**Title:** 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

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## ABSTRACT

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

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

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

## INTRODUCTION

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

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

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

Recreational fishers are diverse and dispersed, which makes them a group of people that is difficult to survey (Pollock et al., 1994), especially in the marine environment where monitoring is constrained across time and space (Hyder et al., 2020 and references therein). Yet, many recreational fishers are active on social media (Vitale et al., 2021), and sharing video contents of their catches and memorable fishing trips on platform such as YouTube is embedded into recreational fishing culture (Sbragaglia et al., 2020b). The content of videos and the information associated with them, including social engagement and comments (Correia et al., 2021), are a valuable resource to investigate the human dimension of recreational fishers. In particular, the quantitative and systematic analysis of digital videos and associated comments can be a powerful tool to characterize the important discussion topics (e.g., fishing strategy, fish behavior, technology, or fishing gear; Sbragaglia et al., 2020b), and their associated sentiments. In this context, the emerging approach of conservation culturomics is particularly interesting because it aims at using digital data to characterize and understand contemporary problems in conservation by looking at them from the perspective of human-nature interactions (Ladle et al., 2016). Similarly, the ecological dimensions of target species is also important to understand recreational fishers (e.g., fish size as a trophy or fish behavior related to capture; Beardmore et al., 2015; Rees et al., 2017). Approaches

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

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

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

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

## MATERIALS AND METHODS

### *Ethical aspects*

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

original comments (i.e. translated and partially paraphrased) to prevent such information allowing the identification of the online content used in this study.

***The case study***

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

***Data mining***

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

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

***Analysis of comments***

We systematically mined the text of all the public comments associated with the videos previously identified and validated. We did a content analysis of comments following the approach presented in a previous study (Sbragaglia et al., 2020b). Specifically, we classified the themes according to their subject (fisher, fish, technology, and others topics) following a general coding scheme (Madden et al., 2013). We paid specific attention to positive and negative feelings toward the species because it was the main objective of this study. Then, we transformed the text of comments into tokens (i.e.,

individual word units). We removed tokens without specific meanings (e.g., conjunctions, logic operators, people names and other meaningless words) and analyzed their frequency of occurrence in comments of videos by recreational anglers and spearfishers. Furthermore, we selected specific keywords to put tokens into context in a concordance view with a total number of 8 tokens to be displayed around the keyword. In particular, we searched for the Italian keywords: "*invas**" (i.e., invasion), "*infest**" (i.e., infestation), "*piag**" (i.e., plague) and "*predat**" (i.e., predator) in order to highlight the discourse addressing the species in terms of invasiveness and predatory behavior and aggressiveness.

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

***Data analysis***

We estimated annual periodicity of the upload patterns of videos for each group (angling and spearfishing) by using RAIN (rhythmicity analysis incorporating nonparametric methods). This method is a robust non-parametric method for the detection of rhythms in data that can detect

arbitrary oscillations (Thaben and Westermark, 2014). We estimated differences in declared mass between angling and spearfishing using the non-parametric Mann–Whitney U test followed by the estimation of Vargha and Delaney's A effect sizes (Vargha and Delaney, 2000). Then, we used Generalized Linear Models (GLM; Nelder and Wedderburn, 1972) to estimate differences between recreational angling and recreational spearfishing videos in the social engagement variables (number of views, likes, and comments). We fitted one model for each social engagement variable (i.e., response variable) and the fishing modality was used as a fixed effect (two levels: Angling and spearfishing). We employed a negative binomial distribution to account for overdispersion of the count data for social engagement variables (Bliss and Fisher, 1953; Gardner et al., 1995). We estimated differences in the proportions of themes, polarity and emotions within comments using a two-tailed z-test. In all the cases, we used a 95% confidence interval. We ran all the analyses in R (https://www.r-project.org/; version 3.5.0) with the additional package "rain" (Thaben and Westermark, 2014) and "effsize" (Torchiano and Torchiano, 2020).

**RESULTS**

We identified 376 videos (283 Angling and 93 Spearfishing) and retrieved the location of the capture from 167 of them (135 for the angling and 31 for spearfishing; Fig. 1A). Moreover, we retrieved the mass of the fish from 50 videos (36 for the angling and 14 for spearfishing; Fig. 1B), which did not reveal significant ($U = 287$; $p = 0.455$; $A = 0.57$) differences between recreational angling (median = 3.7 kg) and spearfishing (median = 2.75 kg; Fig. 1B). We did not identify significant seasonal patterns in the upload of videos for both angling ($p = 0.568$) and spearfishing ($p = 0.954$; Fig. 1C).

Regarding social engagement, we found that the number of views was significantly lower in recreational spearfishing videos compared to videos posted about recreational angling [Rate Ratio = 3.52 (2.56–4.92); $p < 0.001$; Fig. 2A]. The same difference was found in relation to the number of

likes [Rate Ratio = 0.34 (0.24–0.49); $p < 0.001$; Fig. 2B]. We did not find significant ($p = 0.381$) differences in the number of comments left after watching a video by recreational angling and spearfishing (Fig. 2C).

We analyzed the content of 9,091 comments (6,733 for angling and 2,358 for spearfishing) in a total of 320 videos (235 for angling and 85 for spearfishing), and we coded a total of 11,109 themes (7,976 for angling and 3,133 for spearfishing, Table 1). Videos posted by recreational anglers received significantly ($p < 0.05$) more comments with themes related to positive feelings toward the species (1.4%) than videos posted by recreational spearfishers (0.9%), while themes related to negative feelings towards the species had a similar occurrence ($p = 0.292$; 0.4% and 0.5% for angling and spearfishing, respectively; Table 1). Moreover, comments to videos by recreational anglers indicated significantly ($p < 0.001$) more themes related to asking advice about fishing strategy or location (e.g., "*How did you bait the hook*"; 8%) or gears ("*what type of pole did you use?*", 6.8%) compared to videos by recreational spearfishers (1.5% for both themes; Table 1). While videos by recreational spearfishers revealed significantly ($p < 0.001$) more comments related with themes suggesting appreciation for the skill of the fisher (e.g. "*wonderful fishing action*," 5.1%) and athletic performance (e.g., "*wonderful free diving action*") as compared to recreational anglers (0.3% and zero, respectively; Table 1). The quantitative analysis of the text identified a total of 129,534 tokens (i.e., individual word units after breaking the text of comments). After removing meaningless tokens, we identified 12,414 for angling and 5,937 for spearfishing for further analysis. Some tokens only appeared in the comments of videos posted by one of the two groups. For examples, "*bravo*", "*sea*" ("mare"), "friend" ("amico") only appeared in comments of videos by recreational spearfishers (Fig. 3), while "*pesca*" ("fishing"), "*fishing rod*" ("canna"), "*fish*" ("pesce") only appeared in comments of videos by recreational anglers (Fig. 3). Most importantly, the concordance view of the keywords related to invasiveness and predatory behavior of the species indicated 82 matches (60 for angling

and 22 for spearfishing). We highlight the most significant ones for angling and spearfishing (Table 2). For both groups comments refers to the bluefish as an invasive species, a pest, and a magnificent ruthless predator.

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

## DISCUSSION

We show how social media can provide insights into ecological and human dimensions of recreational fishers related to distributional range shifts of an invasive species. There are four major results. First, we found similar declared mass between recreational anglers and spearfishers, which can be linked to similar size-selection potential; moreover, the similar seasonal upload patterns could be linked to seasonal migratory behaviour of the species or to the lack of seasonal patterns of fishing effort. Second, we found higher social engagement (i.e., number of views and likes) with videos by recreational anglers compared to spearfishers, suggesting that recreational anglers may be more engaged in fishing this species than recreational spearfishers. Third, the content of comments suggested differences in the values of the two groups of recreational fishers. Specifically,

284 spearfishers engaged more with fishing actions, while anglers discussed more about fishing strategy
285 and gears shown in the videos. Fourth, comments left after watching the videos indicated a higher
286 frequency of negative polarity and emotions (anger, discuss, fear and sadness) in angling videos in
287 contrast to spearfishing. However, in both groups the sentiments towards the invasiveness and
288 aggressiveness of the species were both negative and positive, which may provide specific
289 information on how focusing adaptation strategies for managing recreational fishing in the context
290 of distributional range shift of this species.

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

305 We did not find differences in the seasonal patterns of videos upload. Previously studies
306 documented that videos by recreational spearfishers showed peaks of upload around the summer
307 for the common dentex and the dusky grouper, which could be associated to seasonal bathymetric

migrations of species (Sbragaglia et al., 2020b; Sbragaglia et al., 2021a). Alternatively, they might be also related to vacation times and more pleasant weather to go fishing during the summer. The lack of differences of videos upload reported here could be linked to seasonal population dynamics such as migration. Seasonal latitudinal migration are well-described for the bluefish (Lund Jr and Maltezos, 1970; Shepherd et al., 2006; Silvano and Begossi, 2010; Brodie et al., 2018). Interestingly, a recent study showed that seasonal migration of the bluefish can be characterized using videos posted on YouTube by recreational anglers when geographical locations are explicitly considered (Eryaşar and Saygu, 2022). In our study, seasonal migration could have confounded the seasonal catchability of the species considering that our results are based on videos covering the entire coast of Italy where this species is expected to perform latitudinal migration following seasonal temperature changes. Further research is needed to assess the existence of a lag time between the recording of videos and their upload on social media and whether video upload patterns on YouTube can be representative of seasonal migration of the bluefish in the area of study

Videos by recreational anglers received more views and likes than videos by recreational spearfishers. This result is the opposite of a previous study where videos by recreational spearfishers targeting the common dentex received more social engagement than those by anglers (Sbragaglia et al., 2020b). This supports the idea that social engagement related to visual media may be linked to specific attitudes of recreational spearfishers and anglers that vary according to the target species (assuming that the public engaged with the videos are mainly recreational anglers and spearfishers, respectively). Such interpretation may be supported by the fact that recreational anglers may be more engaged than spearfishers in fishing this species; indeed 6.9% of the themes in the comments of angling videos were related to asking advice about the type of gear used with respect to 1.5% of spearfishing videos. Additional support for this lies in in the fact that in the videos related to the common dentex, only 3.5% of the themes in the comments of angling videos were related to asking

advice about the type of gear (1.2% for spearfishing; Sbragaglia et al., 2020b), suggesting more interest of anglers in fishing the bluefish than the common dentex.

The results of the content analysis and tokenization of the text of comments suggested that different social and psychological domains are expressed when recreational anglers and spearfishers engage with videos. Recreational spearfishers necessitate developing freediving skills and the athletic performance is a complementary component to be successful in catching many species such as the bluefish that is fished applying a sit-and-wait strategy at the sea bottom (at least in Italy where recreational spearfishing is only allowed via freediving). This may explain why appreciation for athletic performance and fishing skills was more frequent among the themes in the comments of recreational spearfishers when compared to anglers. A similar result was also documented for the common dentex (Sbragaglia et al., 2020b). Moreover, an important non-catch related motivation for recreational spearfishers is to be underwater and in contact with the beauty of the underwater world (Young et al., 2016; Assis et al., 2018). This could explain why the word "*sea*" is one of the most frequent token identified and only appeared in comments to videos by recreational spearfishers. In contrast, the discussion in comments to videos by recreational anglers was mostly about themes that relate to fishing strategy and gears, supported by the fact that the words "*fishing*", "*fish*" and "*fishing rod*" were the most common tokens, only appearing in comments of videos by anglers. This can also be linked to motivation of recreational anglers and the emotions felt during fishing the bluefish (see also table 2), an aspect that among anglers is usually mediated by the jumping, fighting and challenging behaviour of predatory species (Fedler and Ditton, 1994; Arlinghaus, 2006; French et al., 2019). Finally, although we documented a significantly higher frequency of themes related to positive feelings toward the species in comment to videos by anglers with respect to spearfishers, the absolute frequency in the overall number of themes was low (1.4%), which indicates that species attributes were not relevant compared to other themes.

The prevailing sentiments of the comments were positive for both videos by recreational anglers and spearfishers. In particular, positive emotions such as joy were more frequent in comments to videos by recreational spearfishers. This aligns with the results of a recent study with Spanish web-surveyed recreational fishers showing that spearfishers report higher levels of catch and activity satisfaction than recreational anglers (Gordoa et al., 2019), assuming that the comments are mostly made by recreational spearfishers. Interestingly, we documented that negative emotions such as anger were more frequent in comments to videos by recreational anglers. This could be related to three types of criticisms that were more frequent according to the content analysis (table 1): Criticism related to the declared mass of the fish displayed in the video, criticism related to the behaviour of the fisher, or criticism related to the type of gear and strategy used in the video. Finally, we showed that both groups referred to the species as an invasive species and a pest (e.g., "*it is a pest*", "*the bluefish is now an invader of the sea*"). This indicates that despite the species becoming quite common for recreational fishers, it is still perceived a threat for local ecosystems (e.g., "*sooner or later our fishes will be a memory*"). Indeed, the bluefish is addressed to as "*ruthless killer*", "*cruel species*" and "*a predator that kills even if it is not hungry*", which agrees with "*unmitigated butcher*", a definition associated with the species almost 150 hundred years ago (Baird, 1873). On the other hand, the aggressiveness (e.g., "*What a predator and what jaws", "Fantastic and very strong predator"*) and voraciousness (e.g., "*It is a very voracious predator*") of this species is also one of the traits that makes it of interest for both recreational anglers and spearfishers (e.g., "*It is exciting to see this predator in action*", "*I really enjoyed catching this predator*", "*it is a pest, but it is very funny to fish"*).

Our results have implications for management. In cases where the objective is to control invasion of bluefish, for example through culling as is occurring with the alien invasive lionfish (*Pterois miles*) in the Eastern Mediterranean Sea (Jimenez et al., 2017), the sentiments towards

bluefish could be strategically used to foster engagement with control actions. Indeed, angling contests exclusively targeting the bluefish are already emerging in the area of study as voluntary actions that are caused by anglers' perception of the bluefish as an invasive species (VS personal observation). In the case where the management objective is to promote adaptation of recreational fisheries to the arrival of the bluefish (e.g., van Putten et al., 2017), the positive sentiments towards the bluefish could be used as a mechanism facilitating social acceptance of this species. Finally, the content and sentiment analysis presented in our study highlighted that recreational fishers have knowledge and perceptions about the negative impact of the bluefish on marine ecosystems in the area of study, this aspect requires further research because local ecological knowledge of recreational fishers may provide complementary information to understand about the potential ecological impacts of the invasion of the bluefish.

We recognize that our results must be interpreted with caution because the digital videos and associated data used here are not representative of the entire population of Italian marine recreational fishers. A recent study characterized the profile of recreational fishers using social media in Catalonia, Spain (Vitale et al., 2021), and found that between 12% and 21% of recreational fishers share their catches on social media, which could be assumed to be similar in the area of study. This situation can bias our inferences if recreational fishers that do not engage with social media platforms have markedly different views and sentiments. However, it must be considered that recreational fishers can leave comments on YouTube even if they are not sharing their catches, therefore the sentiments documented here likely represent a larger proportion of recreational fishers than that documented in Vitale et al. (2021). Additional biases have been appropriately discussed elsewhere (Jarić et al., 2020b; Sbragaglia et al., 2020b; Sbragaglia et al., 2021a) and include aspects of data availability (e.g., YouTube is a dynamic cultural system and video contents and associated digital data can be modified or erased), and data mining approach (e.g., the keyword

used here for the systematic mining of data could be not entirely representative of all the videos uploaded). Moreover, we did not provide an explicit spatio-temporal analysis of recreational fishers' sentiments, which is a possible limitation because the bluefish could trigger more negative sentiments in the northern part of the area of study where it arrived more recently (Azzurro et al., 2019). Future studies should test whether such methodological approach is suitable to quantify spatio-temporal changes of sentiments. Despite such limitations, our study shows how social media can be used to highlight qualitative and quantitative aspects of human dimensions that may be useful for recreational fisheries management. Our results are based on a local case study in recreational fishing, but they can be extended to larger spatial scales, other species and processes.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interests

**AUTHOR CONTRIBUTIONS**

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

## DATA AVAILABILITY

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

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

| Subject | Theme | Angling | Spearfishing | $X^2$ | $p$ |
|---|---|---|---|---|---|
| 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 (*Dicetrarchus labrax*) | 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 |

611 **Table 2 –** Results of the concordance view related to invasiveness and predatory behavior of *P.*
612 *saltatrix* (keywords used: "*invas**", "*infest**", "*piag**" and "*predat**"). A summary of the discourse
613 going on around the species in terms of invasiveness, pest and aggressive predators is reported for
614 both angling and spearfishing together with negative (-) and positive (+) sentiments.
615

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

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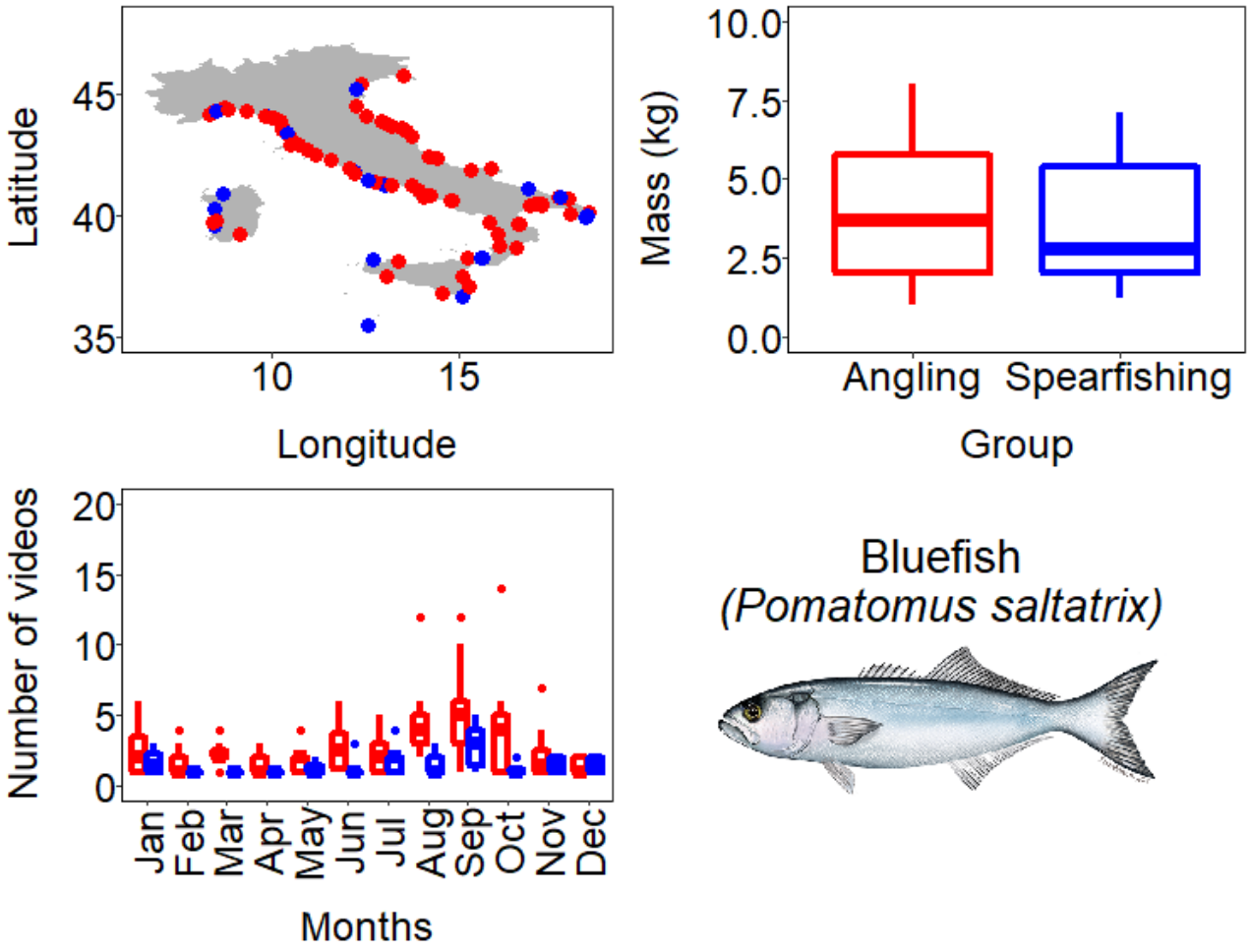



**Figure 1 –** The summary of the data for the videos related to recreational fisheries of the bluefish (*Pomatomus saltatrix*) between 2009 and 2019 in Italy: (A) the geographical distribution of the videos according to the information retrieved in their title, description as well as in the video itself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

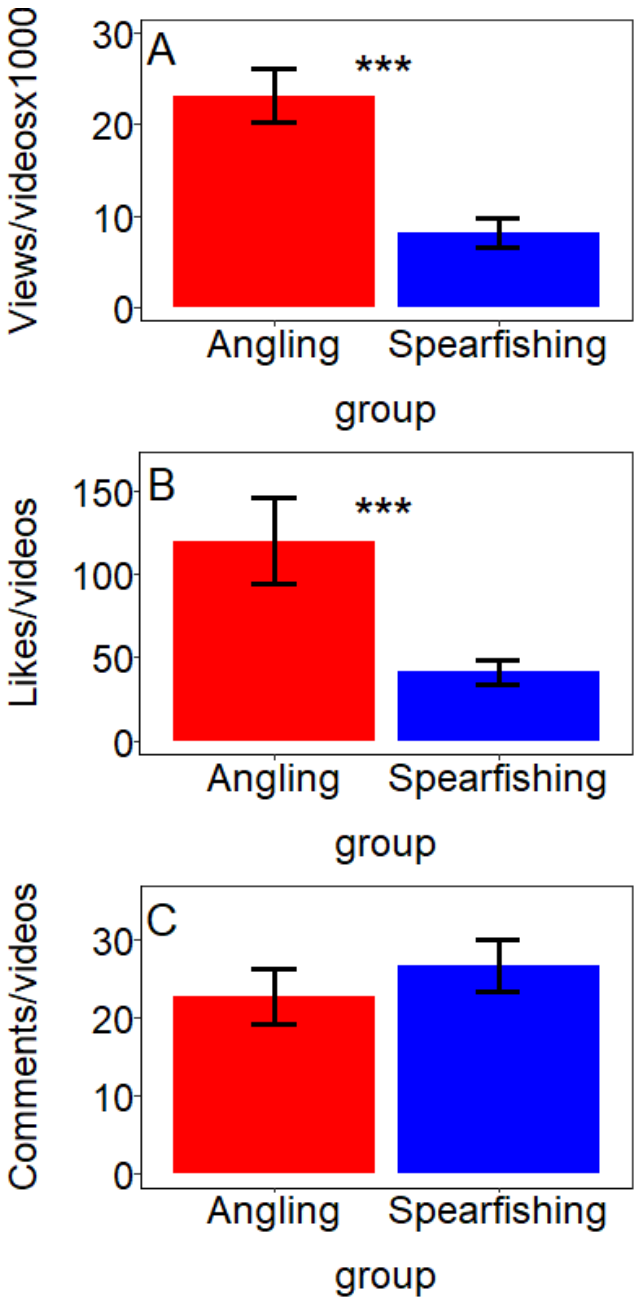
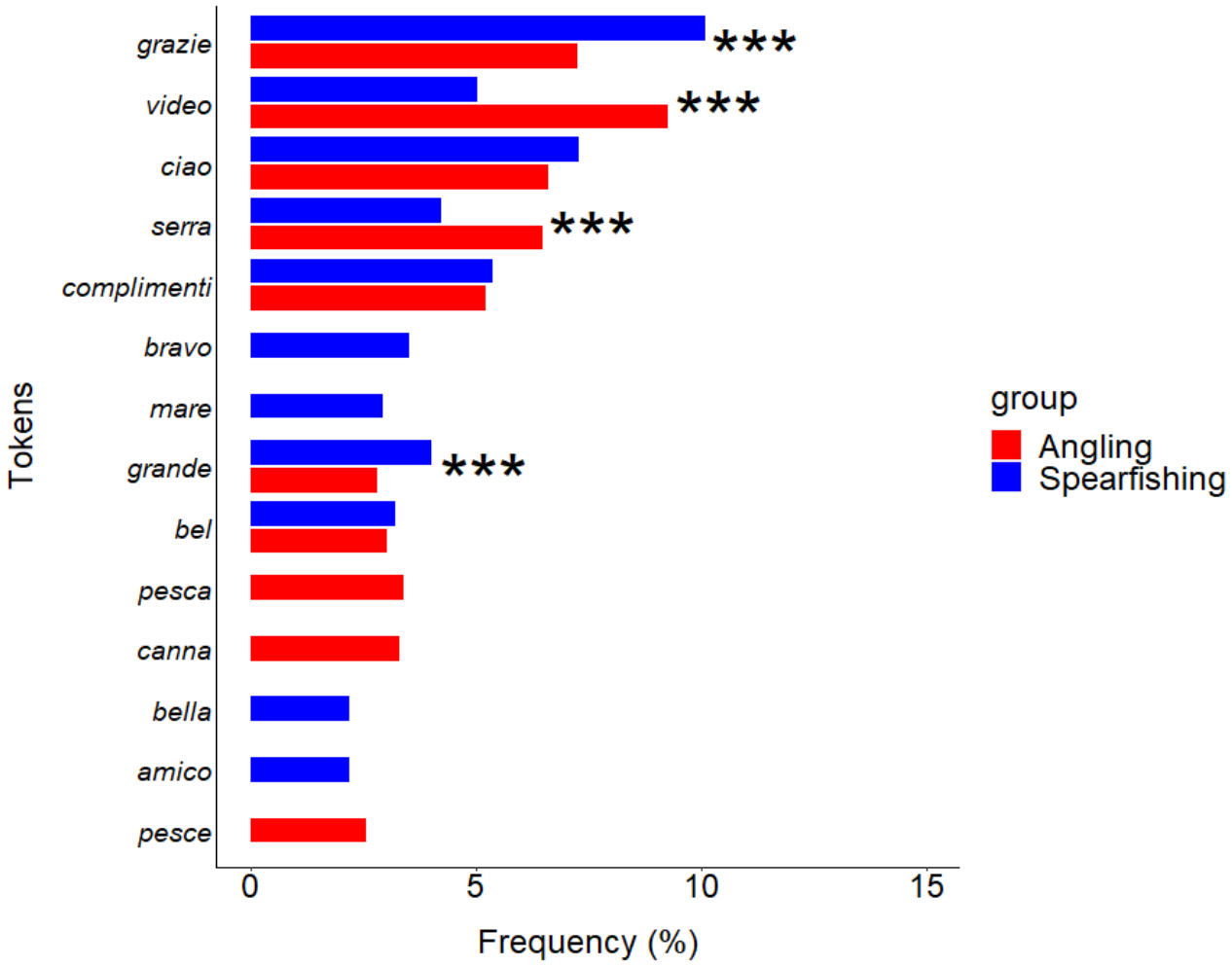



**Figure 2 –** Barplots of the average social engagement for both angling and spearfishing together with standard error of the mean: (A) number of views; (B) number of likes; (C) number of comments. The total number of identified videos is 283 for angling and 93 for spearfishing. Significant differences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

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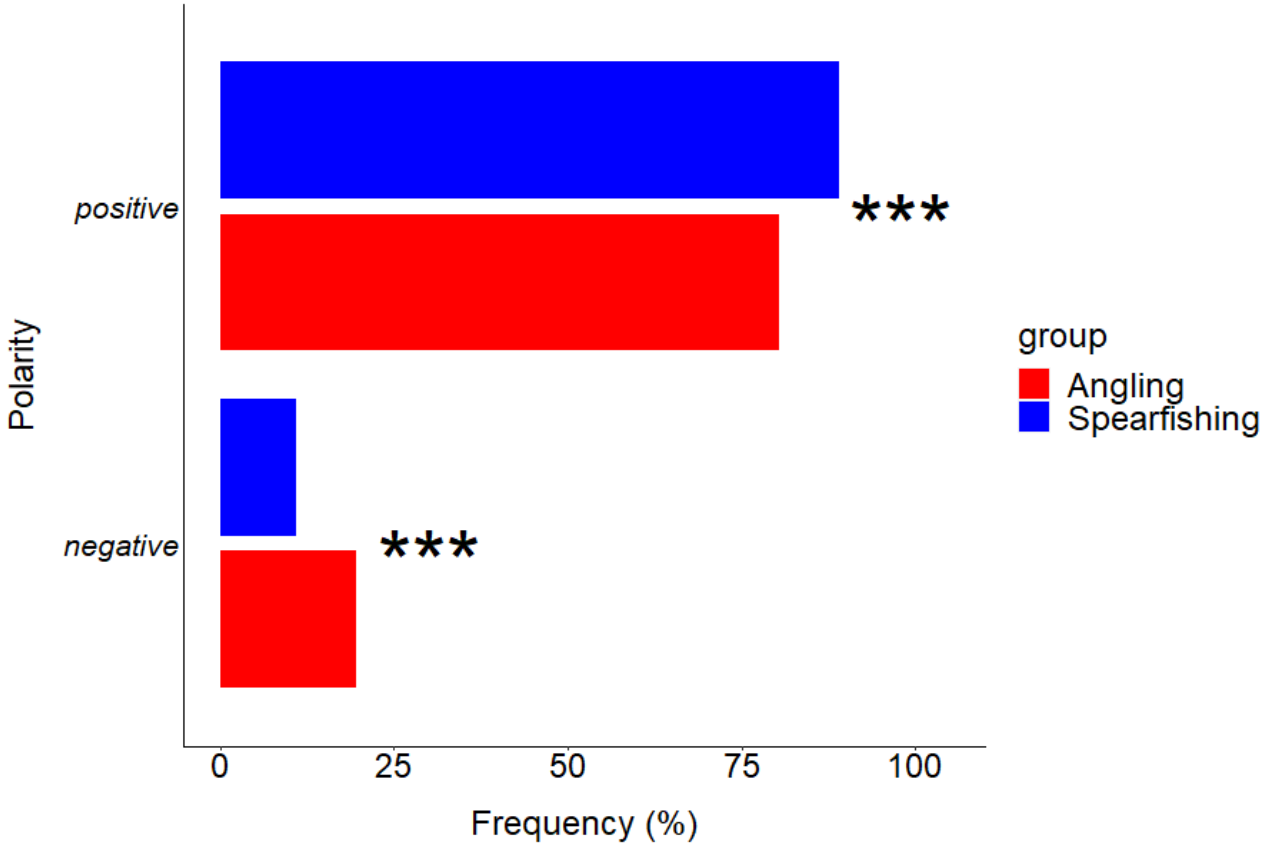
644 **Figure 3 –** Frequency of the most common tokens used in the comments on videos posted by
645 recreational anglers and spearfishers. Tokens are reported in Italian and their relative translation is
646 reported between parenthesis as follow: grazie (thank you); video (video); ciao (hello); serra (the
647 common name for bluefish, *P. saltatrix*); complimenti (congratulations); bravo (bravo); mare (sea);
648 grande (good boy); bel (wonderful); pesca (fishing); canna (fishing rod); bella (wonderful); amico
649 (friend); pesce (fish). Significant differences are reported according to the results of the z-test (***:
650 $p < 0.001$).

651

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654 **Figure 4 –** Frequency of polarity of emotions computed with sentiment analysis using a modified
655 version of the Saif Mohammad's NRC Emotion lexicon (Mohammad and Turney, 2013) for both
656 comments of videos posted by recreational anglers (total sentiments scored = 10837) and
657 spearfishers (total sentiments scored = 5476). Significant differences are reported according to the
658 results of the z-test (***: $p < 0.001$).
659
660

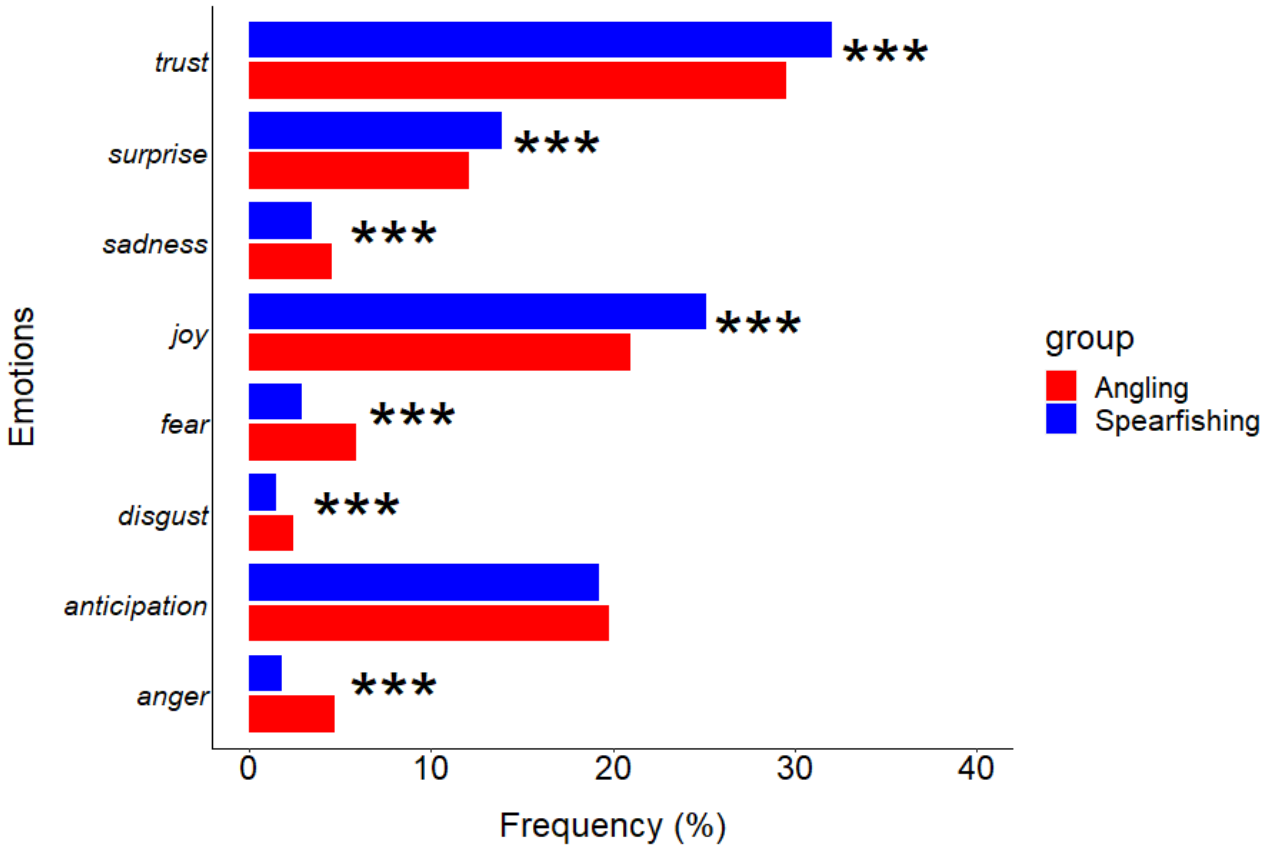


**Figure 5 –** Frequency of emotions computed with sentiment analysis using a modified version of the Saif Mohammad's NRC Emotion lexicon (Mohammad and Turney, 2013) for both comments of videos posted by recreational anglers (total sentiments scored = 23859) and spearfishers (total sentiments scored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