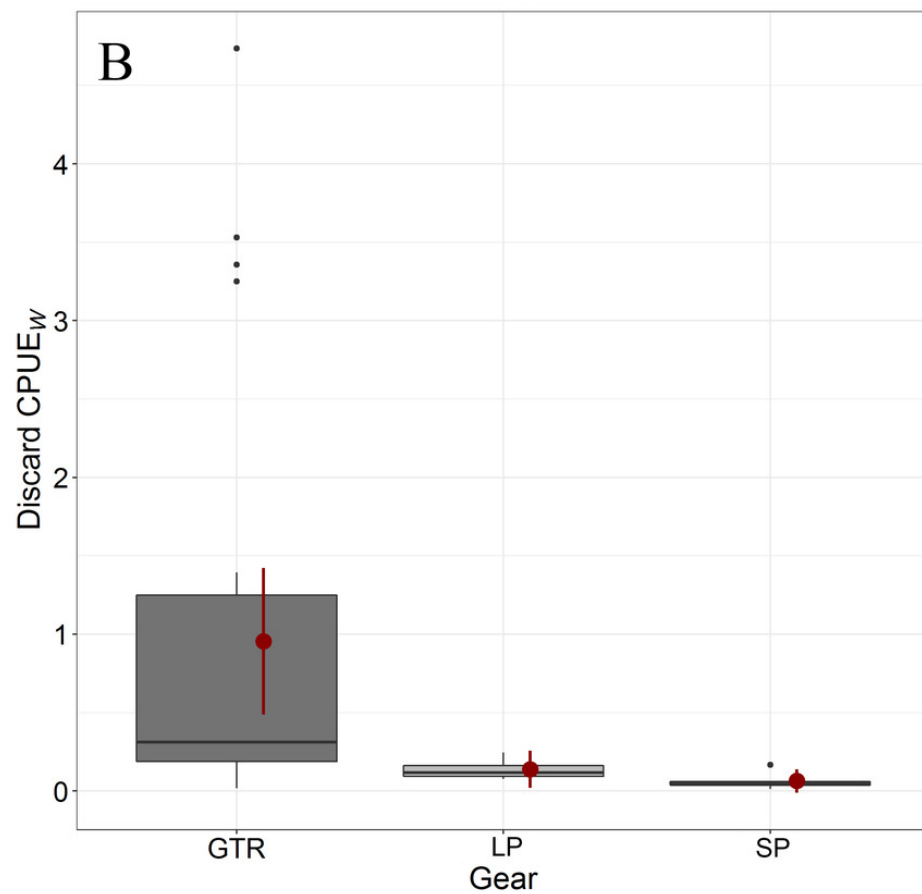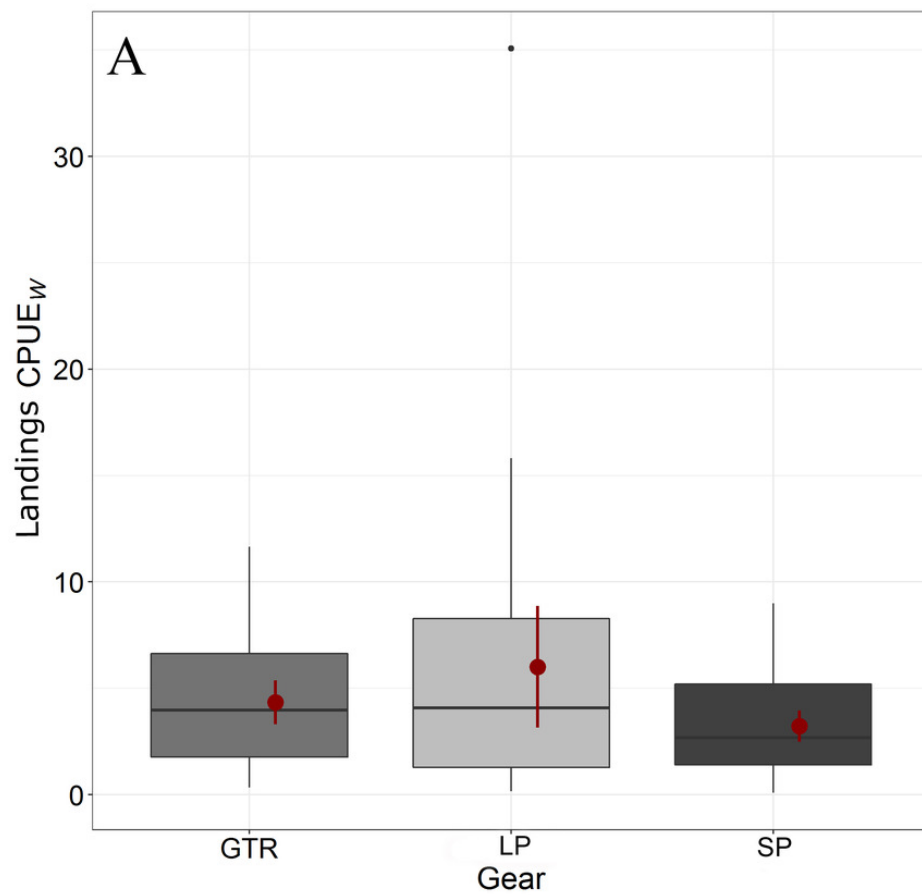
Figure 5

Length frequency distributions (LFDs) of *Sepia officinalis* in each site (A,B,C) and as a whole (D) and LFDs of *Diplodus annularis* in each site (E,F) and as a whole (G).

A,E: Marina di Ravenna, B: Portonovo, C,F: Senigallia. Dashed lines represent GTR (trammel nets); continuous lines represent SP (small pots); dotted lines represent LP (large pots); vertical dotted lines represent MCRS of 12 cm of *D. annularis*.
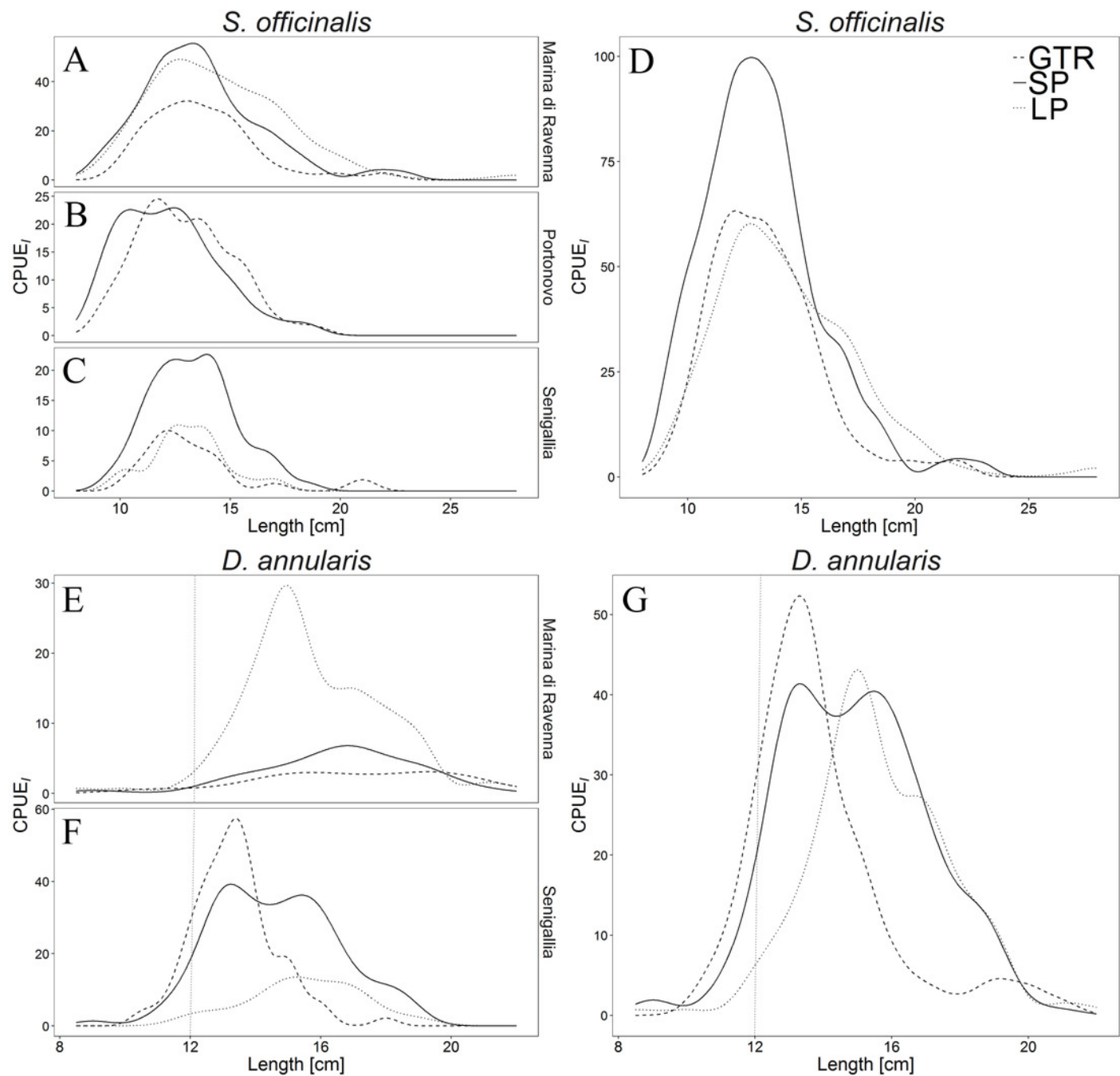
Figure 6

Catch comparison curves for *Sepia officinalis* (A) and *Diplodus annularis* (B), representing the GLMM proportions of the total catches of the three gears.

GTR: trammel nets; LP: large pots; SP: small pots. Dashed and dotted lines represent the mean proportions of LP and SP, respectively; the vertical dotted line represents MCRS of 12 cm of *D. annularis*. Interpretation: a value of 0.5 indicates an even split between GTRs and Pots, whereas a value of 0.25 indicates that the Pots caught 25% of all the fish of that length class whereas 75% were caught by the GTRs. Shaded areas: 95% confidence intervals.