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on harvesting patterns, social engagement and sentiments
related to the distributional range shift of a marine invasive species

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2022-06

Sbragaglia , V , Espasandin , L , Coco , S , Felici , A , Correia , R A , Coll , M & Arlinghaus ,
R 2022 , ' Recreational angling and spearfishing on social media : insights on harvesting
patterns, social engagement and sentiments related to the distributional range shift of a
marine invasive species ' , Reviews in Fish Biology and Fisheries , vol. 32 , pp. 687-700 . <https://doi.org/10.1007/s11160-022-09699-7>

<http://hdl.handle.net/10138/354763>

<https://doi.org/10.1007/s11160-022-09699-7>

acceptedVersion

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1 **Title:** Recreational angling and spearfishing on social media: Insights on harvesting patterns, social
2 engagement and sentiments related to the distributional range shift of a marine invasive species

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19

20 **ABSTRACT**

21 Fisheries are among the human activities that are most strongly affected by ongoing climate-
22 related changes in the presence and abundance of fish species across the globe. The ecological
23 and social repercussions of such changes for recreational fisheries are however still poorly
24 understood. Here, we compare selected ecological and social dimensions of both recreational
25 angling and spearfishing targeting the bluefish (*Pomatomus saltatrix*) in Italy. The bluefish has
26 undergone a northward expansion in the region over the last 20-30 years, during which it reached
27 new areas and increased in abundance. Using digital videos and their associated data published by
28 both recreational anglers and spearfishers on YouTube we characterized ecological and social
29 dimensions using a culturomics approach. Specifically, we focused on harvesting patterns, social
30 engagement and sentiments related to the bluefish. Our study revealed four major results: (i)
31 similar harvesting patterns (i.e., declared mass and seasonal upload patterns) related to videos by
32 both recreational anglers and spearfishers; (ii) higher social engagement (i.e., number of views and

33 likes) for videos by recreational anglers than spearfishers; *(iii)* differences in themes of discussion,
34 with anglers being mainly interested in fishing strategy and gears and spearfishers being more
35 interested in fishing actions shown on the videos; *iv)* positive and negative sentiments of both
36 recreational anglers and spearfishers towards the invasiveness and aggressiveness of the species.
37 The latter represents an interesting trade-off associated with recreational fishing of the bluefish: it
38 is perceived as an invasive species, but it is also a valued target fish because its voracity
39 contributes to the quality of the recreational fishing experience. Our study showcases the value of
40 exploring social media and associated data to better understand the ecological and human
41 dimensions of marine recreational fisheries in relation to distributional range shifts of species
42 associated with climate change.

43

44 **KEYWORDS:** bluefish, climate change, fish, human dimension, invasion, *Pomatomus saltatrix*,
45 recreational fishing

46

47 INTRODUCTION

48 Distributional range shifts of species represent one of the major ecological effects of climate
49 change (Pech et al., 2017). Marine ecosystems are especially sensitive to reshuffling of species
50 because of major changes in environmental variables, such as sea water temperature (Burrows et
51 al., 2011; Poloczanska et al., 2016), which can trigger rapid and large-scale distributional shifts,
52 especially among mobile species (Cheung et al., 2009; Fogarty et al., 2017). Alongside potential
53 ecological effects, distributional range shifts of marine species can also have direct impacts on
54 human well-being by affecting, for example, livelihoods, food security and cultural processes (Pech
55 et al., 2017). In this context, it is crucial to understand human perceptions towards changes in
56 species assemblages to develop effective adaptive management strategies, such as in the case of
57 the arrival of invasive species with potential negative effects (Kapitza et al., 2019; Shackleton et
58 al., 2019). However, the arrival (or increase in abundance) of a species could also have positive
59 effects on human activities such as fisheries targeting that specific species (e.g., Rees et al., 2017).

60 Fisheries are expected to be strongly affected by climate change and biological invasions
61 (Cochrane et al., 2009; Brander, 2010; Azzurro et al., 2019; Plagányi, 2019), with potential
62 repercussions along social and economic dimensions of these social-ecological systems (Cinner et
63 al., 2013; Salgueiro-Otero and Ojea, 2020). For example, distributional range shifts of species can
64 disrupt fishers and fishing communities and threaten their food security (Ojea et al., 2020).
65 Climate change can also have strong repercussions for recreational fisheries (Carpenter et al.,
66 2017; Townhill et al., 2019), but these are rarely considered despite the global importance of
67 recreational fishing both in terms of non-negligible biomass harvested and socio-economic
68 benefits (Arlinghaus et al., 2019). Distributional range shifts of marine species can have both
69 positive and negative effects on the quality of recreational fisheries from a human dimension
70 perspective (Townhill et al., 2019). For example, the arrival of a new species can be perceived as a

71 new opportunity by a group of recreational fishers, but as a pest by others because the motivation
72 and satisfaction in recreational fisheries is individually defined (Hunt et al., 2010; Curtis, 2018;
73 Arlinghaus et al., 2019). For example, the freshwater top predator European catfish (*Silurus glanis*)
74 has been introduced in Spain and Italy and it is spreading through river systems, negatively
75 affecting native species. Yet, an important tourism-based fishery has developed, creating benefits
76 to anglers and local economies (Rees et al., 2017; Cucherousset et al., 2018). Generally, from a
77 management perspective it is paramount to understand the human dimensions of recreational
78 fisheries and how they may be affected by distributional range shifts of native and non-native
79 species.

80 Recreational fishers are diverse and dispersed, which makes them a group of people that is
81 difficult to survey (Pollock et al., 1994), especially in the marine environment where monitoring is
82 constrained across time and space (Hyder et al., 2020 and references therein). Yet, many
83 recreational fishers are active on social media (Vitale et al., 2021), and sharing video contents of
84 their catches and memorable fishing trips on platform such as YouTube is embedded into
85 recreational fishing culture (Sbragaglia et al., 2020b). The content of videos and the information
86 associated with them, including social engagement and comments (Correia et al., 2021), are a
87 valuable resource to investigate the human dimension of recreational fishers. In particular, the
88 quantitative and systematic analysis of digital videos and associated comments can be a powerful
89 tool to characterize the important discussion topics (e.g., fishing strategy, fish behavior,
90 technology, or fishing gear; Sbragaglia et al., 2020b), and their associated sentiments. In this
91 context, the emerging approach of conservation culturomics is particularly interesting because it
92 aims at using digital data to characterize and understand contemporary problems in conservation
93 by looking at them from the perspective of human-nature interactions (Ladle et al., 2016).
94 Similarly, the ecological dimensions of target species is also important to understand recreational

95 fishers (e.g., fish size as a trophy or fish behavior related to capture; Beardmore et al., 2015; Rees
96 et al., 2017). Approaches such as iEcology, which allows the characterization of ecological patterns
97 and processes using digital data generated for other purposes (i.e., characterization of ecological
98 patterns and processes using digital data generated for other purposes; Jarić et al., 2020a), can
99 also play an important role in better characterizing the effects of distributional range shifts on
100 recreational fisheries. Therefore, videos posted on YouTube represent an interesting opportunity
101 to characterize possible differences in harvesting patterns, social engagement and sentiments of
102 recreational fishers towards distributional range shifts of species.

103 In this study, we characterize the ecological and social dimensions associated with videos
104 posted on YouTube by Italian recreational fishers targeting the bluefish, *Pomatomus saltatrix*
105 (Linnaeus, 1766). The species is native to several subtropical areas of the world (Juanes et al.,
106 1996; Silvano and Begossi, 2010; Sabatés et al., 2012) and has undergone a distributional range
107 shift in the North-Western Mediterranean and Adriatic Sea in the last 20-30 years (Sabatés and
108 Martin, 1993; Sabatés et al., 2012; Azzurro et al., 2019; Sbragaglia et al., 2020a). In particular, a
109 significant increase in bluefish commercial landings was observed around 1996 in the Western
110 Mediterranean basin (Sabatés et al., 2012), while in the North Adriatic Sea the first catches of
111 these species were recorded in 2005 (Dulcic et al., 2005). Meanwhile, bluefish has become a
112 regular catch for Italian marine recreational fishers on the Adriatic coast (Pranovi et al., 2016).
113 However, differences may exist between recreational anglers and spearfishers in the attitudes
114 towards species (Sbragaglia et al., 2020b). For example, the voracity and aggressiveness typical for
115 this species – which has been even documented to occasionally attack humans (de Sylva, 1976) –
116 can be perceived as a positive trait by recreational anglers because it can contribute to the quality
117 of the fishing experience (e.g. through high catch rates and strong fighting ability; Arlinghaus,
118 2006; Beardmore et al., 2015; French et al., 2019). In contrast, recreational spearfishers often have

119 intimate contact with the underwater environment and can see the species as a pest because it
120 can outcompete other species through aggressive behavior (Baird, 1873; de Sylva, 1976).

121 The objective of this study was to investigate the ecological and social dimensions of
122 bluefish recreational fisheries in an area where it has recently expanded focusing on recreational
123 anglers and spearfishers. We use videos and associated data posted on YouTube by Italian
124 recreational fishers targeting bluefish to compare recreational angling and spearfishing in terms of
125 harvesting patterns (i.e., seasonal upload patterns and declared mass), social engagement (i.e.,
126 number of views, likes and comments), content of comments (i.e., topics and themes of
127 discussion), and associated sentiments (i.e., polarity and emotions of words used in comments),
128 with specific focus on the discourse around the invasiveness and aggressive behavior of the
129 species.

130

131 **MATERIALS AND METHODS**

132 *Ethical aspects*

133 The data we mined from YouTube are publicly available. However, data privacy concerns and
134 ethical principles associated with human-subject research must be carefully considered when
135 using social media data (Zimmer, 2010; Di Minin et al., 2021). We followed recent
136 recommendations for responsible use of social media data in research (Monkman et al., 2018; Di
137 Minin et al., 2021; Sbragaglia et al., 2021b), considering data privacy concerns and aiming to
138 ensure compliance with the European Union's (EU) General Data Protection Regulation (GDPR).
139 Specifically, we minimized the data by discarding all but the required information and
140 pseudonymised the data by replacing IDs (e.g., channel title, channel ID). We kept all data related
141 to personal information in one dataset, while the rest of data presented in the paper were stored
142 in a separate dataset. Moreover, all the results are presented in aggregated format and

143 representative comments were adapted from the original comments (i.e. translated and partially
144 paraphrased) to prevent such information allowing the identification of the online content used in
145 this study.

146

147 ***The case study***

148 We explored Italian recreational fishing of the bluefish (*P. saltatrix*), and systematically mined data
149 on YouTube from 2009 to 2019 by using a methodological approach previously applied in other
150 studies (Sbragaglia et al., 2020b; Sbragaglia et al., 2021a); see also Correia et al. (2021) for a
151 review. We automatically retrieved the metadata of videos published concerning the species of
152 interest and sorted them into two groups: one related to captures by recreational angling and the
153 other one related to captures by recreational spearfishing. Recreational spearfishing was defined
154 as underwater fishing practiced by the exclusive use of free-diving techniques and a speargun,
155 while recreational angling was defined as hook-and-line fishing from either the coastline or from a
156 boat with natural baits or artificial lures.

157

158 ***Data mining***

159 We collected the data using the YouTube Data Application Program Interface (API v3) in May 2020,
160 following the steps reported in previous studies (Sbragaglia et al., 2020b; Sbragaglia et al., 2021a).
161 Briefly, we interfaced with the YouTube API by creating a customized R script, which we used to
162 download the metadata of videos using the name of the species in Italian (“serra”) as keyword.
163 This approach helped to narrow the results to the study region, but also captured homonyms and
164 other non-relevant content (Correia et al., 2017), and thus data required careful validation (see
165 below). We first compiled a raw dataset with the title and description of videos. In a second step,
166 we automatically searched the title and description of each video for specific keywords that were

167 already used in a previous study (Sbragaglia et al., 2020b). The keywords were subdivided into two
168 groups with the aim to sort the videos regarding recreational angling (e.g., “spinning”, “canna”,
169 “kayak”, which are related to the technique and gear) and recreational spearfishing (e.g.,
170 “aspetto”, “agguato”, “pesca sub”, which are related to the fishing strategy of activity itself). We
171 stored the resulting entries in a separate dataset that was subsequently manually cross-checked.
172 We excluded videos that were not interesting for the objective of this study because they were: (i)
173 not related to the target species; (ii) not showing the catch of the target species (i.e., catch and
174 release or not shooting while spearfishing); (iii) not related to the target country; and (iv)
175 duplicates of previously published videos. Then, we manually cross-checked the automatic
176 classification to identify the occurrence of false negatives (i.e., target videos previously not
177 recognized following the keywords), false positives (i.e., videos erroneously attributed to one of
178 the two groups) and mismatched categorizations (i.e., videos erroneously attributed to one fisher
179 group instead of the other). Once we compiled the final validated dataset, we annotated the mass
180 of the fish and location of the catch according to the information provided by the recreational
181 fisher in the title, description or video itself. Data mining was done with R software
182 (<https://www.r-project.org/>; version 3.5.0) using packages “jsonlite” (Ooms, 2014), “lubridate”
183 (Grolemund and Wickham, 2011), and “curl” ([https://cran.r-](https://cran.r-project.org/web/packages/curl/index.html)
184 [project.org/web/packages/curl/index.html](https://cran.r-project.org/web/packages/curl/index.html)).

185

186 ***Analysis of comments***

187 We systematically mined the text of all the public comments associated with the videos previously
188 identified and validated. We did a content analysis of comments following the approach presented
189 in a previous study (Sbragaglia et al., 2020b). Specifically, we classified the themes according to
190 their subject (fisher, fish, technology, and others topics) following a general coding scheme

191 (Madden et al., 2013). We paid specific attention to positive and negative feelings toward the
192 species because it was the main objective of this study. Then, we transformed the text of
193 comments into tokens (i.e., individual word units). We removed tokens without specific meanings
194 (e.g., conjunctions, logic operators, people names and other meaningless words) and analyzed
195 their frequency of occurrence in comments of videos by recreational anglers and spearfishers.
196 Furthermore, we selected specific keywords to put tokens into context in a concordance view with
197 a total number of 8 tokens to be displayed around the keyword. In particular, we searched for the
198 Italian keywords: “*invas**” (i.e., invasion), “*infest**” (i.e., infestation), “*piag**” (i.e., plague) and
199 “*predat**” (i.e., predator) in order to highlight the discourse addressing the species in terms of
200 invasiveness and predatory behavior and aggressiveness.

201 Finally, we applied sentiment analysis to all the tokens within comments according to the
202 Saif Mohammad’s NRC Emotion lexicon (Mohammad and Turney, 2013), using a modified version
203 of the Italian reference dictionary, which was specifically tailored to recreational fishing context.
204 The NRC emotion lexicon is a list of words and their associations with two sentiments (negative
205 and positive) and eight emotions (anger, fear, anticipation, trust, surprise, sadness, joy, and
206 disgust). We modified some of the associations according to a focus group discussion with
207 experienced recreational fishers (the modified version of the dictionary is available upon request).
208 The output of the sentiment analysis is a dataset with one YouTube comment in each row and ten
209 columns (two sentiments and eight emotions). We run all the analyses related to quantitative
210 analysis of comments in R (<https://www.r-project.org/>; version 3.5.0) with the additional package
211 “*quanteda*” (Benoit et al., 2018), and “*syuzhet*” (Jockers, 2017).

212

213 ***Data analysis***

214 We estimated annual periodicity of the upload patterns of videos for each group (angling and
215 spearfishing) by using RAIN (rhythmicity analysis incorporating nonparametric methods). This
216 method is a robust non-parametric method for the detection of rhythms in data that can detect
217 arbitrary oscillations (Thaben and Westermark, 2014). We estimated differences in declared mass
218 between angling and spearfishing using the non-parametric Mann–Whitney U test followed by the
219 estimation of Vargha and Delaney's A effect sizes (Vargha and Delaney, 2000). Then, we used
220 Generalized Linear Models (GLM; Nelder and Wedderburn, 1972) to estimate differences between
221 recreational angling and recreational spearfishing videos in the social engagement variables
222 (number of views, likes, and comments). We fitted one model for each social engagement variable
223 (i.e., response variable) and the fishing modality was used as a fixed effect (two levels: Angling and
224 spearfishing). We employed a negative binomial distribution to account for overdispersion of the
225 count data for social engagement variables (Bliss and Fisher, 1953; Gardner et al., 1995). We
226 estimated differences in the proportions of themes, polarity and emotions within comments using
227 a two-tailed z-test. In all the cases, we used a 95% confidence interval. We ran all the analyses in R
228 (<https://www.r-project.org/>; version 3.5.0) with the additional package “rain” (Thaben and
229 Westermark, 2014) and “effsize” (Torchiano and Torchiano, 2020).

230

231 **RESULTS**

232 We identified 376 videos (283 Angling and 93 Spearfishing) and retrieved the location of the
233 capture from 167 of them (135 for the angling and 31 for spearfishing; Fig. 1A). Moreover, we
234 retrieved the mass of the fish from 50 videos (36 for the angling and 14 for spearfishing; Fig. 1B),
235 which did not reveal significant ($U = 287$; $p = 0.455$; $A = 0.57$) differences between recreational
236 angling (median = 3.7 kg) and spearfishing (median = 2.75 kg; Fig. 1B). We did not identify

237 significant seasonal patterns in the upload of videos for both angling ($p = 0.568$) and spearfishing
238 ($p = 0.954$; Fig. 1C).

239 Regarding social engagement, we found that the number of views was significantly lower in
240 recreational spearfishing videos compared to videos posted about recreational angling [Rate Ratio
241 = 3.52 (2.56–4.92); $p < 0.001$; Fig. 2A]. The same difference was found in relation to the number of
242 likes [Rate Ratio = 0.34 (0.24–0.49); $p < 0.001$; Fig. 2B]. We did not find significant ($p = 0.381$)
243 differences in the number of comments left after watching a video by recreational angling and
244 spearfishing (Fig. 2C).

245 We analyzed the content of 9,091 comments (6,733 for angling and 2,358 for spearfishing)
246 in a total of 320 videos (235 for angling and 85 for spearfishing), and we coded a total of 11,109
247 themes (7,976 for angling and 3,133 for spearfishing, Table 1). Videos posted by recreational
248 anglers received significantly ($p < 0.05$) more comments with themes related to positive feelings
249 toward the species (1.4%) than videos posted by recreational spearfishers (0.9%), while themes
250 related to negative feelings towards the species had a similar occurrence ($p = 0.292$; 0.4% and
251 0.5% for angling and spearfishing, respectively; Table 1). Moreover, comments to videos by
252 recreational anglers indicated significantly ($p < 0.001$) more themes related to asking advice about
253 fishing strategy or location (e.g., “*How did you bait the hook*”; 8%) or gears (“*what type of pole did*
254 *you use?*”, 6.8%) compared to videos by recreational spearfishers (1.5% for both themes; Table 1).
255 While videos by recreational spearfishers revealed significantly ($p < 0.001$) more comments
256 related with themes suggesting appreciation for the skill of the fisher (e.g. “*wonderful fishing*
257 *action*,” 5.1%) and athletic performance (e.g., “*wonderful free diving action*”) as compared to
258 recreational anglers (0.3% and zero, respectively; Table 1). The quantitative analysis of the text
259 identified a total of 129,534 tokens (i.e., individual word units after breaking the text of
260 comments). After removing meaningless tokens, we identified 12,414 for angling and 5,937 for

261 spearfishing for further analysis. Some tokens only appeared in the comments of videos posted by
262 one of the two groups. For examples, “*bravo*”, “*sea*” (“mare”), “friend” (“amico”) only appeared in
263 comments of videos by recreational spearfishers (Fig. 3), while “*pescà*” (“fishing”), “*fishing rod*”
264 (“*canna*”), “*fish*” (“*pesce*”) only appeared in comments of videos by recreational anglers (Fig. 3).
265 Most importantly, the concordance view of the keywords related to invasiveness and predatory
266 behavior of the species indicated 82 matches (60 for angling and 22 for spearfishing). We highlight
267 the most significant ones for angling and spearfishing (Table 2). For both groups comments refers
268 to the bluefish as an invasive species, a pest, and a magnificent ruthless predator.

269 Sentiment analysis indicated differences in sentiment polarity between comments related
270 to videos posted by recreational anglers and spearfishers (Fig. 4). The prevailing sentiment was
271 positive and it was significantly ($p < 0.001$) lower in comments to videos by recreational anglers
272 (80%) than spearfishers (89%; Fig. 4). The emotions related to comments on videos by spearfishers
273 indicated a significantly ($p < 0.001$) higher frequency of trust (32%) and joy (25%) in comparison to
274 videos posted by anglers (29% and 21%, respectively; Fig. 5). In contrast, the emotions related to
275 comments on videos by anglers indicated a significantly ($p < 0.001$) higher frequency of anger
276 (5%), disgust (3%), fear (6%), and sadness (6%) in comparison to videos posted by spearfishers
277 (2%, 1%, 3%, and 3% respectively; Fig. 5). Finally, anticipation did not show significant differences
278 between comments on videos by anglers and spearfishers (Fig. 5).

279

280 **DISCUSSION**

281 We show how social media can provide insights into ecological and human dimensions of
282 recreational fishers related to distributional range shifts of an invasive species. There are four
283 major results. First, we found similar declared mass between recreational anglers and
284 spearfishers, which can be linked to similar size-selection potential; moreover, the similar seasonal

285 upload patterns could be linked to seasonal migratory behaviour of the species or to the lack of
286 seasonal patterns of fishing effort. Second, we found higher social engagement (i.e., number of
287 views and likes) with videos by recreational anglers compared to spearfishers, suggesting that
288 recreational anglers may be more engaged in fishing this species than recreational spearfishers.
289 Third, the content of comments suggested differences in the values of the two groups of
290 recreational fishers. Specifically, spearfishers engaged more with fishing actions, while anglers
291 discussed more about fishing strategy and gears shown in the videos. Fourth, comments left after
292 watching the videos indicated a higher frequency of negative polarity and emotions (anger,
293 discuss, fear and sadness) in angling videos in contrast to spearfishing. However, in both groups
294 the sentiments towards the invasiveness and aggressiveness of the species were both negative
295 and positive, which may provide specific information on how focusing adaptation strategies for
296 managing recreational fishing in the context of distributional range shift of this species.

297 The similar mass of the bluefish declared in videos by recreational anglers and spearfishers
298 could suggest that the size-selection potential is not different among these two groups. Previous
299 studies indicated that the declared mass was higher in videos posted by recreational anglers than
300 spearfishers targeting the common dentex, *Dentex dentex* (Sbragaglia et al., 2020b), the dusky,
301 *Epinephelus marginatus*, and white grouper, *Epinephelus aeneus* (Sbragaglia et al., 2021a).
302 Differences in declared mass can also be related to social dynamics, such as biases towards
303 particularly memorable and hence large fish or inflation of mass for increasing social engagement
304 (Sbragaglia et al., 2020b). However, it is conceivable that such dynamics depend on differences in
305 the attitudes of recreational anglers and spearfishers towards different species, which could be
306 the case of the results shown here. Importantly, in 40% of the videos by recreational anglers and
307 spearfishers the declared mass of the bluefish was above 5 kg, which already represents a trophy
308 size. This suggests that both groups could only posts videos with trophy catch or have similar

309 chances to target trophy-size specimens and therefore the size of the fish is unlikely to play a
310 major role in the differences in human dimensions highlighted below.

311 We did not find differences in the seasonal patterns of videos upload. Previously studies
312 documented that videos by recreational spearfishers showed peaks of upload around the summer
313 for the common dentex and the dusky grouper, which could be associated to seasonal bathymetric
314 migrations of species (Sbragaglia et al., 2020b; Sbragaglia et al., 2021a). Alternatively, they might
315 be also related to vacation times and more pleasant weather to go fishing during the summer. The
316 lack of differences of videos upload reported here could be linked to seasonal population
317 dynamics such as migration. Seasonal latitudinal migration are well-described for the bluefish
318 (Lund Jr and Maltezos, 1970; Shepherd et al., 2006; Silvano and Begossi, 2010; Brodie et al., 2018).
319 Interestingly, a recent study showed that seasonal migration of the bluefish can be characterized
320 using videos posted on YouTube by recreational anglers when geographical locations are explicitly
321 considered (Eryaşar and Saygu, 2022). In our study, seasonal migration could have confounded the
322 seasonal catchability of the species considering that our results are based on videos covering the
323 entire coast of Italy where this species is expected to perform latitudinal migration following
324 seasonal temperature changes. Further research is needed to assess the existence of a lag time
325 between the recording of videos and their upload on social media and whether video upload
326 patterns on YouTube can be representative of seasonal migration of the bluefish in the area of
327 study

328 Videos by recreational anglers received more views and likes than videos by recreational
329 spearfishers. This result is the opposite of a previous study where videos by recreational
330 spearfishers targeting the common dentex received more social engagement than those by
331 anglers (Sbragaglia et al., 2020b). This supports the idea that social engagement related to visual
332 media may be linked to specific attitudes of recreational spearfishers and anglers that vary

333 according to the target species (assuming that the public engaged with the videos are mainly
334 recreational anglers and spearfishers, respectively). Such interpretation may be supported by the
335 fact that recreational anglers may be more engaged than spearfishers in fishing this species;
336 indeed 6.9% of the themes in the comments of angling videos were related to asking advice about
337 the type of gear used with respect to 1.5% of spearfishing videos. Additional support for this lies in
338 in the fact that in the videos related to the common dentex, only 3.5% of the themes in the
339 comments of angling videos were related to asking advice about the type of gear (1.2% for
340 spearfishing; Sbragaglia et al., 2020b), suggesting more interest of anglers in fishing the bluefish
341 than the common dentex.

342 The results of the content analysis and tokenization of the text of comments suggested
343 that different social and psychological domains are expressed when recreational anglers and
344 spearfishers engage with videos. Recreational spearfishers necessitate developing freediving skills
345 and the athletic performance is a complementary component to be successful in catching many
346 species such as the bluefish that is fished applying a sit-and-wait strategy at the sea bottom (at
347 least in Italy where recreational spearfishing is only allowed via freediving). This may explain why
348 appreciation for athletic performance and fishing skills was more frequent among the themes in
349 the comments of recreational spearfishers when compared to anglers. A similar result was also
350 documented for the common dentex (Sbragaglia et al., 2020b). Moreover, an important non-catch
351 related motivation for recreational spearfishers is to be underwater and in contact with the
352 beauty of the underwater world (Young et al., 2016; Assis et al., 2018). This could explain why the
353 word “*sea*” is one of the most frequent token identified and only appeared in comments to videos
354 by recreational spearfishers. In contrast, the discussion in comments to videos by recreational
355 anglers was mostly about themes that relate to fishing strategy and gears, supported by the fact
356 that the words “*fishing*”, “*fish*” and “*fishing rod*” were the most common tokens, only appearing in

357 comments of videos by anglers. This can also be linked to motivation of recreational anglers and
358 the emotions felt during fishing the bluefish (see also table 2), an aspect that among anglers is
359 usually mediated by the jumping, fighting and challenging behaviour of predatory species (Fedler
360 and Ditton, 1994; Arlinghaus, 2006; French et al., 2019). Finally, although we documented a
361 significantly higher frequency of themes related to positive feelings toward the species in
362 comment to videos by anglers with respect to spearfishers, the absolute frequency in the overall
363 number of themes was low (1.4%), which indicates that species attributes were not relevant
364 compared to other themes.

365 The prevailing sentiments of the comments were positive for both videos by recreational
366 anglers and spearfishers. In particular, positive emotions such as joy were more frequent in
367 comments to videos by recreational spearfishers. This aligns with the results of a recent study with
368 Spanish web-surveyed recreational fishers showing that spearfishers report higher levels of catch
369 and activity satisfaction than recreational anglers (Gordoa et al., 2019), assuming that the
370 comments are mostly made by recreational spearfishers. Interestingly, we documented that
371 negative emotions such as anger were more frequent in comments to videos by recreational
372 anglers. This could be related to three types of criticisms that were more frequent according to the
373 content analysis (table 1): Criticism related to the declared mass of the fish displayed in the video,
374 criticism related to the behaviour of the fisher, or criticism related to the type of gear and strategy
375 used in the video. Finally, we showed that both groups referred to the species as an invasive
376 species and a pest (e.g., *“it is a pest”*, *“the bluefish is now an invader of the sea”*). This indicates
377 that despite the species becoming quite common for recreational fishers, it is still perceived a
378 threat for local ecosystems (e.g., *“sooner or later our fishes will be a memory”*). Indeed, the
379 bluefish is addressed to as *“ruthless killer”*, *“cruel species”* and *“a predator that kills even if it is not*
380 *hungry”*, which agrees with *“unmitigated butcher”*, a definition associated with the species almost

381 150 hundred years ago (Baird, 1873). On the other hand, the aggressiveness (e.g., “*What a*
382 *predator and what jaws*”, “*Fantastic and very strong predator*”) and voraciousness (e.g., “*It is a*
383 *very voracious predator*”) of this species is also one of the traits that makes it of interest for both
384 recreational anglers and spearfishers (e.g., “*It is exciting to see this predator in action*”, “*I really*
385 *enjoyed catching this predator*”, “*it is a pest, but it is very funny to fish*”).

386 Our results have implications for management. In cases where the objective is to control
387 invasion of bluefish, for example through culling as is occurring with the alien invasive lionfish
388 (*Pterois miles*) in the Eastern Mediterranean Sea (Jimenez et al., 2017), the sentiments towards
389 bluefish could be strategically used to foster engagement with control actions. Indeed, angling
390 contests exclusively targeting the bluefish are already emerging in the area of study as voluntary
391 actions that are caused by anglers’ perception of the bluefish as an invasive species (VS personal
392 observation). In the case where the management objective is to promote adaptation of
393 recreational fisheries to the arrival of the bluefish (e.g., van Putten et al., 2017), the positive
394 sentiments towards the bluefish could be used as a mechanism facilitating social acceptance of
395 this species. Finally, the content and sentiment analysis presented in our study highlighted that
396 recreational fishers have knowledge and perceptions about the negative impact of the bluefish on
397 marine ecosystems in the area of study, this aspect requires further research because local
398 ecological knowledge of recreational fishers may provide complementary information to
399 understand about the potential ecological impacts of the invasion of the bluefish.

400 We recognize that our results must be interpreted with caution because the digital videos
401 and associated data used here are not representative of the entire population of Italian marine
402 recreational fishers. A recent study characterized the profile of recreational fishers using social
403 media in Catalonia, Spain (Vitale et al., 2021), and found that between 12% and 21% of
404 recreational fishers share their catches on social media, which could be assumed to be similar in

405 the area of study. This situation can bias our inferences if recreational fishers that do not engage
406 with social media platforms have markedly different views and sentiments. However, it must be
407 considered that recreational fishers can leave comments on YouTube even if they are not sharing
408 their catches, therefore the sentiments documented here likely represent a larger proportion of
409 recreational fishers than that documented in Vitale et al. (2021). Additional biases have been
410 appropriately discussed elsewhere (Jarić et al., 2020b; Sbragaglia et al., 2020b; Sbragaglia et al.,
411 2021a) and include aspects of data availability (e.g., YouTube is a dynamic cultural system and
412 video contents and associated digital data can be modified or erased), and data mining approach
413 (e.g., the keyword used here for the systematic mining of data could be not entirely representative
414 of all the videos uploaded). Moreover, we did not provide an explicit spatio-temporal analysis of
415 recreational fishers' sentiments, which is a possible limitation because the bluefish could trigger
416 more negative sentiments in the northern part of the area of study where it arrived more recently
417 (Azzurro et al., 2019). Future studies should test whether such methodological approach is suitable
418 to quantify spatio-temporal changes of sentiments. Despite such limitations, our study shows how
419 social media can be used to highlight qualitative and quantitative aspects of human dimensions
420 that may be useful for recreational fisheries management. Our results are based on a local case
421 study in recreational fishing, but they can be extended to larger spatial scales, other species and
422 processes.

423

424 **ACKNOWLEDGMENTS**

425 VS is supported by a "*Juan de la Cierva Incorporación*" research fellowship (IJC2018-035389-I)
426 granted by the Spanish Ministry of Science and Innovation. RAC is currently supported by funding
427 from the University of Helsinki. MC acknowledges partial funding from the European Union's
428 Horizon 2020 research and innovation programme under grant agreement No 869300

429 (FutureMares). VS and MC acknowledge the Spanish government through the “Severo Ochoa
430 Centre of Excellence” accreditation to ICM-CSIC (#CEX2019-000928-S). RA is supported by the
431 German Ministry of Education and Research (marEEshift: 01LC1826D and Aquatag 033W046A).

432

433 **CONFLICT OF INTEREST**

434 The authors declare no conflict of interests

435

436 **AUTHOR CONTRIBUTIONS**

437 V.S. conceived the study; V.S. performed the data mining with inputs by R.A.C.; S.C. crossed
438 checked the results and scored the content of comments; V.S. analysed the data, V.S., R.A.C., R.A
439 interpreted the data, V.S. led the writing of the manuscript with inputs by all other co-authors. All
440 authors gave final approval for publication.

441

442 **DATA AVAILABILITY**

443 Data will be available on a public repository upon acceptance of the paper.

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446 recreational fishing: The case of catch orientation of German anglers. *N Am J Fish Manage*,
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613

614 **Table 1** – Frequency of theme occurrence (%) with respect to all the themes coded in the
 615 comments posted by recreational anglers (N = 7976) and spearfishers (N = 3133) subdivided
 616 according to the subject (Sbragaglia et al., 2020b). Results of the z-test are reported in terms on χ^2
 617 and p values.

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Subject	Theme	Angling	Spearfishing	χ^2	p
Fisher	Asking advice about fishing strategy or location	8.0	1.5	165.5	< 0.001
	Appreciation for athletic performance	-	5.8	-	-
	Appreciation for fishing skills	0.3	5.1	318.6	< 0.001
	General appreciation for the fisher	3.8	6.1	26.7	< 0.001
	Criticism related to the declared mass	0.7	0.1	14.5	< 0.001
	Criticism related to the fishing behavior	1.4	0.4	16.9	< 0.001
	Agreement with previous comment	0.6	0.3	2.2	0.136
	Reply to previous comment	36.9	31.1	36.0	< 0.001
	General greetings	11.6	19.6	116.5	< 0.001
	Joke regarding the fishing skills	0.2	1.0	30.0	< 0.001
	Asking personal information	2.5	1.5	11.1	< 0.001
Fish	Appreciation for fish size	1.9	5.5	98.8	< 0.001
	Opinion on fish behavior	0.4	0.3	0.5	0.467
	Opinion of fish conditions	0.1	0.0	-	-
	Criticism related to killing a fish	0.1	-	-	-
	Positive feeling toward the species	1.4	0.9	5.5	< 0.05
	Negative feeling toward the species	0.4	0.5	1.1	0.292
	Comment related to food topics	0.6	0.6	0.0	1
	Comparison with seabass (<i>Dicentrarchus labrax</i>)	0.1	0.1	-	-
Technology	Appreciation for gear used or strategy used	0.8	0.4	3.8	0.051
	Criticism on the type of gear used or strategy used	1.6	0.3	32.5	< 0.001
	Asking advice about the type of gear used	6.8	1.5	130.2	< 0.001
Others	Appreciation for the environmental context	0.4	0.9	10.4	< 0.01
	General appreciation for the video	7.5	8.1	0.9	0.351
	Opinion on the quality of the video	0.5	0.6	0.3	0.569
	Criticism towards pollution and commercial fishing	0.2	0.3	1.9	0.167
	Expression personal feelings on the video	0.3	0.8	8.8	< 0.01
	Fishing anecdote	2.6	1.2	18.0	< 0.001
	Declaration of submission to the channel	1.4	1.1	1.7	0.197
	Non-interpretable comment	5.7	3.8	16.3	< 0.001

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622 **Table 2** – Results of the concordance view related to invasiveness and predatory behavior of *P.*
 623 *saltatrix* (keywords used: “*invas**”, “*infest**”, “*piag**” and “*predat**”). A summary of the discourse
 624 going on around the species in terms of invasiveness, pest and aggressive predators is reported for
 625 both angling and spearfishing together with negative (-) and positive (+) sentiments.

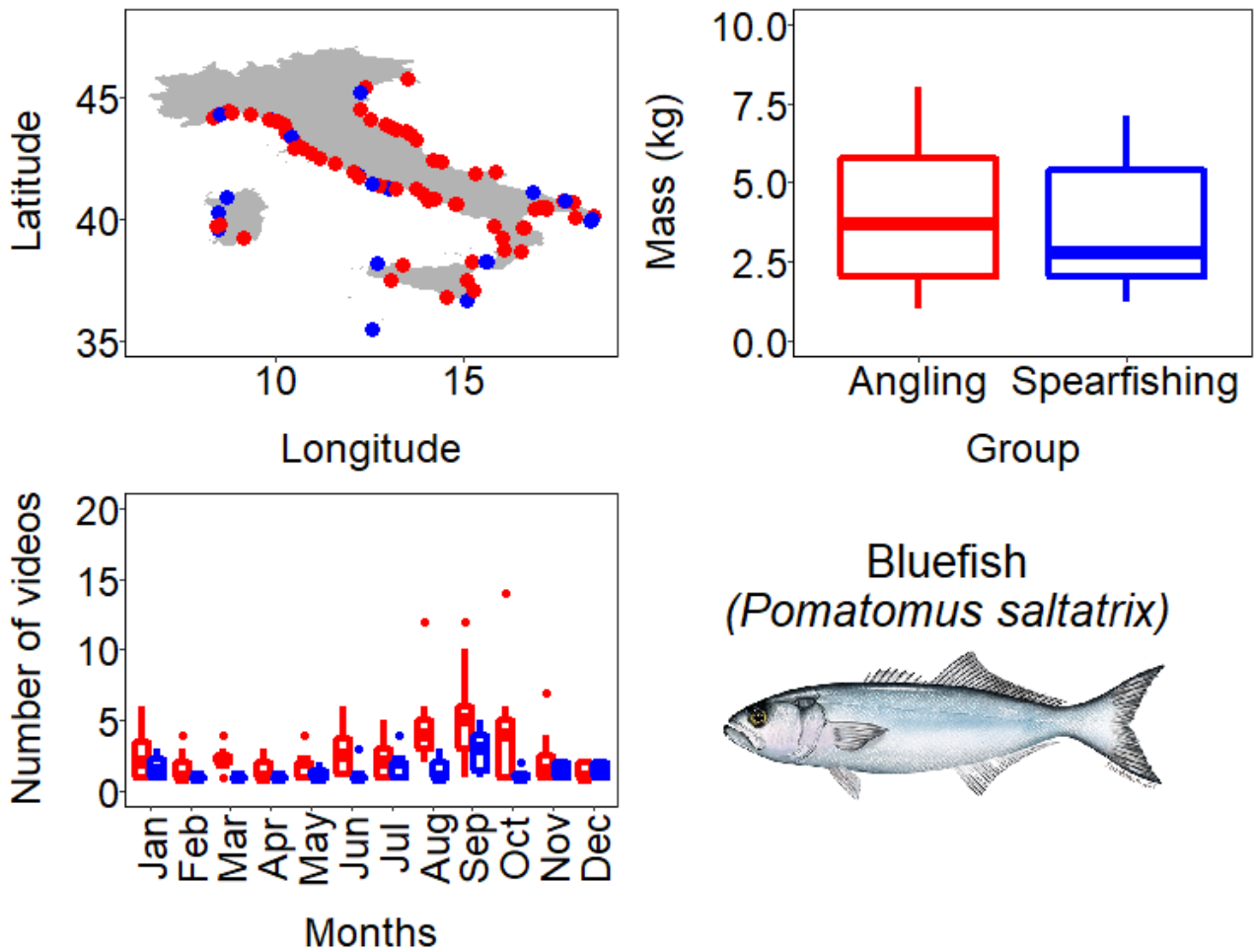
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Group	Summary of comment	Sentiment
angling	<i>This species is a pest</i>	-
angling	<i>Never release it. It is a pest and very voracious. Sooner or later our fish will be a memory</i>	-
angling	<i>It is a damned fish and a pest. It has devoured everything</i>	-
angling	<i>The sea is invaded by the bluefish</i>	-
angling	<i>It has invaded our sea and it has devoured everything</i>	-
angling	<i>The bluefish is now an invader of the sea</i>	-
angling	<i>it is a pest of our sea and a ruthless killer</i>	-
angling	<i>it is a cruel species</i>	-
angling	<i>It is exciting to see this predator in action</i>	+
angling	<i>What a predator and what jaws</i>	+
angling	<i>What a predator</i>	+
angling	<i>Fantastic and very strong predator</i>	+
angling	<i>It is a very voracious predator</i>	+
angling	<i>They are very smart and not dumb as the barracuda</i>	+
spearfishing	<i>It is a pest</i>	-
spearfishing	<i>It is a pest and non-native of the Mediterranean</i>	-
spearfishing	<i>This area is invaded by the bluefish</i>	-
spearfishing	<i>You are is invaded by the bluefish</i>	-
spearfishing	<i>Gillnets and seining nets will protect us from any invasion</i>	-
Spearfishing	<i>School of invasive damned bluefish</i>	-
spearfishing	<i>It is a pest , but it is very funny to fish</i>	-/+
spearfishing	<i>I love this predator</i>	+
spearfishing	<i>Magnificent predator. Cum laude to the bluefish.</i>	+
spearfishing	<i>It is a magnificent predator and it kills even if it is not hungry</i>	+
spearfishing	<i>I really enjoyed catching this predator</i>	+
spearfishing	<i>What a predator</i>	+
spearfishing	<i>It is a ruthless predators</i>	+

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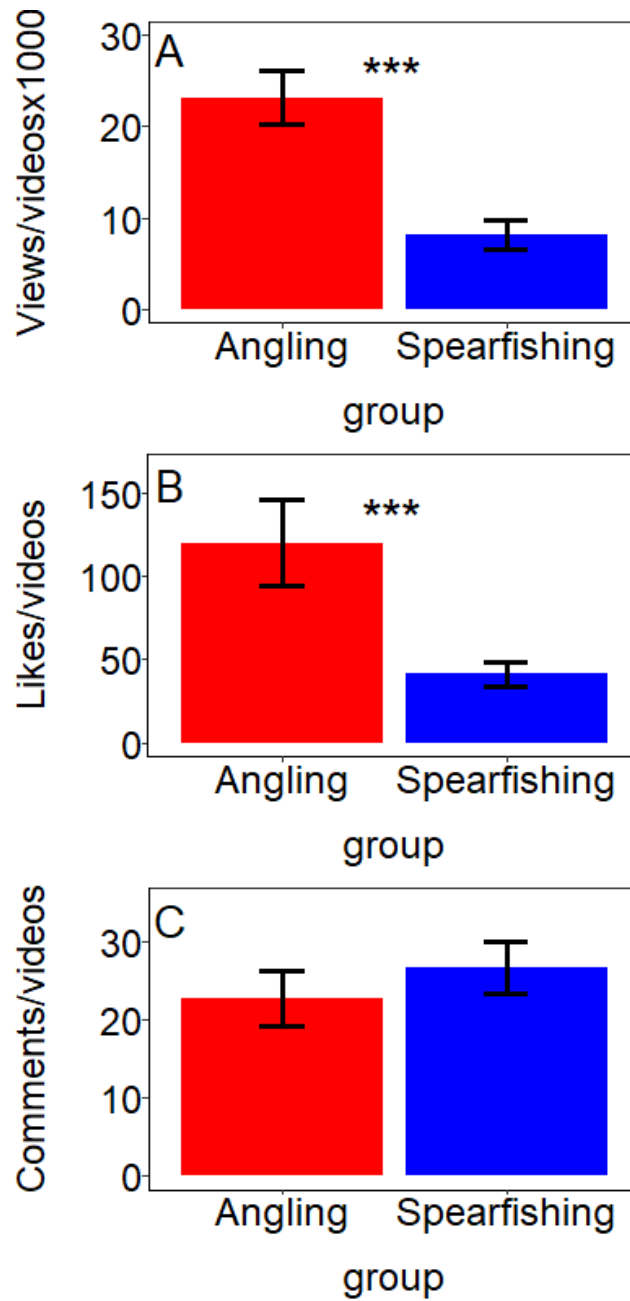
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632 **Figure 1** – The summary of the data for the videos related to recreational fisheries of the bluefish
 633 (*Pomatomus saltatrix*) between 2009 and 2019 in Italy: (A) the geographical distribution of the
 634 videos according to the information retrieved in their title, description as well as in the video itself
 635 (Red circles represents recreational angling, N = 135; while blue circles represent recreational
 636 spearfishing, N = 31); (B) the declared mass (kg) for recreational anglers (N = 36) and recreational
 637 spearfishers (N = 14); (C) videos for each month (angling, N = 283; spearfishing: N = 93); The image
 638 of the bluefish is adapted from: <https://en.wikipedia.org/wiki/Bluefish>.

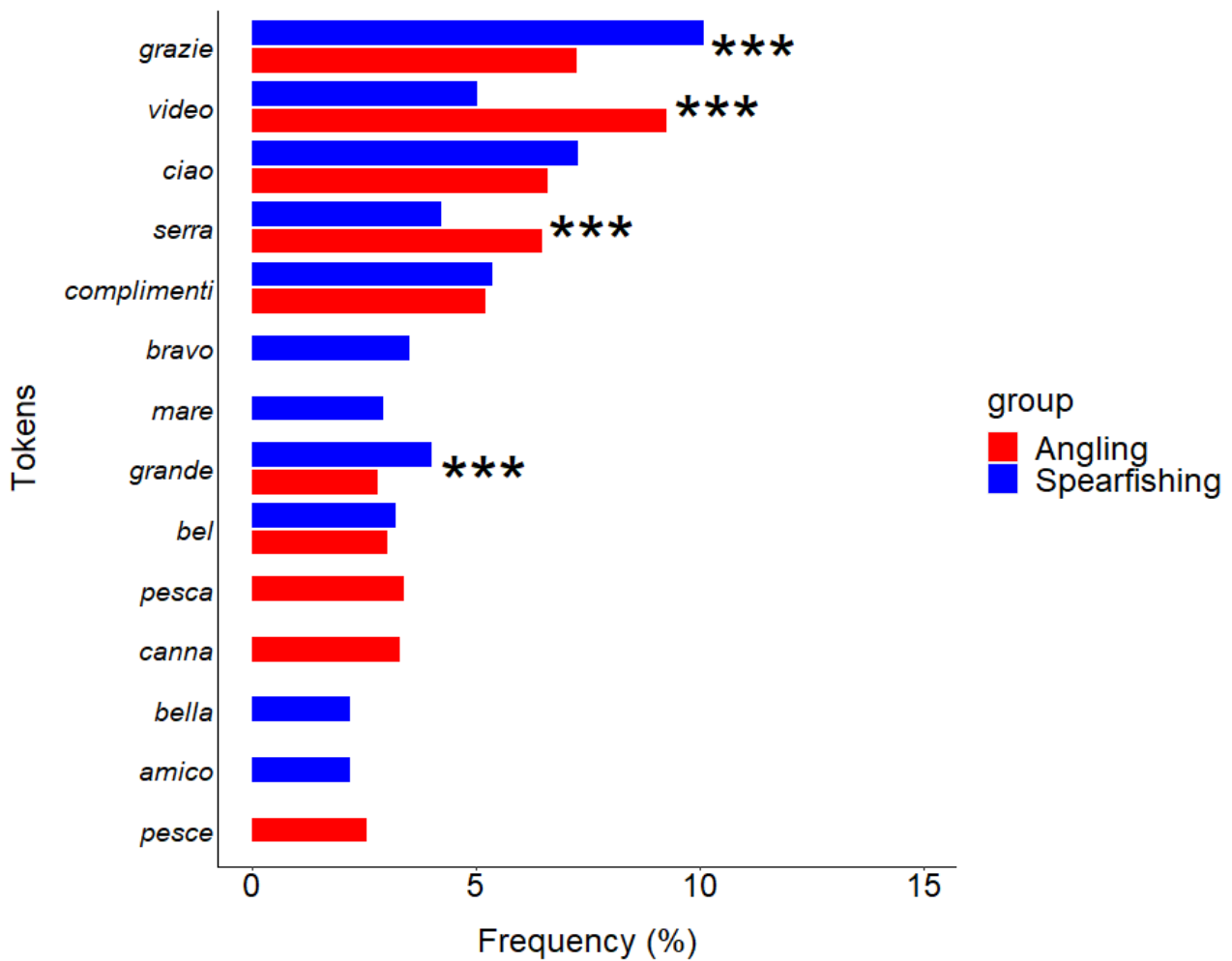
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Figure 2 – Barplots of the average social engagement for both angling and spearfishing together with standard error of the mean: (A) number of views; (B) number of likes; (C) number of comments. The total number of identified videos is 283 for angling and 93 for spearfishing. Significant differences are reported according to the results of the GLM models (***: $p < 0.001$).



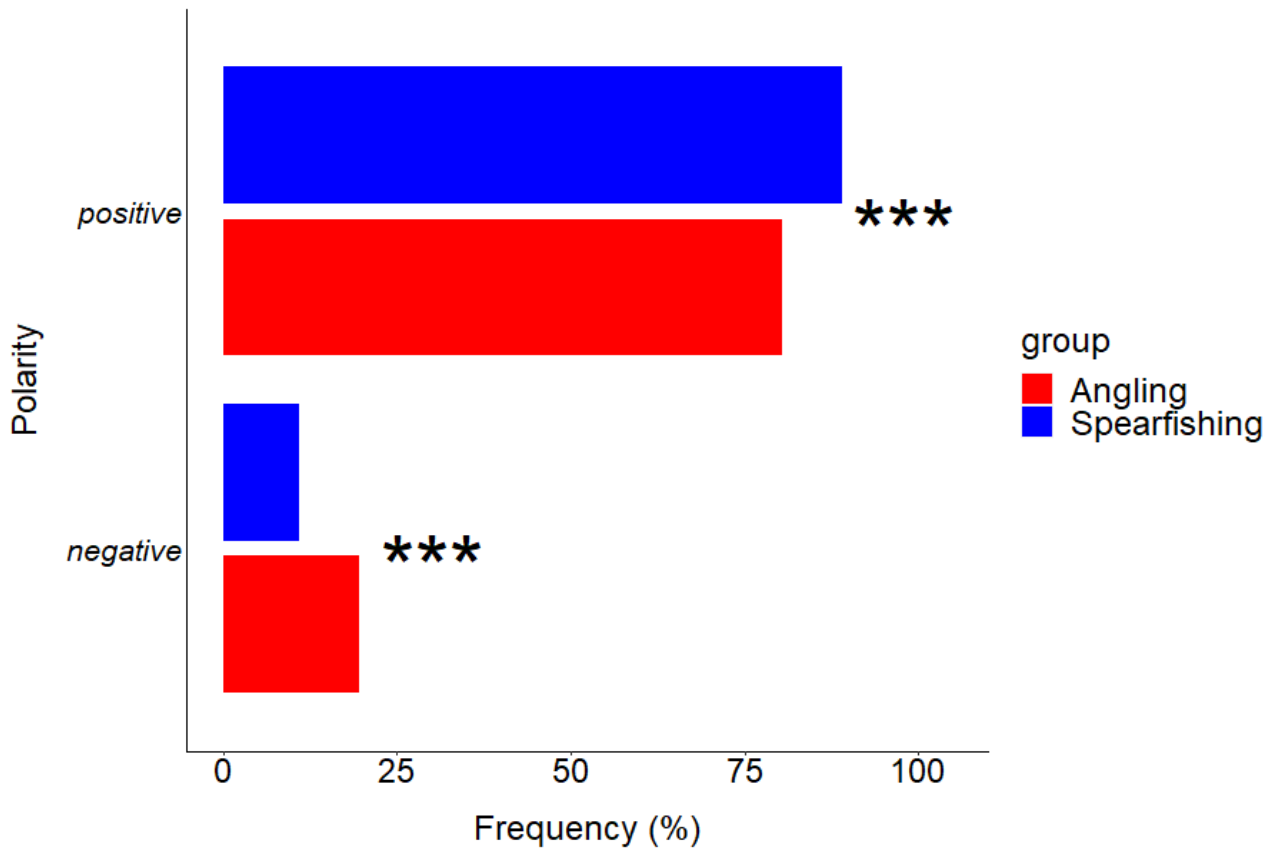
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655 **Figure 3** – Frequency of the most common tokens used in the comments on videos posted by
 656 recreational anglers and spearfishers. Tokens are reported in Italian and their relative translation
 657 is reported between parenthesis as follow: grazie (thank you); video (video); ciao (hello); serra (the
 658 common name for bluefish, *P. saltatrix*); complimenti (congratulations); bravo (bravo); mare (sea);
 659 grande (good boy); bel (wonderful); pesca (fishing); canna (fishing rod); bella (wonderful); amico
 660 (friend); pesce (fish). Significant differences are reported according to the results of the z-test
 661 (***: $p < 0.001$).

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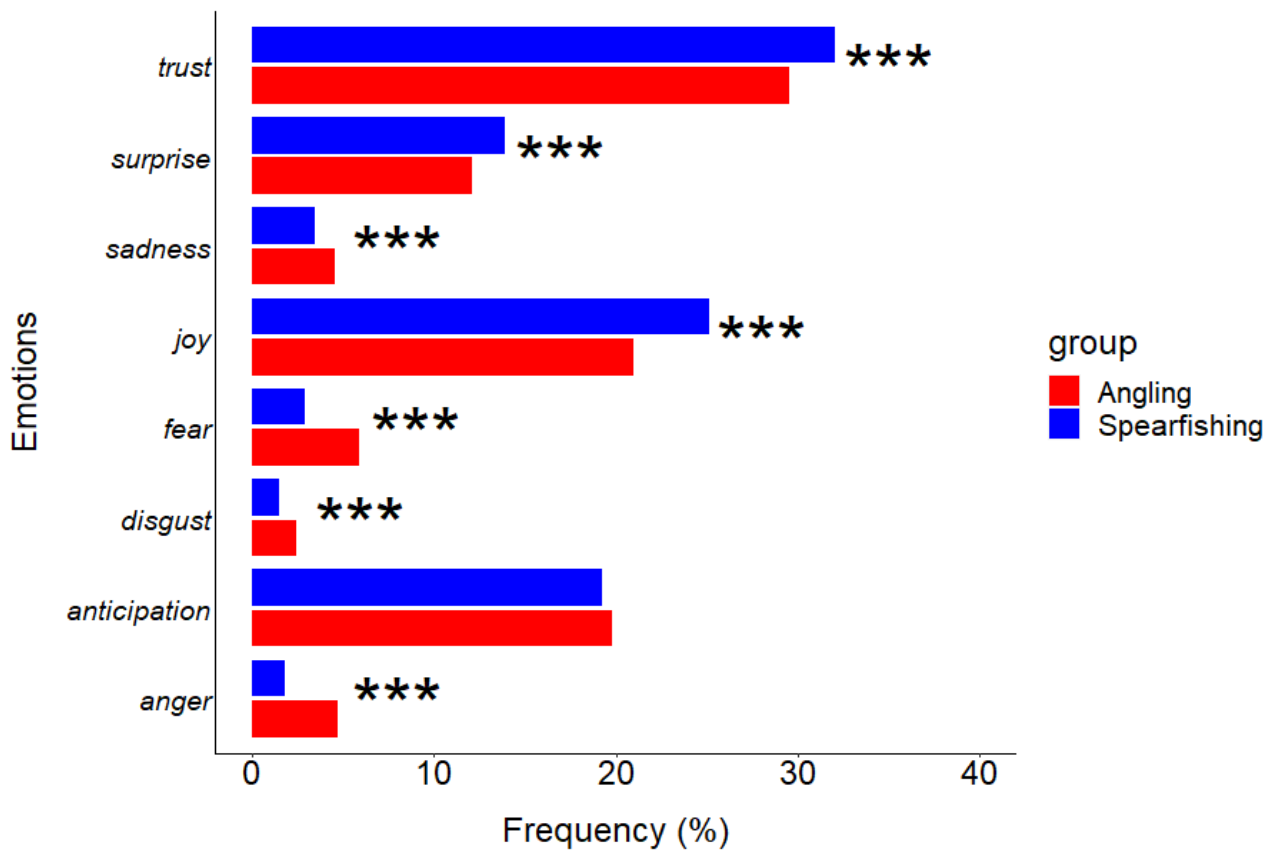
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665 **Figure 4** – Frequency of polarity of emotions computed with sentiment analysis using a modified
 666 version of the Saif Mohammad’s NRC Emotion lexicon (Mohammad and Turney, 2013) for both
 667 comments of videos posted by recreational anglers (total sentiments scored = 10837) and
 668 spearfishers (total sentiments scored = 5476). Significant differences are reported according to the
 669 results of the z-test (***: $p < 0.001$).

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 674 **Figure 5** – Frequency of emotions computed with sentiment analysis using a modified version of
 675 the Saif Mohammad’s NRC Emotion lexicon (Mohammad and Turney, 2013) for both comments of
 676 videos posted by recreational anglers (total sentiments scored = 23859) and spearfishers (total
 677 sentiments scored = 10837). Significant differences are reported according to the results of the z-
 678 test (***: $p < 0.001$).

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