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Holistic investigation of shore angler profiles to support marine protected areas management

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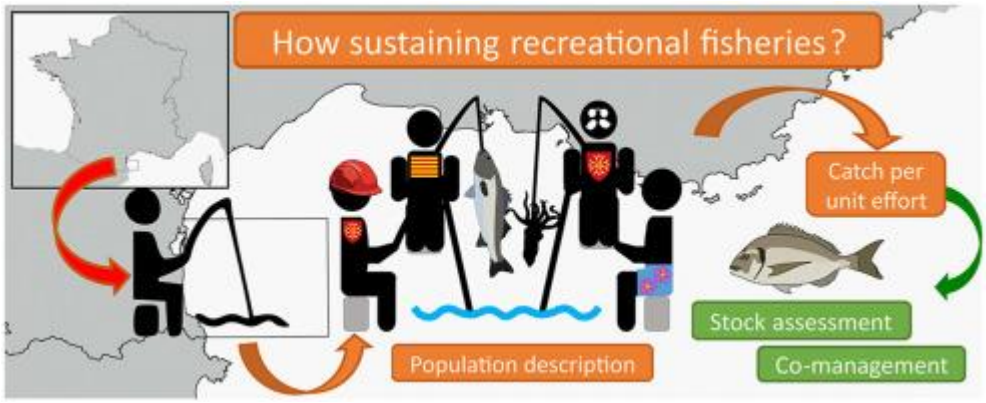
Abstract :

Marine Recreational Fishing (MRF) is growing worldwide in scientific interest, as evidenced by the increasing number of dedicated publications. Studies on the impacts and benefits to socio-ecosystems and mental health are driving this gradual awareness. In the Mediterranean, MRF is currently responsible for 10% of the catches though, in the context of small-scale fisheries decline, it may become dominant. Sustaining this activity represents a universal challenge for the future of mankind. However, the potential influence of anglers' heterogeneity on both the environment and the Catch Per Unit of Effort (CPUE), used internationally to evaluate fish harvest and as a stocks indicator, hinders MRF management. In addition, little data is available on onshore fishing, while the number of practitioners may increase sharply in the context of a socio-economic crisis, especially in marine protected areas (MPA). We conducted a year-round survey in 2017–2018 in a French Mediterranean MPA subject to tourist flows, during which 144 onshore anglers were polled by semi-directive interviews. We used a typology based on technical and socio-economic data of anglers to describe their behaviour diversity and its influence on CPUE and, more broadly, the marine environment in multi-species fisheries. We characterised four onshore angler profiles, segregated in space and time, including one identified as at risk of causing impacts. Our analyses support using total and per species CPUE independently of profiles to evaluate onshore MRF harvest, except for four species. CPUE seem based on the profiles' skills and self-regulation which induce similar yields between anglers in the absence of control. This demonstrates the importance of taking into account angler behaviour, as each profile could react differently to management actions and highlights that CPUE could be used to detect the effect of changes in regulation in the framework of adaptive management. Our results support that MRF regulations should be simplified and homogenised at the national level and cooperation with fishing shops in MPA co-management should be promoted.

Graphical abstract



Highlights

► Onshore recreational fishing is booming in Mediterranean marine protected areas. ► Lack of knowledge on anglers' behaviours hinders sustainable management. ► 4 angler's profiles segregated in space and time emerge from typological analyses. ► The profiles present similar yields (stock indicator's proxy) except for 4 species. ► The profiles exert specific pressures requiring their inclusion in marine policies.

Keywords : Anglers behaviour, Catch per unit of effort, Marine protected area, Participatory science, Recreational fisheries, Socio-ecosystems

1. Introduction

Neglected for a long time, as compared to professional fisheries, recreational fisheries (RF) are of growing interest to the scientific community (Cooke and Cowx, 2006). They are generally described as any fishing activity where the product is intended for the exclusive consumption of the angler's family (defined by the Code rural de la pêche maritime in France, Article R921-83, 2017) and could represent up to 12% of global fish harvest (Cooke and Cowx, 2004). With nearly 220 million anglers worldwide, RF could even become dominant in coastal and marine areas, where they are still marginally studied compared to freshwater (Arlinghaus et al., 2019). Scientists and authorities increasingly recognise marine recreational fisheries (MRF) impacts on fish stocks and the environment (McPhee et al., 2002) as well as their socioeconomic importance (Pita et al., 2018). As a result, they ask for better monitoring and management of the activity, as recently promulgated by the European Union for its member states (EU Parliament Adopted Text, 2018).

At this stage, the global lack of knowledge about MRF activities, particularly the heterogeneity of practitioners and their dynamics, hinders suitable management (Gordoa et al., 2019). On one hand, fishery policies are based on disputable stocks status indicators such as Catch Per Unit of Effort (CPUE), which are also used to extrapolate anglers' harvest (Freire et al., 2020). Generalised for decades in professional fisheries, CPUE involves a direct relationship between the stock's abundancy and the yields (DuFour et al., 2019), yet to be demonstrated for the various practicing populations in MRF. Indeed, the versatility of angler practices and behaviours may influence angling efficiency and raises the question of the validity of CPUE index in MRF (Cabanellas-Reboredo et al., 2017). We therefore hypothesise that the degree of specialisation and the fishing strategies specific to each angler influence his yields, but that the essence of behavioural variability can be summarised through typological approaches (Verdoit et al., 2003). In this case, the proportion of each cluster of individuals sharing common fishing habits (called profiles) would have to be taken into account in calculating the CPUE indicator, otherwise generating poor-reading of fish stocks changes detrimental to MRF management

(Maggs et al., 2016). On the other hand, the lack of knowledge about spatio-temporal fishermen distribution (Hunt et al., 2019) hinders the implementation of efficient awareness actions and restricts communication between managers and anglers. This acts against the interests of both protagonists and limits the impact of fishing regulations such as minimum catch size on stock decline. In the context of supporting sustainable management actions, participatory monitoring is an appropriate tool to characterise fishermen population as well as impacts and expectations (Brownscombe et al., 2019). It also fosters the emergence of ecological awareness and even co-management (Danylchuk and Cooke, 2011) while promoting transdisciplinary approaches and local-scale cooperation with fishermen, which often remains to be built (Symes and Hoefnagel, 2010). We therefore assume that the analysis of anglers' profiles would also provide operational guidance for RF management as their location and seasonality, as well as their knowledge, responses, and investment in the application of management measures, would be profile-dependent.

This study is at the crossroads of the work initiated by Bryan (Bryan, 1977) on the impact of specialisation on catches, which we extend to the onshore socio-ecosystem, and more recent studies on the validity of CPUE' index (Cabanellas-Reboredo et al., 2017; Ward et al., 2013). We propose an interdisciplinary approach unprecedented in France communicating local and national actions in support of RF management in the Natural Marine Park of the Gulf of Lion. We analyse a large dataset from in situ surveys to describe how the composition of the onshore fishing population and respective fishing strategies of each profile impact both the CPUE and more broadly the regional coastal socio-ecosystem in multi-species fisheries. Our study benefits fisheries management by proposing a basis for co-reflection between anglers, managers and fishing shops on the implementation of a seasonal, profile-targeted adaptive management strategy of MRF. It could thus allow a better distribution of managers' efforts both for the co-reflection activity itself and later, via the evaluation of catches, between fishing activities. Our study will support the application of the French Façade Strategic Document 2021-2027 which aims in part to set up a European action plan and surveillance program

for MRF. More broadly, this study could serve as a reference for the monitoring currently underway in the Mediterranean or even on a wider scale, as the Mediterranean represents a potential site of interest for a MRF workshop. The activity is indeed widely practised there (Giovos et al., 2018), likely by highly diverse anglers, from locals to seasonal fluxes of tourists bringing new fishing practices.

2. Material and Methods

2.1. Study area

The Natural Marine Park of the Gulf of Lion (NMPGL), established in France in 2011 (www.parc-marin-golfe-lion.fr), is the second largest park in the Mediterranean Sea (3000 km^2) (*Fig. 1*). Management objectives tend to reconcile environmental protection with human usages including fisheries and tourism (Di Franco et al., 2016). Nevertheless, no fishing licenses are yet required and there are no specific rules targeting RF (apart the Mediterranean-wide minimum catch sizes) inside the NMPGL (Agence des aires marines protégées, 2014), except in the Cerbère-Banyuls Marine Reserve (CBMNR) (www.catalanes.espaces-naturels.fr) (*Fig. 1*).

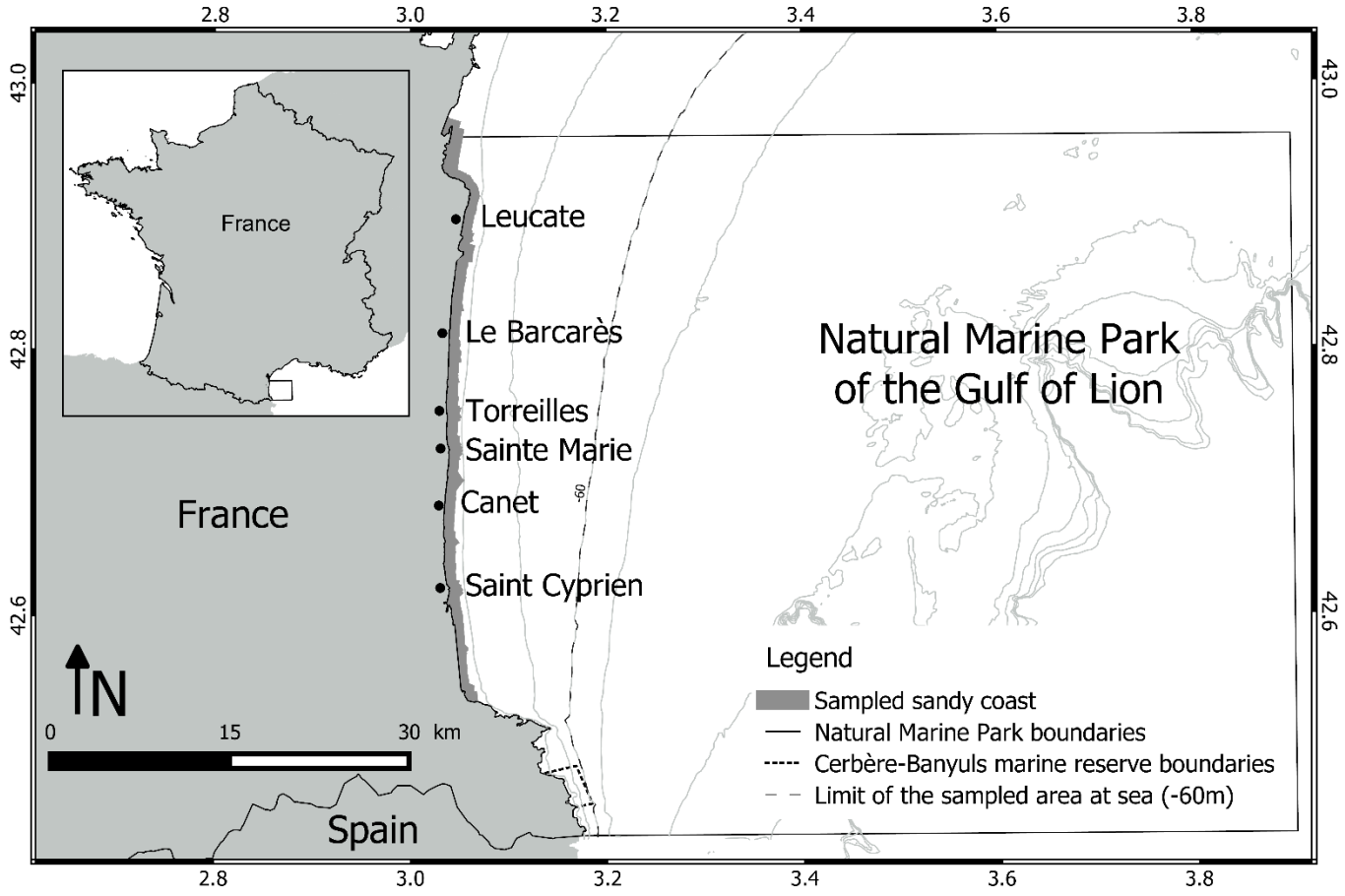


Fig. 1 (2-column fitting image*, no color*)*. Map of the study area indicating the position of the Natural Marine Park of the Gulf of Lion (NMPGL) located in the* Pyrénées-Orientales *department, France, Northwestern Mediterranean Sea. The main harbours and towns are also indicated. Shaded area indicates the sandy coast of the park where this study was conducted (60km stretch).*

67 *2.2. Surveys*

68 A total of 144 outings were performed over a year (November 2017-October 2018) to describe
69 the recreational shore fishermen population of the NMPGL's sandy coast (*Fig. 1*). The dates were
70 randomly selected. For each outing, the number of fishermen was first counted, and then over a
71 quarter were randomly polled in 20-minutes semi-directive interviews using roving-roving methods of
72 sampling, with positions registered by GPS (Lockwood, 2000). The questionnaire focused on a wide
73 range of variables (almost 120) to provide the first complete description of RF in the study area, notably
74 covering socio-economic data and fishermen habits. A second part of the questionnaire focused on the
75 day's fishing activity (techniques, baits type and origin, time allocated to fishing) and was completed
76 by a biometric catch record (species identification, weight and height measurement) to evaluate yields.
77 Over the study period, 795 fishermen were counted and 212 interviewed.

78

79 *2.3. Profiles description*

80 To select the variables that influenced the data set and avoid redundancies, the links between
81 the variables were analysed. Fisher's exact tests were performed for the variables where at least one
82 of the modalities had a statistical headcount of less than 5, and Chi-squared tests otherwise. The
83 resulting p-values were used to create a binomial matrix of significant relationships (linked or not)
84 which permitted classifying the variables by Ascending Hierarchical Classification on binary matrix.
85 After verifying the appearance of the obtained dendrogram, variables with higher weight per cluster
86 were selected and included in the final dataset used to establish typologies. This method allowed
87 selecting the variables with the fewest missing values while preserving the variability of topics included
88 in the questionnaire. Fishermen profiles were then characterised by a typology involving a Multiple

89 Correspondences Factorial Analysis followed by an Ascending Hierarchical Classification using Ward's
90 method (Lebart et al., 1997). To compare each of the profiles, obtained from sub-populations, to the
91 total sample population, each variable class frequency was compared to the population frequency
92 using Fisher's exact tests. All the statistics were performed using R software (R Development Core
93 Team, 2005).
94

2.4. Comparison of yields and catches

95 The respective Catch per unit of effort (namely the yields) in number of individuals (CPUE) and
96 biomass in Weight per unit of effort (WPUE) for both per rod (number of captures or $kg.rod^{-1}.hour^{-1}$)
97 and hook (number of captures or $kg.hook^{-1}.hour^{-1}$) were calculated per fisherman. Total CPUE and
98 WPUE were compared between the profiles using Kruskal-Wallis non parametrical tests, as the
99 assumption of data normality was not verified by Shapiro's test. Nevertheless, the means and standard
100 deviations of total and per profile CPUE and WPUE have been calculated for information purposes and
101 to support possible comparisons. When significant, the Kruskal-Wallis tests were followed by Dunn
102 post-hoc tests to determine which profiles differed significantly. Furthermore, CPUE and WPUE per
103 species were compared in the same way. CPUE and WPUE were calculated for the 14 species present
104 in the biometric sampling which were, in order of importance, the Gilthead Seabream (*Sparus aurata*,
105 Sparidae), the Weever (*Trachinus spp.*, Trachinidae), the Common cuttlefish (*Sepia officinalis*,
106 Sepiidae), the Bogue (*Boops boops*, Sparidae), the Garfish (*Belone belone*, Belonidae), the Common
107 pandora (*Pagellus erythrinus*, Sparidae), the Goby (*Gobius sp.*, Gobiidae), the White seabream
108 (*Diplodus sargus*, Sparidae), the Salema (*Sarpa salpa*, Sparidae), the Squid (*Loligo vulgaris*, Loliginidae),
109 the European seabass (*Dicentrarchus labrax*, Moronidae), the Surmullet (*Mullus surmuletus*, Mullidae),
110 the European eel (*Anguilla anguilla*, Anguillidae), and the Grey Mullet (*Chelon labrosus*, Mugilidae).
111

112 3. Results

3.1. Variables conserved

113

Twenty-four variables (28.8% of the complete dataset) among 144 questionnaires were conserved in the final analysis which can be classified in five categories: “Fisherman”, “Fishing Habits”, “Technical skills”, “Daily practice” and “Perceptions and legislation knowledge”. Two other variables: “Fisherman age” and “Catch-and-release practice” were also selected to advise management actions (*See attachment*).

3.2. Fishermen profiles

3.2.1. Total shore population

The shore fishing population (N=144) sampled in the NMPGL was exclusively composed of men mostly between 50 and 59 years of age (25.18%) with little (1-5 years) to intermediate (11-20 years) fishing experience (*Fig. 3*). It was mostly composed of pensioners (29.17%) or non-qualified workers (45.13%) who fish occasionally (less than 30 times per year) for leisure more than for catches. They preferred practicing in the morning (24.31%), in the municipalities of Canet (34.03%) or Leucate (21.53%), and especially in summer (49.31%). Most fishermen performed from dikes (49.31%), although surfcasting from the beach was also common (43.75%). They chose their fishing spot principally based on tranquillity or accessibility. Most anglers (57.37%) were locals, from the *Pyrénées-Orientales* department, but a broad range of people from other non-neighbouring French departments (34.72%) and a few foreigners (1.39%) were also present. They practiced fishing from the shore only (73.61%), few of them owning or renting a boat. Fishermen generally used live bait (86.81%), especially expensive worms (59.72%) purchased locally, to target *S. aurata* (81.94%). About 29.17% of the fishermen also harvested bait, mainly crabs (54.71%), mussels (42.85%), or marine worms (45.22%). They spent on average 100 to 500 euros (55.56 %) to fish from 0 to 10 kg (63.19%) per year, although budgets allocated to fishing could reach up to 5,000 euros per year for a maximum reported catch of 500 kg. In this fishery, 77.78% of fishermen were surveyed empty-handed and only 11.81% caught at least one target species. A large majority of the fishermen interviewed (73.61%) perceived a decline in fishing resources, which they linked essentially to professional fishing (51.39%) and water pollution

(25%). Most of them considered RF regulations as *Sufficiently strict* (57.64%) or *Not sufficient* (15.97%). However, 60.42% of fishermen admitted that they did not know which species are protected inside the park or, for 59.72%, the minimum legal catch sizes for the main targeted species (*D. labrax* or *S. aurata*). Nevertheless, 92.25% of the interviewed fishermen also practiced catch-and-release.

Among this total shore population, four different profiles were highlighted by the typologies (*Fig. 2*): *Vacationers*, *Occasional Local Fishermen, Experienced Local Fishermen*, and *Local Lure Fishermen*. We named the different profiles according to their main characteristics (*Fig. 3*).

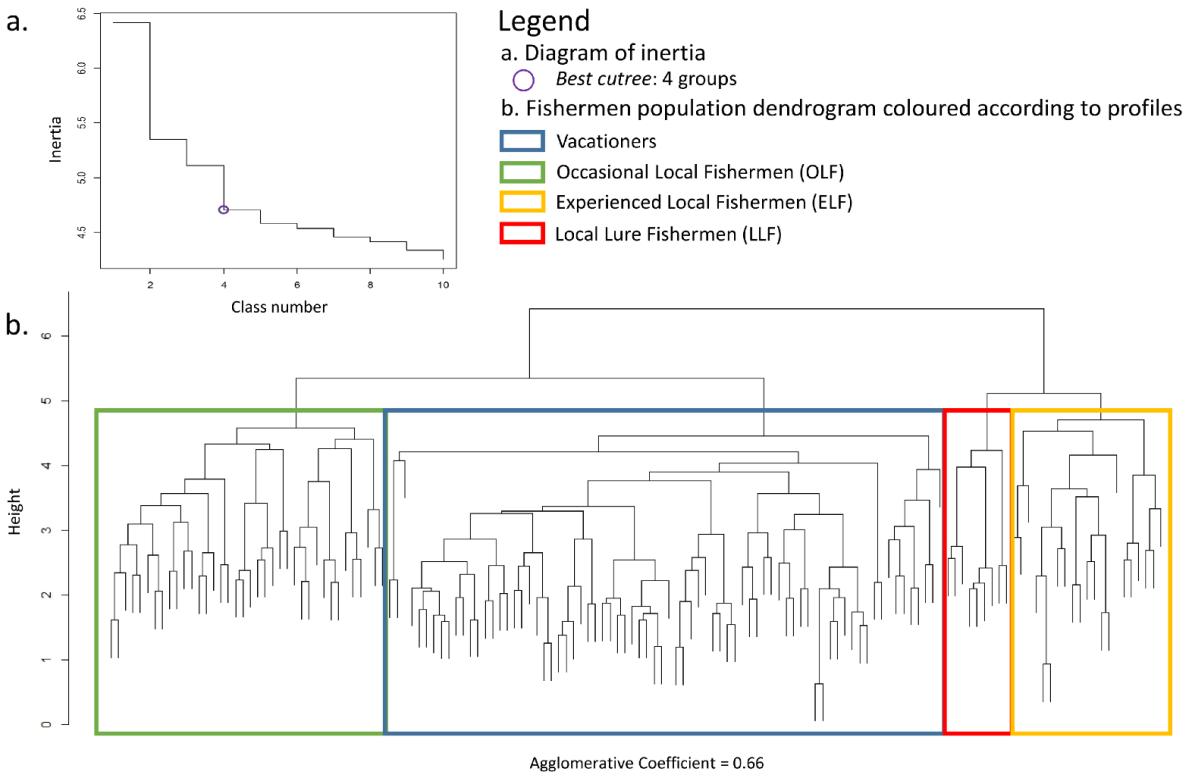
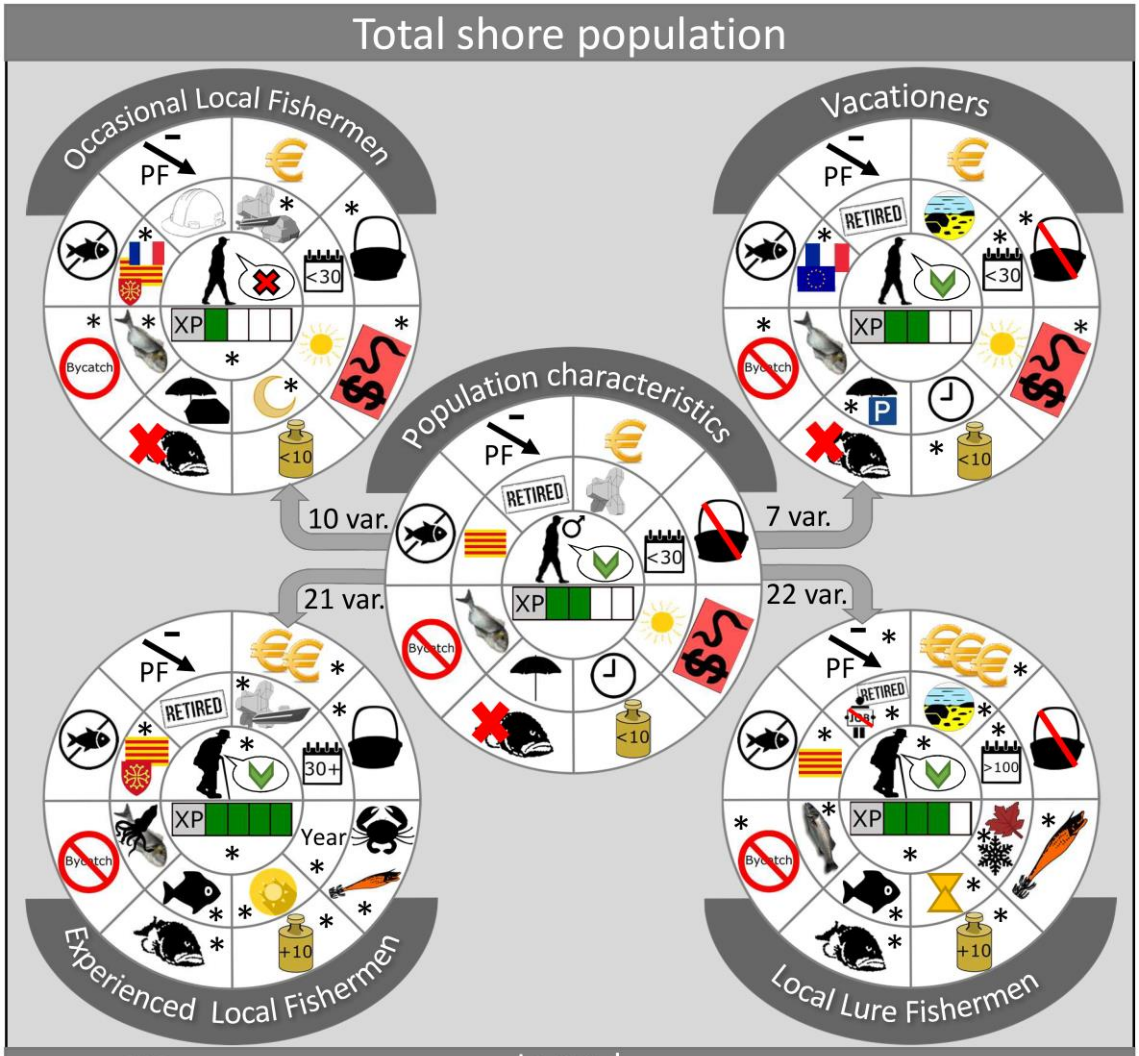
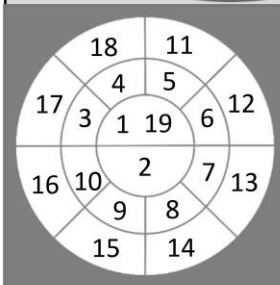


Fig. 2 (2-column fitting image, color). Diagram of the obtained dendrogram (b) and the four clusters emerging as sufficient to describe the recreational fishing population according to the diagram of inertia (a). Indeed, after four classes, the inertia curve appears to reach a plateau.



Legend



1. Age
- 50-59
- 60+

2. Experience (XP)
- XP 6-10 years
- XP Variable
- XP 31-50 years
- XP +50 years

3. Origin
- Local
- Bordering department
- France
- Europe

4. Socio-professional category
- RETIRED Retired
- JOB Unemployed
- Non-qualified worker

5. Substrate
- Dike
- Rocks
- Beach
- Boat

6. Fishing frequency
- <30 Occasional
- 30+ Regular
- >100 Very regular

7. Season
- Summer
- Autumn
- Winter
- Year All year

8. Time of day
- Morning
- Day
- Evening
- Free time

9. Site selection
- Tranquility
- P Parking
- Substrate
- Fish

10. Targeted species
- *Dicentrarchus labrax*
- *Sparus aurata*
- *Loligo vulgaris*

11. Budget
- 100-500 €
- 1,000-2,500 €
- 2,500-5,000 €

12. Harvesting
- Yes
- No

13. Bait used
- Natural
- Lure
- Exogenous Worms

14. Biomass caught
- <10 0-10 kg/year
- +10 > 10 kg/year

15. Regulations knowledge
- Yes
- No

16. Bycath
- Bycatch Yes
- Bycatch No

17. C&R
- Yes

18. Cause of stock decline
- PF Professional fisheries

19. Accessibility
- Open to discussion
- Close to discussion

*: Significant difference from total population

Var: number of significant variables

Fig. 3 (2-column fitting image, color). Diagram of the shared sample population characteristics (central circle) and specific characteristics of each recreational shore fishermen profile (outer circles) along the sandy coast of the Natural Marine Park of the Gulf of Lion for the period 2017-2018. The number of significantly different variables between the total population and the profiles is noted around the arrows.

148 ### *3.2.2.* The *Vacationers*

149 The main profile highlighted was the *Vacationers,* composed predominantly of fishermen from
150 other French departments (52.63%) rather than foreigners (only 2.63%). They represented 52.77% of
151 the sample (N=76). This profile did not differ significantly from the total population in terms of age
152 (mostly 40-49 years) and experience (highly variable but defined by the modality 1-5 years). All socio-
153 professional categories other than students were well represented. Anglers representing this profile
154 were characterised by their occasional, mostly summer (64.47%), practice and their attraction to sites
155 that were less crowded and more accessible for parking (69.74%).

156 In terms of habits, the *Vacationers* practiced almost exclusively from the shore, both from
157 beaches (47.37%) and dikes (43.42%). They used bottom-fishing, generally in the morning (61.84%
158 practiced at least then), to predominantly target *S. aurata* (81.58%). They differed significantly from
159 the total population in their choice of fishing bait, preferring exogenous worms (57.89%). Bait were
160 purchased in 86.84% of cases and represented the highest portion of their fishing budget, with a box
161 of popular American worms costing around 6.90 euros. They were characterised by low rates of
162 harvesting (1.32%) and of lure usage (2.63 %). In two months, they spent the equivalent of one year's
163 fishing budget for the other profiles (100-500 euros) to catch 0 to 10 kg per year on average (82.89%;
164 96.05% under 20 kg/year). This profile significantly represented both the highest rate of adequacy
165 between species targeted and caught (90.89%) and of catch-and-release practicing (95.95%), despite
166 the *Vacationers* showing the lowest level of knowledge on protected species (28.95%) and minimum
167 catch sizes (30.26%).

3.2.3. The *Occasional Local Fishermen*

The second profile highlighted, the *Occasional Local Fishermen (OLF)*, represented 26.39% (N=38) of the total sample population. This group was composed of active men, generally working in a poorly (34.21%) or moderately qualified (21.05%) profession, often in the construction industry. They had the same age distribution as the total population (51.44±15.75, p-value: 0.97) with similar or lower fishing experience (28.95% between 6 and 10 years old). They practiced occasionally along Canet (44.74%) and Leucate (31.58%) coasts, mainly during summer (52.63%). Coming from the *Pyrénées-Orientales* region (55.26%), but also from neighbouring French departments (18.42%), they concentrated significantly on hard substrates (65.78%) that they chose both for their tranquillity (44.74 %) and for their natural settings (42.11%) with a reputation for concentrating fish. Unlike the total population, they fished at night (23.68 %) or any time they had free time (28.95%). They were also much more versatile in their fishing practice, visible in their usage of the marine space (44.74% practicing both shore fishing and spear- or boat-fishing) as well as bait selection (though still favouring the worm at 42.11%) and origin (68.43% harvesting them and 10.53% using exclusively natural bait). They were much more specialised in their targeting, 94.74% fishing for *S. aurata* exclusively. *OLF* did not differ significantly from the total population in terms of catch (0-10 kg) or annual budget (100-500 euros) although an intermediate budget class (500-1,000 euros) was well represented (21.05%). Despite their high level of specialisation and their versatility, their capture rate was low (76.32% are empty-handed) and their bycatch rate high (50%).

They also held the view that fishing stocks were declining (68.42%) because of professional fisheries (47.37%) and pollution (23.68%), though this profile also had the highest proportion of fishermen declaring fish populations as *Increasing* (7.89%) or as *Stagnant* (15.79%). The majority considered legislation as *Sufficiently strict* (60.53%) but *OLF* were also characterised by the highest rate who consider it *Too strict* (7.89%). They generally knew little about minimum catch sizes (42.11% could

192 cite at least one) and less about protected species (63.16% could not name one), but nevertheless
193 practiced catch-and-release at 89.19%.
194
195 ***3.2.4.*** **The *Experienced Local Fishermen***
196 The *Experienced Local Fishermen* (*ELF*) profile represented 14.58% of the sample (N=21). As
197 compared to the *Local Lure Fishermen* (see next section), it brought together the most elderly people
198 above the age of 50 years, and was characterised by the highest rate of the modality *Higher than 70*
199 *years*, absent in the *LLF* profile. This profile was defined by fishermen with average (11-20 years) to
200 high levels of experience, practicing since childhood (51-60 years).
201 They were mostly end-of-career actives (only 28.57% of pensioners) from all socio-professional
202 categories. They were local (90.48%) or from bordering department (9.52%) and practiced regularly
203 (30 to 100 times per year) or very regularly (47.62% each), year-round (80.95%), mostly from dikes
204 (61.9%). They fished both the morning (38.10%) and evening (42.86%) and represented the only profile
205 with individuals performing only in the afternoon (23.81%). For a majority of them (66.67%), the fishing
206 sites were chosen based on the presence of a particular substrate or a targeted species (principally *S.*
207 *aurata* and *L. vulgaris*). Similar to *OLF*, they were versatile in their use of marine space (38.1% of them
208 fishing both onshore and offshore and 14.29% also practicing spear-fishing) but were more specialized
209 in gear and bait. Indeed, ELF preferred using worms alone or in association with crustaceans (partially
210 harvested in 71.43% of the cases) while bottom-fishing or lures, predominantly *Turlutte* to target
211 cephalopods. They were also mobile, 14.29% of them applied for a fishing authorisation for the natural
212 marine reserve of *Cerbère-Banyuls* located along the rocky coast (*Fig. 1*). Their technical knowledge
213 was reflected in their catches (80% of targeted species), though the percentage of catch-free fishermen
214 did not differ from other groups (76.19%). Most likely attributable to their skills, the high budget
215 allocated to fishing (42.86% spent between 1,000 to 2,500 euros per year to fish) and their annual
216 presence, they were the profile that declared the most captures (33.33% reported catching more than

50 kg per year). Nevertheless, 48% of catches were under 20 kg per year and 23.81% were within the total population mean (0-10kg per year).

As with the other profiles, they predominantly perceived that catches were decreasing. However, they were more mitigated in the role of professional fishermen (42.86%), also attributing declines to pollution (42.86%) and poaching (14.29%). They were the most aware of regulations, both in terms of minimum catch sizes (76.19%) and protected species (76.19%) and 57.14% would like the regulation to be reinforced (the majority of the rest considered it as *Strict Enough*). They also had similar catch-and-release rates as the *Vacationers* (about 95.5%).

3.2.5. The *Local Lure Fishermen*

The *Local Lure Fishermen* (*LLF*) profile differed the most from the total population, with 22 variables differing significantly out of 26 (*Fig.3*), and represented 6.25% of the sample (N=9). The *LLF* were generally older and with more fishing experience. The *LLF* profile comprised two distinct groups of practitioners: one group being 40-49 year olds (44.44%), generally unemployed (11.11%) or practicing an intermediate profession (22.22%), with 6 to 20 years of experience (33.3%) and the other being 60-69 year olds (44.44%), pensioners, with 31 to 50 years of experience (55.55%). This profile was characterised by individuals predominantly fishing since childhood and belonging exclusively to the *Pyrénées-Orientales* department (100% locals).

They were characterised by their regularity: 77.77% fishing more than 100 times per year, 44.44% any time possible, and 11.11% sometimes twice a day, morning and evening. They fished year-round exclusively from the shore, characterising daytime fishing during the autumn and winter seasons (33.33% each) and evening fishing during the summer (33.33%). They chose their sites generally for the species targeted or the substrate (77.78%). They did not harvest their baits and exclusively used lures (66.67%) or practiced surfcasting from the beach using purchased crustaceans and fishes. They generally caught a few species of strong gustatory interest such as *D. labrax* (44.44%), *L. vulgaris* (22.22%) and *D. sargus* (11.11%), presenting lower pressure on *S. aurata* (22.22%). Though some were

242 unemployed, they spent more money in RF than the other profiles with two modalities, 100 to 500
243 euros (33.33%) and 2,500 to 5,000 euros (33.33%), characterising the profile. They were also highly
244 variable in their declarations of quantity of captures, with a majority reporting annual catches between
245 0 and 10 kg (33.33%) but some claiming up to 100 kg (20%).
246
247 In terms of regulation, they were an intermediate profile with the highest rate acknowledging
248 their ignorance of the fishing regulations (11.11%) and the lowest rate of catch-and-release (still
249 85.71%). In fact, 55.56% of the fishermen knew both the protected species and the minimum catch
250 size. Among them, 66.67% recognised the regulation as *Strict Enough* whereas 11.11% preferred
251 stronger implementation, none considering it as *Too strict*. Surprisingly, during the interviews, none
252 had a catch, except fishermen with no targeted species (22.22%). They considered the fish populations
253 to be declining (77%) mainly due to professional fishing (66.67%) and poaching (22.22%).
254
255 *3.3. Selectivity of catches and comparison of yields*
256 The analysis of the 144 biometric records showed a differing specific distribution of catches, with
257 only two species, *S. aurata* and *D. sargus* shared among the four fishermen profiles. The *OLF* caught
258 diversified species, some with low gustatory interest, more so than other groups and particularly more
259 than *LLF* who caught few individuals and species (only 3 species).
260 The total CPUE (all species combined) did not show any significant difference if calculated per rod
261 (mean 0.20±0.60) or per hook (mean 0.19±0.63). The same trend was observed for WPUE. For this
262 reason, we chose to present in *Table 1* only the results of the catches per rod, generally easier to obtain
263 by visual surveys.
264 Comparing total CPUE and WPUE between the profiles did not show any significant differences.
265 However, WPUE and CPUE analyses per species revealed a significant difference in yield between the
266 profiles for four species among the 14 tested (*Table 1*). *ELF* presented a particular ability to catch

cephalopods which resulted in a higher yield than other profiles for these two species. *LLF* had significantly higher yields for *D. labrax* despite catches also made by *ELF*. *P. erythrinus'* yield was significantly higher for the *OLF* while they declared targeting the species in only 1.4% of cases. On the other hand, *S. aurata*'s yield, which was overwhelmingly targeted by three out of four profiles, and still 44% by *LLF*, did not show any significant difference between the profiles.

		Profile 1 Vacationers N=76 52.77%	**Profile 2 Occasional Local Fishermen N=38 26.39%**	**Profile 3 Experienced Local Fishermen N=21 14.58%**	**Profile 4 Local Lure Fishermen N=9 6.25%**	**Test**	**p-value**	**Significance**
Species caught per profile among the sample (number of catches)		*B. boops (6)* *S. aurata (23)* *B. belone (1)* *M. surmuletus (1)* *D. sargus (2)*	*A. anguilla (1)* *S. aurata (2)* *G. sp (1)* *P. erythrinus (6)* *D. sargus (1)* *S. salpa (2)* *T. sp (1)*	*L. vulgaris (3)* *S. aurata (1)* *D. labrax (1)* *C. labrosus (1)* *S. officinalis (6)*	*D. labrax (1)* *B. belone (2)* *D. sargus (1)*			
Total CPUE (± standard deviation)		0.21±0.73	0.22±0.66	0.08±0.19	0.29±0.50	Kruskal-Wallis	0.75	Ø
Total WPUE (± standard deviation)		0.02±0.05	0.02±0.06	0.04±0.09	0.06±0.11	Kruskal-Wallis	0.73	Ø
CPUE per species	*Loligo vulgaris*	0	0	0.04±0.11	0	Kruskal-Wallis	2.9e-08 C3***	***
	Dicentrarchus labrax	0	0	0.01±0.06	0.04±0.13	Kruskal-Wallis Post-hoc Dunn	0.02 C4*	*
	Pagellus erythrinus	0	0.02±0.07	0	0	Kruskal-Wallis	0.002 C2**	**
	Sepia officinalis	0	0	0.22±0.68	0	Kruskal-Wallis	0.0005 C3***	***
	Sparus aurata	0.04±0.17	0.01±0.09	0.005±0.03	0	Kruskal-Wallis Post-hoc Dunn	0.23	Ø

Table 1. Comparison of total and per species Catch per Unit Effort in number of captures.rod^{-1}.h^{-1} (CPUE) and in kg. rod^{-1}.h^{-1} (WPUE) of the recreational fishermen profiles within the sample of the shore fishermen population of the sandy coast of the Natural Marine Park of the Gulf of Lion in 2017-2018**.**

Significance of Kruskal-Wallis tests: Ø No significance, * : p-value<0.05, ** : p-value<0.01, *** : p-value<0.001

4. Discussion

The four profiles from our typology generate different impacts on catch composition and the onshore socio-ecosystem according to their fishing strategy and specialisation. The population heterogeneity appears to have both an influence on the spatiotemporal distribution of effort and on the response to management measures but not on total and per species CPUE except for four species. Understanding the heterogeneity could therefore be used to guide management measures of spatial planning and resource sharing, benefitting professional fishing (Brown, 2016). Despite being identified as a promising area of research, the study of anglers populations remains at its infancy (Arlinghaus et al., 2019). Describing their heterogeneity appears to be a fundamental first step towards sustainable resource management, while understanding CPUE variation, one of the most accessible indicators for stock assessment, according to angler type is likewise crucial and understudied (Ward et al., 2016).

4.1. Exploring the link between profiles and yields

Our analyses seem to support that both total CPUE and WPUE can be used in onshore MRF as a relative indicator (Quinn and Deriso, 1999) for stock status independent of anglers profiles as they present similar yields. The population can therefore be considered as homogeneous when evaluating harvest and analysing CPUE trends. This result is contrary to our hypothesis and could be counterintuitive considering the strong differences between profiles as *LLF* and *ELF* seem more efficient. In fact, NMPGL's anglers appeared to behave opportunistically, exploiting the range of species available without being specialised enough for selectivity, except *LLF* and *ELF*. The similar CPUE of *ELF* and *LLF* profiles could be due to a fine balance between their selectivity and the catchability of highly gustatory, targeted species. Given that this was a multi-species fishery, these profiles did not differ from non-selective anglers, which can compensate for a lack of knowledge in open-access fisheries or in the absence of control. That is why *OLF,* and more broadly *Vacationers*, may be good

295 indicators of stocks status, as their CPUE may be less subject to the phenomenon of hyperstability,
296 “the illusion of plenty” (Erisman et al., 2011), observed in specialised and selectively-sized populations
297 (Wilson et al., 2020).

298 The typology cross-referenced to the CPUE analysis clearly showed the importance of anglers’
299 specialisation, but only for 4 species (*D. labrax*, *L. vulgaris*, *P. erythrinus*, *S. officinalis*). Since
300 management policies, particularly establishing quotas, often depend on stock-targeted management
301 the interpretation of changes in yields for these species should be verified with regard to the degree
302 of specialisation in anglers *in situ*. These profiles can be assimilated, analogous to professional fishing,
303 as constituting different professions in the area.

304 4.2. *Ranking profiles to improve awareness*
305
306 Categorising NMPGL heterogeneous anglers’ population into four typical profiles with various
307 influence on the socio-ecosystem that stand out as symptomatic of seasons and municipalities
308 provides a framework for testing management and awareness actions addressing global or profile-
309 targeted needs.

310 The *LLF* and *ELF* profiles were the most experienced and technical in targeting highly gustatory
311 interest species. They were familiar with the area and specialists within their respective species range.
312 Their selectivity, proven by low bycatch and high catch-and-release rates, and knowledge of
313 regulations makes these profiles less of a priority for awareness actions. However, due to their large
314 allocated budgets, they should be monitored to evaluate their impacts on the local economy and high
315 trophic level stocks. *Vacationers* represented an intermediate profile for awareness and control needs
316 with high economic value and impacts spread over different species. Their impacts should not be
317 perceived as minimal, due to their number, yields and the influence they can therefore exert on certain
318 stocks, particularly those of commercial interest. As a large part of the RF activity in the NMPGL
319 depends on a small number of moving species (Kayal et al., 2020) notably caught during their breeding
320 period and in nurseries (Cheminée et al., 2017), instilling good practices in *Vacationers* is all the more

321 important. In contrast, *OLF* seems to be the most impactful profile. They represented empirical catch-
322 driven approaches leading to a high bycatch rate. This partially unreleased bycatch suggested an
323 additional mortality on small individuals and low expectations in managers for increasing catch-and-
324 release rates, a controversial but widespread management measure (Arlinghaus et al., 2007). Their
325 common practices of harvesting bait may also impact low trophic levels. The aggregation of *OLF* on
326 dikes during summer makes them easier to monitor. This study validates that management must adapt
327 to seasonal changes in fishing population (Wilson et al., 2020) and highlights the importance of
328 operational presence during summer. Summer profiles have a similar harvest per daytrip as other
329 season profiles yet also seem the most numerous and sensitive to management pressure, and
330 therefore should be prioritized.

331 Overall, anglers' population analysis reveals a great lack of knowledge about the fishing
332 regulations, especially protected species. These shortcomings demonstrate the ineffectiveness of the
333 current means deployed to reach the anglers and to convince them. Interestingly, the anglers of the
334 NMPGL possess a certain ecological awareness and apply their own version of fisheries regulations
335 whether or not they are familiar with them (Brownscombe et al., 2019), particularly the *Vacationers*
336 and *ELF*. Evidence of this "self-regulation" is partly reflected in the high rate of catch-and-release for
337 all profiles also observed in other European countries (Ferter et al., 2013). They are generally easy to
338 reach and open to awareness campaigns with the exception of *OLF*. *OLF* were less open to discussion
339 with managers, with a high rate considering the regulations as *Too strict*.

340 4.3. *Management implication and limits*

341 The success of sustainable management depends on three vectors: an anglers-centered
342 management aimed at engaging their responsibility with respect to the resource, local operational
343 management using traditional management tools such as seasonal closures, and a long term
344 monitoring involving all the fishing actors to inform adaptive management (Cooke et al., 2019). The
345 predominance of self-regulation and the low level of knowledge of the law demonstrate the need for

multiscale management (Elmer et al., 2017), as MRF in the NMPGL depend on intensive national and international tourist flows. The importance of these migrating anglers highlights the partial nature of current RF management, as a major portion of *Vacationers* annual activity is outside the NMPGL's jurisdiction. Anglers-targeted management could be effective by seasonally increasing controls on minimum catch sizes (MCS), as requested by *ELF*, which would mainly be restrictive for summer dwellers. Nevertheless, the effort required is currently a barrier, as strong inclusive federations do not exist unlike freshwater (Ward et al., 2016).

In addition, the low catch rates (Kayal et al., 2020) and regulatory knowledge raises the question to the relevance of introducing stricter anglers-targeted regulations for onshore MRF in areas heavily subjected to tourists. The catch difficulty along the shore associated with a consumption-oriented MRF (Cooke et al., 2018), though no anglers reported economic needs, casts doubts on the efficiency of quotas or licenses in the absence of strict control. These measures are all the more difficult to put in place since local shore anglers do not approve of them (Tunca et al., 2016).

Too little or over-complication of regulation can lead to the collapse of societal population's organisation, which would be detrimental to the socio-ecosystem. Here, the fact that the majority of anglers are witnessing a decline in stocks and are trying to manage themselves in spite of lacking regulatory knowledge underscores the opportunity and the importance of firstly homogenising and simplifying the current fishing regulations, at least on a national scale. This could facilitate the adherence and the appropriation of populations to simple management measures such as catch-and-release even if the MCS have to be revised upwards. Furthermore, raising awareness should be primarily carried out upstream, in departments where the populations originate. Few people imagine that each angler in France catches the equivalent of 10kg per year (Herfaut et al., 2013), which contributes to the 47 billion fish caught annually worldwide (Cooke and Cowx, 2004). Thus, the national level should provide a common legislative and educational framework, placing sustainable RF practices

on an equal footing with consumption. These actions could provide the psychological tools (Arlinghaus et al., 2019) and incentive-based approaches (Grafton et al., 2006) necessary to preserve resources.

In addition to anglers-targeted actions, local adaptations involving the entire fabric of actors to prevent impacts and adapt fishing strategies upstream must be deployed (Martin and Pope, 2011). As most of the bait were purchased locally, implementing agreements with the commercial sector on available minimum hook sizes or a list of banned high-performance bait could increase selectivity and/or lower the yield of anglers (Alós et al., 2009). These measures would be easy for managers to implement and monitor and, through analysing sales, provide a proxy for the state of health of the activity or detect changes in the fishing population.

Typological approaches allow spatio-temporal profile-targeting management actions, particularly relevant for species whose yields stand out as profile-dependent. In addition, estimating specific strategies' potential for adaptation theoretically allows the anticipation of the anglers' responses to the proposed management measures (Arlinghaus et al., 2019). For example, because of their selectivity, *LLF* and *ELF* do not seem to fish to their maximum capacity and should be monitored as they could adapt to fishing evolutions (e.g. stock decrease). The comparative study of profiles' CPUE could potentially serve as an indicator of the efficiency of management measures as profiles may differ in terms of adaptability.

These multi-scale approaches are all the more important as they allow upstream control of anglers' flow and accompanies the change in practice for future generations, reviving the role of educational MPA (Elmer et al., 2017). This approach could prove to be of priority interest in the context of a socio-economic crisis where it seems fundamental preserve the nature of RF (e.g. anticipating overfishing or poaching) and its benefits, especially on mental health (Cooke et al., 2018).

4.4 Towards a generalisation of profiling?

While there are many descriptions of fishing populations based on a large number of socio-economic parameters, they are often single-factorial, focus on freshwater and vary in analysis used,

thus limiting comparisons at national, Mediterranean and international levels. However, some signs reinforce the hypothesis of a common trend at the north-western Mediterranean level and perhaps at broader scales. For example, squid's catches stand out in our study as a trait of skilled anglers, which is shared with the Adriatic Sea (Cabanellas-Reboredo et al., 2017). As the profiles seem to be defined by specialisation towards one or a range of species and fishing centrality to lifestyle, it seems consistent that they could be generalised at least on a scale for which the species are common. At international scales, anglers profiles in the NMPGL present interesting similarities with those of American freshwater lakes, especially with the trout fishermen population (Bryan, 1977). Indeed, the four profiles of the study, described according to a specialisation continuum, seem sufficient to also capture the complexity of the NMPGL anglers' population. While other studies recognise 3 profiles (e.g. Beardmore et al., 2013), the democratisation of lures induces in our analysis the appearance of a fourth class among the experienced likely to evolve rapidly. Furthermore, the socio-economic variables emerging in the classification are close to those found by other authors (e.g. Graefe, 1981). Surprisingly, it is the variables linked to the bait (choice and origin) that emerge here as structuring the clusters. The fact that similar profiles emerge from similar variables suggests two hypotheses, one of a certain temporal stability, though their proportions can vary between sites or years, and the other that these profiles could be generalised to developed countries where RF do not present a subsistence fishery. This is particularly possible since techniques used within the NMPGL were by the way nationally and internationally shared (Font et al., 2012; Herfaut et al., 2013). Practices seem to be globalised by the commercial flows of equipment and bait, but also by tourism fluxes. Indeed, the NMPGL is under the influence of strong national tourist flows as the rest of the Mediterranean and the world (Freire et al., 2020).

These results could presuppose that the Mediterranean could be a model RF study, as it concentrates international issues on a smaller scale. Moreover, in addition to the profiles' similarities, the analysis of Mediterranean RF highlights common trends with the international studies, e.g. catch rates, since RF is estimated to be responsible for 10% of total catches in the Mediterranean (WWF,

2018) and 12% internationally (Cooke and Cowx, 2004). Promoting similar analysis protocols appears necessary as inter-site comparisons is fundamental for validating hypotheses.

5. Conclusion

Our study provides the first integrative vision of the onshore RF practising population in the French NW Mediterranean, highlighting the importance of the activity for local economy. It presents an opening for reflection on the interconnection of typological and fisheries management approaches and highlights international similarities between angler profiles. It also underscores the importance of classification approaches along the specialisation gradient, which seems particularly suited to management and yield analysis. Our study also further supports the use of total shore CPUE and WPUE in RF to evaluate stock status independent of profiles in the study area, but shows that this would need to be standardised for the four species with yields influenced by anglers strategies. Participatory monitoring permitted evaluating the current state of angler awareness and presents a pre-requisite for a shift towards public engagement. Acquiring data through the cooperation of non-federated anglers will increase the inclusion of their perspective in management workshops and benefit to anglers and professional fishermen by preventing conflicts suspected in our analysis. Finally, our typological analysis underlines the importance of bait choice and origin in the profiles' construction. Moving forward, it seems essential to characterise RF impacts on low marine trophic levels. Bait collection in RF may be of greater environmental impact than on exploitation of stocks as compared to professional fisheries. In the long term, it would be interesting to monitor the evolution of anglers profiles, to detect changes in behaviours, especially after implementing new regulations or in the context of ongoing socio-economical crisis.

Author contribution

P.L, M.V-J and L. V. led the project. E.C, A.B and M.V-J designed the methodology. E.C. performed the analyses and wrote the manuscript. P.L, M.V-J and M.K reviewed the entire document. All the authors contributed to field data acquisition, proofreading and gave final approval for the publication.

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Data availability

The data having been collected for less than 3 years, they are not yet made publicly available but they will thereafter. The data are currently stored in a database available from Marion VERDOIT-JARRAYA (marion.jarraya@univ-perp.fr) and belong to the CEFREM laboratory affiliated to the University of Perpignan and to the French Office for Biodiversity.

References

Agence des aires marines protégées, 2014. Plan de gestion du parc naturel marin du golfe du Lion - version 1.21.

Alós, J., Arlinghaus, R., Palmer, M., March, D., Álvarez, I., 2009. The influence of type of natural bait on fish catches and hooking location in a mixed-species marine recreational fishery, with implications for management. Fisheries Research 97, 270–277. https://doi.org/10.1016/j.fishres.2009.03.003

Arlinghaus, R., Cooke, S.J., Lyman, J., Policansky, D., Schwab, A., Suski, C., Sutton, S.G., Thorstad, E.B., 2007. Understanding the Complexity of Catch-and-Release in Recreational Fishing: An Integrative

471 Synthesis of Global Knowledge from Historical, Ethical, Social, and Biological Perspectives. Reviews in
472 Fisheries Science 15, 75–167. https://doi.org/10.1080/10641260601149432

473 Arlinghaus, Robert, Abbott, J.K., Fenichel, E.P., Carpenter, S.R., Hunt, L.M., Alós, J., Klefoth, T., Cooke,
474 S.J., Hilborn, R., Jensen, O.P., Wilberg, M.J., Post, J.R., Manfredo, M.J., 2019. Opinion: Governing the
475 recreational dimension of global fisheries. PNAS 116, 5209–5213.
476 https://doi.org/10.1073/pnas.1902796116

477 Arlinghaus, R., Beardmore, B., Riepe, C., Pagel, T., 2019. Species-specific preference heterogeneity in
478 German freshwater anglers, with implications for management. Journal of Outdoor Recreation and
479 Tourism 100216. https://doi.org/10.1016/j.jort.2019.03.006

480 Beardmore, B., Haider, W., Hunt, L.M., Arlinghaus, R., 2013. Evaluating the Ability of Specialization
481 Indicators to Explain Fishing Preferences. Leisure Sciences 35, 273–292.
482 https://doi.org/10.1080/01490400.2013.780539

483 Brown, C.J., 2016. Social, economic and environmental effects of closing commercial fisheries to
484 enhance recreational fishing. Marine Policy 73, 204–209.
485 https://doi.org/10.1016/j.marpol.2016.08.010

486 Brownscombe, J.W., Hyder, K., Potts, W., Wilson, K.L., Pope, K.L., Danylchuk, A.J., Cooke, S.J., Clarke,
487 A., Arlinghaus, R., Post, J.R., 2019. The future of recreational fisheries: Advances in science,
488 monitoring, management, and practice. Fisheries Research 211, 247–255.
489 https://doi.org/10.1016/j.fishres.2018.10.019

490 Bryan, H., 1977. Leisure value systems and recreational specialization: The case of trout fishermen.
491 Journal of leisure research 9, 174–187. doi:10.1080/00222216.1977.11970328

492 Cabanellas-Reboredo, M., Palmer, M., Alós, J., Morales-Nin, B., 2017. Estimating harvest and its
493 uncertainty in heterogeneous recreational fisheries. Fisheries Research 188, 100–111.
494 https://doi.org/10.1016/j.fishres.2016.12.008

495 Cheminée, A., Rider, M., Lenfant, P., Zawadzki, A., Mercière, A., Crec'hriou, R., Mercader, M.,
496 Saragoni, G., Neveu, R., Ternon, Q., Pastor, J., 2017. Shallow rocky nursery habitat for fish: Spatial
497 variability of juvenile fishes among this poorly protected essential habitat. Marine Pollution Bulletin
498 119, 245–254. https://doi.org/10.1016/j.marpolbul.2017.03.051

499 Code rural de la pêche maritime, Article R921-83, 2017. Article R921-83 du Code rural et de la pêche
500 maritime, Modifié par Décret n°2017-942 du 10 mai 2017 - art. 7 [WWW Document]. URL
501 https://www.legifrance.gouv.fr/affichCode.do?idSectionTA=LEGISCTA000029979371&cidTexte=LEGI
502 TEXT000006071367 (accessed 9.5.19).

503 Cooke, S.J., Cowx, I.G., 2004. The Role of Recreational Fishing in Global Fish Crises. BioScience 54,
504 857–859. https://doi.org/10.1641/0006-3568(2004)054[0857:TRORFI]2.0.CO;2

505 Cooke, S.J., Cowx, I.G., 2006. Contrasting recreational and commercial fishing: Searching for common
506 issues to promote unified conservation of fisheries resources and aquatic environments. Biological
507 Conservation 128, 93–108. https://doi.org/10.1016/j.biocon.2005.09.019

508 Cooke, S., Twardek, W., Lennox, R., Zolderdo, A., Bower, S., Gutowsky, L., Danylchuk, A., Arlinghaus,
509 R., Beard, D., 2018. The nexus of fun and nutrition: Recreational fishing is also about food. Fish and
510 Fisheries 19, 201–224. https://doi.org/10.1111/faf.12246

Cooke, S.J., Twardek, W.M., Reid, A.J., Lennox, R.J., Danylchuk, S.C., Brownscombe, J.W., Bower, S.D., Arlinghaus, R., Hyder, K., Danylchuk, A.J., 2019. Searching for responsible and sustainable recreational fisheries in the Anthropocene. Journal of Fish Biology 94, 845–856. https://doi.org/10.1111/jfb.13935

Danylchuk, A.J., Cooke, S.J., 2011. Engaging the recreational angling community to implement and manage aquatic protected areas. Conservation Biology 25, 458–464. doi: 10.1111/j.1523-1739.2010.01631.x

Di Franco, A., Thiriet, P., Di Carlo, G., Dimitriadis, C., Francour, P., Gutiérrez, N.L., De Grissac, A.J., Koutsoubas, D., Milazzo, M., del Mar Otero, M., 2016. Five key attributes can increase marine protected areas performance for small-scale fisheries management. Scientific reports 6, 38135. https://doi.org/10.1038/srep38135

DuFour, M., Qian, S., Mayer, C., Vandergoot, C., 2019. Evaluating catchability in a large-scale gillnet survey using hydroacoustics: Making the case for coupled surveys. Fisheries Research 211, 309–318. https://doi.org/10.1016/j.fishres.2018.11.009

Elmer, L.K., Kelly, L.A., Rivest, S., Steell, S.C., Twardek, W.M., Danylchuk, A.J., Arlinghaus, R., Bennett, J.R., Cooke, S.J., 2017. Angling into the Future: Ten Commandments for Recreational Fisheries Science, Management, and Stewardship in a Good Anthropocene. Environ Manage 60, 165–175. https://doi.org/10.1007/s00267-017-0895-3

Erisman, B., Allen, L., Claisse, J., Pondella, D., Miller, E., Murray, J., Walters, C., 2011. The illusion of plenty: Hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Canadian Journal of Fisheries and Aquatic Sciences 68, 1705–1716. https://doi.org/10.1139/f2011-090

EU Parliament Adopted Text, 2018. European Parliament resolution of 12 June 2018 on the state of play of recreational fisheries in the European Union (2017/2120(INI)) http://www.europarl.europa.eu/doceo/document/TA-8-2018-0243_EN.html (accessed 9.6.19).

Ferter, K., Weltersbach, M.S., Strehlow, H.V., Vølstad, J.H., Alós, J., Arlinghaus, R., Armstrong, M., Dorow, M., de Graaf, M., van der Hammen, T., Hyder, K., Levrel, H., Paulrud, A., Radtke, K., Rocklin, D., Sparrevohn, C.R., Veiga, P., 2013. Unexpectedly high catch-and-release rates in European marine recreational fisheries: implications for science and management. ICES J Mar Sci 70(7), 1319–1329. https://doi.org/10.1093/icesjms/fst104

Font, T., Lloret, J., Piante, C., 2012. Pêche de loisir dans les Aires Marines Protégées en Méditerranée. Projet MedPAN Nord. WWF-France. 259 pages.

Freire, K.M.F., Belhabib, D., Espedido, J.C., Hood, L., Kleisner, K.M., Lam, V.W.L., Machado, M.L., Mendonça, J.T., Meeuwig, J.J., Moro, P.S., Motta, F.S., Palomares, M.-L.D., Smith, N., Teh, L., Zeller, D., Zylich, K., Pauly, D., 2020. Estimating Global Catches of Marine Recreational Fisheries. Front. Mar. Sci. 7. https://doi.org/10.3389/fmars.2020.00012

Giovos, I., Keramidas, I., Antoniou, C., Deidun, A., Font, T., Kleitou, P., Lloret, J., Matic-Skoko, S., Said, A., Tiralongo, F., Moutopoulos, D., 2018. Identifying recreational fisheries in the Mediterranean Sea through social media. Fisheries Management and Ecology 25, 287–295. https://doi.org/10.1111/fme.12293

551 Gordoa, A., Dedeu, A.L., Boada, J., 2019. Recreational fishing in Spain: First national estimates of
552 fisher population size, fishing activity and fisher social profile. Fisheries Research 211, 1–12.
553 https://doi.org/10.1016/j.fishres.2018.10.026

554 Graefe, A.R., 1981. Understanding diverse fishing groups: the case of drum fishermen. Marine
555 recreational fisheries 6, 69–79.

556 Grafton, R.Q., Arnason, R., Bjørndal, T., Campbell, D., Campbell, H.F., Clark, C.W., Connor, R., Dupont,
557 D.P., Hannesson, R., Hilborn, R., Kirkley, J.E., Kompas, T., Lane, D.E., Munro, G.R., Pascoe, S., Squires,
558 D., Steinshamn, S.I., Turris, B.R., Weninger, Q., 2006. Incentive-based approaches to sustainable
559 fisheries. Can. J. Fish. Aquat. Sci. 63, 699–710. https://doi.org/10.1139/f05-247

560 Herfaut, J., Levrel, H., Thébaud, O., Véron, G., 2013. The nationwide assessment of marine
561 recreational fishing: A French example. Ocean & Coastal Management 78, 121–131.
562 https://doi.org/10.1016/j.ocecoaman.2013.02.026

563 Hunt, L.M., Camp, E., Poorten, B. van, Arlinghaus, R., 2019. Catch and Non-catch-related
564 Determinants of Where Anglers Fish: A Review of Three Decades of Site Choice Research in
565 Recreational Fisheries. Reviews in Fisheries Science & Aquaculture 27, 261–286.
566 https://doi.org/10.1080/23308249.2019.1583166

567 Kayal, M., Cigala, M., Cambra, E., Soulat, N., Mercader, M., Lebras, A., Ivanoff, P., Sébési, L., Lassus-
568 Debat, A., Hartmann, V., Bradtke, M., Lenfant, P., Jabouin, C., Dubreuil, J., Pelletier, D., Joguet, M.,
569 Mellionnec, S.L., Brichet, M., Binche, J.-L., Payrot, J., Saragoni, G., Crec'hriou, R., Verdoit-Jarraya, M.,
570 2020. Marine reserve benefits and recreational fishing yields: the winners and the losers. PLoS ONE
571 15(12):e0237685. https://doi.org/10.1371/journal.pone.0237685

572 Lebart, L., Morineau, A., Piron, M., 1997. Statistique exploratoire multidimensionnelle, 2e cycle.
573 Dunod, Paris.

574 Lockwood, R.N., 2000. Chapter 14: Conducting Roving and Access Site Angler Surveys. In Schneider,
575 James C. (Ed) *Manual of fisheries survey methods II*

576 Maggs, J.Q., Mann, B.Q., Potts, W.M., Dunlop, S.W., 2016. Traditional management strategies fail to
577 arrest a decline in the catch-per-unit-effort of an iconic marine recreational fishery species with
578 evidence of hyperstability. Fisheries Management and Ecology 23, 187–199.
579 https://doi.org/10.1111/fme.12125

580 Martin, D.R., Pope, K.L., 2011. Luring anglers to enhance fisheries. Journal of Environmental
581 Management, Adaptive management for Natural Resources 92, 1409–1413.
582 https://doi.org/10.1016/j.jenvman.2010.10.002

583 McPhee, D.P., Leadbitter, D., Skilleter, G.A., 2002. Swallowing the bait: is recreational fishing in
584 Australia ecologically sustainable? Pac. Conserv. Biol. 8, 40–51. https://doi.org/10.1071/pc020040

585 Pita, P., Hyder, K., Gomes, P., Pita, C., Rangel, M., Veiga, P., Vingada, J., Villasante, S., 2018. Economic,
586 social and ecological attributes of marine recreational fisheries in Galicia, Spain. Fisheries Research
587 208, 58–69. https://doi.org/10.1016/j.fishres.2018.07.014

588 Quinn, T.J., Deriso, R.B., 1999. Quantitative Fish Dynamics. Oxford University Press.

589 R Development Core Team (2005). R: A language and environment for statistical computing. R
590 Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL:http://www.R-
591 project.org.

592 Symes, D., Hoefnagel, E., 2010. Fisheries policy, research and the social sciences in Europe:
593 Challenges for the 21st century. Marine Policy 34, 268–275.
594 https://doi.org/10.1016/j.marpol.2009.07.006

595 Tunca, S., Ünal, V., Miran, B., Güçlüsoy, H., Gordoa, A., 2016. Biosocioeconomic analysis of marine
596 recreational fisheries: A comparative case study from the Eastern Mediterranean, Turkey. Fisheries
597 Research 174, 270–279. https://doi.org/10.1016/j.fishres.2015.10.025

598 Verdoit, M., Pelletier, D., Bellail, R., 2003. Are commercial logbook and scientific CPUE data useful for
599 characterizing the spatial and seasonal distribution of exploited populations? The case of the Celtic
600 Sea whiting. Aquatic Living Resources 16, 467–485. https://doi.org/10.1016/j.aquliv.2003.07.002

601 Ward, H.G.M., Askey, P.J., Post, J.R., 2013. A mechanistic understanding of hyperstability in catch per
602 unit effort and density-dependent catchability in a multistock recreational fishery. Can. J. Fish. Aquat.
603 Sci. 70, 1542–1550. https://doi.org/10.1139/cjfas-2013-0264

604 Ward, H.G.M., Allen, M.S., Camp, E.V., Cole, N., Hunt, L.M., Matthias, B., Post, J.R., Wilson, K.,
605 Arlinghaus, R., 2016. Understanding and Managing Social–Ecological Feedbacks in Spatially
606 Structured Recreational Fisheries: The Overlooked Behavioral Dimension. Fisheries 41, 524–535.
607 https://doi.org/10.1080/03632415.2016.1207632

608 Wilson, K.L., Foos, A., Barker, O.E., Farineau, A., Gisi, J.D., Post, J.R., 2020. Social–ecological feedbacks
609 drive spatial exploitation in a northern freshwater fishery: A halo of depletion. Journal of Applied
610 Ecology 57, 206–218. https://doi.org/10.1111/1365-2664.13563

611 www.catalanes.espaces-naturels.fr. http://www.catalanes.espaces-naturels.fr/les-rnc/reserve-de-
612 cerbere-banyuls (accessed 27.3.20).

613 WWF, 2018. Evaluating Europe's course to sustainable fisheries by 2020. pp 18.

614 www.parc-marin-golfe-lion.fr, http://www.parc-marin-golfe-lion.fr/ (accessed 1.17.20).

615