ORIGINAL RESEARCH

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: (1) similar harvesting patterns (i.e., declared mass and seasonal upload patterns) related to videos by both recreational anglers and spearfishers; (2) higher social engagement (i.e., number of views and likes) for videos by recreational anglers than spearfishers; (3) differences in themes of discussion, with anglers being mainly interested in fishing strategy and gears and spearfishers being more

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interested in fishing actions shown on the videos; (4) 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.

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

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

The case study

We explored Italian recreational fishing of the bluefish (*P. saltatri*x), and systematically mined data on YouTube from 2009 to 2019 by using a methodological approach previously applied in other studies (Sbragaglia et al. 2020b, 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, 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: (1) not related to the target species; (2) not showing the catch of the target species (i.e., catch and release or not shooting while spearfishing); (3) not related to the target country; and (4) 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
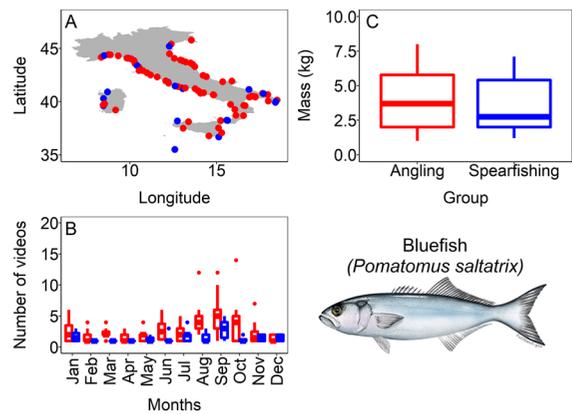

Fig. 1 The summary of the data for the videos related to recreational fisheries of the bluefish (*Pomatomus saltatrix*) between 2009 and 2019 in Italy: **A** the geographical distribution of the videos according to the information retrieved in their title, description as well as in the video itself (Red 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

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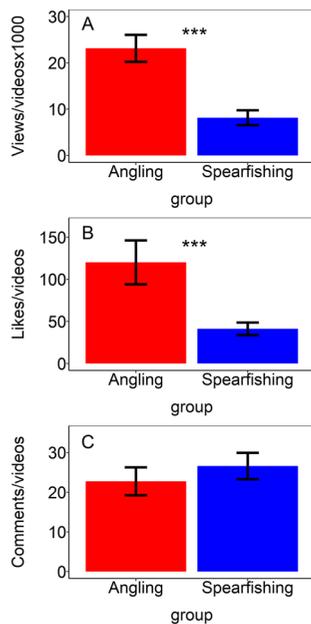
Fig. 2 Barplots of the average social engagement for both angling and spearfishing together with standard error of the mean: **A** number of views; **B** number of likes; **C** number of comments. The total number of identified videos is 283 for angling and 93 for spearfishing. Significant differences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

(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 9091 comments (6733 for angling and 2358 for spearfishing) in a total of 320 videos (235 for angling and 85 for spearfishing), and we coded a total of 11,109 themes (7976 for angling and 3133 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 of 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). 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
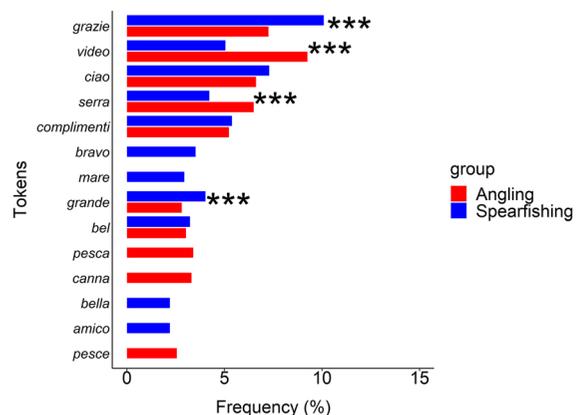

Fig. 3 Frequency of the most common tokens used in the comments on videos posted by recreational anglers and spearfishers. Tokens are reported in Italian and their relative translation is reported between parenthesis as follow: grazie (thank you); video (video); ciao (hello); serra (the common name for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

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)

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

Results of the z-test are reported in terms on X^2 and p values

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

The similar mass of the bluefish declared in videos by recreational anglers and spearfishers could suggest that the size-selection potential is not different among these two groups. Previous studies indicated that the declared mass was higher in videos posted by recreational anglers than spearfishers targeting the common dentex, *Dentex dentex* (Sbragaglia et al. 2020b), the dusky, *Epinephelus marginatus*, and white grouper, *Epinephelus aeneus* (Sbragaglia et al. 2021a). Differences in declared mass can also be related to social dynamics, such as biases towards particularly memorable and hence large fish or inflation of mass for increasing social engagement (Sbragaglia et al. 2020b). However, it is conceivable that such dynamics depend on differences in the attitudes of recreational anglers and spearfishers towards different species, which could be the case of the results shown here. Importantly, in 40% of the videos by
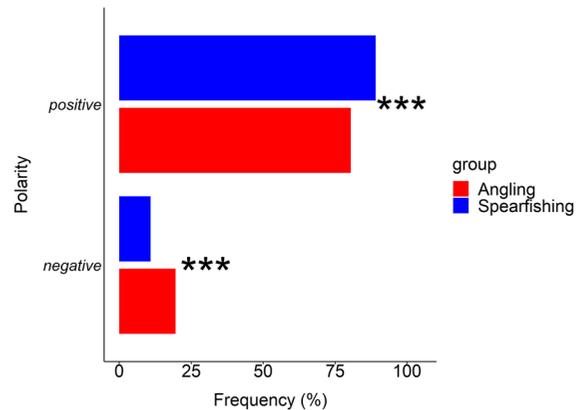
Fig. 4 Frequency of polarity of emotions computed with sentiment analysis using a modified version of the Saif Mohammad's NRC Emotion lexicon (Mohammad and Turney 2013) for both comments of videos posted by recreational anglers (total sentiments scored = 10,837) and spearfishers (total sentiments scored = 5476). Significant differences are reported according to the results of the z-test (*** $p < 0.001$)

recreational anglers and spearfishers the declared mass of the bluefish was above 5 kg, which already represents a trophy size. This suggests that both groups could only posts videos with trophy catch or have similar chances to target trophy-size specimens and therefore the size of the fish is unlikely to play
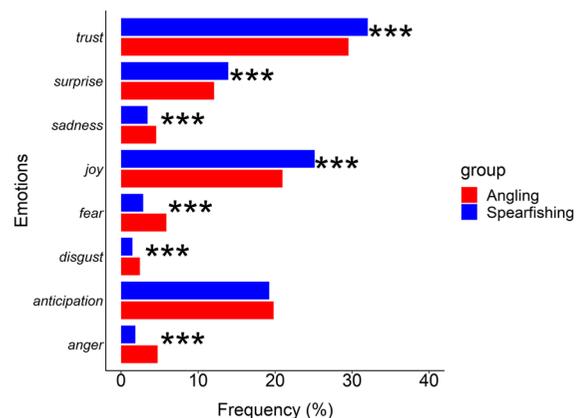
Fig. 5 Frequency of emotions computed with sentiment analysis using a modified version of the Saif Mohammad's NRC Emotion lexicon (Mohammad and Turney 2013) for both comments of videos posted by recreational anglers (total sentiments scored = 23,859) and spearfishers (total sentiments scored = 10,837). Significant differences are reported according to the results of the z-test (*** $p < 0.001$)

Table 2 Results of the concordance view related to invasiveness and predatory behavior of *P. saltatrix* (keywords used: "*invas**", "*infest**", "*piag**" and "*predat**")

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*	+

A summary of the discourse going on around the species in terms of invasiveness, pest and aggressive predators is reported for both angling and spearfishing together with negative (−) and positive (+) sentiments

a major role in the differences in human dimensions highlighted below.

We did not find differences in the seasonal patterns of videos upload. Previously studies documented that videos by recreational spearfishers showed peaks of upload around the summer for the common dentex and the dusky grouper, which could be associated to seasonal bathymetric migrations of species (Sbragaglia et al. 2020b, 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 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 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 as 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, 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.

Author contributions VS conceived the study; VS performed the data mining with inputs by RAC; SC crossed checked the results and scored the content of comments; VS analysed the data, VS, RAC, RA interpreted the data, VS 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.

Declarations

Conflict of interest The authors declare no conflict of interests.

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