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Baseline data for Marine Protected Areas planning and fisheries monitoring: Potential conflicts between recreational IUU and commercial fisheries in the proposed “Taza” MPA (Algeria, SW Mediterranean)

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Abbreviations: IUU: Illegal, Unreported, and Unregulated; REC: Recreational fisheries; SSF: Small-Scale Fisheries; MPA: Marine Protected Area; CPUE: Catch Per Unit of Effort; DPRH: Directorate of Fisheries and Aquaculture; RBF: Recreational Boat Fishing; MedPAN: Mediterranean Protected Areas Network; SR: Species Richness; MC: Mean Catch; FT: Fishing Trips; TEK: Traditional Ecological Knowledge; ESRI: Environmental Systems Research Institute.

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1

2 **Abstract**

3 Nowadays, recreational fisheries (REC) have a great impact on marine
4 ecosystems and create conflicts with other human coastal activities such as
5 commercial small-scale fisheries (SSF). In the proposed “Taza” marine protected
6 area (MPA) (Algeria, SW Mediterranean), recreational boat fishing is poorly regulated
7 and its catches remain unmonitored. In addition, a significant number of REC fishers
8 sell their catch illegally, an activity we could refer to as IUU (Illegal, Unreported, and
9 Unregulated) fishing. This study is a good opportunity to evaluate the potential
10 conflicts between recreational IUU and commercial fisheries and can be extremely
11 valuable in terms of MPA planning and fisheries monitoring by providing baseline
12 data for setting up sound fisheries management and conservation plans. Two fishing
13 harbors are located near the proposed “Taza” MPA: Boudis and Ziama. Illegal REC
14 boats from Ziama harbor were studied via a direct observation method of landings
15 developed by the Ifremer (French Research Institute for Exploitation of the Sea). A
16 comparison between illegal REC and SSF boats was highlighted in terms of catches
17 and fishing effort. A total of 54 taxa belonging to 24 families were observed in the
18 catches of the 32 recreational active boats in this harbor between May 2013 and April
19 2014. The proportion of the harvest attributed to illegal REC represented about 50%
20 of the SSF harvest. Illegal REC in the proposed “Taza” MPA is an important
21 socioeconomic activity which is intensively practiced throughout the year. From
22 November to April, the mean catch was almost the same for both fishing categories.
23 Strong competition between recreational and professional fishers for the natural
24 resources was highlighted as 81% of the 54 caught taxa were present in the catches
25 of both fishing categories (i.e. 44 taxa). Moreover, 4 species of high commercial
26 value were caught exclusively by recreational fishers. Finally, the managers of the
27 proposed “Taza” MPA must address and regulate all fishing activities and use the
28 best available information in order to provide important benefits to marine
29 ecosystems, fishers, and the local population.

30 **Keywords:** Recreational fisheries; Small-scale fisheries; Marine protected areas;
31 Mediterranean; Algeria.

32 **1. Introduction**

33 Nowadays, there is growing concern about the impact of recreational fisheries
34 (referred to as REC throughout this article) on marine ecosystems (Lloret et al., 2019)
35 and the related conflicts with other human activities, such as commercial fisheries
36 (Cooke and Cowx, 2006; Arlinghaus and Cooke, 2009). While commercial fisheries
37 are the dominant fisheries worldwide (McPhee et al., 2002; Post et al., 2002; Cooke
38 and Cowx, 2004), a growing portion of many harvested fish stocks over the world is
39 carried out by recreational fishers (Coleman et al., 2004; Arlinghaus and Cooke,
40 2005; Lewin et al., 2006). According to Hyder et al. (2018), in some European
41 countries, fish removals by marine REC for northern European sea bass
42 (*Dicentrarchus labrax*) and western Baltic cod (*Gadus morhua*) stocks, represent
43 27% of the total catches (recreational and commercial). In 2012, recreational fishers
44 were responsible for up to 53% of the total fish removals of European sea bass in
45 Belgium (Hyder et al., 2018). In the Mediterranean, REC represent an important
46 share of the fish caught and may locally amount up to 50% of the total commercial
47 catches (European Commission, 2004; FAO, 2008; Font et al., 2012;), however they
48 are still poorly managed and less studied compared to commercial fisheries (Font
49 and Lloret, 2014; Prato et al., 2016; Pita et al., 2020). An increasing number of
50 studies supports the idea that the increasing REC effort can have similar, or even
51 higher effects on fish populations than artisanal fishing (Cooke and Cowx, 2006;
52 Lloret et al., 2008; Zischke et al., 2012).

53 During the summer, the human population increases considerably in coastal
54 areas, when the pressure of local tourism is highest. Consequently, aquatic leisure
55 activities such as scuba-diving and REC (i.e. boat angling, shore angling, and
56 spearfishing) have flourished on the Mediterranean shores and their additional
57 impact on coastal and maritime ecosystems has grown (Morales-Nin et al., 2005).
58 Therefore, fisheries managers need to consider all forms of harvesting if they are to
59 manage these resources sustainably by improving national data reporting of
60 recreational catches (Hyder et al., 2014; Ryan et al., 2016; Freire et al., 2020).

61 In Algeria, to practice REC only boat-owners are required to have recreational
62 fishing authorizations (licenses), while spearfishers need an individual license (Babali
63 et al., 2018). These licenses are issued by local fisheries authorities after payment of
64 an annual fee and must be renewed each year. Up until December 2014, in the
65 department of Jijel (SW Mediterranean, NE Algeria) where the proposed “Taza” MPA

66 is planned (Fig. 1), the fishing fleet had a capacity of 776 fishing boats (309
67 professional and 467 recreational), with only 292 updated licenses for recreational
68 boat-owners (of these, 59 individual licenses are for spearfishers) issued by the
69 DPRH (Directorate of Fisheries and Aquaculture) of Jijel (DPRH, 2014).
70 Nevertheless, recreational boats have started to become more important since 2012,
71 with their number doubling in a very short timeframe and almost filling the carrying
72 capacity of Zlama fishing harbor (Boubekri and Djebar, 2016). Moreover, the impact
73 of REC on coastal ecosystems can be greater in marine protected areas (MPAs),
74 given the increasing number of visitors fishing for pleasure (Cooke and Cowx, 2006).
75 MPAs are often seen as a way to develop and demonstrate the benefits of
76 management methods that allow multiple-use to coexist sustainably in areas that are
77 subjected to a variety of pressures (Lester et al., 2009; Pike et al., 2010; Horta e
78 Costa et al., 2013).

79 The recent data on the number of recreational fishers and fishing effort within
80 the European Mediterranean countries has been estimated to be approximately 2.8
81 million and 20.9 million sea fishing days per year, respectively (Hyder et al., 2018).
82 However, the estimates in non-European Mediterranean countries remain scarce or
83 totally absent despite the popularity of REC in these countries (Belhabib et al., 2013;
84 Babali et al., 2018; Ben Lamine et al., 2018). In Algeria, the REC sector is poorly
85 regulated and its catches remain unmonitored (Babali et al., 2018). More recently,
86 efforts are underway in Algeria to reconstruct preliminary estimates of recreational
87 catches, based on catch data reported by the Ministry of Fisheries and Aquaculture.
88 Between 1970 and 2010, the total estimated landings from recreational boats
89 increased globally until the early 2000s, peaked at 1200 t·year⁻¹ in 2002, and began
90 declining thereafter to about 1000 t·year⁻¹ in 2010 (Belhabib et al., 2013), raising
91 concerns that the Algerian coastal resources may be overexploited. Another study
92 also highlighted the great economic impact of REC which deprives the Algerian
93 national treasury - through lost tax, license income, and revenues from illegal sales of
94 fish - of 45 million USD annually (Babali et al., 2018). In addition, recreational fishers
95 have been without legal restrictions for a long time (Abdelguerfi, 2002).

96 The most popular REC technique in Algeria by far is the recreational boat
97 fishing (referred to as RBF throughout this article) which means fishing on board of
98 recreational boats. According to Belhabib et al. (2013), RBF in Algeria represents

99 80% of REC. The term “recreational fisheries” can be considered as part of “small-
100 scale fisheries” even though many differences between the two fishing categories are
101 pointed out (Table 1). In the present study “professional fisheries” indicates any
102 fishing exercise reserved for fishers holding certificates of registration to a
103 professional category without any reference to fishing boat categories, while “small-
104 scale fisheries” indicates strict implication of the “professional fisheries”. In the
105 Algerian context, the difference between recreational and professional fisheries is so
106 highly nuanced - with many recreational fishers selling illegally their landings - that
107 we could refer to “IUU (Illegal, Unreported, and Unregulated) recreational fishing”.
108 Throughout this article we will refer to “illegal REC” due to the common usage of this
109 term in the Algerian context as well as to SSF (Small-Scale Fisheries) when referring
110 to “commercial fisheries” because all the small-scale boats surveyed were practicing
111 commercial fishing.

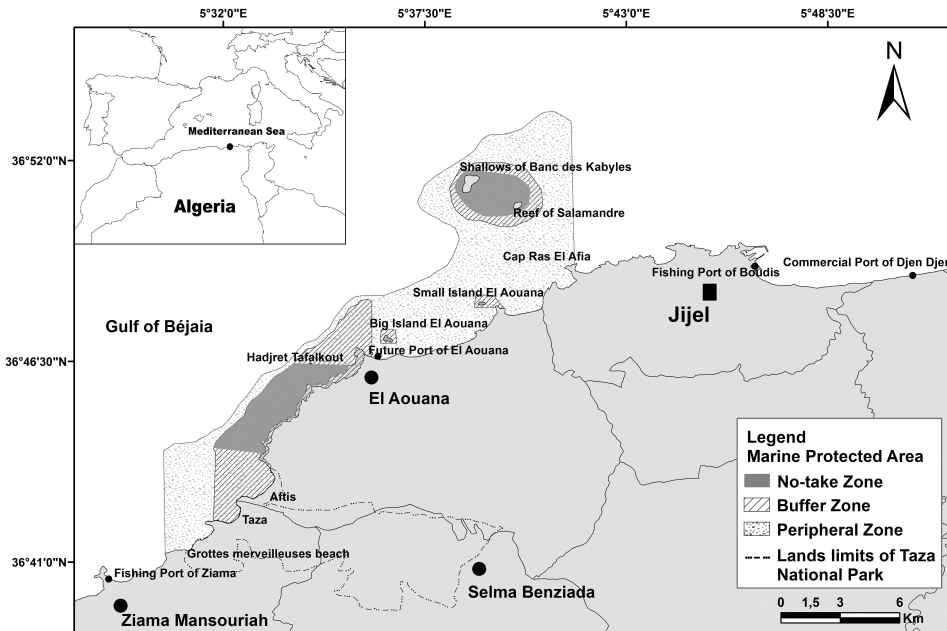
112 Table 1. Definitions of the different fishing categories in Algeria.

113 Fishing category	Definition	Foundation text
114 Recreational fishing 115 (REC)	Any fishing exercise as a sport or as a leisure activity and for non-commercial purposes.	Decree No. 2003-481 of 13 December 2003 (Art. 61)
116 Professional fishing	Any fishing exercise reserved for fishers holding a professional booklet.	Decree No. 2003-481 of 13 December 2003 (Art. 3)
117 Small-Scale Fishing 118 (SSF)	Any traditional fishing practiced in territorial sea. This fishing activity is carried out with boats less than 12 m in length.	Law No. 07-12 of 31 December 2007 (Art. 55)
119 Commercial fishing	Any fishing exercise reserved for fishers holding a professional booklets onboard professional boats with an active tax assessment.	Decree No. 2003-481 of 13 December 2003 (Art. 5)
120 Recreational Boat Fishing 121 (RBF)	Fishing on board of recreational boats.	Decree No. 2003-481 of 13 December 2003 (Art. 13)
122 Recreational boats	Boats with recreational fishing authorizations (licenses). The fishing authorization is issued to the boat-owner.	Decree No. 2003-481 of 13 December 2003 (Art. 13)
123 Professional boats	Boats with professional fishing authorizations (licenses). The fishing authorization is issued to the boat-owner.	Decree No. 2003-481 of 13 December 2003 (Art. 13)

134 The increase in REC effort can have similar or even greater effects than that of
135 commercial fishing on the structure of some fish populations (Bianchi et al., 2000;
136 Coll et al., 2004; Lewin et al., 2006), and also on the conservation status of certain
137 species (Lloret et al., 2018), such as endangered and vulnerable ones (Morales-Nin
138 et al., 2010; Lloret et al., 2012; Biton-Porsmoguer and Lloret, 2018). Unfortunately no
139 statutory instrument has yet been adopted to date for the creation of the “Taza” MPA
140 and this situation can result in a huge conflict over the exploitation of resources and
141 the use of space between recreational and professional fishers in the near future.

142 The zoning plan of the proposed “Taza” MPA comprises 2 no-take zones (Fig.
143 1). The regulatory proposal for the no-take zones stipulates the authorization of boat
144 navigation without mooring and scientific research, while prohibiting recreational and
145 commercial fisheries as well as all the other marine extractive uses (e.g. extraction of
146 aggregates for construction). However, both REC and SSF are allowed in the buffer
147 and the peripheral zones where fishers can use only lines and trammel nets
148 (Boubekri and Djébar, 2016). Thus, the benefits of the proposed “Taza” MPA in terms
149 of protection and sustainable management of commercial fish stocks can fail if the
150 basic data on REC are missing (e.g. effort and catches). Alongside the ecological
151 impact of REC on coastal fish stocks and the potential risks of overfishing arising
152 from the use of forbidden gears, the illegal selling of recreational catches in the local
153 market is creating unfair competition and conflict between REC and SSF fishers in
154 the area of the proposed “Taza” MPA.

155 The aim of this study is to evaluate the potential conflicts between illegal REC
156 and commercial SSF and to compare their catches and fishing effort in the area of
157 the proposed “Taza” MPA. This study can be extremely valuable in terms of MPA
158 planning and fisheries monitoring by providing baseline data for the managers of this
159 proposed MPA in their work to set up sound fisheries management and conservation
160 plans. To this end, SSF data were used together with REC data from the perspective
161 of the development of integrated fisheries management plans. Therefore, the future
162 management plan of this MPA will serve as a scientific reference for ensuring both
163 safeguarding of the commercial fisheries, especially SSF which is the main socio-
164 economic activity in the study area (Chakour, 2012), and the sustainability of the
165 REC which become increasingly important in the economies of a number of
166 Mediterranean countries (Pita et al., 2017; Babali et al., 2018; Lloret et al., 2018).
167 Moreover, the study is geographically focused on the southern part of the
168 Mediterranean basin, a region where little is known about REC and on a forthcoming
169 MPA that will play a crucial role to stimulate the implementation of specific measures
170 for enhancing fisheries management in this region.



171 **Fig. 1.** Map showing the location and zoning plan of the proposed “Taza” MPA, Algeria.

172 **2. Materials and Methods**

173 *2.1. Study area*

174 Two fishing harbors are located near the proposed “Taza” MPA: Boudis (latitude
 175 36° 49’ 6”N, longitude 5° 46’ 27”E) and Zama (latitude 36° 40’ 37”N, longitude 5° 28’
 176 44”E) pending the completion of work to build a third port in the municipality of El-
 177 Aouana (Fig. 1). This study was conducted in the fishing harbor of Zama, located in
 178 the South-Western Mediterranean Sea off the Gulf of Béjaia in Algeria (Fig. 1). In
 179 2009, with the support of the network of MPA managers in the Mediterranean
 180 (MedPAN), Taza National Park began a process to include its adjacent marine area
 181 covering 9603 ha (Boubekri and Djebbar, 2016). The planned MPA (latitude 36° 41’
 182 13”N and 36° 53’ 19”N; longitude 5° 30’ 26”E and 5° 41’ 15”E) is located in the East
 183 part of the Gulf of Béjaia and extends about 23 km along rocky coasts and sandy
 184 beaches (Fig. 1). Along this Gulf, the fishing harbor of Zama has traditionally been
 185 home to an important fishing community including both recreational and professional
 186 fishers (Boubekri et al., 2019).

187 Furthermore, one of the specificities of this fishing harbor is the absence of the
 188 Algerian Coast Guard (in Algeria, the Algerian Coast Guard has responsibility for
 189 supervising fishing activity), which encouraged a practice of illegal REC on a large

190 scale (Kacher, 2010). According to Kacher (2010), the use of nets in RBF is now a
191 common fishing technique for almost half of the REC fishers in the study area. It
192 should be noted that nets are not prohibited to REC fishers provided that they are
193 holding a special authorization issued by local fisheries authorities. However, a
194 significant number of recreational fishers sold their catch, a practice which is at odds
195 with what the Algerian regulation defines as recreational fishing (see Table 1).

196 *2.2. Data collection*

197 The fishing harbor of Ziama is the only harbor in the study area where
198 recreational catches are reported. In this study, catch data were collected via a direct
199 observation method of landings (Griffiths et al., 2007; Merrien et al., 2008). On a daily
200 basis from May 2013 to April 2014, and with the help of two observers from the
201 DPRH of Jijel, all the recreational boats involved in illegal REC in the fishing harbor of
202 Ziama were surveyed. In total, 32 recreational boats out of 46 (70%) were considered
203 in this study. For these boats, all fishing trips were taken into account.

204 It should be noted that the same survey method was used by Boubekri et al.
205 (2018) for SSF for the surveying of 24 small-scale boats. Moreover, both REC and
206 SSF surveys did cover the same study area and were conducted throughout the
207 same studied year. Details of SSF survey are given in Boubekri et al. (2018). The
208 catch and fishing effort data of SSF were used in this article to highlight the potential
209 conflicts between commercial SSF and illegal REC. For each fishing category three
210 variables were considered in this study: 1) the mean Fishing Trips (FT) - this was
211 calculated monthly as the number of fishing trips per boat per day and used as an
212 indicator of fishing effort; 2) the Mean Catch (MC) - this was calculated monthly as
213 mean catch per active boat per day (kg/boat/day); and 3) average Species Richness
214 (SR) in the catch - this was calculated monthly as the total number of species (or
215 higher taxonomic level) caught per boat per day.

216 The choice of Ziama harbor allowed us to overcome logistical constraints (i.e.
217 widespread geographical dispersion of landing places) while targeting a significant
218 component of illegal recreational boats that are mainly operational in the western
219 perimeter of the proposed "Taza" MPA (Fig. 1). As boats returned to the harbor,
220 catch data was collected by counting the number of fish crates and expressing the
221 weight in (kg). However, when fish crates were not classified by species (i.e. genus

222 or family), the weights recorded were grouped at a higher taxonomic level (please
223 see Appendix A for more details about the concerned species).

224 In addition, weekly surveys were conducted using semi-quantitative
225 questionnaires to obtain information on: 1) target species, 2) fishing gear used, and
226 3) visited fishing ground (depth, location, and habitat characteristics). For the latter,
227 map-based interviews were conducted with fishers, for which the interviewer and the
228 informant used a hard copy map (Close and Hall, 2006). It should be noted that
229 fishers' Traditional Ecological Knowledge (TEK) is recognized as an effective tool for
230 the management of artisanal fisheries and MPAs in the Mediterranean (Coll et al.,
231 2014; Léopold et al., 2014; Pita et al., 2016).

232 In contrast to the survey carried out for SSF in this fishing harbor (see Boubekri
233 et al., 2018), the collection of catch data classified by gear was not possible because
234 illegal recreational fishers appeared reluctant to provide this information, most likely
235 because they are practicing IUU fishing. In its place, an inventory of the fishing gears
236 used by illegal recreational fishers was listed based on field observation (see Table
237 3).

238 *2.3. Data analysis*

239 We used a Kruskal-Wallis H test to test for main differences between the three
240 variables: fishing trips (FT), mean catch (MC), and specific richness (SR) among the
241 four seasons, and a Mann-Whitney U test to test the same variables (FT, MC, and
242 SR) using seasonal mean values for comparisons between illegal REC and SSF. In
243 this perspective we ran the Kruskal-Wallis H test among the seasonal mean daily
244 values, while the Mann-Whitney U test was run between the mean daily values of
245 illegal REC and SSF. We have chosen non-parametric statistical tests because our
246 data did not meet the assumptions required for parametric statistics. The level of
247 significance was $\alpha = 0.05$. All the statistical analysis was performed using Prism
248 version 5.03 for Windows.

249 The fishing grounds visited by recreational and professional fishers as inferred
250 from the map-based interviews, have been processed in relation to the number of
251 fishing trips (frequency of visits), using the software ArcGIS 10.3.1. ESRI (Falautano
252 et al., 2018). In order to evaluate spatial competition between the two fishing

253 categories, the total counts of fishing trips directed by illegal REC and SSF in each
 254 fishing area is represented as a point with geographical coordinates corresponding to
 255 the center of that area and visualized on a georeferenced map as a pie chart whose
 256 width is proportional to the total frequency of visits partitioned per illegal REC and
 257 SSF.

258 3. Results

259 3.1. Illegal REC fleet composition, gears used, target species, and fishing effort

260 3.1.1. Illegal REC fleet composition

261 In total 1839 fishing trips, covering 16 fishing grounds were completed during
 262 the study year and 32 recreational boats were found to be active.

263 RBF in the area of the proposed “Taza” MPA was carried out by 46 boats. 70%
 264 of these boats (32 boats) were considered in this study (Table 2). This is the total
 265 number of recreational boats that sold their catches to sale operators inside the
 266 fishing harbor of Ziama and involved in illegal REC.

267

268 **Table 2.** Fleet characteristics (range and average) of the overall length (m) and engine power (kW) of
 269 the two fishing boats categories: REC, illegal recreational boat (present study) and SSF, small-scale
 270 boats (Boubekri et al., 2018).

271 Boat 272 category	Number of active boats	273 Fleet characteristics	
		274 Overall length (m)	275 Engine power (kW)
276 Recreational 277 (REC)	32	3.5 – 5.8 (4.61)	7 – 63 (17.05)
Professional (SSF)	24	4.8 – 10 (6.53)	15 – 180 (46.07)

278 3.1.2. Gears used and target species

279 The illegal REC fishers of Ziama Harbor use a variety of gears and target a
 280 wide range of commercial species (Table 3). Among the gears used, we count nets
 281 the use of which is restricted.

282

283

284

285 **Table 3.** Gears used and target species of REC (present study) and SSF (Boubekri et al., 2018) at the
 286 fishing harbor of Ziama, Jijel, Algeria. (REC, illegal recreational fishing; SSF, small-scale fishing).
 287 *Sensu* FAO (1980).

288	Fishing category	Gear	Standard abbreviation	FAO code	Main target species
289	SSF & REC	Set gillnets (anchored)	GNS	07.1.0	<i>Pagellus</i> spp., European hake, scorpionfish
290					
291	SSF & REC	Driftnets	GND	07.2.0	Atlantic Bonito, bullet tuna
292					
293	SSF & REC	Trammel nets	GTR	07.5.0	Red mullets, sparids, cuttlefish
294					
295	SSF & REC	Gillnets (not specified)	GN	07.9.1	Sparids, Greater amberjack
296					Atlantic bonito
297	REC	Handlines and pole-lines (hand operated)	LHP	09.1.0	<i>Serranus</i> spp., <i>Dentex</i> spp. <i>Pagellus</i> spp.
298					
299					
300	REC	Handlines and pole-lines (mechanized)	LHM	09.2.0	<i>Dentex</i> spp., <i>Epinephelus</i> spp.
301					
302					
303	REC	Drifting longlines	LLD	09.4.0	Swordfish
304					
305	REC	Trolling lines	LTL	09.6.0	Greater amberjack, Atlantic bonito
306					
307	REC	Hooks and lines (not specified)	LX	09.9.0	<i>Serranus</i> spp., sparids
308					

309 3.1.3. Fishing effort

310 The total counts of fishing trips carried out by recreational fishers identified a
 311 more equally distributed effort between spring and summer, where most of the fishing
 312 trips occurred, and also between autumn and winter (Table 4). Spring was thus the
 313 season where recreational fishers carried out the most fishing trips during the year
 314 with 31.64% followed by summer which accounted for 31.04% of the total fishing trips
 315 (Table 4).

316 **Table 4.** Number of the total fishing trips per month and per season for REC (present study) and SSF
 317 (Boubekri et al., 2018) at the fishing harbor of Ziama, Jijel, Algeria. (REC, illegal recreational fishing;
 318 SSF, small-scale fishing). The numbers of the total monthly active boats between May 2013 and April
 319 2014 are indicated between brackets. An active boat is defined as a boat carrying out at least 1 fishing
 320 trip during the month.

321	Months	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14
322	REC	205	227	220	124	114	136	85	125	143	83	123	254
323		(22)	(24)	(25)	(19)	(20)	(20)	(18)	(18)	(19)	(20)	(15)	(24)
324	SSF	175	278	130	98	53	33	43	136	93	39	97	155
325		(18)	(21)	(13)	(14)	(10)	(8)	(8)	(10)	(8)	(7)	(19)	(11)
326	Total		Summer			Autumn			Winter			Spring	
327	REC		571			335			351			582	
328			(32)			(29)			(25)			(31)	
329	SSF		506			129			268			427	
330			(24)			(13)			(11)			(19)	

331 The difference in fishing effort allocation among seasons was not significant for
 332 REC but it was highly significant for SSF (Table 5).

333 **Table 5.** Kruskal-Wallis H analysis of variance for FT, MC, and SR and Mann-Whitney U comparisons
 334 between REC (present study) and SSF (Boubekri et al., 2018). FT, fishing trips; MC, mean catch; SR,
 335 specific richness; REC, recreational boat fishing; SSF, small-scale fishing; SUM, summer; AUT,
 336 autumn; WIN, winter; SPR, spring. Between brackets Standard Deviations s.d.

Catch and effort Characteristics	Kruskal-Wallis H for REC					Kruskal-Wallis H for SSF				
	SUM	AUT	WIN	SPR	P	SUM	AUT	WIN	SPR	P
FT mean values (s.d.)	8.157 (4.193)	6.321 (3.675)	7.313 (3.697)	8.083 (4.238)	0.0526	8.437 (4.696)	3.824 (1.466)	5.000 (1.927)	6.412 (2.274)	< 0.0001
MC mean values (s.d.)	5.299 (5.202)	3.343 (1.851)	3.760 (1.654)	4.019 (2.024)	0.0591	21.02 (15.54)	7.866 (7.623)	4.509 (1.689)	9.669 (10.59)	< 0.0001
SR mean values (s.d.)	5.942 (3.338)	3.740 (2.058)	5.043 (2.377)	5.761 (3.647)	0.0010	9.371 (3.612)	4.156 (2.952)	4.628 (2.171)	6.368 (4.772)	< 0.0001

337 However, by using seasonal mean values of FT, the Mann-Whitney U test showed
 338 significant differences in the fishing effort between REC and SSF only in the cold
 339 season (autumn and winter) (Table 6).

340 **Table 6.** Mann-Whitney U comparisons for FT, MC, and SR between REC (present study) and SSF
 341 (Boubekri et al., 2018). FT, fishing trips; MC, mean catch; SR, specific richness; REC, recreational
 342 boat fishing; SSF, small-scale fishing; SUM, summer; AUT, autumn; WIN, winter; SPR, spring.
 343 Between brackets Standard Deviations s.d.

Catch and effort Characteristics	Mann-Whitney U test for REC vs. SSF									
	REC		SUM		AUT		WIN		SPR	
FT mean values (s.d.)	8.157 (4.193)		6.321 (3.675)		7.313 (3.697)		8.083 (4.238)			
MC mean values (s.d.)	5.299 (5.202)		3.343 (1.851)		3.760 (1.654)		4.019 (2.024)			
SR mean values (s.d.)	5.942 (3.338)		3.740 (2.058)		5.043 (2.377)		5.761 (3.647)			
SSF	SUM		AUT		WIN		SPR			
FT mean values (s.d.)	8.437 (4.696)		3.824 (1.466)		5.000 (1.927)		6.412 (2.274)			
MC mean values (s.d.)	21.02 (15.54)		7.866 (7.623)		4.509 (1.689)		9.669 (10.59)			
SR mean values (s.d.)	9.371 (3.612)		4.156 (2.952)		4.628 (2.171)		6.368 (4.772)			
REC vs. SSF	U	P	U	P	U	P	U	P		
FT	2481	0.9884	517	0.0008	636	0.0015	1998	0.0585		
MC	421	< 0.0001	531.5	0.0013	775	0.0406	1554	0.0002		
SR	1201	< 0.0001	798	0.9885	904	0.3877	2375	0.8702		

344

345

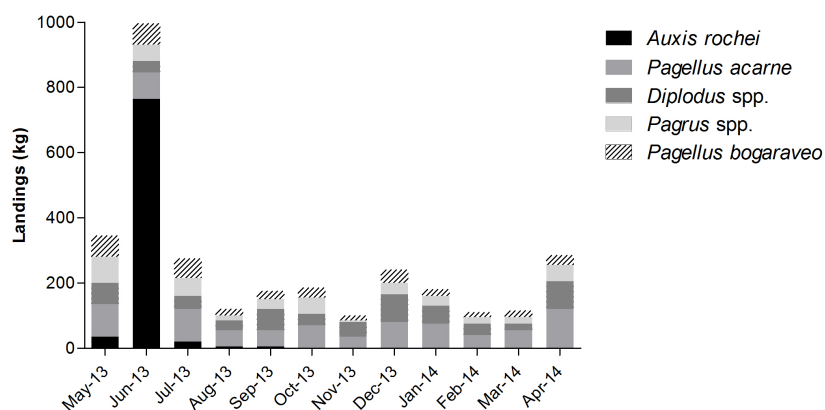
346

347 3.2. Catch composition and seasonal distribution patterns

348 3.2.1. Catch composition

349 A total of 54 taxa belonging to 24 families were observed in the catches of the
350 32 illegal recreational active boats, reflecting a highly varied exploitation of the fauna,
351 constituted of 50 species (or higher taxonomic level) of fish (47 Actinopterygii and 3
352 Elasmobranchii), 2 species of crustaceans *Palinurus elephas* and *Scyllarides latus*,
353 and 2 species of cephalopod molluscs *Octopus vulgaris* and *Sepia officinalis*. The
354 Sparidae family was the best represented in the total catches because 20 of the 54
355 species belonged to that family. In total, 7.7 tons of illegal REC total catch were
356 assessed, of which 40.58% consisted of the 5 main target species: the bullet tuna
357 *Auxis rochei* (10.78%) and 4 species of Sparidae: *Pagellus acarne* (11.10%),
358 *Diplodus* spp. (7.73%), *Pagrus* spp. (5.71%), and *Pagellus bogaraveo* (5.26%) (Fig.
359 2). It should be noted that the bullet tuna is the dominant catch during the month of
360 June which coincides with its coastal presence, while it is almost absent the rest of
361 the year as opposed to the other species (Fig. 2). Moreover, the resulting mean catch
362 among seasons was not significant for REC but it was highly significant for SSF (see
363 Table 5). By using the seasonal mean values of the MC, the Mann-Whitney U test
364 showed that the difference in the mean catch between REC and SSF is significant
365 among all seasons, especially in the warm season (spring and summer) (see Table
366 6).

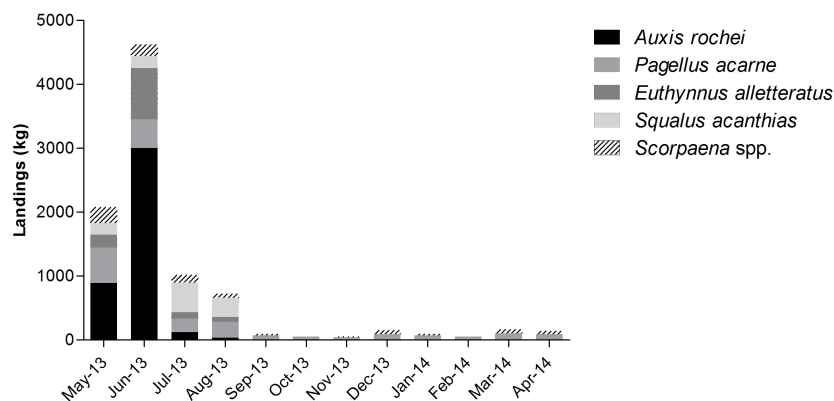
367



368 **Fig. 2.** Monthly mean of daily landings of the most-abundant species (those that accounted for over
369 5% of the total catch) for illegal REC (present study).

370 For SSF, a total of 40 taxa belonging to 27 families were observed in the
371 catches of the 28 small-scale boats of the harbor of Zياما between May 2013 and

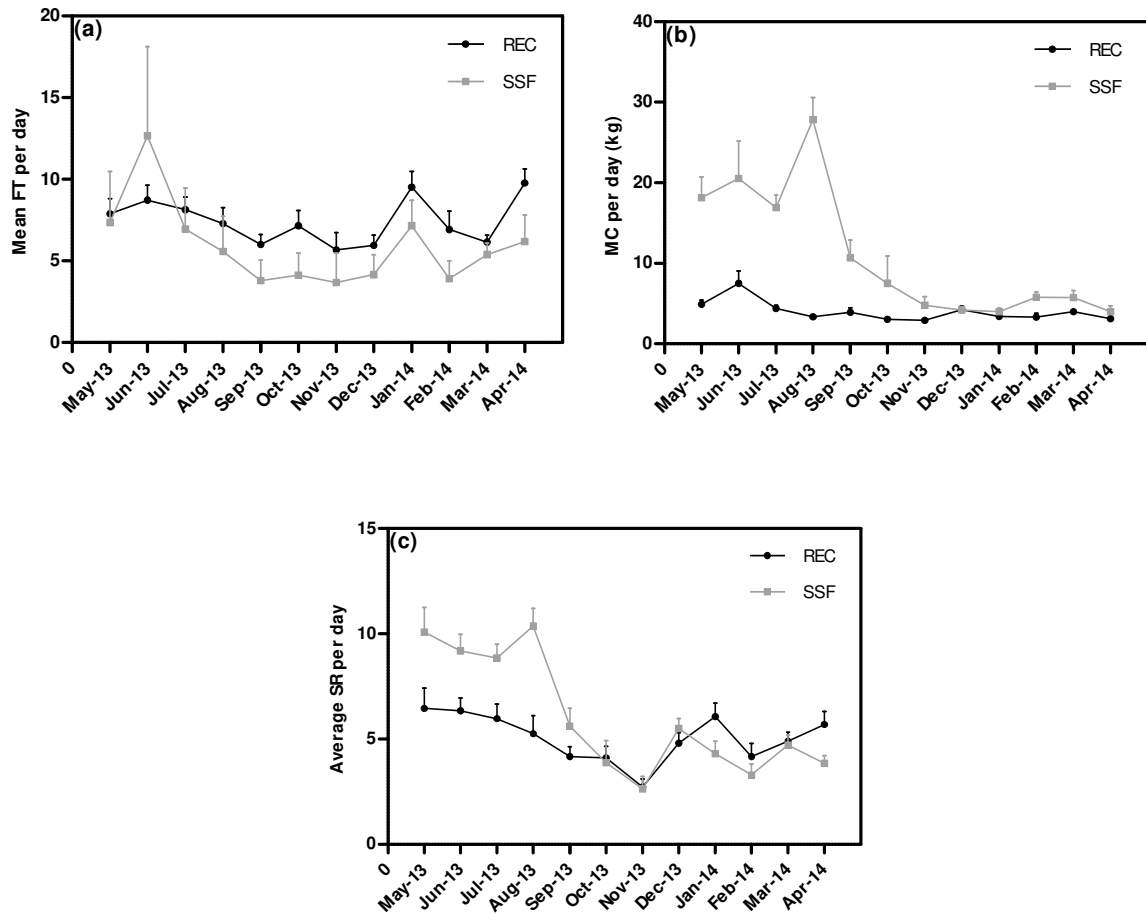
372 April 2014, comprising of 36 species (or higher taxonomic level) of fish (31
 373 Actinopterygii and 5 Elasmobranchii), 1 of crustaceans *Palinurus elephas*, and 3 of
 374 cephalopod molluscs *Loligo vulgaris*, *Octopus vulgaris*, and *Sepia officinalis*. In total,
 375 15.215 tons of catch were assessed, of which 60.50% consisted of the 5 main target
 376 species: *Auxis rochei* (26.55%), *Pagellus acarne* (13.31%), *Euthynnus alletteratus*
 377 (7.76%), *Squalus acanthias* (7.46%), and *Scorpaena* spp. (5.42%) (Fig. 3). The data
 378 obtained are summarized in Appendix A where the list of species (or higher
 379 taxonomic level) caught and their total catches per fishing category are reported.



380 **Fig. 3.** Monthly mean of daily landings of the most-abundant species (those that accounted for over
 381 5% of the total catch) for SSF (Boubekri et al., 2018).

382 3.2.2. Seasonal distribution patterns

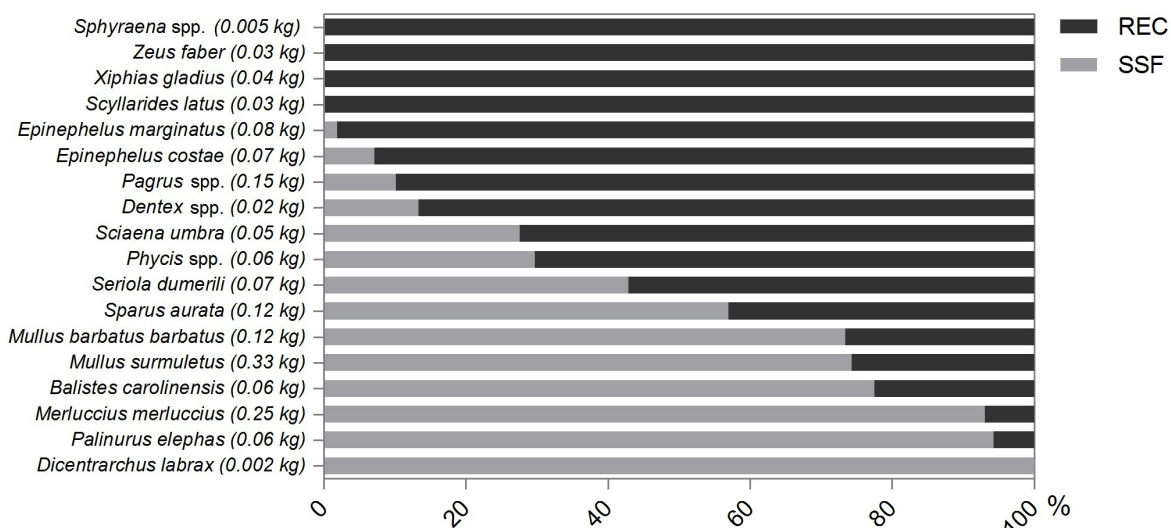
383 The monthly mean of daily values for the two variables (MC and SR) showed
 384 that illegal REC and SSF varied throughout the year (Fig. 4). However, the results of
 385 the Kruskal-Wallis statistical test showed that FT did not vary significantly between
 386 seasons for illegal REC ($H = 7.704$, $P = 0.0526$), while the difference was extremely
 387 significant for SSF ($H = 53.90$, $P < 0.0001$) (see Table 5). Fig. 4b shows that during
 388 the warm season (i.e. May to September); MC for SSF was higher than for illegal
 389 REC. However, for the rest of the year, this variable was almost the same for both
 390 fishing categories. Species richness varied consistently at the temporal scale (i.e.
 391 months) for both professional and recreational fisheries, with higher values during the
 392 warm season (from May to September) (Fig. 4c). However, the SR in the catches of
 393 SSF decreased significantly after September while it increased for illegal REC and
 394 maintained such higher values during the whole cold season (i.e. from October to
 395 April).



396 **Fig. 4.** (a) Monthly mean of daily Fishing Trips (FT + s.e.), (b) Monthly mean of daily catch (kg) (MC +
 397 s.e.), and (c) Monthly average of daily Species Richness (SR + s.e.) for REC (present study) and SSF
 398 (Boubekri et al., 2018) at Ziama fishing harbor, Algeria (SW Mediterranean). REC, illegal recreational
 399 fishing; SSF, small-scale fishing.

400 3.3. Catch economic value

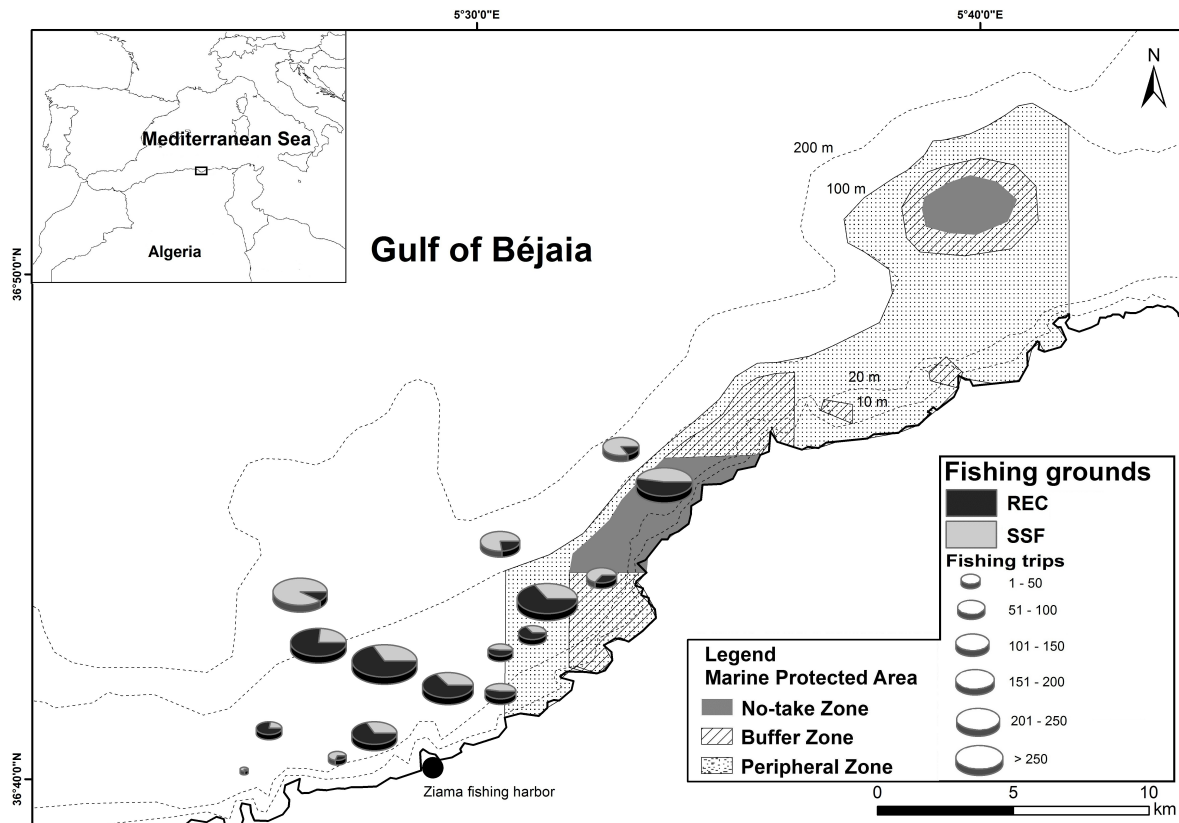
401 High economic value species such as *Scyllarides latus*, *Xiphias gladius*, *Zeus*
 402 *faber*, and *Sphyræna* spp. were caught exclusively by illegal REC while
 403 *Dicentrarchus labrax* was caught exclusively by SSF (Fig. 5). Whilst the recreational
 404 and the professional fishers competed for *Sparus aurata* and *Seriola dumerili*
 405 (between 40% and 50% for species caught respectively by illegal REC), species such
 406 as *Mullus barbatus barbatus*, *Mullus surmuletus*, *Balistes carolinensis*, *Merluccius*
 407 *merluccius*, and *Palinurus elephas* were caught mainly by SSF (between 73% and
 408 94% of species caught). For the remaining high economic value species, they were
 409 caught mainly by illegal REC between 70% (i.e. *Phycis* spp. and *Sciaena umbra*),
 410 80% (i.e. *Dentex* spp. and *Pagrus* spp.), and 92% and 98% for *Epinephelus costae*
 411 and *Epinephelus marginatus*, respectively (Fig. 5).



412 **Fig. 5.** Mean daily catch (kg) of high economic value fish species (as defined by Ben Lamine et al.,
 413 2018, see also Appendix B for further details), for REC (present study) and SSF (Boubekri et al., 2018)
 414 and percentage per fishing category. REC, illegal recreational fishing; SSF, small-scale fishing. Daily
 415 catch calculated on the number of total fishing trips.

416 3.4. Spatial fishing effort distribution

417 The area of the proposed “Taza” MPA is home to many fishing grounds used by
 418 both recreational and professional Ziama harbor fleets (Fig. 6). The 16 fishing
 419 grounds used by the Ziama harbor SSF boats, as identified in a previous study by
 420 Boubekri et al. (2018), were also exploited by the illegal recreational boats in this
 421 study (Fig. 6). Four fishing grounds located inside the perimeter of the proposed
 422 “Taza” MPA were used by recreational fishers representing 32.08% of total fishing
 423 trips. Moreover, the REC spatial patterns showed a high concentration of fishing
 424 effort near the harbor, especially at a depth between - 20 and - 100 m (Fig. 6). In
 425 addition, the relatively offshore fishing grounds were mainly used by SSF fishers
 426 while the most costal ones were largely exploited by recreational fishers (Fig. 6).



427 **Fig. 6.** Concentration of fishing trips within the different fishing grounds. The width of the pie chart is
 428 proportional to the total number of fishing trips in each fishing area (frequency of visits) partitioned per
 429 REC (present study) and SSF (Boubekri et al., 2018). REC, illegal recreational fishing; SSF, small-
 430 scale fishing

431

432 **4. Discussion**

433 The present study provides relevant information on the illegal REC in the area
 434 of the proposed “Taza” MPA (SW Mediterranean, NE Algeria). Illegal recreational
 435 fishers use all fishing gears SSF fishers use except the purse seine (Boubekri et al.,
 436 2018), they compete in some target species and sell their catch illegally rather than
 437 using it for personal or family consumption. This finding is in agreement with what
 438 Ben Lamine et al. (2018) have reported at two future MPAs in Tunisia (SW
 439 Mediterranean). Furthermore, Kacher (2010) already indicated a strong competition
 440 between recreational and professional fishers in the area of the proposed “Taza”
 441 MPA. In Mediterranean MPAs, recreational fishing competes for space and resources
 442 with other marine uses such as traditional artisanal fishing (Lloret and Font, 2013;
 443 Prato et al., 2016; Tunca et al., 2016; Ben Lamine et al., 2018; Venturini et al., 2019).

444 Given that MPAs are crucial tools for marine biodiversity conservation and
445 sustainable utilization of marine resources through fisheries management (García-
446 Charton et al., 2008; Alós and Arlinghaus, 2013), monitoring of REC must be a
447 priority for MPA managers, or else consequences of such an unmonitored activity
448 may negate the expected conservation outcomes. Moreover, the combined impact of
449 recreational and commercial fisheries leads to serious consequences on the
450 management of coastal fisheries (Albouy et al., 2010; Veiga et al., 2010; Lloret and
451 Font, 2013; Marengo et al., 2015; Prato et al., 2016).

452 The proposed “Taza” MPA is used extensively as a recreational fishing location
453 by the local population. These recreational fishers use a wide variety of gears and the
454 total count of fishing trips show a more equally distributed effort within two periods of
455 the year; from October to April (cold season) and from May to September (warm
456 season). Our results highlight the pressure that the illegal recreational fishers exert
457 on the coastal resources in this area, where the sea fishing days mean is 7.56 ± 4.04
458 days per month. Lower values for individual monthly fishing effort have been
459 observed in other western Mediterranean regions (spear fishers included) such as in
460 Majorca Island (5.5 ± 0.11 ; Morales-Nin et al., 2005), the Portofino MPA (2.08 ± 1.75 ;
461 Venturini et al., 2019), and in Tunisia (4 ± 2 ; Ben Lamine et al., 2018), while
462 comparable values have been found in Cap de Creus (8.13, typically during the
463 weekends, and 5.78 typically between April and September; Lloret et al., 2008).
464 Moreover, the monthly fishing effort of illegal REC is also higher than what Boubekri
465 et al. (2018) have found for SSF (i.e. 6.38 ± 2.49 days per month), which can most
466 likely be attributed to the fact that illegal REC is practiced intensively during the whole
467 year.

468 Spatial information is a crucial element in the zonal management and design of
469 MPAs (Costello et al., 2010; Parnell et al., 2010). The knowledge of the spatial
470 distribution of the fishing effort thus provides valuable elements to the managers of
471 the proposed “Taza” MPA in terms of identification of the most frequented areas in
472 order to estimate the pressures and impacts on the fishing habitats. The proposed
473 zoning plan was conceived with support from the MedPAN network within the
474 MedPAN South Project (Gomei and Di Carlo, 2012). Data from the survey conducted
475 between 2009 and 2012 in this area assessed marine biological diversity (Ramos-
476 Espla, 2010), fisheries (Kacher, 2010), and socio-economic aspects (Chakour, 2012;

477 Grimes, 2010) and served as a basis to achieve the final proposal which was then
478 subjected to a wide consultation process within the different user-groups of the
479 proposed MPA to avoid social conflicts and economic impacts.

480 In our case study, the spatial patterns of the fishing activity show a competition
481 between illegal REC and SSF in all the 16 fishing grounds although at different
482 levels. However, the frequency of fishing trips results and their spatial distribution
483 show that both illegal REC and SSF are practiced regularly in one of the proposed
484 no-take zones. This argues for a strengthening of controls in this area once the MPA
485 is established. Moreover, and taking into account the distances to the fishing harbor,
486 our results show a higher concentration of fishing effort by illegal REC than by SSF in
487 fishing grounds near the fishing harbor, while the SSF boats operate mainly in the
488 most remote fishing grounds. This disparity can be related to the differences in boat
489 technical characteristics. In fact, the characteristics of the SSF boats (larger than
490 recreational ones) allow them to explore offshore fishing areas. Furthermore, the
491 results of the monthly distribution of fishing activity do not show seasonality for illegal
492 REC, in contrast to SSF where summer represents the season of highest fishing
493 activity (i.e. maximum number of fishing trips).

494 According to Boubekri et al. (2018), the activity of SSF in the fishing harbor of
495 Ziama is distinctly seasonal, requiring fishers to rotate between various métiers
496 throughout the year and to adapt to variations in resource availability. Due to the
497 illegal selling of the catch by recreational fishers, a similar behavior to SSF fishers is
498 now observed for REC fishers. Illegal REC is thus practiced year-round with almost
499 the same intensity, using a variety of gears (e.g. rod, lines, nets, etc.) and capturing a
500 total number of 54 fish species. Our results do not coincide with those obtained for
501 recreational boat fishers in Spain which are characterized by a pronounced
502 seasonality in the distribution of fishing activity, with a maximum in summer and a
503 minimum in winter (Morales-Nin et al., 2005; Lloret et al., 2008), nor with those
504 reported by Ünal et al. (2010) in Turkey, where autumn and winter are the preferred
505 seasons for recreational boat-based fishing. These disparities in seasonality are due
506 to the fact that most recreational fishers in the study area are practicing REC for
507 livelihood and commercial purposes rather than leisure as opposed to many
508 especially in developed countries around the Mediterranean basin who practice it
509 mainly for pleasure during summer holidays.

510 In the proposed “Taza” MPA the SSF show discernible seasonal fishing effort
511 patterns with the highest activity during summer. This corresponds to the period of
512 cessation of trawler activity in the three nautical mile zone (starting on the 1st of May
513 and ending on the 31th of August each year) as advocated by the Algerian legislation
514 (Decree No. 04-74 of 24 April 2004). In fact, this is the period where most of the
515 fishing trips occur for SSF (51.20%) which can be responsible for the statistically
516 significant differences in the fishing trips between illegal REC and SSF (Mann-
517 Whitney test; $U = 21386$, $P = 0.0006$). Boubekri et al. (2018) have mentioned the
518 spatial competition and conflicts between small-scale and trawl fisheries in relatively
519 offshore areas, while this study shows a new conflict with recreational fishers in most
520 coastal fishing areas (near the harbor). The SSF appear thus to be the most affected
521 by this spatial competition.

522 Consequent to this high fishing effort, recreational fishers target a large number
523 of species (i.e. 54) and one of the highest compared to the number of species caught
524 in other western Mediterranean regions (e.g. 58 species in the MPA of Cap de Creus;
525 Lloret and Font, 2013; 54 species in Majorca Island; Morales-Nin et al., 2005; 51
526 species in the Strait of Çanakkale; Ünal et al., 2010; 44 species in Portofino MPA;
527 Venturini et al., 2017; and 32 species in Serra Gelada Marine Park; Luna-Pérez,
528 2010). According to Sheaves et al. (2016), some recreationally targeted species are
529 being overexploited. As a result, in some cases effort is shifted towards new target
530 species which may include endangered ones (Bower et al., 2014). Thereby, five of
531 the species caught by illegal REC in the study area are included in Annex III of the
532 Barcelona Convention (i.e. *Epinephelus marginatus*, *Palinurus elephas*, *Sciaena*
533 *umbra*, *Scyllarides latus*, and *Xiphias gladius*), which lists those species whose
534 exploitation should be regulated because they are vulnerable to fishing (UNEP-MAP-
535 Barcelona Convention, 2011). Furthermore, four species are also included in the Red
536 List of the IUCN as endangered: *Epinephelus marginatus* or vulnerable: *Dentex*
537 *dentex*, *Merluccius merluccius*, and *Sciaena umbra* (Abdul Malak et al., 2011).
538 However, it is noteworthy to mention here that these species are not yet frequently
539 caught by illegal recreational fishers. The increase of recreational boat anchoring
540 areas also causes huge damages on coastal habitats and especially seagrass
541 meadows, one of the key habitats of two iconic Mediterranean marine coastal fish:
542 *Sciaena umbra* and *Dentex dentex* (Marengo et al., 2015).

543 Comparing illegal REC catches from this study with commercial SSF catches is
544 interesting. In the fishing harbor of Ziama, 24 professional SSF boats operate in the
545 area of the proposed “Taza” MPA, predominantly gillnetters. Their commercial
546 landings amount was 15.2 tons between May 2013 and April 2014 (Boubekri et al.,
547 2018). The annual illegal REC catch studied here for the same period, was about 7.7
548 tons. Consequently, the illegal REC contribute significantly to fishing mortality as the
549 proportion of the harvest attributed to illegal REC represents about 50% of the small-
550 scale fishery harvest. This is by far higher than the world average (12% according to
551 Cooke and Cowx, 2004) and also compared to what has been reported (i.e. ~30%) in
552 many Mediterranean regions such as Cap de Creus in Spain (Lloret et al., 2008) and
553 the Strait of Çanakkale in Turkey (Ünal et al., 2010). Our results therefore show a
554 huge biological impact of illegal REC, which can exacerbate the magnitude of the
555 negative effects of high fishing mortality on coastal fish stocks, especially vulnerable
556 species characterized by slow growth and late maturity, by limiting their reproductive
557 potential (Roberts and Hawkins, 1999). Moreover, the competition between illegal
558 REC and SSF for the natural resources in the proposed “Taza” MPA is highly
559 important since the two main species targeted by SSF (i.e. *Pagellus acarne* and
560 *Auxis rochei*) (Boubekri et al., 2018) are among the most-abundant species
561 (accounting each for over 10% of the total catch) targeted by recreational fishers.

562 In addition, compared with commercial fishing mean catch per day (i.e. $12.08 \pm$
563 9.42 kg/boat/day) (Boubekri et al., 2018), recreational catches in this study represent
564 ~35% (i.e. 4.18 ± 1.38 kg/boat/day) of the mean catch. In Tunisia, Ben Lamine et al.
565 (2018) have reported a similar value (i.e. 40%) in two future MPAs. However,
566 regarding the temporal variations, for illegal REC the catch rates do not change
567 significantly between seasons, as is the case in Tunisia, but also in other
568 Mediterranean MPAs (Lloret and Font, 2013; Marengo et al., 2015). The CPUEs can
569 be strongly influenced by the varying characteristics of fishing gear, the heterogeneity
570 of fishermen’s local knowledge, seasonal patterns of abundance, and outlying data
571 due to exceptional catches (Maunder and Punt, 2004; Smith et al., 2006). For SSF,
572 the results of Boubekri et al. (2018) show the highest catch rate in summer, which
573 may be a consequence of the spatial patterns that characterize the study area
574 instead of the allocated fishing effort. Indeed, during July and August, and despite an
575 almost identical fishing effort intensity (number of fishing trips) to the period from

576 September to April, SSF record a much higher MC in summer. In fact, the fishing
577 grounds visited by SSF boats during that period, when there is less competition with
578 illegal REC, can be responsible for this situation. This is unfortunate for them, since
579 SSF fishers cannot keep the same yields throughout the year because of the trawling
580 activity carried out in these fishing grounds between September and April, the period
581 where SSF boats are forced to return to explore more coastal fishing grounds and
582 then record a lower MC, almost equivalent to those of illegal REC. The drop in MC
583 observed for SSF between September and May can most likely be attributed to the
584 high competition with illegal recreational boats in exploiting the same fishing grounds.
585 Moreover, the characteristics of the nets (i.e. big size) used by SSF allow fishers to
586 record highest MC in relatively offshore areas characterized by soft bottoms. In more
587 coastal fishing grounds however, recreational fishers are more efficient in terms of
588 fishing techniques. For instance, using small size nets, which are easily
589 manoeuvrable, allows them to explore hard bottoms better than SSF fishers.

590 Recreational activities have a core social role for coastal populations (Bellanger
591 and Levrel, 2017). In the context of this study, REC includes the activity of people
592 fishing for commercial purposes or to obtain some extra income. The current
593 economic difficulties of the local population therefore, are now putting many
594 recreational fishers in unfair competition with professional ones through selling their
595 catch on the local market. Moreover, this form of IUU fishing leads to a devastating
596 and perverse outcome of encouraging non-compliance. Furthermore, the cost of a
597 professional boat license is about 1200 USD per year while that of a recreational
598 boat is about 30 USD (DPRH of Jijel, 2014). As a consequence, a huge number of
599 small-scale professional fishers prefer to convert to recreational because of the
600 higher operational costs (i.e. from paying taxes) and consequent lower profit they
601 obtain compared to that of recreational fishers. The potential economic impact of
602 illegal REC for the future of commercial fisheries is therefore extremely significant,
603 especially as the Government does not collect any taxes from recreational fishers,
604 assuming fishers abide by the law (Babali et al., 2018).

605 The establishment of MPAs, particularly of multiple-use areas, aims to protect
606 natural populations and ecosystems and the goods and services they provide to
607 society (Watson et al., 2014; Rodríguez-Rodríguez et al., 2019). Even though
608 partially protected areas (or partial reserves) that restrict some extractive uses or

609 regulate professional and recreational fishing in different ways can potentially
610 enhance fish density and biomass (Zupan et al., 2018), the strongest fisheries
611 outcome benefits occur in areas with total exclusion of fishing activities (Roberts et
612 al., 2008; Di Lorenzo et al., 2016). The proposed “Taza” MPA is conceived as a tool
613 for developing management approaches that enable multiple-use on a sustainable
614 basis (Gomei and Di Carlo, 2012). However, unsuitable MPA establishment might
615 result in low effectiveness or even deterioration of the existing condition. This study
616 shows that REC should be taken into account given its huge impact linked to the
617 rising concern about overfishing. Indeed, the latter represents one of the main
618 challenges in marine conservation, with MPA zoning and multi-use management
619 regarded as a critical fisheries management tool (Costanza et al., 1998). To this end,
620 the development of an efficient monitoring system is a key element for understanding
621 and addressing the issues of REC (Green et al., 2005). However, to assess all
622 recreational boats operating in the area of the proposed “Taza” MPA, survey
623 techniques are required which are usually expensive and onerous to assess because
624 of the widespread geographical distribution of landing places. However, attempts to
625 better quantify the biosocioeconomic implications of REC and its relative contribution
626 to overall fishing pressure will provide managers of the proposed “Taza” MPA the
627 baseline needed to guide management actions and fisheries restrictions.

628 According to Font and Lloret (2014), subsistence fishing appears to be
629 increasing in some areas of the Mediterranean due to the current economic crisis,
630 and it is becoming increasingly difficult to distinguish between people who fish for
631 pleasure and people who fish for food. However, it is noteworthy to mention that this
632 study does not take into account subsistence fishing (i.e. fishing for food rather than
633 for commercial purposes) nor other techniques of recreational fishing (e.g. angling,
634 spearfishing, etc.). It would therefore be recommendable to collect data on all
635 recreational fishing techniques for future monitoring programs. In fact, identifying the
636 impact of each fishing technique would certainly lead to more accurate estimations of
637 recreational fishing pressure on coastal resources.

638

639

640

641 **5. Conclusion**

642 This study highlights the importance of the characterization of REC in a
643 proposed MPA considering the annual dynamic of the fishing effort and the resulting
644 catches in order to set up a sustainable fisheries management, one which takes into
645 account the global picture of the fishing pressure on coastal resources. Our results
646 show the presence of an important illegal REC in the study area with a great potential
647 impact on the coastal resources, but also on the socioeconomic situation because of
648 the unfair competition with commercial fisheries. Therefore, based on the information
649 and the data presented, some fisheries restrictions should be applied to prevent an
650 overexploitation of fishing resources, which could compromise the role of the
651 establishment of this MPA in a context of a data-poor situation and low regulation
652 enforcement. To this end, more monitoring effort is needed to detect the significant
653 number of illegal recreational fishers who use the same fishing gears as the
654 professional ones (i.e. nets) and target the same species. Moreover, illegal REC
655 distort the estimates of the real fishing effort and bias the stock assessment on a
656 national level since REC catches are not reported in official statistics.

657 **Appendix A**

658 List of caught taxa and their total weight (kg) for catches of SSF (Boubekri et al., 2018) and REC
 659 (present study). SSF, small-scale fisheries; REC, illegal recreational fisheries. For some species, the
 660 recorded weights were grouped at a higher taxonomic level; please see footnote for the concerned
 661 species.

Caught taxa	SSF landings (kg)	REC landings (kg)
Elasmobranchii		
Dasyatidae	15	25
Rajidae	195	175
Scyliorhinidae		
<i>Scyliorhinus canicula</i>	750	-
Squalidae		
<i>Squalus acanthias</i>	1135	-
Torpedinidae		
<i>Torpedo</i> spp.	75	125
Actinopterygii		
Balistidae		
<i>Balistes carolinensis</i>	155	45
Carangidae		
<i>Seriola dumerili</i>	90	120
<i>Trachurus trachurus</i>	-	305
Congridae		
<i>Conger conger</i>	20	150
Coryphaenidae		
<i>Coryphaena hippurus</i>	-	5
Gadidae		
<i>Phycis</i> spp.	55	130
Lophiidae		
<i>Lophius</i> spp.	170	-
Merlucciidae		
<i>Merluccius merluccius</i>	735	55
Moronidae		
<i>Dicentrarchus labrax</i>	5	-
Mugilidae¹	55	70
Mullidae		
<i>Mullus barbatus barbatus</i>	290	105
<i>Mullus surmuletus</i>	780	270
Muraenidae		
<i>Muraena helena</i>	30	165
Sciaenidae		
<i>Sciaena umbra</i>	40	105
Scombridae		
<i>Auxis rochei</i>	4040	830
<i>Euthynnus alletteratus</i>	1180	30.00
<i>Sarda sarda</i>	340	135
<i>Scomber</i> spp.		10
Scorpaenidae		
<i>Scorpaena</i> spp.	825	115
Serranidae		
<i>Epinephelus costae</i>	15	195
<i>Epinephelus marginatus</i>	5	255
<i>Serranus</i> spp.	-	25

Appendix A continued

Caught taxa	SSF landings (kg)	REC landings (kg)
Soleidae	35	-
Sparidae		
<i>Boops boops</i>	-	85
<i>Dentex</i> spp. ²	10	65
<i>Diplodus</i> spp. ³	380	595
<i>Lithognathus mormyrus</i>	50	65
<i>Oblada melanura</i>	20	65
<i>Pagellus acarne</i>	2025	855
<i>Pagellus bogaraveo</i>	50	405
<i>Pagellus erythrinus</i>	290	215
<i>Pagrus</i> spp. ⁴	50	440
<i>Sarpa salpa</i>	225	160
<i>Sparus aurata</i>	5	170
<i>Spicara smaris</i>	-	150
Sphyraenidae		
<i>Sphyraena</i> spp.	-	15
Xiphiidae		
<i>Xiphias gladius</i>	-	130
Zeidae		
<i>Zeus faber</i>	-	95
Trachinidae		
<i>Trachinus draco</i>	85	-
Triglidae		
<i>Trigla Lucerna</i>	115	-
Cephalopoda		
Loliginidae		
<i>Loligo vulgaris</i>	315	-
Octopodidae		
<i>Octopus vulgaris</i>	135	240
Sepiidae		
<i>Sepia officinalis</i>	260	385
Malacostraca		
Palinuridae		
<i>Palinurus elephas</i>	165	10
Scyllaridae		
<i>Scyllarides latus</i>	-	110
Total (kg)	15215	7700

662 ¹ *Mugil cephalus*, *Chelon labrosus*, *Liza aurata*, *Liza ramada*, and *Liza saliens*.

663 ² *Dentex dentex*, *Dentex gibbosus*, *Dentex maroccanus*, and *Dentex macrophthalmus*.

664 ³ *Diplodus annularis*, *Diplodus cervinus cervinus*, *Diplodus puntazzo*, *Diplodus sargus sargus*, and
665 *Diplous vulgaris*.

666 ⁴ *Pagrus auriga*, and *Pagrus pagrus*.

667 **Appendix B**

668 Fish species economic value in Algeria. As defined by Ben Lamine et al. (2018): high economic value
669 species: price per kg>the daily remuneration (i.e. 600 DZD) (18000 DZD is the minimum guaranteed
670 wage per month in 2014 in Algeria <http://www.ons.dz/-Masse-Salariale->).

Fish species	Commercial interest	Landing price per kg (DZD)
<i>Palinurus elephas</i>	High	1800
<i>Merluccius merluccius</i>	High	950
<i>Dicentrarchus labrax</i>	High	900
<i>Xiphias gladius</i>	High	900
<i>Zeus faber</i>	High	900
<i>Mullus surmuletus</i>	High	850
<i>Mullus barbatus barbatus</i>	High	800
<i>Dentex</i> spp.	High	800
<i>Scyllarides latus</i>	High	800
<i>Epinephelus marginatus</i>	High	800
<i>Epinephelus costae</i>	High	700
<i>Pagrus</i> spp.	High	700
<i>Sciaena umbra</i>	High	700
<i>Seriola dumerili</i>	High	700
<i>Sparus aurata</i>	High	700
<i>Sphyraena</i> spp.	High	700
<i>Balistes carolinensis</i>	High	600
<i>Phycis</i> spp.	High	600

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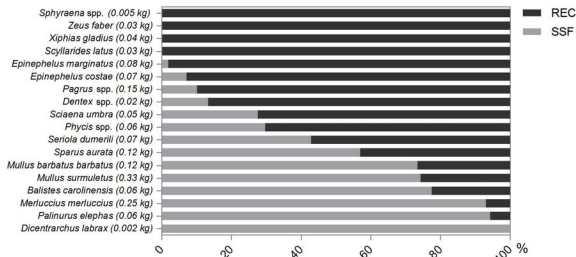
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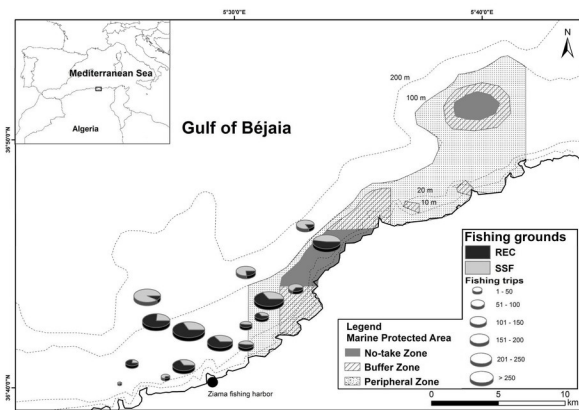
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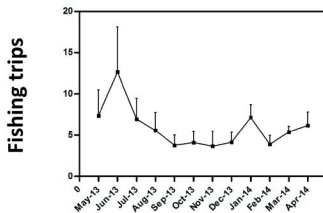
Mean daily catch (kg) of high economic value fish species



Concentration of fishing trips within the different fishing grounds

Commercial boats

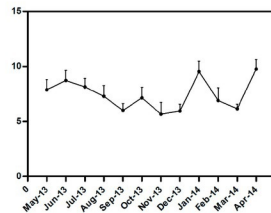
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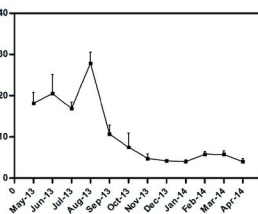
Fishing trips

Recreational boats

REC



Mean catch (kg)



Species richness

