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Characterization of purse seine fishery of Zياما Bay (Gulf of Béjaia, SW Mediterranean): Implications for sustainability management

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Abbreviations: DPRH: Directorate of Fisheries and Aquaculture; IFAD, International Fund for Agriculture Development; FIDA: Fonds International de Développement Agricole; IUU: Illegal, Unreported, and Unregulated; MedPAN: the network of Marine Protected Areas managers in the Mediterranean; MSP, MedPAN South Project.

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ABSTRACT

The establishment of marine protected areas (MPAs) in Algeria faces several obstacles, particularly lack of legislation and poor management of local resources. The attempt to establish an MPA at Taza (Gulf of Béjaia, SW Mediterranean) is part of a broader project to set up a network of MPAs in the Mediterranean basin. The MPA of Taza was first proposed by the staff of Taza National Park in 2000, who, with the support of the MedPAN (Network of Managers of Marine Protected Areas in the Mediterranean) South Project (MSP), began promoting this initiative in 2009. This study analyzes the purse seine fishery in this coastal area through the study of landings and yields, in order to characterize one of the most important fishing activities in the Gulf of Béjaia. In addition, the study assesses the impact of non-purse seine vessels which has detrimental effects leading to a *de facto* open access fishery situation. Landings observation and interviews with purse seine fishers (i.e. vessels with a license to practice purse seining) were conducted from May 2013 to April 2014 to record catches, the characteristics of fishing gear, and the fishing grounds. At the same time, non-purse seine fishing vessels - that is, vessels without a license to practice purse seining - were also monitored. The purse seine fishery of Ziama shows a seasonal pattern in the selection of fishing grounds. The species most frequently landed by purse seine and non-purse seine vessels throughout the study period was the sardine (*Sardina pilchardus*). Other less frequently caught species such as the European anchovy (*Engraulis encrasicolus*) make a seasonal appearance. This data could be useful to understand fishery dynamics and the behavior of fishers prior to the establishment of an MPA in a given zone.

Keywords: Purse seine fishery; Marine protected areas; Sustainable management; Mediterranean; Algeria; Ziama.

1 **1. Introduction**

2 Small pelagic fishes are the main fish resource in the world. They account for
3 the largest amount of world marine catches with 19.9 million tons in 2009, or 22% of
4 global world catches (FAO, 2011). In the Mediterranean, these mainly consist of
5 sardine (*Sardina pilchardus*), European anchovy (*Engraulis encrasicolus*), Atlantic
6 mackerel (*Scomber scombrus*), European sprat (*Sprattus sprattus*), and round
7 sardinella (*Sardinella aurita*) and account for almost 50% of the total annual landings
8 (Stergiou et al., 2016; FAO, 2017). Among them, sardine and European anchovy are
9 the most important species in terms of commercial interest and biomass (Lleonart
10 and Maynou, 2003; Pinnegar et al., 2003; Palomera et al., 2007; FAO, 2011). In the
11 last decade, catches of sardine in many areas have decreased, and stocks have
12 been recognized as fully exploited, for example, in the eastern Mediterranean
13 (Antonakakis et al., 2011), western Mediterranean - Gulf of Lion, and in the Atlantic
14 Ocean – northern Spain (ICES, 2013).

15 In Algeria, the exploitation of sardine, round sardinella, and European anchovy
16 is of strategic importance in terms of both economic and social values (Bacha and
17 Amara, 2009). Thus, they are predominant in landings (volume and value) within the
18 purse seine fishery and contribute especially to the supply of the local market.
19 However, other benthopelagic species such as the Mediterranean horse mackerel
20 (*Trachurus mediterraneus*) and the bogue (*Boops boops*) are also part of an
21 important by-catch of this type of fishery.

22 The Algerian purse seine fleet operates in the coastal waters of the continental
23 shelf throughout the year and is regulated by national legislation (without any
24 limitations of fishing days per year, weekend stops, or maximum catch per year).
25 Management measures for this fishery include some restrictions such as minimum
26 landing fish size (e.g. 11 cm for sardine; Decree No. 08-118, April 9th 2008),
27 minimum fishing gear mesh size (e.g. 40 mm for pelagic trawl), and prohibition of the
28 use of explosive devices and firearms (Decree No. 06-250, July 9th 2006). Purse
29 seine fishing activity usually occurs near the home harbor, on short (daily) trips where
30 the net is set once, twice, or as many times as necessary around dawn. For the most
31 part the fishing trip is spent searching for fish using equipment such as echo-
32 sounders, and once schools of small pelagic fish have been detected, the net is
33 quickly set up using an auxiliary vessel.

34 In the department of Jijel (Fig. 1), the inshore purse seine fleet is responsible for
35 about 5,884 t of fish per year and between 79% and 83% of the total landings over
36 the period 2007 – 2012. The total value of small pelagic landing has been estimated
37 to be ~8,000,000€ in 2012 (DPRH of Jijel, 2014). The purse seine fishery in the study
38 area has expanded significantly since the 1990s mainly due to facilitating access to
39 credit funding for fishermen from the harbor of Ziama (Fig. 1) for boats up to 6.80
40 meters long. Through this scheme, the fishermen provide 5% of the funds to
41 purchase the boat, the Algerian government covers a further 30%, and the remaining
42 65% comes from the “IFAD” (International Fund for Agriculture Development) FAO
43 project which aims for the development of artisanal fishing in Algeria (Chakour,
44 2015).

45 The professional fishing fleet operating in Ziama Bay is divided in three vessel
46 categories - trawlers whose home harbor is Béjaia, and purse seine and small-scale
47 vessels whose home harbor is Ziama (Fig. 1). The Ziama purse seine fishing fleet
48 (hereafter indicated as PS) consists of 13 vessels. However, a purse seine fishing
49 activity operated by small-scale fishing vessels (hereafter indicated as non-purse
50 seine vessels “NPS” without a fishing license for this type of fishery as opposed to
51 PS, which denotes purse seine vessels), using the same gear and methods of purse
52 seine fishers is observed in this fishing harbor. Thus, in 2014, the bulk of small
53 pelagic catches have been hauled by 26 NPS vessels (6.8 to 10 m size).
54 Approximately one-third (34%) of these (9 vessels) are below 7 m size (6.8 m) and
55 have high significance in terms of landing volume of small pelagic fish. These 9
56 vessels, called “FIDA: Fonds International de Développement Agricole” (French
57 version of “IFAD: International Fund for Agriculture Development”), are part of a
58 certain number of vessels that capture small pelagic species in relatively shallow
59 water by night and can target species more valuable than sardine such as demersal
60 fish by day (Chakour, 2015). The double activity of this set of vessels should be
61 considered as one of the most serious threats to the sustainable management of
62 fisheries in this area as their fishing effort is underestimated, leading to an
63 overexploitation of fishing resources and compromising the role of any management
64 decisions based on biased data in a data poor context. Nevertheless, the fishing
65 activity of NPS is not referable to IUU (Illegal, Unreported, and Unregulated) fishing,
66 which is defined as an illegal/poaching activity (FAO, 2001), given that the NPS

67 fishers in the department of Jijel are provided with a special permission to use the
68 purse seine gear and their catches are declared.

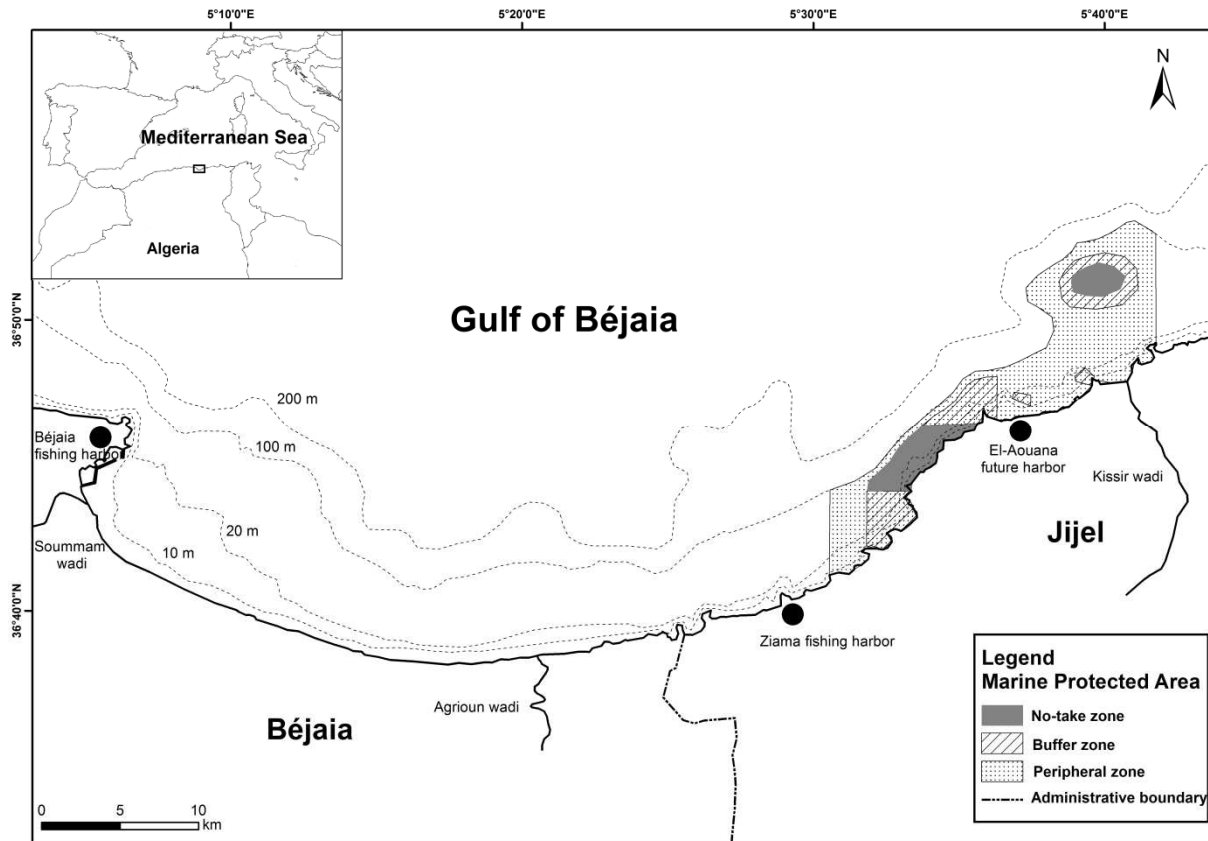
69 The recent scientific interest in artisanal fisheries has increased due to its
70 involvement in marine protected areas (MPAs) management (Leleu et al., 2014;
71 Rodríguez-Rodríguez, 2014; Boubekri and Djebbar, 2016; Boubekri et al., 2018).
72 Since purse seine fishery is one of the main activities of artisanal fishery in the study
73 area, this is one of the main issues for the conservation and the sustainability
74 management of marine resources in the Gulf of Béjaia. The future MPA of “Taza” is
75 located within the Gulf of Béjaia (Algeria, SW Mediterranean) (Fig. 1). In 2009, with
76 the support from the network of MPA managers in the Mediterranean (MedPAN),
77 Taza National Park began a process to include its adjacent marine area covering
78 9603 ha (Fig. 1). The future MPA of “Taza” will comprise 2 no-take zones where
79 navigation without mooring and scientific research will be authorized, while
80 commercial and recreational fisheries as well as all the other extractive uses will be
81 prohibited.

82 The present study is an attempt to characterize purse seine fishery before the
83 establishment of a multiple-use MPA through the description and monitoring of the
84 landings data. The data analyzed are from May 2013 to April 2014. Given that the
85 future establishment of the “Taza” MPA may affect the fisheries in this area,
86 description data of the purse seine fishery obtained by direct observation of landings
87 has been used to create baseline information. First, the characterization of the
88 current situation is assessed; secondly, the general characteristics of the spatio-
89 temporal patterns of effort allocation and the resulting catches are examined; and
90 finally, the potential consequences of the creation of the MPA is investigated. Such
91 baseline information could be extremely valuable for the managers of this future MPA
92 to set up sound fishery management plans.

93

94

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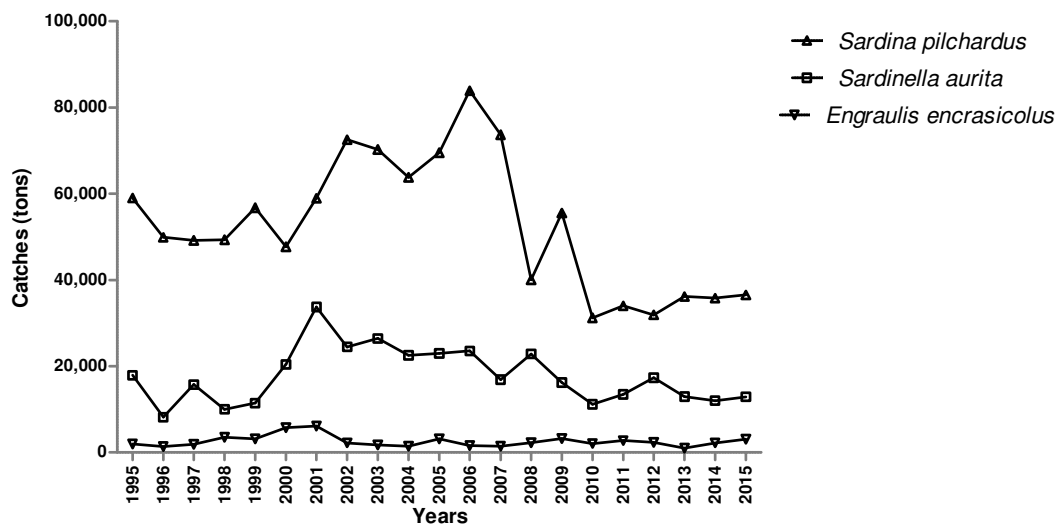


96

97 **Fig. 1.** Map showing the fishing harbors situated in the Gulf of Béjaia, the location and the zoning plan
 98 of the future MPA of “Taza”, Algeria (SW Mediterranean).

99

100



101

102 **Fig. 2.** Global catches between 1995 and 2015 in Algeria of the three main small pelagic fishes: (a)
 103 *Sardina pilchardus*, (b) *Sardinella aurita*, and (c) *Engraulis encrasicolus*. Data source: FAO, 2017.

104 Fishery and Aquaculture Statistics. Global capture production 1950-2015 (FishstatJ).

105

106

107 **2. Material & Methods**

108 *2.1. Study area*

109 This study was conducted in the fishing harbor of Ziama, located in the South-
110 Western Mediterranean Sea off the coast of Algeria (Fig. 1). Landings data for the
111 vessels belonging to this port were chosen based on their spatial distribution during
112 fishing operations, which spanned along the Gulf of Béjaia in search of fish schools,
113 and due to their importance in terms of amounts of vessels and landings. The data
114 examined accounted for the activity of ~70% of the whole purse seiner fleet
115 operational in the Gulf of Béjaia (I. Boubekri, personal observations). Along this Gulf,
116 the fishing harbor of Ziama has traditionally been home to an important purse seine
117 fishing activity, and accounts for all the purse seiners operating in the area of the
118 future MPA of “Taza” (Kacher, 2010). Furthermore, the specificity of this fishing
119 harbor is that it is the only one nationwide to house an important fleet of small-scale
120 vessels authorized by the fisheries administration to use purse seine gear. In 2009,
121 with support from the regional MedPAN South Project (MSP) initiative, a process to
122 establish a marine protected area in the Department of Jijel was launched (Boubekri
123 and Djebbar, 2016). The planned MPA (latitude 38° 34' 8"N and 38° 23' 43"N;
124 longitude 9° 14' 05"W and 8° 53' 46"W) is situated in the East part of the Gulf of
125 Béjaia and extends about 23 km along rocky coasts and sandy beaches (Fig. 1). The
126 Algerian Coast Guard has responsibility for supervising purse seine fishing where
127 effort allocation is controlled only by limiting the minimum mesh size and individual
128 fish size. No other measures such as weekend stops or Total Allowable Catch are
129 applied.

130 *2.2. Data collection*

131 Official fleet data (length, engine power, gross tonnage, and year of
132 construction) on PS (purse seine) and NPS (non-purse seine) vessels were provided
133 by the Directorate of Fisheries and Aquaculture (DPRH) of Jijel (updated to 2014).
134 These data have been verified in the field to determine active vessels. From May
135 2013 to April 2014, catch data were collected via a direct observation method of
136 landings (Griffiths et al., 2007; Merrien et al., 2008) on a daily basis with the help of
137 two observers from the DPRH of Jijel. As vessels returned to the harbor to land their
138 catch, the observers counted the number of fish crates per species and per boat

139 during the sale to the operators which was carried out immediately after the vessels
140 returned to the harbor. When direct observations were not possible, declaration by
141 the captain and/or the sale operator were retained. In addition to interviewing
142 fishermen, weekly surveys were conducted to get information on the length of the
143 gear used and the fishing areas visited during the past 7 days (i.e. local name of the
144 fishing ground, depth, and location on the map). Interview data shows that this
145 approach can produce a lot of useful information for assessing fisheries (Neis et al.,
146 1999; Rocha et al., 2004).

147 The fishing locations visited by PS and NPS have been represented in relation
148 to the frequency of visits (fishing trips) by using a map of the Gulf of Béjaia (Fig. 1) at
149 1: 120,000 and the software ArcGIS 10.3.1. Landings (total weight and weight per
150 caught species) were recorded for both PS and NPS.

151 In total, 5,076 fishing trips covering 17 fishing grounds were completed during
152 the study year and 13 PS and 26 NPS vessels were found to be active.

153 *2.3. Data analysis*

154 The number of active vessels for both PS and NPS and their characteristics
155 (length, engine power, gross tonnage, and year of construction) were calculated for
156 the fishing harbor of Ziama. Given that the weight of a fish crate is equal to 25 kg, the
157 total catch (kg) by PS and NPS and the species contribution to total weight were
158 registered by computing the number of crates. Monthly landings for species that
159 contributed to the total catch were also calculated.

160 For identifying any discernible spatio-temporal patterns of fishing effort, the total
161 counts of fishing trips directed by PS and NPS have been represented as a point with
162 geographical coordinates corresponding to the center of that area, and visualized on
163 a georeferenced map as a pie chart, whose width is proportional to the total
164 frequency of visits partitioned per two seasons (i.e. warm season for summer and
165 autumn and cold season for winter and spring). For the species that mostly contribute
166 to the global catch, we used a Kruskal-Wallis H test to test for main effects between
167 the four seasons (i.e. summer, autumn, winter, and spring) in terms of productivity,
168 and a Mann-Whitney U test for *post-hoc* tests for differences between PS and NPS.
169 These tests helped us to identify the seasons of high productivity per species for

170 each fishing vessel category. We chose non-parametric statistical tests because our
171 data did not meet the assumptions required for parametric statistics. Finally, the level
172 of significance was $\alpha=0.05$.

173 In order to evaluate the yield temporal variation, the average daily Catch Per
174 Unit Effort (CPUE \pm standard error) was calculated monthly for both fishing vessel
175 categories as kilograms per day per boat (kg/day/boat). Given that the minimum net
176 length used by PS and NPS is 150 m, the CPUE was calculated as kilograms caught
177 by this length (kg/150 m).

178 In order to evaluate the fluctuations of sardine price and its potential relationship
179 with the landings, the daily landing prices of sardine were calculated and graphed
180 together with landings. All statistical analysis was performed using Prism v 5.03 for
181 Windows (GraphPad Software, Inc. www.graphpad.com).

182 **3. Results**

183 *3.1. Fleet structure and catch composition*

184 *3.1.1. Fleet structure*

185 Purse seine fishing in the area of the future MPA of “Taza” was carried out by
186 39 vessels (13 PS and 26 NPS) with a length of between 6.8 to 18.5 m, equipped
187 with 24 - 265 kW engine power. About 66% of vessels were under 20 years of age.

188 Table 1 summarizes the characteristics and the number of active boats of the
189 two fishing vessel categories operated in the study area between May 2013 and April
190 2014. Almost half of the PS vessels (44.5%) were built before 1984, their overall
191 length varying between 9 and 18.5 meters (average length = 11.9 ± 2.9 m), and with
192 an auxiliary vessel of between 3.2 and 4.8 meters (Table 1). Moreover, 26 NPS were
193 observed to operate in the same area. These were very different, almost one third of
194 them called “FIDA” and of smaller dimensions (average length = 8.1 ± 1.2 m).
195 Consequently, these vessels had lower gross tonnage (0.9 - 7 grt) and engine power
196 (24 - 132 kW). All the vessels were observed to be active for at least four months
197 during the one-year study period.

198

199 **Table 1.** Fleet characteristics (range, mean, and standard deviation) of the overall length (m), gross
 200 tonnage (grt), engine power (kW), and age of the two fishing vessel categories practicing purse
 201 seining in the harbor of Ziama (Gulf of Béjaia, Algeria) between May 2013 and April 2014.

202

Vessel categories	Number of active boats	Fleet characteristics			
		Overall length (m)	Gross tonnage (grt)	Engine power (kW)	Age of the vessels
Purse seine (PS)	13	9 – 18.5 (11.9 ± 2.9)	5.4 – 28 (12.5 ± 7.7)	85 – 265 (142.1 ± 57.5)	2 – 60 (22 ± 19)
Non-purse seine (NPS)	26	6.8 – 10 (8.1 ± 1.2)	0.9 – 7 (4.3 ± 1.9)	24 – 132 (58.4 ± 37)	1 – 31 (13.3 ± 6.1)

212

213 3.1.2. Global catch and catch composition

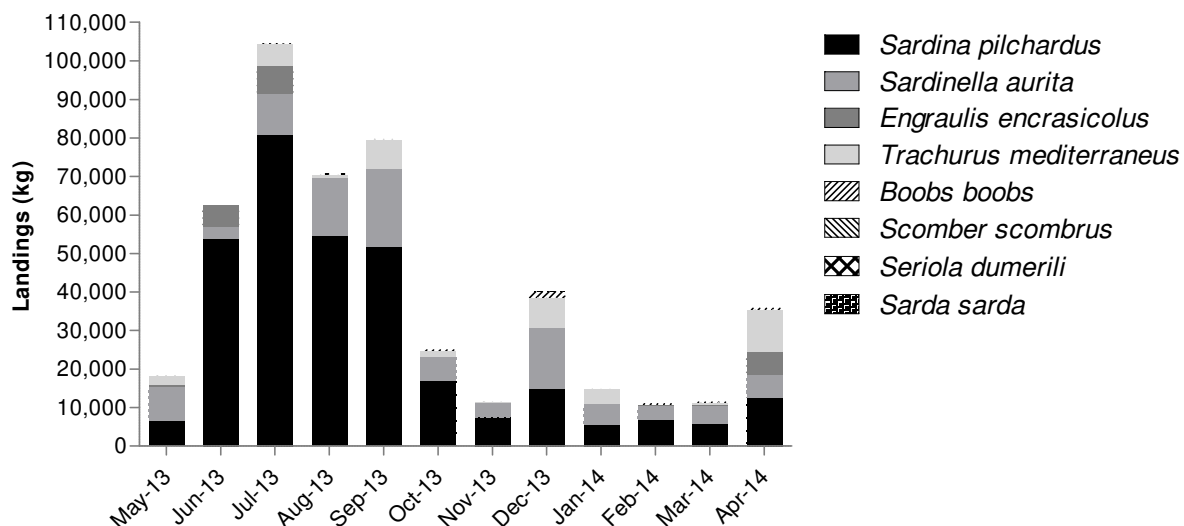
214 The species caught by PS vessels were: sardine, round sardinella, European
 215 anchovy, Mediterranean horse mackerel, and to a lesser extent: bogue, Atlantic
 216 mackerel, greater amberjack (*Seriola dumerili*), and Atlantic bonito (*Sarda sarda*).
 217 The NPS' catches were most diversified and included, in addition to the above
 218 mentioned species, salema (*Sarpa salpa*) and saddled seabream (*Oblada melanura*).
 219 The data obtained are summarized in the Appendix where the list of species caught,
 220 their total catch per month, and the numbers of monthly fishing trips for both vessel
 221 categories are reported.

222 3.1.2.1. Global catch and catch composition for PS

223 In total, 485,500 kg of catch were landed by PS vessels, out of which 86.5%
 224 representing the two main species of Clupeida caught on the Gulf of Béjaia, sardine
 225 and round sardinella, followed by Mediterranean horse mackerel which accounted for
 226 8.58% of the total catch (Fig. 3).

227 Sardine was landed during all months and accounted for 64.2% of the total
 228 catch (316,750 kg). During the summer season, more than half of the annual catch
 229 (59.7%) of this species was landed, peaking in July 2013 (25.5%). However, round
 230 sardinella accounted for 103,400 kg of the total catch and was most abundant in
 231 autumn, peaking in September 2013 with 19.7% (Fig. 3). European anchovy was only
 232 present in PS landings between February and July (Fig. 3).

233

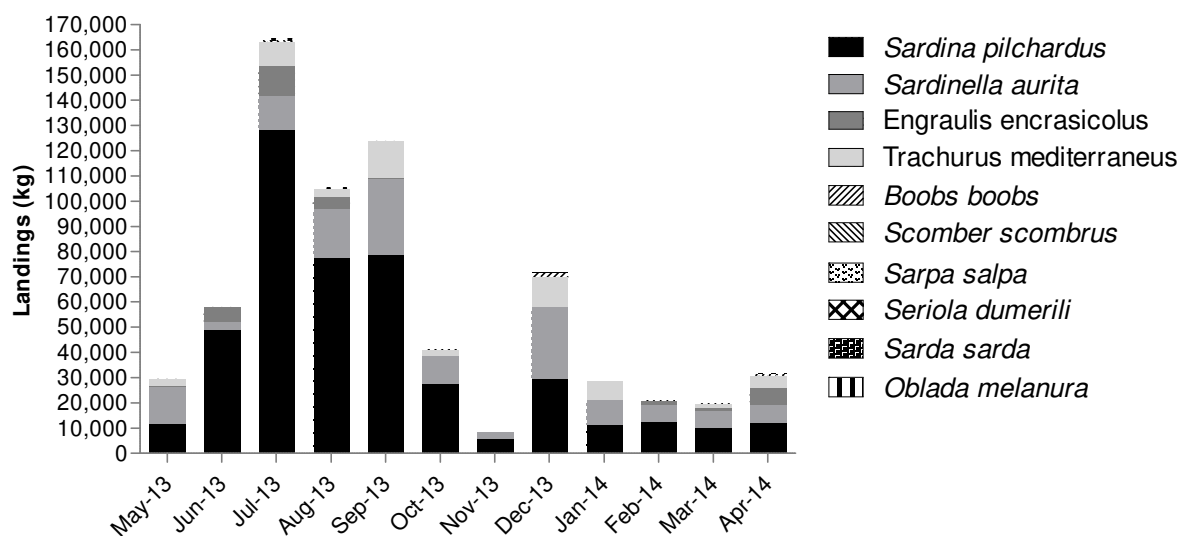


234
235

Fig. 3. Monthly landings and catch composition for PS vessels.

236 **3.1.2.2. Global catch and catch composition for NPS**

237 The total NPS catch was 703,225 kg, of which 46.6% was caught during the
 238 summer, 24.6% during the autumn, 17.3% during the winter, and the remainder
 239 11.5% during the spring (Fig. 4). Sardine accounted for 64.4% of the total catch
 240 (452,650 kg) for NPS vessels, followed by round sardinella (21.8%). European
 241 anchovy represented 4.7% of the total catch (Fig. 4). While sardine, round sardinella,
 242 and Mediterranean horse mackerel were present almost throughout the year,
 243 European anchovy was absent from NPS vessel landings during the period between
 244 October and January included (Fig. 4).



245
246

Fig. 4. Monthly landings and catch composition for NPS vessels.

247 *3.2. Fishing trip distribution and spatio-temporal patterns*

248 *3.2.1. Fishing trips*

249 A total of 5,076 fishing trips - 1,527 for PS and 3,549 for NPS - were carried out
250 by a set of 39 boats using purse seine fishing gear. For these boats, all fishing trips
251 were recorded via direct observation of landings on a daily basis between May 2013
252 and April 2014. The total counts of fishing trips carried out by PS and NPS identified
253 a seasonal pattern for both fishing vessel categories, in which most of the fishing trips
254 occurred in the summer season (Table 2). Thus, summer represents the season
255 where both PS and NPS carried out the most fishing trips during the year with 37.1%
256 and 34.2% respectively, whereas the trips carried out during the remaining three
257 seasons were more equally distributed for both fishing vessel categories (Table 2).

258

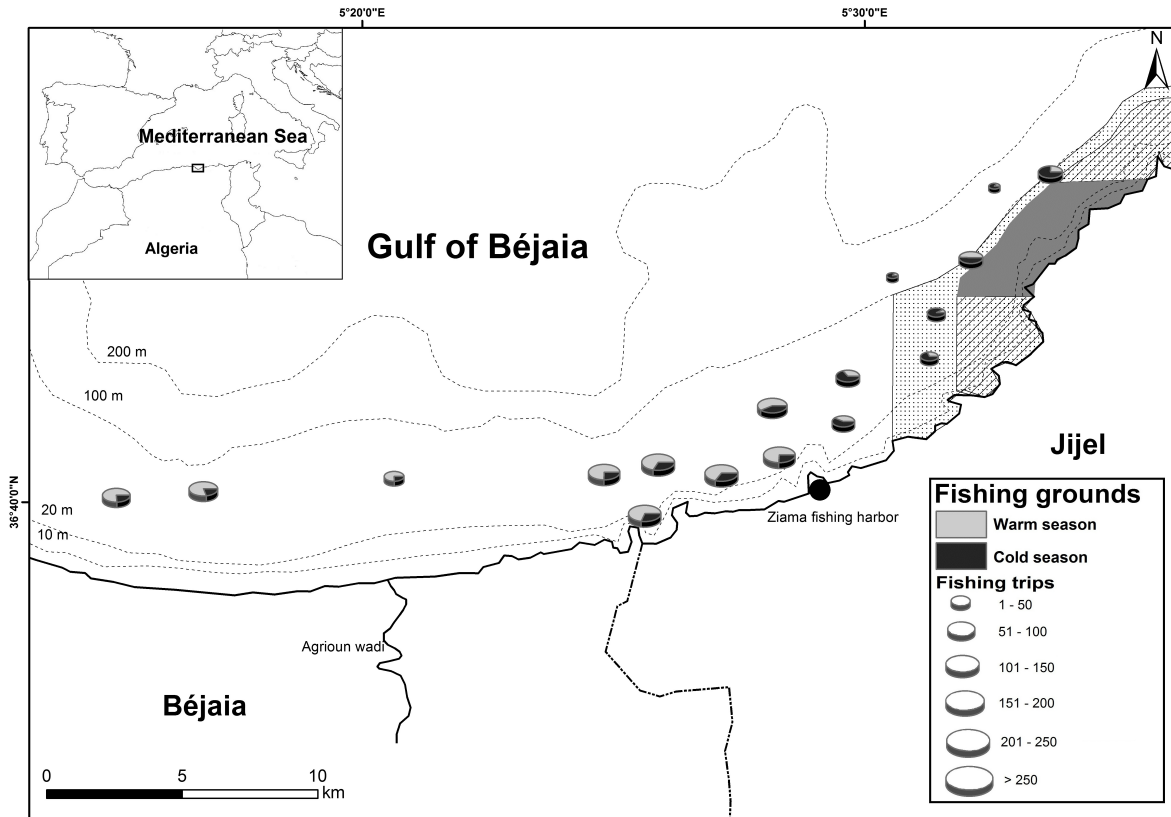
259 **Table 2.** Number of fishing trips per season for the two fishing vessel categories (PS & NPS).

260

	Summer	Autumn	Winter	Spring
261 PS	567	329	297	334
262 NPS	1214	775	779	781

263

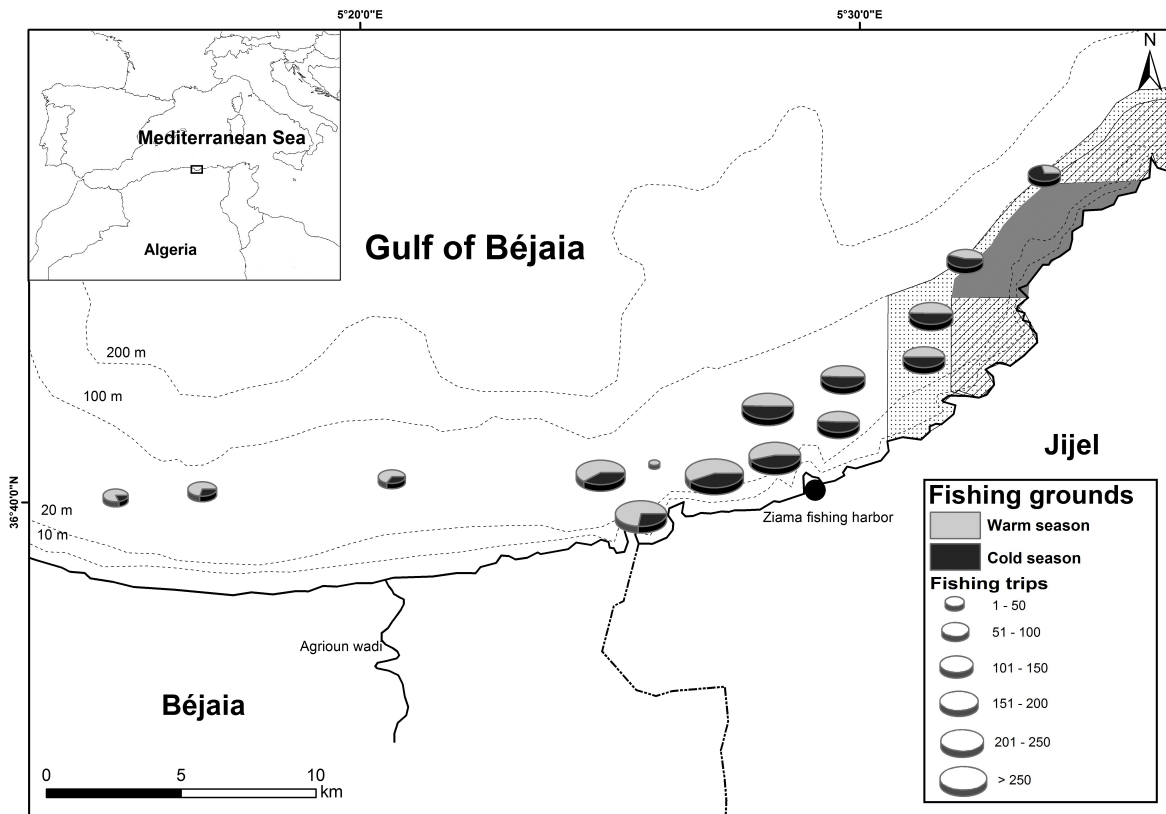
264 Over the one-year study period, the number of fishing trips for both PS and NPS
265 showed clear effort distribution patterns (Figs 5 and 6), although these patterns were
266 more discernible for PS than for NPS. The distribution of the fishing effort carried out
267 by PS showed seasonality, with more concentration in the West part of the Gulf of
268 Béjaia in summer and autumn seasons (hereafter warm season), whereas the fishing
269 effort during winter and spring seasons (hereafter cold season) was mostly
270 concentrated in the East (Fig. 5). However, the trips carried out by NPS were more
271 equally distributed between the warm and cold seasons and mostly concentrated
272 around the fishing harbor (Fig. 6).



273

274 **Fig. 5.** Seasonal concentration of fishing trips within the different fishing grounds for PS. The width of
 275 the pie chart is proportional to the total number of trips in that area partitioned per warm and cold
 276 seasons.

277



278

279 **Fig. 6.** Seasonal concentration of fishing trips within the different fishing grounds for NPS. The width of
 280 the pie chart is proportional to the total number of trips in that area partitioned per warm and cold
 281 seasons.

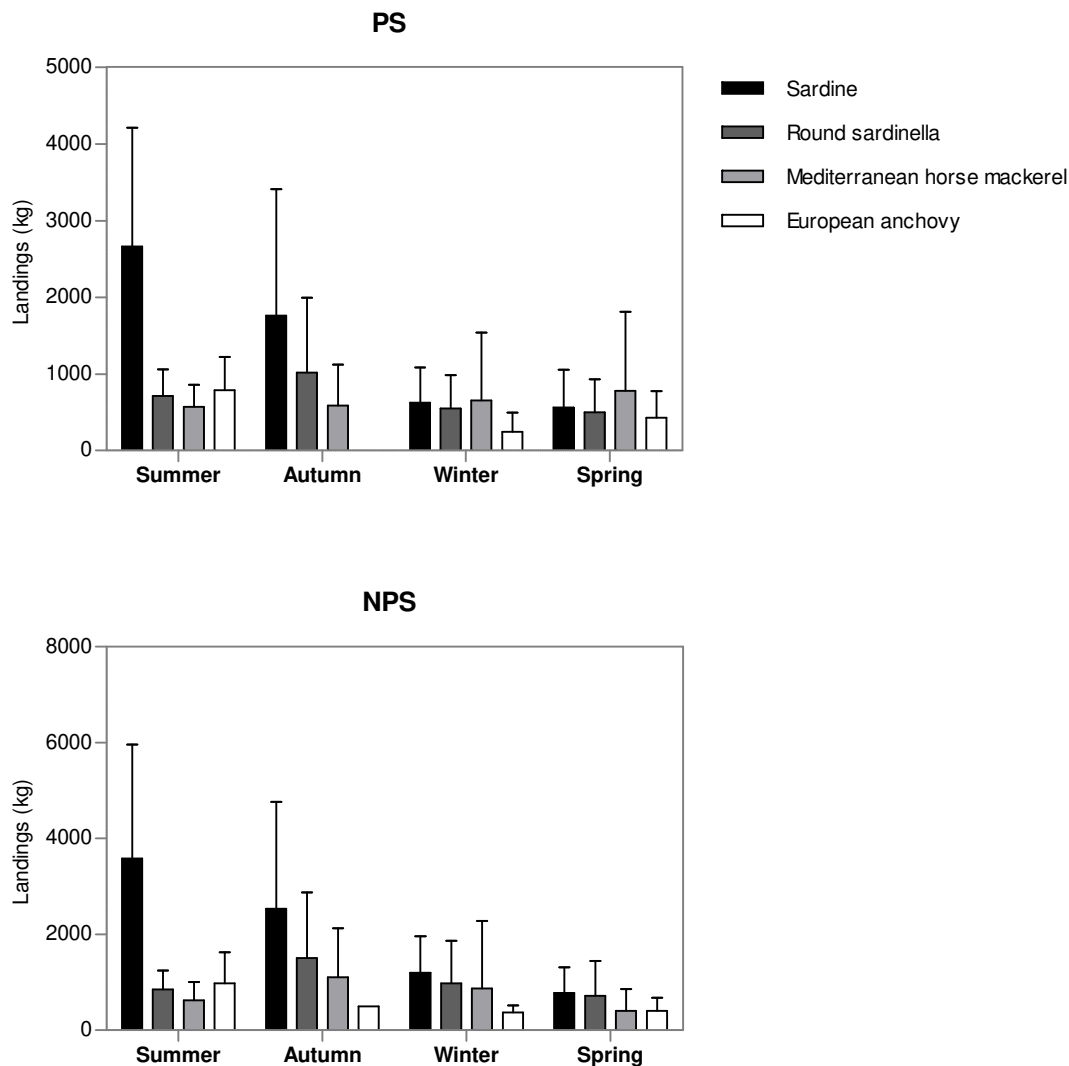
282 **3.2.2. Seasonal distribution patterns of catches**

283 The difference in catches between the different seasons was statistically
 284 significant for both PS and NPS for the three species: sardine, round sardinella, and
 285 European anchovy, whereas the catches of Mediterranean horse mackerel were
 286 statistically significant only for NPS (Table 3). The Mann-Whitney U test also showed
 287 significant differences between the two fishing vessel categories for sardine and
 288 round sardinella only (Table 3).

289 **Table 3.** Kruskal-Wallis H analysis of variance and *post hoc* Mann-Whitney U comparisons for catch
 290 differences between PS and NPS.

Species	Kruskal-Wallis H for PS		Kruskal-Wallis for NPS		Mann-Whitney U for PS vs. NPS	
	H	P	H	P	U	P
293 <i>Sardina pilchardus</i>	90.03	< 0.0001***	75.13	< 0.0001***	16098	0.0003***
294 <i>Sardinella aurita</i>	15.89	0.0012**	11.25	0.0105*	9060	0.0002***
295 <i>Trachurus mediterraneus</i>	0.7314	0.8658 (ns)	12.27	0.0065**	2315	0.4022 (ns)
296 <i>Engraulis encrasicolus</i>	7.050	0.0294*	75.13	< 0.0001***	766.5	0.6410 (ns)

297 Figure 7 highlights that for PS, the sardine was targeted mainly during the warm
 298 season. Consequently, the seasonal pattern in the selection of fishing grounds for PS
 299 showed that during this period, fishing trips mainly occurred in the West part of the
 300 Gulf of Béjaia (Fig. 5). However, for NPS, the difference in catches was statistically
 301 significant for all the main species with the sardine in the top of catches for all
 302 seasons, especially in warm season and catches generally equivalent between the
 303 different species during the cold season (Fig. 7).



304

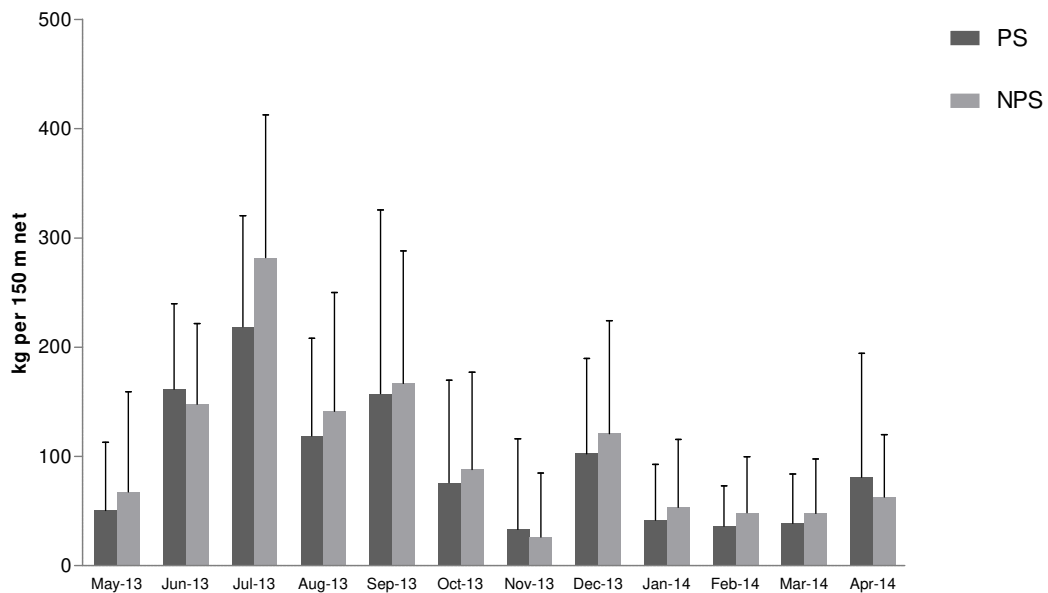
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306 **Fig. 7.** Seasonal catches of the four main species: sardine, round sardinella, Mediterranean horse
 307 mackerel, and European anchovy for Ziama Bay (Algeria) purse seiners (PS) and non-purse seiners
 308 (NPS) between May 2013 and April 2014.

309 *3.3. Yield temporal variation (CPUEs) and sardine price fluctuation*

310 Average daily CPUEs (\pm s.e.) were calculated monthly for both fishing vessel
 311 categories (Fig. 8). Summer was the season when maximum CPUE values were

312 recorded for both PS and NPS. Thus, the highest value of 281.87 kg/150 m ± 130.85
 313 was recorded for NPS in July 2013 against 226.92 kg/150 m ± 93.70 for PS for the
 314 same month. During the study year, the average monthly values of the NPS' CPUEs
 315 were higher than those of PS for 9 months out of 12 highlighting more a trend than a
 316 statistical significance (Fig. 8).



317

318 **Fig. 8.** Monthly CPUEs ± s.e. of purse seiners (PS) and non-purse seiners (NPS) of the Ziam, Algeria
 319 (SW Mediterranean) purse seine fishery.

320 Sardine was predominant in landings within the purse seine fishery of Ziam
 321 Bay with a maximum of 208,900 kg and 50,375 kg in summer and autumn
 322 respectively over the period May 2013 - April 2014 (Fig. 9). The captures and the
 323 daily landing price of sardine were inversely proportional. Significant correlation ($P <$
 324 0.0001 ; $r = 0.69$; $n = 205$) between landings and the daily landing price of sardine
 325 revealed that variability in landing price is highly influenced by the quantity of
 326 captures.

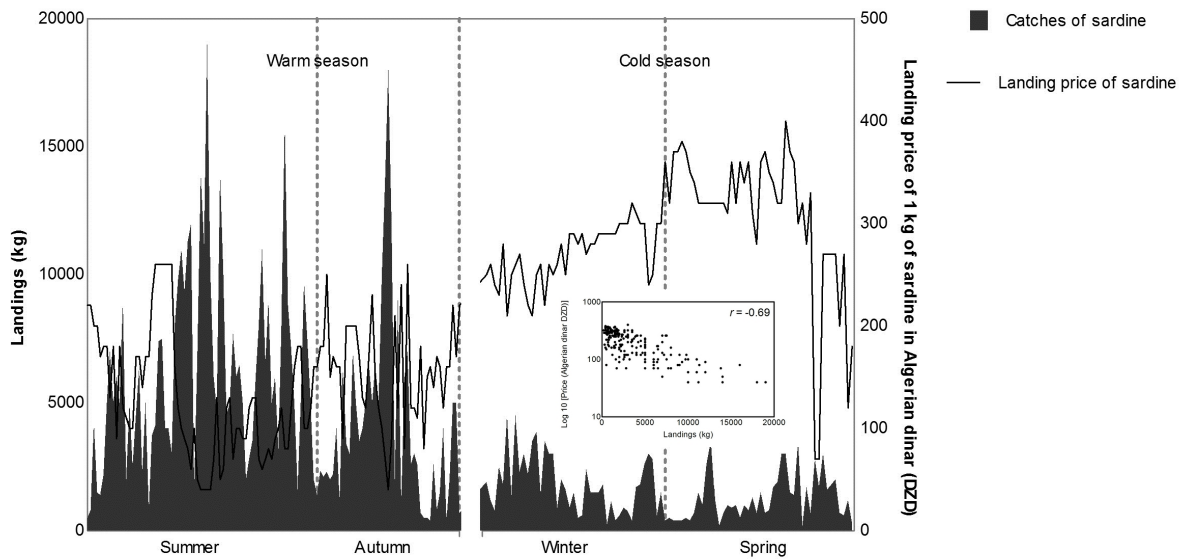
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334 **Fig. 9.** Sardine landings for the purse seine fishery of Ziamia (PS and NPS), Algeria (SW
 335 Mediterranean) from May 2013 to April 2014 and the fluctuation (solid line) of the daily landing price
 336 per unit weight (DZD.kg⁻¹).

337

338 4. Discussion

339 This study focuses on the spatio-temporal patterns of purse seine fishery for
 340 two fishing vessel categories in the area of Ziamia Bay (Gulf of Béjaia, Algeria), where
 341 the establishment of an MPA is planned. Sardine fishery has a high socio-economic
 342 relevance for the purse seiners of Ziamia as it represents an important share of the
 343 fish caught and constitutes about 65% of purse seine fishery in terms of landings. In
 344 the context of the future establishment of the MPA of “Taza”, there is a need to
 345 characterize this fishing activity in order to provide a baseline that could be extremely
 346 valuable for the managers of this future MPA to set up sound fishery management
 347 plans. During the present study, a strong presence of unlicensed fishing vessels for
 348 purse seine fishing activity, referred to as NPS, has been detected with 26 vessels
 349 confirmed as operating in the area, which is double the number of licensed purse
 350 seine vessels (13 vessels). Of these NPS vessels, half (i.e. 13) operate with two
 351 crews, one crew for small-scale fishing during the day and the other crew for purse
 352 seine fishing during the night. Given that these vessels do not pay the taxes relative
 353 to purse seine fishing activity, these fishermen create an unfair competition for PS
 354 ones. Another example of conflicting interests in the study area is the competition

355 between recreational and commercial fisheries. According to Kacher (2010), many
356 recreational fishers use the same fishing gear as the professional fishers, target the
357 same species, and sell their catch illegally. In addition, in the short to medium term,
358 this situation will lead to overfishing by excessive pressure on the small pelagic
359 resources. In the future, the managers of “Taza” MPA should take into account this
360 double activity and include it in the monitoring of fishing effort.

361 The PS and NPS fishing vessels catch a similar array of species. However, the
362 catches of the NPS vessels are more diversified than the PS ones. This variety in the
363 fishing catches is partly attributable to the variety of fishing grounds visited and
364 habitat types. The - 100 m bottoms within the Gulf of Béjaia are characterized by a
365 central part that occupies 25 km of the coastline with sandy bottoms, whereas in the
366 eastern part, there are mainly hard bottoms (Refes, 2011). In addition, because of
367 their small nets, NPS can explore hard bottoms more easily than PS, increasing the
368 catch of species associated with these stretches. In the Mediterranean, these areas
369 are characterized by high environmental heterogeneity and are very rich from the
370 point of view of biodiversity (García-Charton et al., 2000). Although MPAs have been
371 proposed as an efficient way to resolve user conflicts, in our case study, NPS fishers
372 might be the source of serious conflicts with small-scale fisheries, resulting in
373 territorial and resource competition between them. Thus, when the haul is so coastal,
374 the net height covers the entire water column reaching the proximity of the seabed.
375 This fishing practice “transforms” the purse seine from a pelagic fishing gear to a
376 benthic one while putting many NPS fishers in unfair competition with small-scale
377 ones because they target the same species.

378 The yield of small pelagic catches depends on fishermen’s perception of the
379 spatial patterns of fish and the ability of these fishers to identify areas of high fish
380 density (Hieu et al., 2014). Therefore, the discernible patterns in the exploitation of
381 fishing grounds between seasons depend on the structure of the resource (small
382 pelagic fishes), which in turn depends on environmental conditions and how they
383 change spatio-temporally (Quattrocchi and Maynou, 2018). Overall, the catches per
384 species made by PS and NPS display seasonal patterns by targeting sardine during
385 the warm season. In addition, the fishing effort directed towards sardine, expressed
386 in number of fishing trips, shows a spatial distribution pattern in terms of selection of
387 fishing grounds. The results show that the spatial fishing effort distribution during the

388 cold season does not vary among the two fishing vessel categories, in contrast to the
389 warm season (i.e. summer and autumn), when the PS only visit fishing grounds
390 located in the central part of the Gulf of Béjaia. In addition, the seasonal fishing effort
391 allocation, expressed as the number of fishing trips per season, indicates that similar
392 fishing effort allocation patterns occur during the cold season when the catches of
393 sardine drop, whereas the fishing effort allocation during the period of the availability
394 of sardine (i.e. warm season) shows discernible fishing effort patterns which could be
395 responsible for the statistically significant differences in the catches of sardine
396 between PS and NPS vessels.

397 Purse seine fishing activity usually occurs inside the Gulf of Béjaia, during short
398 trips where the fishing grounds can be reached within 1 to 2 hours of navigation from
399 the harbor. At national level, the maximum legal limit of a purse seine fishing trip is 12
400 hours (Maouel et al., 2014). In the fishing port of Ziama, fishing trips occur daily
401 starting around 7:00 p.m. in summer and 3:00 p.m. in winter (I. Boubekri, personal
402 observations). In general, only one trip per day is carried out and it depends mainly
403 on the state of the sea; the reason why the summer season records the highest
404 number of the fishing trips.

405 Several reasons may be behind the variability in the distribution, abundance,
406 and size of populations of pelagic fishes, such as climate variability (Cury et al., 2000;
407 Sabatés et al., 2007; Ramos et al., 2009), currents, and geographical features of the
408 habitats (Basilone et al., 2004; Checkley et al., 2009). In the northeastern Algerian
409 coast, the autumn season corresponds to the peak of sardine spawning (Bouhali et
410 al., 2015) and the Gulf of Béjaia could be considered as a nursery of small pelagic
411 fishes because of the existence of huge continental inputs and the vertical mixing of
412 water. The large freshwater input in the area comes mainly from the Soummam
413 River, whose catchment basin extends over about 9118 km² (Tafoukt et al., 2017)
414 and pours in the West of the Gulf, but also from the Kissir River, whose mouth is
415 situated inside the area of the future MPA of “Taza”, and the Agarioun River situated
416 between the two (Fig. 1). The mixing of water is induced by the instability of the
417 Algerian current which commonly forms coastal eddies of 50 to 100 km in diameter,
418 which move eastward along the North African margin (Millot et al., 1990). The
419 seasonal distribution pattern of the fishing effort within the Gulf of Béjaia suggests

420 that fishers use the local ecological knowledge of the targeted species to increase
421 their catches.

422 Despite the eventual restrictive regulations for fishery to be expected within the
423 future MPA, local artisanal fishers tend to go fishing along the no-take zone edges
424 which increases the fishing pressure on these areas (Stelzenmüller et al. 2007;
425 Kellner et al. 2007), thus reducing or negating the positive effects of MPAs. During
426 the MedPAN South project (2009 - 2012), the staff of Taza National Park pioneered
427 the first marine zoning plan in Algeria for the area adjacent to the existing terrestrial
428 park (Gomei and Di Carlo, 2012). However, the fishers of Ziama harbor initially
429 expressed strong opposition to the first proposed zoning plan, as they thought it
430 would limit their activities and reduce their income (Boubekri and Djebar, 2016).
431 Consequently, “Taza” MPA adopted a second multiple-use zoning plan to achieve
432 sustainable use consistent with conservation. To this end, three differentiated zones
433 have been defined (i.e. “no-take zone”, “buffer zone”, and “peripheral zone”, Fig. 1),
434 resulting from a consultation process which was conducted between 2009 and 2012
435 with all stakeholders. Since then, Taza National Park has introduced the zoning plan
436 as a tool allowing the management body to supervise fishing activities, including
437 monitoring the activity of purse seine vessels with spatial regulations. Thus, purse
438 seining is authorized only on the “peripheral zone” within bottoms >35 m. In our case
439 study, almost all the fishing grounds (i.e. fifteen out of seventeen) are at depths <100
440 m, while four of them are located inside the “peripheral zone” of the future MPA. The
441 patterns of activity show a higher concentration of fishing efforts by NPS than by PS
442 in these fishing grounds mainly because of the presence of hard bottoms in this
443 zone. In fact, the characteristics of the net (i.e. small size) used by NPS compared to
444 PS ones, which is more easily manoeuvrable, allow NPS fishers to explore hard
445 bottoms.

446 The CPUEs could be strongly influenced by the varying characteristics of fishing
447 gear, the heterogeneity of fishermen’s local knowledge, seasonal patterns of
448 abundance, and outlying data due to exceptional catches (Maunder and Punt, 2004;
449 Smith et al., 2006). The global catch per unit effort (CPUE; kg/150 m of net) is higher
450 for NPS vessels in 9 months throughout the study year. However, PS vessels present
451 the highest CPUEs relative to the three remaining months; June, November, and
452 April. The CPUE values for PS vessels during these 3 months are relatively low,

453 never exceeding 175 kg/150 m of net. Moreover, these months are characterized by
454 the lowest number of trips carried out by PS and NPS vessels during the study year.
455 Larger boats operate in relatively offshore areas with longer operating times, which
456 allow them to spend sufficient time searching for sardine schools. This could be in
457 their favor especially in the months of low abundance of fish species. However,
458 because the activity of purse seine fishery does not stop throughout the year, serious
459 conflicts are raising between purse seiners and trawlers. The pelagic trawlers operate
460 inside the Gulf which may further damage the spawning grounds of the small-pelagic
461 fishes. For this purpose, another of the perspectives of the establishment of the
462 “Taza” MPA is the prohibition of trawling at a depth less than 50 m and to ensure
463 better application of the existing regulation on fisheries which already bans trawling
464 within waters less than 40 m deep in all jurisdictional waters (Ministerial Order of 12
465 July 2004).

466 Sardines are the primary contributor to fishery landings in terms of captures in
467 Ziama Bay. Nevertheless, the great variability of its consumer price seems to be
468 inversely related to the inter-seasonal availability of this resource throughout the
469 year. Thus, during the period of high productivity, the price is at its lowest.
470 Conversely, when the productivity of this species is at its lowest, the price increases
471 and remains at the highest even after a short period of high productivity. This
472 suggests that the commercial market of this species is subject to a strong speculation
473 for further social and economic factors that lie outside the scope of this study.
474 However, this situation could be in favor of the creation of the MPA because as long
475 as fishermen incomes remain relatively stable even during periods of low productivity,
476 the first years of the establishment of the MPA could be endorsed by the fishermen.
477 Even if the MPA contributes to the increase of fishery resource biomass in the future,
478 it will still be necessary to establish limitations to the fishing effort (days per year,
479 weekend stops, maximum catch per year, etc.) in order to keep fishermen’s incomes
480 at the highest level by employing an optimal fishing effort. This hypothesis has
481 already been tested by Chakour (2008) through the Pêchakour model and has
482 resulted in a fishing effort not exceeding 40 purse seine fishing vessels per year in
483 Ziama Bay. Another alternative is to explore other ways of marketing product outside
484 of the traditional sale to the local market. To do this, processing units will create an

485 opportunity to make the catches more profitable and to encourage local development
486 of the fishing sector.

487 **5. Conclusion**

488 This study is based on the collection of information from landings observation, a
489 method considered appropriate for collecting information on fishing activities. It
490 should be noted that the results presented here are based on observations made
491 over a short period of 12 months and do not cover the entire purse seine fleet
492 operating in the Gulf of Béjaia but provide detailed and valuable information on
493 fishing activity in a coastal area candidate to become an MPA. A large-scale study is
494 only feasible within an observations program.

495 The results of this short term study are based on data from an annual cycle and
496 do not allow comparison with the results of previous studies from this area.
497 Nevertheless, this allows us to characterize this fishing activity at a key period, just
498 before the establishment of an MPA. These results will allow the creation of a
499 reference database to make comparisons before and after the establishment of the
500 MPA. This will enhance the effect of the protection on the fish population of the MPA
501 and allow the assessment of its performance.

Appendix

List of caught species and their total weight (kg) per month, for the fishing harbor of Ziama (Gulf of Béjaia, Algeria SW Mediterranean) purse seine (PS) and non-purse seine (NPS) fishing vessels.

Purse seine fishing vessels (PS)	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	Total (kg)
Number of fishing trips	99	162	209	196	211	86	32	133	79	85	97	138	1527
Species													
Carangidae													
<i>Sarda sarda</i>	–	–	–	–	–	–	–	100	–	–	–	–	100
<i>Seriola dumerili</i>	–	–	–	300	–	–	–	–	–	–	–	–	300
<i>Trachurus mediterraneus</i>	2500	–	5500	800	7700	1450	300	7800	4000	–	500	11100	41650
Clupeidae													
<i>Sardina pilchardus</i>	6500	53800	80800	54550	51600	16750	7400	14850	5500	6700	5800	12500	316750
<i>Sardinella aurita</i>	9000	3000	10500	15000	20350	6400	3800	15850	5300	3600	4500	6100	103400
Engraulidae													
<i>Engraulis encrasicolus</i>	300	5900	7500	–	–	–	–	–	–	500	500	5700	20400
Scombridae													
<i>Scomber scombrus</i>	–	–	200	–	–	–	–	–	–	–	–	–	200
Sparidae													
<i>Boops boops</i>	–	–	–	–	–	400	–	1600	–	200	100	400	2700
Total (kg)	18300	62700	104500	70650	79650	25000	11500	40200	14800	11000	11400	35800	485500
Non-purse seine fishing vessels (NPS)	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	Total (kg)
Number of fishing trips	206	297	490	427	494	205	76	385	227	194	223	352	3549
Species													
Carangidae													
<i>Sarda sarda</i>	–	–	–	–	–	–	–	400	–	–	–	–	400
<i>Seriola dumerili</i>	–	–	800	600	–	–	–	–	–	–	–	–	1400
<i>Trachurus mediterraneus</i>	3000	150	9650	2800	14700	2000	–	11950	7325	–	1350	5125	58050
Clupeidae													
<i>Sardina pilchardus</i>	11600	48900	128100	77350	78550	27450	5700	29525	11200	12175	10100	12000	452650
<i>Sardinella aurita</i>	14500	3100	13500	19350	30025	11300	2400	28300	9900	6950	6700	7100	153125
Engraulidae													
<i>Engraulis encrasicolus</i>	500	5750	11800	5100	500	–	–	–	–	1500	1100	6600	32850
Scombridae													
<i>Scomber scombrus</i>	–	–	600	–	–	–	–	–	–	–	–	100	700
Sparidae													
<i>Boops boops</i>	–	–	–	–	–	400	–	1900	–	350	400	300	3350
<i>Sarpa salpa</i>	–	200	–	–	–	–	–	–	–	–	–	–	200
<i>Oblada melanura</i>	–	–	–	–	–	–	–	–	–	–	–	500	500
Total (kg)	29600	58100	164450	105200	123775	41150	8100	72075	28425	20975	19650	31725	703225

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