



Social Media Use by Citizen Science Projects: Characterization and Recommendations

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Citizen science projects often use social media, which is not surprising since they constitute a great opportunity to recruit, retain, and train volunteers. This study intended to quantitatively characterize the current use of social media by biodiversity- and environment-related projects and to reason on the best management practices. For this purpose, a database of projects was compiled and analyzed. The results revealed that 42% of the projects were present at least in one social platform, with Facebook being the most popular. Facebook posts were mainly intended to raise awareness and disseminating knowledge, but recruitment- and retainment-dedicated posts were also regularly shared.

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INTRODUCTION

Citizen science is a form of science communication that can be defined as the active involvement of a non-expert public in scientific research projects (ECSA, 2015; McKinley et al., 2017; Newman et al., 2017; ACSA, 2018). In the last years, the popularity of citizen science has grown immensely. Bautista-Puig et al. (2019) stated that the number of scientific publications addressing this topic increased by 78% between 2006 and 2017. In the field of biodiversity and environmental research, citizen science is often regarded as a great opportunity to collect scientific data, concomitantly improving literacy in the society (Chandler et al., 2017; McKinley et al., 2017; Phillips et al., 2019). So far, this approach has been employed to accomplish a vast number of ecology-related tasks, like finding rare species, tracking migrations, detecting shifts in abundance of certain organisms, and assessing water quality (Chandler et al., 2017; McKinley et al., 2017). However, one of the main constraints of citizen science is the recruitment of participants (Pocock et al., 2014; Wald et al., 2016; West and Pateman, 2016) and this is where the importance of social media raises.

According to Kaplan and Haenlein (2010), social media can be classified in several types: social networking sites (e.g., Facebook, LinkedIn, and Instagram); blogs, including microblogs (e.g., Twitter); content communities (e.g., YouTube, Flickr, and Pinterest); collaborative projects (e.g., Wikipedia); virtual social worlds (e.g., Second Life); and virtual game worlds (e.g., Sims). In the present study, we focused on social networking sites, content communities and microblogs, henceforth designated by “social platforms.” Facebook and Youtube are the most popular social platforms, with around 2.7 and 2 billion active users per month, respectively (Statista, 2020). Having so many people gathered in one place constitutes a great opportunity for promoting volunteering calls among potential participants, facilitating the recruitment process (Ambrose-Oji et al., 2014; Van Vliet et al., 2014; Wald et al., 2016; West and Pateman, 2016; Skelton et al., 2018). In addition, social

platforms allow to maintain a regular communication with citizen scientists (Kaplan and Haenlein, 2010; Bhalla, 2011; Ambrose-Oji et al., 2014; Skelton et al., 2018) and, as some support a multi-way conversation, they can also enable participants to interact with each other and with the project managers (Bhalla, 2011). Both aforementioned features are considered essential for the retainment of volunteers and, thus, key to the success of citizen science projects (Wald et al., 2016; West and Pateman, 2016; Skelton et al., 2018; Phillips et al., 2019). Social platforms can even work as a stage for raising awareness and disseminating knowledge (Ambrose-Oji et al., 2014; Van Vliet et al., 2014; Hallman and Robinson, 2015; Taylor and Sammons, 2019), which is a key goal of many citizen science projects focusing on biodiversity (Chandler et al., 2017). Finally, it is worth mentioning that some citizen science projects use social platforms to collect data directly from participants (e.g., Rocha et al., 2017). Clearly, there are many synergies that can be set between social platforms and citizen science goals and requirements.

Despite social platforms holding a great potential for citizen science application, it is still unclear how often and for what purpose they are being used by citizen science projects worldwide. As far as the authors are aware of, there is no published scientific literature addressing these questions, which motivated the present study, aiming specifically at: (1) characterizing the usage of social platforms by citizen science projects that focus on biodiversity and environment monitoring; and (2) reasoning and defining best practices that citizen science projects should follow in order to maximize the benefits provided by social platforms.

METHODS

In order to characterize the usage of social platforms by ongoing citizen science projects, a global database of citizen science projects that focused on biodiversity and environment monitoring (e.g., species distribution, water physicochemical parameters) was compiled. The worldwide database assembled by Chandler et al. (2017) was used as a starting point. This database was completed with citizen science projects implemented in Portuguese language to better cover our own country, as well as significant Portuguese-speaking areas of the globe in South America and Africa. This search was carried out on Google, by using the keyword string “ciência cidadã” (Portuguese term for “citizen science”), and on dedicated websites of wide coverage, such as the Portuguese citizen science conference (<https://www.cienciacidada.pt/encontrocc2019/index.php>) and the European Union’s citizen science database (<https://eu-citizen.science/>). During this search, other projects using the English language were also found and added to the database. Note that, for the purpose of this study, only projects active in 2019 were considered, e.g., projects that were accepting data submissions in that year.

For each citizen science project, information about its geographical scope, time range, ecosystem targeted, and social platform presence was retrieved from the website and social platforms of the project or the project’s promoter(s). Descriptive statistics were used to briefly characterize the projects composing the

database as well as their social platform presence. The social platform used by the highest number of projects (Facebook) was then targeted for further analysis. When possible, three projects from each continent plus three global ones were chosen, according to the following criteria: (1) highest number of Facebook followers (only projects with over 1,000 followers were considered), (2) diversity in terms of the projects’ geographical scope and location, and (3) language used in Facebook posts (only projects that published mostly in English or Portuguese were considered for this stage). This allowed for the selection of 18 projects that were targeted for a more thorough analysis focusing on the content published during three randomly chosen months of 2019 (namely March, July, and September) on Facebook. This analysis consisted of user engagement metrics (number of likes, shares, and comments) plus content analysis of 1162 Facebook posts.

For the content analysis, five categorial variables were deemed relevant and a coding scheme was developed for each one based on previous literature (Table 1). Two authors of this study first coded the same random sample of 251 posts, then the intercoder reliability was evaluated by computing Cohen’s kappa (κ) using IBM SPSS Statistics (version 26), which evidenced a high agreement ($\kappa \geq 0.80$; Table 1) for all coded variables (McHugh, 2012). Afterwards, all remaining posts were manually coded, and a database was created on Microsoft Office Excel (2016 version).

After coding, the frequency of each code was determined for all qualitative variables. When relevant, statistical tests were employed to assess the presence or absence of statistically significant differences among data groups. Pearson correlations were computed to address the association between the median interactions per Facebook post and the number of page followers, while Spearman’s correlation was used to test the relationship between the posting frequency and the number of page followers. To assess whether there were statistically significant differences among projects regarding their total engagement (number of likes, comments, and shares) in Facebook, a Kruskal-Wallis test was applied followed by post-hoc Dunn’s testing. These statistical tests were selected as, according to the Kolmogorov-Smirnov test ($p < 0.05$) and the Q-Q plot, the total engagement was not normally distributed early on. Plus, Levene’s testing indicated that the variances for this variable were not homogeneous ($p < 0.05$). For the same reasons or to keep consistency, this non-parametric approach was followed for the remaining comparisons among groups (variable categories) in order to assess: (1) whether own content generates more interactions than third-party content; (2) which is the most engaging type of content; (3) which is the most engaging content category; (4) whether posts focusing on charismatic taxonomic groups generate more interaction. This analysis was performed by taking into account all the projects as a whole.

Unless otherwise stated, the statistical analyses were run in IBM SPSS Statistics (version 26).

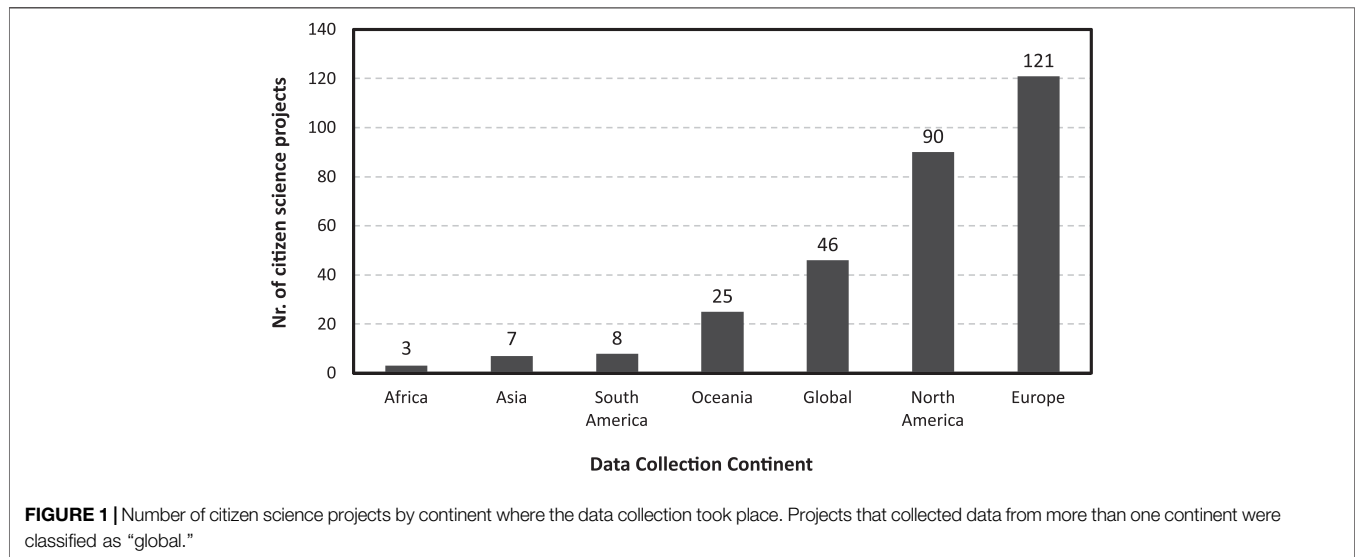
RESULTS AND DISCUSSION

Characterization of the Citizen Science Database

The compiled database comprises 300 citizen science projects from around the world. Portals – projects that included two or more

TABLE 1 | Categorical variables used in the content analysis of Facebook publications. Cohen's kappa values (κ) were calculated using IBM SPSS Statistics (version 26) to evaluate the intercoder reliability. For more details on the coding schemes, please see **Supplementary Table S1**.

Categorical variables	Description or categories	References	κ
Authorship	Own content, Third-party content	Handy (2011); Pew Research Center (2018)	0.905
Typology	Video, Image, Text-only, Hyperlink, Event, and Poll	Pew Research Center (2018); Feehan (2020); Sprout Social (2020)	0.949
Content category	Science and nature news/facts, Commemorative dates, Scientific outputs, Calls to action/Share events, Backstage, Project results, Surveys, Others	Ambrose-Oji et al. (2014); West and Pateman (2016); Pew Research Center (2018)	0.816
Taxonomic group	Taxa in which the post was mostly focused on	Chandler et al. (2017)	0.816
Citizen science use	Collection of data, Promotion of awareness and dissemination of knowledge, Recruitment of volunteers, Retainment of volunteers, Training of volunteers, Others	Ambrose-Oji et al. (2014); Van Vliet et al. (2014); West and Pateman (2016)	0.850



distinct citizen science activities (Chandler et al., 2017) – were considered as one entry in the database, except when their activities had a very distinguishable character (e.g., different geographical scope and taxonomic focus plus somewhat separate management approach), such as the case of British Trust for Ornithology's bird surveys and Norfolk Bat Survey. Europe and North America are by far the most well-represented continents in the dataset (Figure 1). Regarding their geographical range, in North America, citizen science projects had mostly a local scope (67%), while in Europe the majority of them (83%) was either national or regional (projects that collected data in more than one country of the same continent were classified as regional).

Most of the projects in the database were running for 10 years or over ($n = 53$). The database also comprises 53 projects that were active during 4 to 9 years, 38 projects that operated for 3 years or less, and 48 projects of unknown duration. The majority of the projects targeted more than one ecosystem ($n = 42$) or focused exclusively on terrestrial ecosystems ($n = 40$), possibly due to the facilitated access to terrestrial environments and their biota for carrying out activities involving biodiversity inspection. Marine and freshwater ecosystems were the sole focus of 44 and 10 projects, respectively. This tendency is

similar to the one reported by Chandler et al. (2017), where most projects focused on terrestrial ecosystems only ($n = 55$ %), followed by the ones that targeted multi-ecosystems ($n = 30$ %).

Social Media Presence

More than one third of the documented projects used at least one social platform (42%). On average, the projects that used social platforms had an account on 2.2 ± 1.1 different websites. Facebook was the most used one (38%), followed by Twitter (29%), Instagram (13%), and YouTube (11%). Flickr (2%), Pinterest (1%), and LinkedIn (1%) were also utilized, but only by a few projects. Facebook was the most used social platform in all continents. However, in global and European projects, Twitter was utilized almost as often. Overall, South American projects seemed to be the ones with a stronger social media presence, as they cumulatively held the highest percentage of social platforms use and the second greatest average number of social platforms per project (Figure 2). It is also worth mentioning that local citizen science projects resorted less to social platforms than projects with a wider geographical scope, displaying simultaneously the least percentage of use and the lower average number of social platforms.

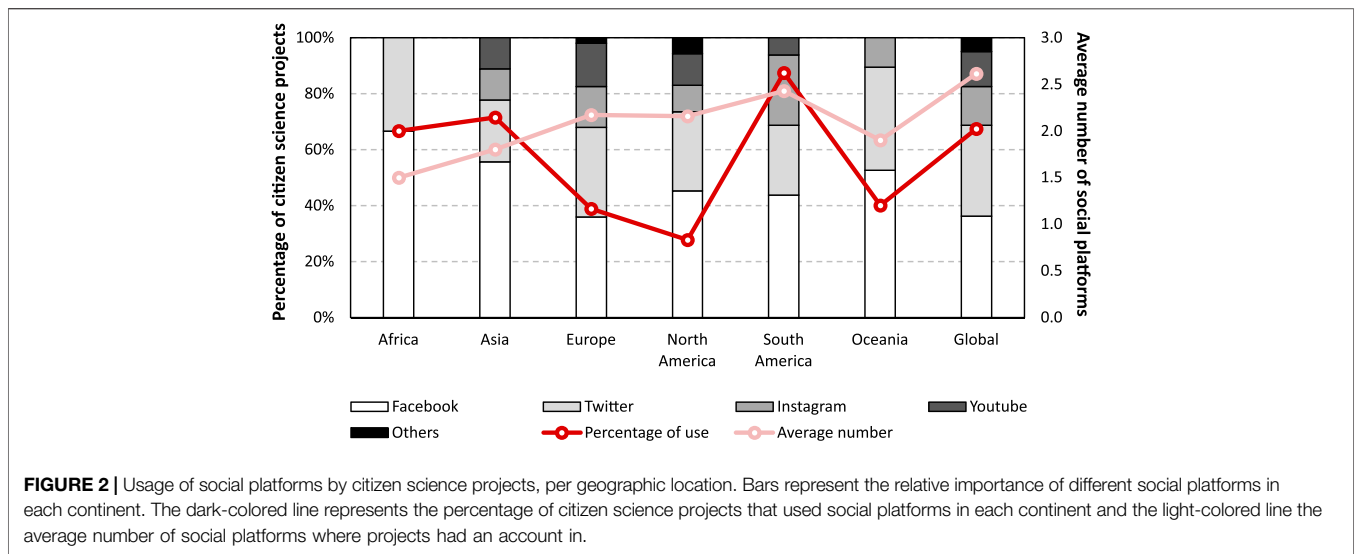


FIGURE 2 | Usage of social platforms by citizen science projects, per geographic location. Bars represent the relative importance of different social platforms in each continent. The dark-colored line represents the percentage of citizen science projects that used social platforms in each continent and the light-colored line the average number of social platforms where projects had an account in.

TABLE 2 | Citizen science projects selected for a more thorough analysis and their respective Facebook following, posting frequency and median interaction obtained by each post. The last column exhibits projects with statistically similar engagement values ($p > 0.05$), which was achieved by running a Kruskal-Wallis test ($H_{16} = 613.916$; $p < 0.001$) followed by Dunn's testing.

Project	Followers ^a	Median interaction	Posting frequency	Similar projects (source of variation: Total engagement; $p > 0.05$)
1	>50,000	102.0	1.01	3, 15, 17
2	<5,000	21.5	0.26	4, 5, 8, 11, 16
3	<5,000	123.0	0.12	1, 4, 6, 7, 10, 11, 14, 15, 17
4	5,000–15,000	42.0	0.52	2, 3, 6, 7, 8, 11, 14
5	15,000–50,000	23.0	1.68	2, 8
6	15,000–50,000	42.0	1.45	3, 4, 7, 8, 11, 14
7	<5,000	41.0	0.42	3, 4, 6, 8, 11, 14
8	<5,000	16.0	0.03	2, 4, 5, 6, 7, 11, 12, 13, 16
9	>50,000	456.0	0.95	10
10	>50,000	182.5	0.50	3, 9, 15
11	5,000–15,000	35.0	0.45	2, 3, 4, 6, 7, 8, 14
12	<5,000	12.0	0.84	8, 13, 16
13	5,000–15,000	5.0	1.29	8, 12, 16
14	<5,000	57.0	0.60	3, 4, 6, 7, 11
15	5,000–15,000	121.0	0.30	1, 3, 10, 17
16	>50,000	15.5	0.96	2, 8, 12, 13
17	15,000–50,000	87.0	1.25	1, 3, 15
18	<5,000	—	0.00	—

^aThe Facebook following is displayed by class to ensure the anonymity of the projects. However, for all performed analysis, the exact number of Facebook followers (retrieved on September/October 2019) was used

General Overview on Facebook Usage

The citizen science projects selected for a more comprehensive analysis varied greatly in regard to the number of Facebook followers, median interactions, and posting frequencies (Table 2). According to grey literature in the realm of social media marketing, it is recommended that Facebook pages publish an average of one post per day (Rezab, 2011; Ellering, 2017; Meyers, 2020). In fact, 10 of the selected projects followed this guideline by publishing between 0.5 and 1.4 posts per day. Most projects that did not abide by this guideline published too sporadically, which may cause their audience to lose interest

in their project (Rezab, 2011). On the other end of the spectrum, there was one project that posted 1.7 publications per day, on Facebook, which can be considered excessive. Publishing too frequently is not advisable as this is one of the factors that cause people to unfollow social platforms' pages (Sprout Social, 2020), diminishing the potential unpaid audience reach of future posts. Plus, overpublishing is often linked to a decrease of the engagement generated by each post (Rezab, 2011; Ellering, 2017; Meyers, 2020). In the present study, a moderate significant correlation between the posting frequency and the number of Facebook followers ($r_s = 0.591$; $p = 0.010$) was found:

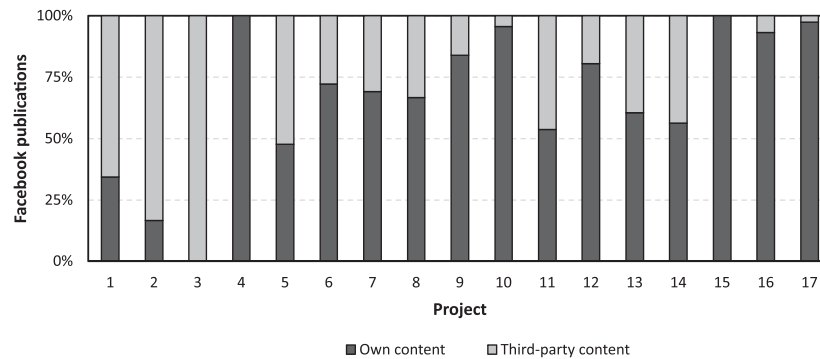


FIGURE 3 | Percentage of Facebook posts that corresponded to own content and third-party content, for each selected citizen science project.

the pages with more followers generally showed higher posting frequencies. One possible explanation is that the projects with the largest number of followers gained their audience by applying the best practices available regarding Facebook page management, including the ones related to the posting frequency. Similarly, there was a strong significant linear positive correlation between the median interactions obtained per post and the number of followers ($r = 0.718$; $p = 0.001$), which was expected as pages with greater number of followers have a potentially superior number of viewers per post. Nonetheless, some exceptions were noted. For instance, the engagement obtained by project 16 was significantly lower ($p < 0.05$) than the one obtained by projects within the same range of followers (e.g., projects 1 and 9), while being similar to the engagement generated by projects with much less followers (e.g., projects 8 and 12). These discrepancies are likely a result of the quality of the published content as well as the management practices adopted. Indeed, it is documented that Facebook pages may generate more or less interactions than expected based solely on their number of followers according to the quality of their performance (Handy, 2011; Rezab, 2011; Ellering, 2017; Clarke, 2019; Meyers, 2020; Sprout Social, 2020). Project 18 did not publish any posts on Facebook during the considered time frame, thus it was excluded from further analysis.

Own Content vs Third-Party Content Engagement on Facebook

Regarding their authorship, the large majority of the documented publications corresponded to the project's own content ($n = 811$; 70%). Despite own content bearing a slightly superior engagement overall (medians: 37 > 36 interactions), the engagement obtained by these publications did not significantly differ from the one generated by third-party content ($H_1 = 0.056$; $p = 0.814$). According to social media marketing experts, companies can be broadly classified in three groups regarding the percentage of published posts corresponding to third-party content: self-promoters ($\leq 50\%$), balanced (50–75%), and curators ($\geq 75\%$) (Handy, 2011; Sukhraj, 2018). Following this classification, 13 projects were self-promoters, two were curators, and two adopted a balanced strategy in the present study (Figure 3).

It is widely acknowledged that third-party content, when properly chosen, has the potential to generate more interactions, while being less time consuming (Handy, 2011; Sukhraj, 2018). The discrepancies between the literature and the current results are probably due to the lack of effective content curation practices by many projects, e.g., sharing content that has little relevance for the respective audience. On the other end of the spectrum, creating own content to publish on social platforms is more time demanding, but this option often generates more conversions (e.g., clicks to the project website, project enrollments) (Handy, 2011; Sukhraj, 2018). Since conversions were not quantified during the present study due to the unavailability of such data to persons other than the Facebook page managers, it was not possible to assess whether or not own content was more successful in generating data submissions or recruiting participants. Overall, companies with a balanced strategy usually obtain the best results, generating more engagement than self-promoters and more conversions than curators (Handy 2011).

Responsiveness of Citizen Science Projects on Facebook

In general, the selected projects were not very responsive on Facebook, with only four projects 22% replying to the comments left by their audience on over 50% of their publications (Figure 4). This includes project 8, whose team replied to at least one comment left by their audience in all their Facebook publications. This exception was possibly largely influenced by the very restricted number of posts they published during the analyzed timeframe ($n = 3$). The overall low response rate of the selected projects is not positive given that maintaining regular communications with citizen scientists and providing them feedback is an important factor for the retainment of volunteers (West and Pateman, 2016). Besides, promptly replying to comments is identified as a good management practice of social platforms (Clarke, 2019).

Engagement per Post Typology on Facebook

Considering their typology, most analyzed publications consisted of images ($n = 557$; 48%), hyperlinks ($n = 480$; 41%), and videos

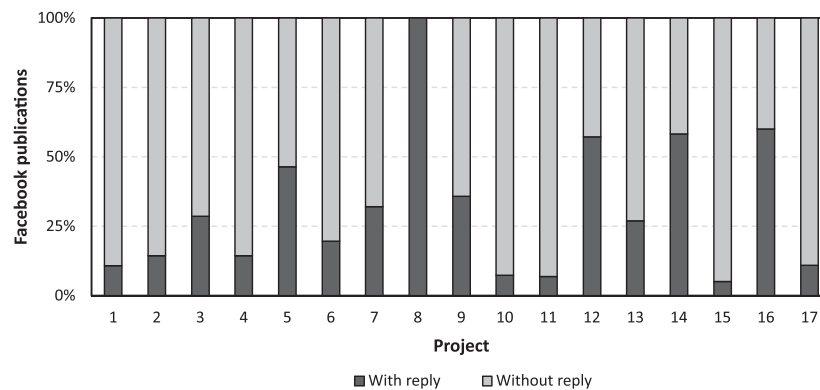


FIGURE 4 | Percentage of Facebook posts where the project's management team replied, or not, to at least one comment left by their audience.

TABLE 3 | Engagement of Facebook posts assigned to different typologies.

Typology	Median interaction
Hyperlink	48.0
Images	42.0
Video	37.0
Event-format	21.0
Text-only	14.0
Poll	—

($n = 95$; 8%). Text-only ($n = 7$; 1%) and event-format ($n = 23$; 2%) posts were barely used, while polls were completely absent from the dataset. These results are in accordance with the most recent literature on social platforms that recognizes images as the most common type of content published on Facebook (Feehan, 2020). When considering each project individually, 10 56% posted mainly images, six 33% shared predominantly hyperlinks, while one project 6% focused on a balanced publication of videos and images. In general, images are considered the most engaging type of content on Facebook (Feehan, 2020; Sprout Social, 2020). Sprout Social (2020) also revealed that 30% and 26% of inquired people expressed an intention of interacting with text-only posts and polls on social media, respectively, while only 16% mentioned they wanted to interact with hyperlinks. Unlike what the literature indicates, hyperlinks collected higher interactions than image-based posts in the present study (Table 3). The disparity between the cited literature and the current results may be due to the fact that this work focused on a very narrow sector; in fact, previous studies have shown that the average interaction obtained by different typologies of posts differ between industry sectors (Feehan, 2020). Despite the literature suggesting that text-based posts and polls might be more effective in obtaining interactions than hyperlinks, these types of posts were either very poorly represented in our dataset or completely absent, preventing extended conclusions about their engagement potential in the specific context of citizen science projects targeting biodiversity and/or environment. However, it is worth noticing that, in the scope of the current research,

TABLE 4 | Engagement of Facebook posts coded as different content categories.

Content category	Median interaction
Others	67.0
News/Facts	53.0
Commemorative dates	53.0
Scientific outputs	29.0
Backstage content	27.5
Calls to action/Share events	24.0
Project results	19.5
Surveys	15.0

publications assigned to different typologies did not generate significantly different interactions ($H_4 = 9.017$; $p = 0.061$). Nonetheless, each project management team may wish to invest in adjusting their content according to their audience-specific preferences. For that purpose, they may test the effectiveness of the different typologies themselves by publishing a few posts of each type and comparing their engagement metrics, which are freely and automatically available on Facebook.

Engagement per Content Category on Facebook

Most of the compiled publications focused on the following content categories: news/facts about science and/or the environment ($n = 398$; 34%); others ($n = 336$; 29%); and calls to action to participate in the project or promotion of events ($n = 265$; 23%). Project results ($n = 76$; 7%) and backstage content ($n = 64$; 6%) were also shared somewhat often. On the other hand, commemorative dates posts ($n = 15$; 1%), scientific outputs of the citizen science project (e.g., published papers or conference participations) ($n = 4$; 0.3%), and surveys ($n = 4$; 0.3%) were rarely shared on Facebook. Publications coded as different content categories showed statistically significant differences regarding their engagement ($H_7 = 99.843$; $p < 0.001$). Specifically, the content categories “news/facts”, “commemorative dates”, and “others” obtained significantly

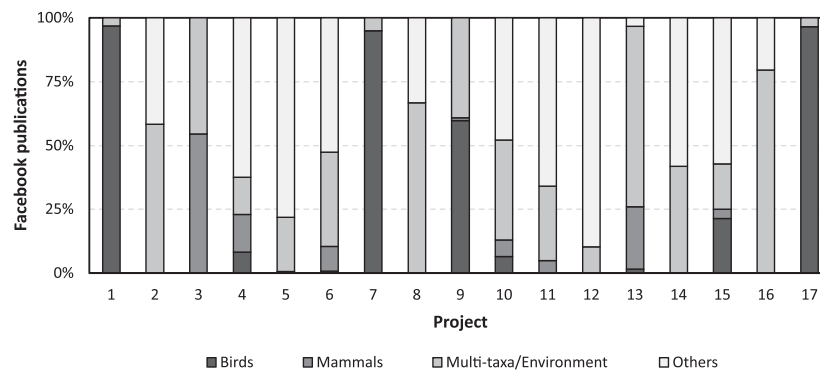


FIGURE 5 | Taxonomic focus of each citizen science project on Facebook: percentage of posts concerning multi-taxa/environment, birds, mammals, and other taxa.

higher interactions than “project results”, “backstage”, and “calls to action/Share events” (Table 4). These results indicate that, in general, the selected projects are already frequently publishing posts under highly engaging content categories.

Engagement per Taxonomic Group on Facebook

In regard to the focus towards specific biota, the majority of the analyzed Facebook publications concerned the environment in general or multiple taxa ($n = 373$; 35%), birds ($n = 307$; 29%), plants ($n = 220$; 21%), terrestrial invertebrates ($n = 126$; 12%), and mammals ($n = 62$; 5%). When Kidd et al. (2018) analyzed posts on Twitter mentioning Australian threatened and extinct fauna, they found out that most tweets concerned birds and mammals. In fact, birds and mammals usually receive a rather disproportionate attention by conservation actions as well as by public awareness efforts (Clucas et al., 2008; Sitas et al., 2009; Troudet et al., 2017), which is likely at least partially due to the charismatic character of many of these taxa (Clucas et al., 2008; Sitas et al., 2009; Troudet et al., 2017; Albert et al., 2018; Courchamp et al., 2018; Kidd et al., 2018). Although birds were indeed featured in most single taxon posts within the present study, mammals were largely surpassed by both plants and terrestrial invertebrates. When analyzing each project individually, the results are even less biased towards birds and mammals: less than one third of the projects ($n = 5$; 28%) posted mainly (>50% of publications) about these taxa (Figure 5). In addition, only one project that collected data on multiple species focused their Facebook publications on mammals. These findings indicate that citizen science is committed to raise awareness about often neglected taxonomic groups; this conclusion is also supported by the existence of many citizen science projects that work mostly with plants and terrestrial invertebrates (Chandler et al., 2017). Taxonomic groups rich in charismatic species (e.g., mammals; Albert et al., 2018; Courchamp et al., 2018) were expected to generate more interactions on social platforms, since they are perceived as more likable and appealing by the general public (Albert et al., 2018). In fact, significant differences in interaction were detected among posts

TABLE 5 | Number of Facebook posts focusing on different taxonomic groups and their respective obtained engagement.

Taxonomic group	<i>n</i>	Median interaction
Macrofungi	5	142.0
Birds	307	96.0
Reptiles	13	62.0
Terrestrial invertebrates	126	53.0
Amphibians	7	47.0
Mammals	62	45.0
Saltwater fish	22	32.5
Multi-taxa/Environment	373	26.0
Plants	220	19.0
Freshwater and migratory fish	5	18.0
Macroalgae	4	15.5
Aquatic invertebrates	16	14.0
Microorganisms	2	13.5

with different taxonomic focus ($H_{12} = 253.869$; $p < 0.001$); however, there was not an evident bias towards charismatic species as expected (Table 5). First, posts about birds got significant higher interactions than posts with any other taxonomic focus, except for macrofungi (see Supplementary Table S2 in the supplementary material for the statistical support to this interpretation and those below). Although this seems to support the idea that charismatic species get more attention on social platforms, it is important to highlight that this result is strongly influenced by the presence of two projects that publish frequently about birds, which have a large number of followers and a high median interaction per post. Hence, this may also be a consequence of the adoption of good management practices by these Facebook pages. Besides, mammals got statistically similar interactions to other groups that are not typically associated with charismatic species, like amphibians and reptiles. Macrofungi also generated significant higher interactions than most other groups, but this result is biased by the poor representation of this group in the dataset (group portrayed in only five posts). In the other end of the spectrum, plants got significantly lower interactions than many groups, including terrestrial invertebrates and saltwater fish. Overall, the

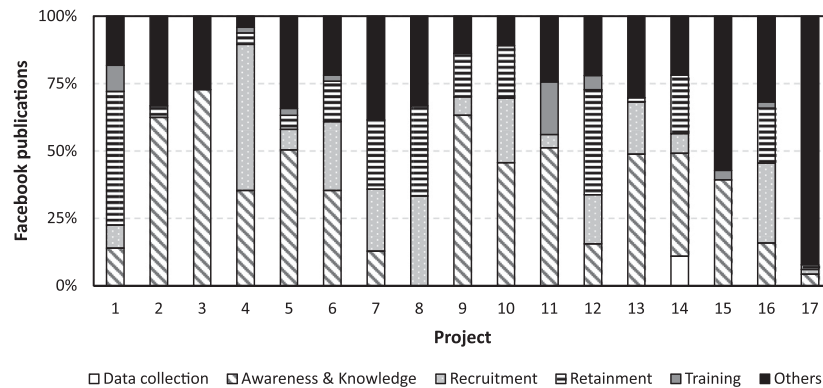


FIGURE 6 | Percentage of posts that represented each citizen science usage for each selected project.

lack of a clear bias in interaction towards charismatic species is again a surprising result. This may be linked to the fact that citizen science often attracts public that is already interested in the theme of these projects (Alender, 2016; Skelton et al., 2018), and, hence, may be more sensitized to biodiversity often thought of as less attractive.

Citizen Science-Related Purposes of Facebook Posts

The most frequent citizen science usage of the compiled Facebook publications was the promotion of awareness and dissemination of knowledge ($n = 401$; 35%). Many posts were also dedicated to the recruitment ($n = 178$; 15%) and to the retention of volunteers ($n = 175$; 15%), while only a few concerned volunteer training ($n = 32$; 3%) and data collection ($n = 6$; 1%). It is also worth mentioning that a high proportion of publications did not fit any of the aforementioned categories ($n = 370$; 32%). When analyzing each project individually, the results are fairly similar: for seven of them, the predominant use of the publications was to raise awareness and disseminate knowledge, while six projects used their Facebook posts primarily to recruit and retain citizen scientists (Figure 6). These results are somewhat similar to the ones obtained by Ambrose-Oji et al. (2014), who reported that forestry-related citizen science projects based in the United Kingdom commonly used social platforms to recruit and retain volunteers, while some also used them as part of their educational approach. In addition, Wald et al. (2016) showed that social platforms are the primary mean of recruitment for many citizen science projects.

In the scope of the present research, the retainment of citizen scientists was attempted mostly by rewarding them with prizes or distinctions (e.g., featured observation of the week), which is a good practice supported by the literature (West and Pateman, 2016). Nonetheless, according to West and Pateman (2016), providing citizen scientists with feedback on what the data they collected is being used for and sharing research findings with them are important factors for the retainment of volunteers. Plus, sharing this information with volunteers is considered one

of the ten guiding principles of citizen science, as advocated by specialized international associations (ECSA, 2015; ACSA, 2018). Still, only 7% ($n = 80$) of the analyzed posts corresponded to scientific outputs (e.g., published papers or conference participations) or results of the citizen science projects. Although some citizen science projects used Facebook for direct data collection (e.g., Rocha et al., 2017), this option seems to be rather unusual, as suggested by the fact that, in the present study, only six posts belonging to a single project portrayed this kind of use. This may be explained by the existence of more suitable means for data collection, such as an own APP or website, iNaturalist, and Google Forms, all of which were used by many projects identified in the scope of the present study.

The training of citizen scientists is widely regarded as a great option to ensure the collection of high-quality data (Kosmala et al., 2016; McKinley et al., 2017). While some Facebook posts coded as promotion of awareness and dissemination of knowledge might have been intended to provide volunteers with some level of training, only a few publications ($n = 32$; 3%) actually challenged readers to practice the skills they will need when participating the project (e.g., species identification quizzes). So, despite social media's potential to be applied in learning contexts (Javaeed et al., 2020), the selected citizen science projects barely used them for training purposes. Although not separately quantified, some publications in the current dataset referred to the promotion of in person and online training events, which might be a preferred method to assist volunteers in skill development.

CONCLUSION

The great number of people concentrated in social platforms turn them into a promising useful tool for citizen science projects. Although these online resources are commonly used by citizen science projects, there is a shortage of studies in this field. So, there is necessarily a lack of insight on to which extent and for what purpose social platforms are being used by citizen science. In the present study, we found that (1) more than one

third of the documented citizen science projects were present on at least one social platform; (2) that local projects resorted less to social platforms than projects with wider geographical scopes (ex. national, global); and that (3) Facebook and Twitter were the most popular ones. On Facebook, most analyzed projects published an average of one post per day, preferably sharing own content. Overall, the projects targeted for content analysis were not very responsive on Facebook, often leaving the comments of their public unaddressed. Images and hyperlinks were the type of content published more often, and these were found to be very engaging by the online audience of citizen science projects focusing on biodiversity and/or environment. Facebook was predominantly utilized to raise awareness and disseminate knowledge, nonetheless six projects used this social platform mainly as a mean to recruit and retain volunteers. The retention of volunteers through Facebook posts was mostly accomplished by offering prizes and distinctions to the citizen scientists, while sharing the project results and scientific outputs (a guiding principle of citizen science) was found to be a rare practice.

The Facebook performance of the selected citizen science projects was very heterogeneous: some were adopting good managing practices and achieving relatively high interaction rates, while others struggled to gain interactions despite having a large number of followers. Besides, a few projects did not seem to be taking advantage of the full potential of this social platform for their citizen science purpose, as evidenced by the large proportion of posts coded as “others” for the categorical variable “citizen science use”. Based on the available literature and on the results of the current research endeavor, a list of ten recommendations was prepared with the aim of aiding citizen science projects focusing on biodiversity and/or environment in maximizing the benefits collected throughout their social platform journey:

1. Choose wisely the social platforms to be present in according to the target audience of the project: different social platforms have distinct usage percentages in different regions of the globe and their popularity also varies with population demographics.
2. Use social platforms to recruit, retain, and also to train citizen scientists.
3. Adopt a balanced creation-curation strategy for better time-efficiency as a baseline approach to social platforms.
4. Publish own content when the intention is to recruit volunteers as own content tends to generate more website visits.
5. Allocate some time specifically to reply to comments on social platforms.
6. Post consistently and frequently to maintain people interested in the project. An average of one post per day is considered a good guideline for Facebook pages.
7. On Facebook, share mainly images and hyperlinks, as these seem to be the most appealing content typologies.
8. Publish news and previously established scientific facts about the topic of the project on Facebook as this content seems to be engaging for this specific population segment.

9. Share project results and scientific outputs on a regular basis. Letting volunteers know how and for what their data is being used is a key guiding principle of citizen science and contributes to retain participants.
10. Regularly check the interaction statistics of the posted content to gain insights on what kind of content works best for the specific audience of the project.

The recommendation list above reflects the ideal scenario that citizen science projects should aim for when managing their social platforms. Unfortunately, implementing these recommendations might be challenging for projects that are underfunded. In these cases, we recommend focusing on one social platform only, posting on the lower end of the recommended frequency (e.g., 3 to 4 times per week on Facebook), and slightly skewing page management towards a curation strategy. Even for projects with lower resources, replying to user comments should still be a priority, but, for timesaving purposes, managers can opt for replying to the ones that address concerns/questions shared by a high number of followers. When the budget of a citizen science project is limited, managers might tend to use their social platforms to directly benefit the project as much as possible, e.g., by constantly posting calls to action to participate in events. Nonetheless, for better overall results, it is also necessary to take into account the needs of the followers and providing them with content they find engaging.

In the present study, projects with 1,000 followers or less were excluded from the Facebook content analysis because the engagement values of each post would typically be very low, making it harder to distinguish any engagement preferences. Nonetheless, we believe that the conclusions and recommendations evidenced in this article can equally guide smaller citizen science projects in their social media endeavors.

In conclusion, this work represents a first attempt at characterizing the worldwide use of social media by biodiversity- and environment-related citizen science projects with the ultimate aim of providing some guidelines for science communicators and scientists managing these projects. In the future, it would also be relevant to expand this content analysis to other commonly used social platforms (such as Twitter and Instagram) and to carry out a qualitative analysis of user comments. Besides, it would be of utmost importance to assess the efficacy of social platforms in raising awareness and in disseminating knowledge as well as in recruiting, retaining, and training citizen scientists. This could be accomplished by using mixed methods, including consulting the traffic statistics of websites and directly surveying citizen scientists.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because, although no sensitive were collected, the datasets include information that can be used to identify the analyzed projects. Requests to access the datasets should be directed to oliveira.scads@gmail.com.

AUTHOR CONTRIBUTIONS

Conceptualization, SO, JP, PS, and RP; investigation, SO and BB; methodology, SO, JP, PS, and RP; project administration, JP, PS, and RP; supervision, JP, PS, and RP; validation, SO and BB; visualization, SO; writing original draft, SO; writing review and editing, JP, PS, and RP.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2021.715319/full#supplementary-material>

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