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Contribution to the Themed Section: '*Marine recreational fisheries – current state and future opportunities*'

Original Article

Data mining on YouTube reveals fisher group-specific harvesting patterns and social engagement in recreational anglers and spearfishers

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We applied data mining on YouTube videos to better understand recreational fisheries targeting common dentex (*Dentex dentex*), an iconic species of Mediterranean fisheries. In Italy alone, from 2010 to 2016 spearfishers posted 1051 videos compared to 692 videos posted by anglers. The upload pattern of spearfishing videos followed a seasonal pattern with peaks in July, a trend not found for anglers. The average mass of the fish declared in angling videos (6.4 kg) was significantly larger than the one in spearfishing videos (4.5 kg). Videos posted by spearfishers received significantly more likes and comments than those posted by anglers. Content analysis suggested that the differences in engagement can be related to appreciation of successful spearfishers necessitating relevant personal qualities for catching *D. dentex*. We also found that the mass of the fish positively predicted social engagement as well as the degree of positive evaluation only in spearfishing videos. This could be caused by the generally smaller odds of catching large *D. dentex* by spearfishing. Our case study demonstrates that data mining on YouTube can be a powerful tool to provide complementary data on controversial and data-poor aspects of recreational fisheries and contribute to understanding the social dimensions of recreational fishers.

Keywords: *Dentex dentex*, mass, Mediterranean, monitoring, social media

Introduction

Recreational fishers contribute a non-negligible proportion to the total fish harvested around the globe (Cooke and Cowx, 2004; World Bank, 2012; Hyder *et al.*, 2018; Brownscombe *et al.*, 2019). At the same time, recreational fishing generates manifold social and economic benefits to fishers and society at large (Rudd *et al.*, 2002; Hyder *et al.*, 2018; Arlinghaus *et al.*, 2019; Brownscombe *et al.*, 2019). Monitoring recreational fisheries poses several challenges due to their high heterogeneity in space and time (Arlinghaus *et al.*, 2017; Brownscombe *et al.*, 2019). As such, many recreational fisheries are characterized by widespread lack of data regarding fishing effort, harvest and socio-economic aspects, making global monitoring and assessment difficult (FAO, 2012; Arlinghaus *et al.*, 2016; Elmer *et al.*, 2017). Available data

are often obtained with methods that are resource intensive (e.g. creel surveys; random telephone surveys; Pollock *et al.*, 1994; Board and Council, 2006; Hartill *et al.*, 2012; Rocklin *et al.*, 2014; Hartill and Edwards, 2015; Zarauz *et al.*, 2015; Bellanger and Levrel, 2017; Holdsworth *et al.*, 2018; Hyder *et al.*, 2018; van Poorten and Brydle, 2018). As a complement to more traditional methods, less resource-demanding data sourced from digital applications and social media platforms are attracting increasing attention (Martin *et al.*, 2014; Carter *et al.*, 2015; Venturelli *et al.*, 2017). These data can provide important complementary insights of relevance for management and monitoring of recreational fisheries.

The recent development and accessibility of video recording devices, including submergible ones, have increased the possibilities for recreational fishers to film their fishing activity and at the same time opened new possibilities for aquatic research (Bulleri and Benedetti-Cecchi, 2014; Struthers *et al.*, 2015; Giovos *et al.*, 2018). Once shared on social media, analysis of video footage posted by recreational fishers can potentially be a useful source of digital data, for example to compare the harvesting pattern of different types of recreational fishers (e.g. different groups of anglers or anglers and spearfishers). Furthermore, analysing social media posting can allow comparing how users react to different forms of recreational fisheries. For example, it is possible that capture videos of the very same species of fish trigger different reactions (either negative or positive) and social engagement (e.g. number and type of comments) when captured by a recreational angler with hook and line or by a recreational spearfisher. Although the behaviour of video users has been studied in several field of research, such as medicine and marketing (Kousha *et al.*, 2012), this approach is still unexplored in recreational fisheries. Characterizing the type of communication around video footages can provide valuable insights about various social aspects of recreational fisheries.

Data mining on social media refers to the extraction of information from a dataset that is not readily apparent and not always easily obtainable (Barbier and Liu, 2011). Data mining from social media can play an important role in conservation science and in understanding and quantifying human–wildlife interactions (Di Minin *et al.*, 2015; van der Wal and Arts, 2015; Ladle *et al.*, 2016; Hausmann *et al.*, 2018; Toivonen *et al.*, 2019). For example, Monkman *et al.* (2018b) demonstrated that user knowledge retrieved by Google Search engines can be used as a proxy indicator of coastal utilization in marine recreational fisheries. Monkman *et al.* (2018c) employed text and data mining on social media to provide information on the spatio-temporal scales of species-specific marine recreational fisheries. Shiffman *et al.* (2017) used posts by recreational anglers on online forums to assess shark conservation issues, such as illegal catches, and Martin *et al.* (2014) showed that the activity on an online recreational fishing social network was related to the spatial distribution of fishing effort. These examples show that data mining of social media can provide relevant insights into the patterns and dynamics of selected recreational fisheries.

YouTube represents a worldwide dynamic cultural system where diverse groups interact around video footages (Burgess and Green, 2018). YouTube is also embedded into the recreational fishers' culture and appears to be one of the main web platforms used to share videos of catches or memorable fishing trips. YouTube videos have previously been used to document that recreational fisheries in the Mediterranean Sea are multispecies and exhibit spatially homogeneous patterns among different countries (Giovos *et al.*, 2018). In another recent study, Belhabib *et al.* (2016) used YouTube videos to retrieve data for recreational catches in West Africa where such data are extremely scarce. It is worthwhile to conduct further studies using YouTube data because, in contrast to many other survey methods, one can also characterize how users react to video footages in quantitative (e.g. number of views and comments) and semi-quantitative (e.g. content analysis of comments) ways.

In this study, we used YouTube to better understand recreational fisheries of the common dentex (*Dentex dentex*) in Italy. *Dentex dentex* is an iconic target species for Mediterranean fisheries exploited by both recreational anglers and recreational spearfishers (Morales-Nin and Moranta, 1997; Morales-Nin *et al.*, 2005; Font and Lloret, 2011; Marengo *et al.*, 2014, 2015). In the overview of the conservation status of the marine fishes of the Mediterranean Sea published by the International Union for Conservation of Nature, *D. dentex* was reported as a vulnerable species that experienced declines between 30 and 50% in the Mediterranean region (Malak *et al.*, 2011). The establishment of restrictions to recreational spearfishing has been recommended as a possible solution for the recovery of the species (Carpenter and Russel, 2014). This recommendation implies that spearfishing harvesting of *D. dentex* is higher than recreational angling; however, previous studies suggested the opposite in terms of harvesting rate and number of specimens caught (Marengo *et al.*, 2015). In this context, the videos uploaded on YouTube can inform about differences in catch patterns between recreational anglers and recreational spearfishers. Moreover, as many recreational fishers declare the mass of the fish shown in video footage, analysing YouTube videos from the same region provides an interesting opportunity to infer differences in the average mass of catches between groups. This could be particularly important for collecting complementary data to the ones already available on the vulnerability of large specimens of *D. dentex* to the different forms of recreational fishing (Morales-Nin *et al.*, 2005; Marengo *et al.*, 2015). Indeed, preserving large as well as small individuals could be one of the keys for improving the conservation status of exploited species (Gwinn *et al.*, 2015), including *D. dentex* (Grau *et al.*, 2016).

In terms of social dimensions, the social engagement (e.g. number of views and comments and type of comments) recorded on YouTube videos as well as its relationship with the mass of the reported catch can provide insights about the online behaviour of recreational fishers. Angling and spearfishing differ in energy investment (e.g. boats), required skills (e.g. athletic performance), and possibly aesthetics. Recreational fisheries has a strong component of masculinity (Bull, 2009), and given the specific fishing style recreational spearfishers might be perceived differently from for example recreational angling from a motorized boat. Therefore, it is possible that the very same fish posted by either recreational anglers or recreational spearfishers induces different reactions among social media users. As the size of the fish captured is of fundamental importance in the utility function of most recreational fishers (Arlinghaus *et al.*, 2014) and is systematically related to fisher satisfaction (Beardmore *et al.*, 2015), one would expect more social engagement to happen with videos showing larger sized specimens. Because spearfishers and anglers may differ in their general ability to catch large specimens (Marengo *et al.*, 2015), we expected that the social engagement

for a given mass of fish reported in the video to be specific to the type of recreational fisheries.

Our main objective was to provide complementary knowledge on *D. dentex* recreational fisheries in Italy by using data mined from YouTube. We compare the harvesting pattern of *D. dentex* between recreational anglers and recreational spearfishers and provide first results on the potential of YouTube to characterize social aspects of recreational fisheries. Our research questions were:

(i) What is the upload pattern of *D. dentex* YouTube videos in recreational angling and recreational spearfishing and are there differences in the seasonal upload patterns among the two types of recreational fisheries?

(ii) Are there differences in the mass of *D. dentex* reported in the videos between recreational angling and recreational spearfishing?

(iii) Are there differences in the social engagement of videos between recreational angling and recreational spearfishing?

(iv) Does the mass declared in the video predict social engagement, and does this relationship differ between recreational angling and recreational spearfishing?

(v) Are there differences in the content of comments posted in relation to recreational angling and recreational spearfishing videos?

(vi) Does the fish mass declared in the video predict the content of comments, and does this relationship differ between recreational angling and recreational spearfishing?

Material and methods

Ethical aspects

Data mining on YouTube does not require specific ethical review because the data are publicly available. However, we followed the framework presented by Monkman *et al.* (2018a) on the ethics of using social media in fisheries research. In particular, we anonymized all the data after performing the sorting of the videos according to their title and description. Moreover, we extended the anonymization to all possible direct and indirect identifiers of the people who uploaded the video footage (i.e. video id, date of publication, channel id, channel title, video duration).

The case study

We present a case study aiming at exploring the harvesting patterns of *D. dentex* in Italy using videos uploaded on YouTube from 2010 to 2016. We used a systematic analysis on videos to collect quantitative and semi-quantitative data on harvesting patterns and social engagement. We automatically retrieved all the 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. Spearfishing was defined as underwater fishing practiced by the exclusive use of free-diving techniques and a speargun (Sbragaglia *et al.*, 2016, 2018); angling was defined as hook-and-line fishing from either the coastline or a boat with natural baits or artificial lures.

Data mining

We collected the data by using the YouTube Data API (v3), following the steps reported in Figure 1. First, we extracted the data from YouTube's API in April 2017 using two keywords: the name of the species in Italian ("*Dentice*") and the scientific name of the species ("*Dentex*"). Although mentions to vernacular and scientific names are usually highly associated in online databases (Jarić *et al.*, 2016; Correia *et al.*, 2017), both terms were employed to ensure all videos of potential interest were identified. We carried out searches with the Italian vernacular species name to limit data collection to Italian recreational fishers. With regards to the scientific species name, we only used the genus name as a search term to ensure that videos citing occasionally used synonyms (e.g. *Dentex vulgaris*) were also captured (Correia *et al.*, 2018). We compiled a raw dataset with the title and descriptions of videos along with social engagement metrics such as number of views, likes and comments.

In a second step, we automatically searched the title and description of each video for specific keywords as reported in Table 1. We subdivided the keywords into two groups with the aim to sort the videos regarding recreational angling and recreational spearfishing. We choose keywords following the most popular fishing techniques, the most common gears used and the most common tackle brands. We stored the results in a dataset that was subsequently manually cross checked.

Manual cross check of the automatic identification

We first excluded the videos that 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 diving underwater); (iii) not related to the target country; and (iv) repetitions of previously

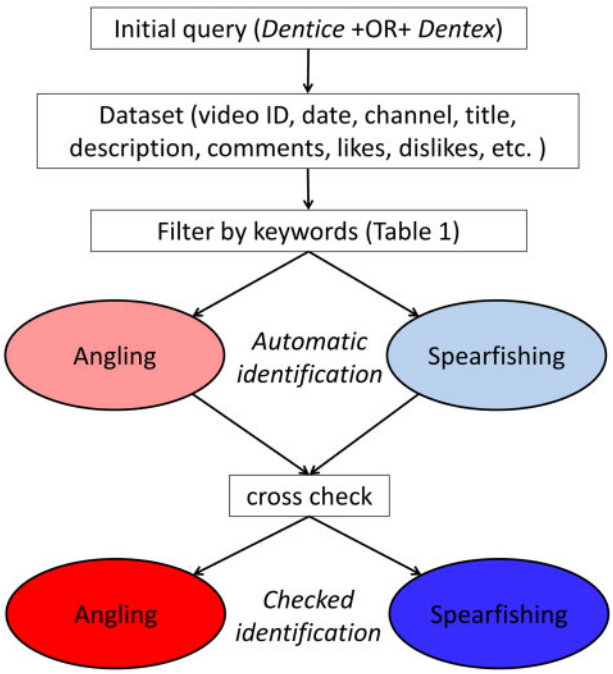

Figure 1. Schematic representation of the data mining and filtering according to the keywords reported in Table 1. A first step is represented by the automatic identification of videos followed by a second step represented by the cross-checked identification.

Table 1. The keywords used in the automatic identification for recognizing whether a video was about the capture of a *D. dentex* by angling or spearfishing.

Angling	Spearfishing
Traina, spinning, jigging, surfcasting, calamaro, barca, canna, rockfishing, spiaggia, inchiku, shimano, kayak, strike, bolentino, scogliera, palamito	Aspetto, agguato, caduta, pesca sub, apnea, spearfishing, pesca subacquea, dapiran, discesa, saber, bassofondo, seawolf, alemanni, michelangelo, tuffo, strappato, poca acqua, sea hawk, abisso, saber, roller, seawolf, gimansub, calibro

Keywords are in Italian to limit the search to Italian recreational fishers and they represent the most popular angling techniques (e.g. "*traina*" meaning trolling), the most common spearfishing techniques (e.g. "*aspetto*" meaning sit-and-wait hunting), and the most common tackles' brands (e.g. *shimano*).

published videos. Then, we applied a manual cross check of 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 mismatch recognitions (i.e. videos erroneously attributed to one fisher group instead of the other). Finally, during the manual cross check, we also annotated the mass of the fish reported in the title or description of the videos. We run all the analyses related to data mining in R (https://www.r-project.org/; version 3.5.0) with the additional package "*jsonlite*" (Ooms, 2014), "*lubridate*" (Grolemund and Wickham, 2011), and "*curl*" (https://cran.r-project.org/web/packages/curl/index.html).

Content analysis of comments

Content analysis allows making inferences through a systematic and objective characterization of messages using a coding system (Holsti, 1968; Mayring, 2004; Elo and Kyngäs, 2008). To develop the coding system, we identified repeatedly occurring themes in the comments by pre-scoring a subsample of 10 videos for each group and assigning codes to a previously published classification system focused on the analysis of YouTube comments (Madden *et al.*, 2013). In particular, we classified the themes according to their subject (fisher, fish, technology, and others topics) and subsequently assigned codes to categories (e.g. opinion/give, general conversation/greetings, or feelings/positive) following the coding scheme published by Madden *et al.* (2013). For example, categorical comments coded as opinion/give express people's views on the video or person in the video and are characterized by the use of evaluative words like "*good*," "*pretty*," "*right*," and "*wrong*." Comments coded as conversation/greetings fulfil particular purposes in initiating and maintaining conversation (e.g. "*hello*," "*where do you live?*"). A final example, comments coded as related to personal feelings/positive are those containing adjectives such as "*happy*," "sad," with specific constructions such as "*I love*" (or "*I hate*" for a feelings/negative combination) or referencing to physical expression, such as "*That made me cry*," "*that made me remain open-mouthed*" (see Madden *et al.*, 2013 and Table 5). After coding content categories, we finally assigned positive, neutral, or negative codes to each theme to organize them into five global coding groups (Riepe and Arlinghaus, 2014): comments with only positive associations; at least one positive and at least one neutral association; only neutral associations; at least one positive/neutral and at least one negative association; and only negative associations. After developing the coding system with ten example videos for each of the two fisher groups, we randomly selected 50 videos (25 for recreational angling and 25 for recreational spearfishing) and conducted a full content analysis of all the 532 comments mentioned in these videos.

Data analysis and statistical approach

We first used the cross-checked dataset to estimate the annual oscillation in the upload patterns of videos by group (question i) 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). Then, we used Generalized Linear Models (GLM; Nelder and Wedderburn, 1972) to estimate differences between recreational angling and recreational spearfishing videos in the reported mass of the fish declared in the video footage (question ii) and in the social engagement parameters (number of views, likes, and comments; question iii). Finally, we used GLMs to estimate the relationship between variables indexing social engagement and the reported mass of the fish (question iv). To reduce the skewness of the mass distribution between groups and have comparable regression results, we limited the comparison to reported masses between 2.5 and 10.0 kg. We employed a Gaussian distribution with GLM for modelling the data related to the mass of the fish, while we used a negative binomial distribution to account for overdispersion of the count data for social engagement variables (Bliss and Fisher, 1953; Gardner *et al.*, 1995).

As regards the statistical treatment of the content analysis, we first compiled the frequency of occurrence of each theme for both recreational anglers and recreational spearfishers (question v). Then, we used a multinomial logit model to estimate the relationship between the global coding groups and the declared mass of the fish for both recreational angling and recreational spearfishing videos (question vi). We only used three of the coding groups because the frequency of occurrence of the other two groups was too low (at least one positive/neutral and at least one negative association: N angling = 2, N spearfishing = 5; only negative associations: N angling = 11, N spearfishing = 0).

We assessed model fits by checking the plot of the residuals vs. the fitted values. In all cases we used a 95% confidence interval. We run all analysis in R (https://www.r-project.org/; version 3.5.0) with the additional packages: "*mass*" (Ripley *et al.*, 2013), "rain" (Thaben and Westermark, 2014), and "*mlogit*" (Croissant, 2012).

Results

We identified a total of 21 441 videos published between 2010 and 2016. From a methodological perspective, 1680 (7.8%) of the videos initially identified with the query were not related to the target species and target country or were videos where the fish was not captured. During the second cross check on the remaining 19 761 videos, we found that the automatic identification following the keywords in Table 1 overestimated (+18%) the number of videos related to recreational angling and underestimated (−17%) those related to recreational spearfishing

(Table 2). Moreover, during the manual cross check we found that 42% of the videos showing the capture of *D. dentex* were wrongly assigned to the recreational angling group, and 38% wrongly assigned to the recreational spearfishing group. After the cross check, we identified 692 videos related to recreational angling and 1051 videos related to recreational spearfishing (Table 2).

Using the final cross-checked dataset, we did not find significant ($p = 0.163$) annual oscillations (i.e. seasonality) in the upload pattern in the recreational angling group. In contrast, the recreational spearfishing group revealed significant ($p < 0.001$) seasonality with a peak of uploads of videos in July (Figure 2). During the cross check, we annotated the reported mass of the fish from either the title or description of 540 videos (214 for recreational angling and 326 for recreational spearfishing). The fish were significantly ($F_{1,538} = 76.64$; $p < 0.001$) lighter in recreational spearfishing videos compared to angling ones [−1.9 (−2.4 to −1.5) kg; Figure 3].

Regarding social engagement, we did not find significant differences between recreational angling and recreational spearfishing in terms of views ($p = 0.200$; Table 3, Figure 4). However, the number of likes was significantly greater in recreational spearfishing videos compared to videos posted about recreational angling of common dentex [Rate Ratio, RR = 2.15 (1.85–2.49); $p < 0.001$; Table 3, Figure 4]. The same difference was found in relation to the number of comments [RR = 5.34 (4.55–6.25); $p < 0.001$; Table 3, Figure 4]. Furthermore, the mass of the fish declared in the videos significantly ($p < 0.001$; Table 4) and positively predicted all social engagement variables (views, likes, and comments) in recreational spearfishing: larger fish increased the degree of social engagement [views: RR = 1.92 (1.73–2.12), likes: RR = 1.57 (1.45–1.70), and comments: RR = 1.23 (1.13–1.35); Table 4, Figure 5]. The mass of the fish had a weak, yet significant impact on the number of views ($p < 0.001$; Table 4) and comments ($p < 0.05$; Table 4) for recreational angling videos: the lighter the fish the larger was the social engagement [views: RR = 0.84 (0.74–0.95); comments: RR = 0.85 (0.74–0.97); Table 4 and Figure 5]. All the relationships between the mass of the fish and social engagement variables obtained for videos of recreational spearfishing were significantly different (i.e. no overlap of confidence intervals) from the ones revealed for recreational angling (Table 4).

We content analysed a total of 532 comments (138 for angling and 394 for spearfishing) in a total of 50 randomly selected videos (25 for each of the two fisher groups), and we coded a total of 867 themes (201 for angling and 666 for spearfishing, Table 5). The occurrence of themes in the comments was heterogeneous among recreational anglers and spearfishers. Themes related to a general appreciation of the fisher (e.g. "*you are very good*," "*congratulations*") were the most frequent in both groups (22.4 and 30.3% for recreational anglers and spearfishers, respectively; Table 5). Videos by recreational anglers received more comments with themes related to general appreciation of the video (e.g. "*nice video*," "*exciting video*," 19.4%) compared to recreational spearfishers (9.2%). In contrast, videos by recreational spearfishers received more specific comments with themes related to

Table 2. The comparison of the results of the automatic identification and manual cross-checked identification in terms of false positive, false negative, and group mismatch.

Automatic identification	Checked identification	N
n.c.	n.c.	0
Angling	n.c.	15
Spearfishing	n.c.	13
Total false positive		28
Angling	Angling	472
n.c.	Angling	216
Spearfishing	Angling	4
Total angling		692
Spearfishing	Spearfishing	540
n.c.	Spearfishing	511
Angling	Spearfishing	0
Total spearfishing		1 051

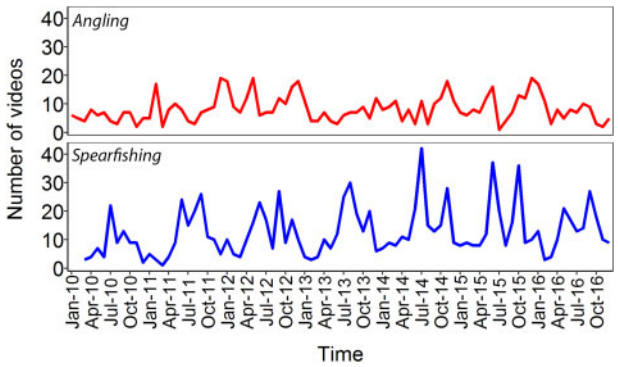

Figure 2. The upload monthly patterns related to angling and spearfishing. The total number of identified videos is 692 for angling and 1051 for spearfishing.

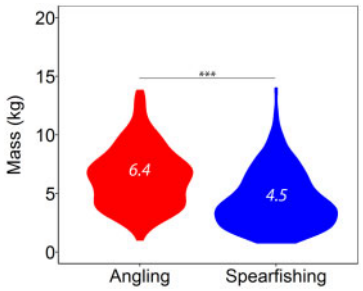

Figure 3. Violin plots of the mass of the fish declared in the title and description of the videos for both angling and spearfishing. Numbers inside the violin plots indicate the mean mass. The total number of identified videos with the declared mass of the fish is 214 for angling and 326 for spearfishing. The black horizontal line represents significant differences between groups (***$p < 0.001$).

Table 3. Modelling results related to the differences in social engagement parameters between spearfishing and angling groups.

Dependent variable	Predictor variable	Estimate	Z value	p-value
Views	Spearfishing	1.10 [0.95–1.28]	1.283	0.200
Likes	Spearfishing	2.15 [1.85–2.49]	10.050	<0.001
Comments	Spearfishing	5.34 [4.55–6.25]	20.740	<0.001

Estimates (rate ratio) and confidence intervals [2.5–97.5%] are reported together with *Z* statistics and *p*-values for spearfishing group ($N = 692$) with respect to angling one ($N = 1051$).

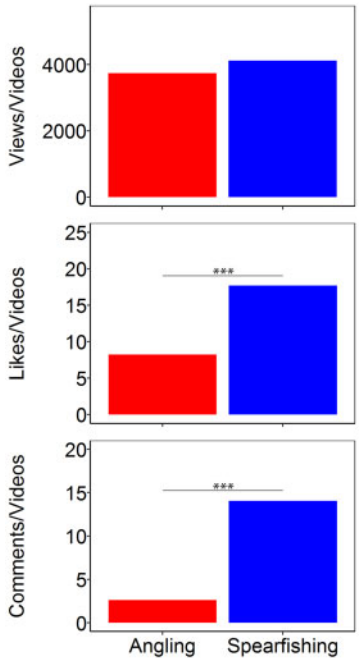

Figure 4. Barplots of the average social engagement parameters for both angling and spearfishing. The total number of identified videos is 692 for angling and 1051 for spearfishing. Black lines represent significant differences between groups (***$p < 0.001$).

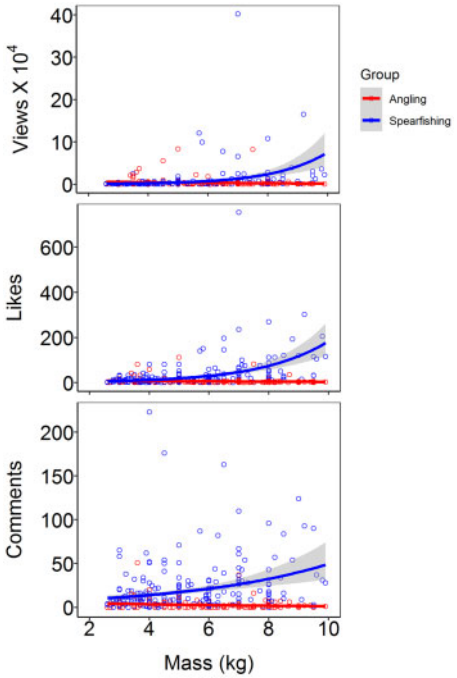

Figure 5. Scatter plots of the mass of the fish against social engagement parameters for both angling ($N = 184$) and spearfishing ($N = 234$) groups. Lines represent a negative binomial smoothing function together with 95% confidence interval (grey area).

Table 4. Modelling results related to the correlation between mass of the fish declared in the video and social engagement parameters.

Dependent variable	Predictor variable	Estimate	*Z* value	*p*-value
Views	Mass: angling	0.84 [0.74–0.95]	−3.09	<0.001
	Mass: spearfishing	1.92 [1.73–2.12]	14.30	<0.001
Likes	Mass: angling	0.90 [0.80–1.01]	−1.90	0.057
	Mass: spearfishing	1.57 [1.45–1.70]	11.27	<0.001
Comments	Mass: angling	0.85 [0.74–0.97]	−2.40	<0.05
	Mass: spearfishing	1.23 [1.13–1.35]	4.86	<0.001

Estimates (rate ratio) and confidence intervals [2.5–97.5%] are reported together with *Z* statistics and *p*-values for both recreational angling ($N = 184$) and recreational spearfishing ($N = 234$).

appreciation for the skill of the fisher (e.g. "*wonderful fishing action*," 10.2%) and positive personal feelings (e.g. "*I remained open-mouthed*," 7.5%) as compared to recreational anglers (0.5 and 1.4%, respectively). Finally, from a global perspective related to the key evaluative dimensions of the comments, we found that an increase in the mass of the fish declared in spearfishing videos significantly ($p < 0.05$) increased the odds of comments with only positive associations [RR = 1.17 (1.02–1.34); Table 6] and with positive/neutral associations [RR = 1.25 (1.02–1.52); Table 6] compared to comments with only neutral associations. In other words, the increase in the mass of the fish declared in spearfishing videos increased the odds of comments with positive associations. Such mass-dependent appreciation effect was not observed for the comments related to angling videos (Table 6).

Discussion

Our study showed that data mining on YouTube is a promising method for providing complementary data on recreational fisheries. It offers potential for understanding harvesting patterns and specific aspects of the social dimensions in different types of recreational fisheries. We showed a peak of video posting in July only for spearfishing group, suggesting that the odds of catching *D. dentex* shows seasonality in recreational spearfishers, but not in anglers. Moreover, recreational spearfishing videos registered more social engagement (i.e. likes and comments) compared to recreational angling videos, supporting the idea that spearfishing videos stimulate enhanced social rewards. This can be related to the fact that spearfishers necessitate developing sophisticated skills before being able to catch a *D. dentex* as suggested by the content analysis; appreciation for fishing skills was a frequent theme in comments to videos by spearfishers, but not in postings related to anglers. Finally, the mass of the fish positively predicted social engagement and globally positive comments only in recreational spearfishing probably because they have less chances of catching large *D. dentex* than recreational anglers, as suggested by the average mass of the harvested fish documented here and in previous studies (Marengo *et al.*, 2015). Consequently, videos with bigger fish triggered more social engagement and more positive reactions.

The pattern of videos upload indicated seasonality only for recreational spearfishing with a peak of uploads in the month of July. There are several reasons that could explain these results. A first explanation—assuming that the videos are uploaded within few days after the fishing trip—could be related to a seasonal change of vulnerability of *D. dentex* to spearfishing with a peak of vulnerability in the month of July. Seasonal vertical movements of *D. dentex* have been recently documented. Aspillaga *et al.* (2017) demonstrated that *D. dentex* prefers the warm suprathermoclinal layer whose shallowest depths (at about 20–30 m) are

Table 5. Frequency of theme occurrence (%) with respect to all the themes coded in the comments posted by recreational anglers (*N* themes = 201) and spearfishers (*N* themes = 666) subdivided according to the subject, category/subcategory (adapted by Madden *et al.* 2013), and global evaluative dimension of the content of each comment.

Subject	Category	Subcategory	Dimension	Theme	Angling	Spearfishing
	Advice	Request	Neutral	Asking advice about fishing strategy	3.5	1.5
Fisher	Opinion	Give	Positive	Appreciation for athletic performance	–	2.4
			Positive	Appreciation for fishing skills	0.5	**10.2**
			Positive	General appreciation for the fisher	**22.4**	**30.3**
			Negative	Criticism related to the declared mass	1.0	–
			Negative	Criticism related to the fishing behaviour	0.5	–
	Responses	Agree	Positive	Agreement with previous comment	2.0	8.4
			Neutral	Reply to previous comment	6.0	**8.6**
	General conversation	Greetings	Positive	General greetings	4.0	6.9
		Joke apology	Positive	Joke regarding the fishing skills	**7.5**	1.8
		Request personal information	Neutral	Asking personal information	0.5	1.7
Fish	Opinion	Give	Positive	Appreciation for fish size	**10.0**	**10.5**
			Neutral	Opinion on fish behaviour	1.0	1.2
			Neutral	Opinion of fish conditions	0.5	–
			Negative	Criticism related to kill a fish	0.5	–
			Negative	Criticism related to kill the prey immediately	1.0	–
Technology	Opinion	Give	Positive	Appreciation for gear used	1.0	0.3
			Negative	Criticism on the type of gear used	1.0	0.5
			Neutral	Asking advice about the type of gear used	3.5	1.2
Others	Opinion	Give	Positive	Appreciation for the environmental context	1.5	1.4
			Positive	General appreciation for the video	**19.4**	**9.2**
			Neutral	Opinion on the quality of the video	–	0.3
			Negative	Criticism towards pollution and commercial fishing	2.5	0.3
	Expression of personal feelings	Positive	Positive	Expression personal feelings on the video	**7.5**	1.4
	General conversation	Anecdote	Neutral	Fishing anecdote	1.5	0.9
	Site process	Profiles and subscriptions	Positive	Declared submission to the channel	0.5	1.2
	Non-response comments	Nonsense words/random	Neutral	Non-interpretable comments	1.0	–

The most frequent five themes are indicated in bold for each group.

Table 6. Modelling results related to the relationship between mass of the fish declared in the video and the global coding groups.

Dependent variable	Predictor variable	*N*	Estimate	*Z* value	*p*-value
Only positive associations	Mass: angling	93	1.13 [0.99–1.30]	1.810	0.070
	Mass: spearfishing	288	1.17 [1.02–1.34]	2.309	<0.05
At least one positive and at least one neutral association	Mass: angling	10	1.15 [0.93–1.42]	1.256	0.209
	Mass: spearfishing	38	1.25 [1.03–1.52]	2.237	<0.05

Estimates (rate ratio) and confidence intervals [2.5–97.5%] are reported together with *Z* statistics and *p*-values for both recreational angling and recreational spearfishing with respect to the reference coding group where we found only neutral associations. Note that the results for two of the five coding groups are not modelled because of the reduced number of observations (see Material and methods section).

usually reached in July and August. Furthermore, Sbragaglia *et al.* (2019) revealed that *D. dentex* presence at an artificial reef at 22 m depth was higher during summer months and positively correlated with the water temperature. It is plausible that anglers can pursue *D. dentex* at all depths throughout the year; in contrast, spearfishing usually perform their free-diving hunting actions at maximum depths of about 18–25 m (FIPSAS, 2002). Consequently, spearfishers have more chances of encountering *D. dentex* during summer months (e.g. July) than in other months, in line with the upload patterns we found. A second interpretation could be related to seasonality in the fishing activity of spearfishers. However, this explanation is not supported by previous results in the Mediterranean area that indicated angling has a more marked seasonality in fishing activity than spearfishing (Morales-Nin *et al.*, 2005). Finally, our results could also be explained by fisher-specific seasonal activity on social media or variation in the "personalities" of different fisher groups.

The *D. dentex* harvested in the videos posted by recreational anglers were significantly heavier than those harvested by recreational spearfishers. This is in accordance with the qualitative data reported by Marengo *et al.* (2015) for the Bonifacio strait showing that recreational angling (in particular trolling) harvested larger specimens relative to spearfishing. Moreover, the average mass reported in our study from YouTube for *D. dentex* harvested by

spearfishers (4.5 kg) was larger than the average harvested mass of individual common dentex reported during an onsite survey in Cap de Creus, North-West Mediterranean Sea (1.8 kg; Lloret *et al.*, 2008), suggesting that the average mass estimated here for spearfishing could be overestimated in YouTube videos compared to the true average in real fisheries. A possible explanation is that the upload of spearfishing videos may be biased towards particularly memorable and hence large fish. Alternatively, spearfishers may inflate the mass of the fish declared in the videos for reasons of increasing prestige, possibly to generate more social engagement (see below). Our study, together with previous studies (Marengo *et al.*, 2015), suggest that spearfishers have lower chances than anglers of capturing large *D. dentex*.

YouTube users left more likes and comments to spearfishing videos than to angling ones. Although we are unable to characterize what kind of public engaged with the videos (e.g. fishers or members of the non-fishing public), it is likely that most of the social engagement with videos was triggered by either recreational spearfishers or recreational anglers. If this is the case, our results suggest that spearfishers either have a larger online community from which to draw social engagement or spearfishing videos truly trigger more online engagement than angling. The latter could be related to the fact that catching a *D. dentex* with spearfishing techniques requires more skill (e.g. long freediving usually at considerable depths and specific sit-and-wait or ambush hunting strategies) and elevated personal investment of energy relative to angling, such that the posting of particularly remarkable individuals (large) stimulates increased feelings of excitement and arousal, in turn motivating more likes and comments. Such interpretation is strongly supported by the fact that 12.6% of the themes in the comments of spearfishing videos were related to appreciation for the freediving and hunting actions; something not observed for angling where appreciation-related comments only encompassed 0.5% of all comments. The intrinsic difficulty of catching *D. dentex* by spearfishing is reflected by the extremely low species abundance during spearfishing competitions (0.16–0.50% of total number of fish; Coll *et al.*, 2004). In fact, the first capture of a *D. dentex* is considered as the final graduation among spearfishers (FIPSAS, 2002).

The differences observed in the social engagement may also be related to a stronger masculine moral identity of spearfishers related to providing food for their families by challenging the adverse conditions of underwater hunting, as described for another hand-fishing technique with strong masculine traits targeting catfish (e.g. *Pylodictis olivaris*) in rivers of the United States by "hand-fishing" (also known as noodling or grabbing; Grigsby, 2009, 2011). Finally, experiencing nature and mastering challenging situations constitute among the main motivations of recreational anglers and recreational spearfishers (Knopf *et al.*, 1973; Holland and Ditton, 1992; Fedler and Ditton, 1994; Beardmore *et al.*, 2011; Young *et al.*, 2016). Spearfishing is a peculiar fishing modality that is more similar to hunting than fishing; it implies a particularly direct contact with the prey in its own habitat, and it has been reported that spearfishers reveal higher levels of satisfaction than anglers (Gordoa *et al.*, 2019). Therefore, spearfishing videos could be more effective in triggering enhanced appreciation among spearfishers and consequently they receive more likes and comments than when the same-sized fish is posted by anglers, often captured from motorized boats.

The capture of large *D. dentex* triggered a particularly positive increase in several social engagement variables (i.e. views, likes, and comments) and comments with general positive associations, but only in the spearfishing group. *Dentex dentex* may reach a maximum mass above 13 kg (Marengo *et al.*, 2014), but fishes of 7 kg or larger may be already considered a unique trophy size by recreational fishers. As documented above, spearfishers have lower chances of catching a trophy *D. dentex*; in particular, the percentage of the videos where the declared mass of the fish was above 7 kg represent 34% of the videos posted by recreational anglers compared to only 14% of those posted by recreational spearfishers. A study conducted with online terrestrial hunting photographs similarly revealed that prey size influenced emotional signals (i.e. smiles) of hunters; true smiles were 1.5 times greater when posing with large prey compared to small prey (Child and Darimont, 2015). This can be related to an activity-specific achievement satisfaction of hunters for harvesting a large and rare prey (Potter *et al.*, 1973; Child and Darimont, 2015). Our results regarding spearfishers are in agreement with this view, but relate to social appreciation, rather than individual satisfaction as shown by the fisher himself or herself.

Although data mining produced interesting complementary information for characterizing recreational fisheries, there are several aspects that need to be addressed in the future before the technique can be more readily used. First, there is a need for a systematic study as to how recreational fishers posting on YouTube differ from the representative population of recreational fishers. Once these data are available, one could weight YouTube data and infer insights about the population of users from YouTube data. Second, we do not know what kind of YouTube users contributed to the social engagement variables, and a proper identification is needed. Third, the automatic classification we applied was only based on sorting the videos of different forms of recreational fisheries according to specific keywords, which likely contributed to the large disparity of the automatic screening and the manual cross check; this is probably due to users tagging a broad range of keywords to attract more views. Future methodological refinements for implementing the sensitivity of automatic sorting should also consider machine learning approaches (Roll *et al.*, 2018).

Our study opens a new avenue in using digital applications and social media platforms for producing complementary data for characterizing catch patterns and social aspects of different forms of recreational fisheries. The approach we present is not overly time-consuming and can be implemented with limited resources. This will be particularly important for marine recreational fisheries in Europe where there are still significant gaps in knowledge (Hyder *et al.*, 2018), and for countries where there are not many resources available for the monitoring of recreational fisheries. Data mining on YouTube could contribute to characterize multispecies harvest patterns at national level and generally help understanding the human dimensions of recreational fishers (Arlinghaus *et al.*, 2013; Hunt *et al.*, 2013).

Author contributions

V.S. conceived the study; R.A.C. performed the data mining with inputs by V.S.; S.C. and V.S. analysed the data; V.S. statistically analysed the data, V.S. and 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.

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