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An explorative study on the effects of the recent pandemic on online Citizen Science: lessons learnt for improving project management and implementation

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ABSTRACT: While the literature captures various aspects of how the recent pandemic affected citizen science (CS), there appears to be a shortage of empirical studies investigating its impact on online CS projects. This mixed methods study intends to shed light on research concerns pertaining to the pandemic's effects on participation, project coordinators' perceptions and experiences of the situation and, how the pandemic's effects were counterbalanced. Results indicate that although the pandemic was an opportunity for online CS and resulted a relatively high increase in participation, it also highlighted a number of challenges such as the need for recognizing citizens' contributions and the need for sustaining engagement with citizen scientists.

KEYWORDS: Citizen science, pandemic, participation, crisis, management.

I. INTRODUCTION

Citizen science (CS) is an area that has drawn a lot of attention during the last decade. As a multidisciplinary endeavor, it is characterized by the participation of the general public in the process of scientific knowledge production [1] and its capacity to produce data at scales unachievable for professional scientists alone [2]. CS has been also endorsed by various actors due to its potential in understanding how galaxies interact with each other, addressing important issues in ecology and the preservation of wild species or even increasing science literacy [3,4].

During March and April of 2020, various CS communities and platforms reported a sudden increase in CS participation. This change coincided with the start of the Covid-19 pandemic [5,6] and it has been suggested [7] that as restrictions forced people to stay indoors, citizen scientists increasingly turned to online CS projects. For example, Zooniverse, one of the most popular CS platforms, reported that during the first lockdown period, 200,000 citizens made over five million contributions, which is equivalent to conducting 48 years of research in just one week [8]. Apart from participation, the pandemic seems to have also affected the focus of CS since during this period many projects sought to leverage the potential of CS in collecting large amounts of data for studying the corona virus itself [9-12].

Despite that, the pandemic's effects on CS are not well documented, with current literature failing to provide adequate answers regarding the extent to which the pandemic affected participation in online CS projects and how CS project coordinators actually experienced and managed the changes brought by the pandemic. The current study undertakes to explore on such effects by adopting a mixed methods approach which incorporates analysis of participation data from the Zooniverse platform and interviews with coordinators from CS projects. It is an integral part of the work activity being performed in CS-Track, a Horizon 2020 project funded by the European Commission (https://cstrack.eu) whose principal aim is to broaden the knowledge base on CS from diverse perspectives and by doing so, to support the implementation of CS with the emerging knowledge base.

II. THE PANDEMIC AS A CRISIS FOR CITIZEN SCIENCE PROJECTS

CS projects are often called to co-prioritize a number of different areas such as education, environmental responsibility as well as research and social justice [13]. At a practical level, coordinators of online CS projects engage in a variety of activities which include collecting data, uploading data to an online platform, providing training to citizen scientists in performing the envisioned analyses or organizing outreach events for communicating results and/or building bonds among citizen scientists. Thus, managing a CS project seems to be

connected with a variety of challenges, especially during a crisis such as the current pandemic.

In the organizational literature, crises are considered as highly salient, unexpected and potentially disruptive events that can threaten an organization's goals and have profound implications for its relationships with various stakeholders [14]. Crises like the pandemic can be classified as belonging to the so called "victim cluster" in which an organization has very weak responsibility and includes events such as natural disasters [15]; in this manner, the COVID-19 pandemic can be viewed as a crisis since it was an unexpected event which had the potential to interfere with CS related activities. Bundy et al.'s [14] framework of crisis management conceptualizes a crisis as a three-stage process: the pre-crisis prevention stage, which involves detecting, preventing and preparing for a crisis; the crisis management stage, which involves recognizing the events that triggered the crisis and responding to the crisis and; the post-crisis outcomes stage, which involves following up activities, investigations and learning from the crisis itself.

An organization's ability to respond in the immediate aftermath of a crisis can be studied by focusing on the within-organization dynamics of managing risk (internal perspective) of crisis management, or on the interactions between organizations and external stakeholders (external perspective). The internal perspective considers a leader's role critical and emphasizes factors that can affect a leader's ability to act accordingly. Some of these factors are conditional in nature and are related to an entity's governance features such as a board's size, a leader's ability to make rapid decisions or on characteristics such as an organization's structural complexity. On the other hand, the external perspective, priorities factors related to an entity's response strategies when communicating with stakeholders and the actions taken to influence the ways stakeholders perceive and react to the ongoing crisis. Based on the framework proposed by Bundy et al. [14], investigation onto the parameter of crisis management of CS projects benefits from the review of conditional factors related to a project's governance and structure as well as actions taken to counterbalance the effects of the pandemic.

III. CURRENT STATE OF AFFAIRS

In identifying CS literature examining the pandemic from an organizational point of view, we performed searches on two major databases, Scopus and Web of Science. We used a combination of the terms "covid-19", "pandemic", "citizen science", "management" and "crisis", and retrieved a total of 148 documents. After selecting documents written in English, we reviewed the title and abstract of each journal article and proceedings paper (editorials, books, book chapters and book reviews were excluded) and determined whether its content was relevant to CS. This resulted a corpus of 42 publications which were included in our review and were organized in four thematic groups. Although none of these directly pertain to the issue of managing an online CS project during a crisis or how the pandemic affected participation in online projects, there is value in providing a background of the main points covered in each group.

Group 1: studying the effects of the pandemic on humans or wildlife

Literature in the first group, includes empirical studies or proposals using CS projects and/or principles as means for studying the effects of the pandemic on humans or wildlife (n=20). Most of them include initiatives utilizing CS as a way of collecting data for the pandemic's outbreak in a region [16] or identifying characteristics and behaviors that increase the odds of being infected [17]. Some adopt the ethos of CS in order to propose an open, participatory and democratized approach in dealing with the effects of the pandemic on citizens' health [18] while others focus on studying how the absence of human activity in urban areas during lockdowns affected wildlife and biodiversity [19, 20].

Group 2: impact of the pandemic on outdoors CS projects

The second group consists of studies reporting how the pandemic impacted participation in outdoors CS projects (n=5). These include investigations of how lockdown measures resulted a significant decline in the number of citizen scientists or observations made [21] or differences in participation between countries and, urban and rural areas [22, 23]. None of these studies report on how the pandemic affected participation in online CS projects.

Group 3: using CS to teach science online

Studies in the third group include investigations (n=9) into how CS can be employed for the teaching of online science courses across all educational levels. These include mostly case studies of replacing a science lab with activities inspired from CS and propose that limitations posed by the pandemic can be partially lifted if instructors employ CS procedures as a way of enhancing their students' learning [24].

Group 4: opinions about citizen science's role in society

Finally, the fifth group consists of opinion papers (n=8) that treat CS as having a pivotal role in

re-establishing the relations between the public and various aspects of our society, a need that the current pandemic has highlighted. These cover a number of areas ranging from managing a pandemic at a local level [25] to setting new policies for transforming public health [26, 27], inspiring future generations of scientists [28] or attending the failings of modern democracies [29].

In summary, the literature informs the knowledge base on perspectives focusing on the study of the pandemic's effects on humans or on wildlife and biodiversity; how participation in outdoors CS projects was influenced and; ways of rethinking teaching science online or approaching various societal issues by adopting CS principles. As such, CS-related research does not adequately demonstrate the effects of the pandemic on online participation nor how mitigation requirements driven by the recent crisis have been addressed by CS projects' coordination. In this study we set to investigate the aforementioned issues by shedding light on the following concerns:

- How did the pandemic affect participation in online CS projects?
- How was the pandemic perceived and experienced by CS coordinators?
- How did CS coordinators react in counterbalancing the pandemic's potential effects?

IV. METHODOLOGY

This explorative study followed a sequential mixed methods design [30] consisting of two phases (strands), one quantitative and one qualitative. The first phase aimed at assessing the pandemic's impact on online CS participation as well as selecting representative cases (in terms of discipline, geographical distribution, participation and number of contributions per participant) that would inform data collection for the second phase of our research. The second phase aimed at obtaining a deeper understanding of the pandemic's effect on participation; capturing CS project coordinators' experience of the pandemic as well as their actions in managing the pandemic's effects by following a multiple case study design [31]. The use of a mixed methods approach allowed us to select representative cases for the second phase, as well as obtaining complementary views on the changes that the pandemic resulted in participation.

Phase 1: Collection of participation data and selection of cases

a. Collecting the data

Data were obtained from the Zooniverse platform since it includes projects across various scientific disciplines and offers freely participation data. Our initial dataset consisted of 332 projects hosted in Zooniverse. At the time of collecting data (August 2021), 16.6% of these had a finished status, 58.7% were paused, while the rest (24.7%) were active. For each project, the project's name, total number of participants, total number of contributions, contributions per month, discipline and launch date were gathered and entered into SPSS. Since Zooniverse uses multiple and sometimes overlapping descriptors, each project's discipline was inferred according to the project's description and aim, based on OECD's revised field of science and technology classification in the Frascati manual (OECD 2007). The vast majority of this set consisted of projects in the Natural sciences (Biological: 58.7%, Physical: 17.5%, Earth and Environmental: 6.9%, Computer science: 0.6%), while the rest in the Humanities (9.9%), Social sciences (3.6%) and Medical and Health sciences (2.7%). In terms of the launch date, only 12,8% of the active projects started before 2020.

b. Preparing the data for analysis

Prior to any analysis, all outliers and extreme cases were identified by inspecting boxplots (univariate level) and by computing the Mahalanobis distance (multivariate level) for each project's total number of participants and contributions [32]. This resulted a database of 259 Zooniverse projects. As Zooniverse does not provide data for the number of citizens participating in a project on a monthly basis, a new metric (named ratio) was created by dividing the total number of contributions over the total number of participants for each project. Since all outliers and extreme cases were removed, ratio provides a reliable measure for assessing the average number of contributions per participant for each project.

c. Selection of representative cases

In order to identify representative projects that would inform the study's second phase, a cluster analysis on ratio (number of contributions per participant) was performed. This was done by first performing a hierarchical cluster analysis for obtaining an initial estimation of the number of clusters, and by using this estimation as an input for performing a K-means cluster analysis [33]. The hierarchical cluster analysis indicated a 5-cluster solution and the final results for each cluster were obtained by performing a K-means analysis (k=5).

d. Selection criteria

Subsequent work for selecting cases (projects) was informed by a set of preselected five relevant to the current period criteria:

1. Discipline: the total number of cases per discipline should reflect the overall distribution of projects across our sample (Biological sciences: 58.7%; Physical sciences: 17.5%, Humanities:

9.9%, Earth and Environmental sciences: 6.9%, Social sciences: 3.6%, Medical and Health sciences: 2.7%, and Computer science: 0.6%).
2. Status: each case should be active at the time of conducting our research.
3. Country: selected cases should offer a 50/50 proportion between EU and non-EU projects.
4. Number of projects per cluster: selected cases should reflect the distribution of projects across each cluster (Table 1).
5. Distance from the cluster center: the ratio for each case should be representative of the cluster's center belonging to.

The above criteria pertain to data availability (criterion 2) and assurance of representativeness (criteria 1, 3, 4 and 5).

Table 1: Number of projects, cluster's center (number of contributions per participant) and distribution across disciplines for each cluster.

Cluster	Number of projects	Cluster's center	Discipline
1	91	7.14	Biological Sciences: *n*=50 Medical Sciences: *n*=3 Physical Sciences: *n*=14 Earth and Environmental sciences: *n*=4 Social Sciences: *n*=2 Humanities: *n*=17 Computer Science: *n*=1
2	19	93.52	Biological Sciences: *n*=16 Medical Sciences: *n*=1 Physical Sciences: *n*=1 Earth and Environmental sciences: *n*=1
3	30	70.04	Biological Sciences: *n*=19 Medical Sciences: *n*=1 Physical Sciences: *n*=4 Earth and Environmental sciences: *n*=1 Social Sciences: *n*=2 Humanities: *n*=3
4	62	27.91	Biological Sciences: *n*=36 Medical Sciences: *n*=3 Physical Sciences: *n*=11 Earth and Environmental sciences: *n*=4 Social Sciences: *n*=4 Humanities: *n*=3 Computer Science: *n*=1
5	34	47.93	Biological Sciences: *n*=23 Physical Sciences: *n*=3 Earth and Environmental sciences: *n*=4 Social Sciences: *n*=1 Humanities: *n*=3

Phase 2: The case study

a. Recruiting participants

Having identified projects that satisfied our criteria (N=36), we invited their coordinators to participate in our study and in total, nine of them replied to our invitation (25% response rate). Table 2 provides information on the projects that comprises the study's cases.

Table 2: Description, cluster membership, distance from the cluster's center (distance), year launched, country and scientific discipline for each of the nine projects whose coordinators agreed to participate in our study. For projects launched in 2020, the month is also indicated.

Description	Cluster (distance)	Year	Country	Discipline
Tag Along with Adler is a project from the Adler Planetarium that invites anyone to join in the curatorial process of describing images of objects. It looks to see how inviting volunteers into the traditionally professionally curated process of describing collections can help to not only create engaging experiences for guests, but also create a more representative and diverse set of search terms for collections.	1 (3.28)	2021	USA	H
UK Tides aims at turning scanned pages from ledgers of tide gauge measurements into usable scientific data which will provide valuable insights into how the tide, mean sea level, and storm surges have changed over the past two centuries.	1 (2.04)	2021	UK	EE
Based at the University of Oxford, **Penguin Watch** aims to understand the threats to penguins and inform policy changes to promote healthy and resilient polar regions.	1 (5.11)	2018	UK	B
Manatee Chat investigates the form and function of manatee vocalizations as a way of learning more about what signals manatees produce, what potential function they might serve, and what differences individual manatee calls have.	3 (0.17)	2018	USA	B
Measuring the ANZACs is a collaborative effort to transcribe key documents from all of New Zealand's World War I soldiers and nurses' personnel files. The project was initially launched in 2015 on the Scribe software stack and then relaunched in 2019 on newer more stable software.	4 (8.83)	2019	USA, NZ	S
In **Aurora Zoo** citizens classify short clips of dynamic fine scale aurora recorded on Svalbard, in the high Arctic. This enables large statistical studies into the different shapes and motion seen in the aurora, which help to understand the physical mechanisms producing the structures and the flow of energy from the Sun to the upper atmosphere via the geomagnetic field.	4 (8.66)	4/2020	UK	EE
Radio Galaxy Zoo: LOFAR is an astronomical project which uses data from the Low-Frequency Array (LOFAR) radio telescope. By looking at images made by LOFAR and comparing these with images of known galaxies the project aims at finding the location of supermassive black holes.	4 (2.79)	2/2020	NL, UK	P
In **Wild Mont-Blanc** participants identify all the different animals caught in camera trap images. This project developed by the Research Center for Alpine Ecosystems (CREA) contributes to a better understanding of how alpine species adapt to changes in their environment.	5 (0.15)	4/2020	FR	B
Beluga Bits aims at studying the beluga whales which spend their summers within the Churchill River estuary in northern Manitoba, Canada. It uses underwater photos and videos to non-invasively monitor the beluga whales and answer questions about beluga biology, social structure, threats, and ocean health.	5 (9.95)	2018	CA	B

Note: H: Humanities, EE: Earth and Environmental sciences, B: Biological sciences, S: Social sciences, P: Physical sciences

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b. The interview process

Prior to the interview, the interviewees were informed on the study's purposes and specific questions we sought information on. A semi-structured interview approach was adopted of 40-60 minutes duration. Besides the oral communication, coordinators also provided written responses to the protocol questions. All coordinators provided consent forms for the inclusion of their contributions for analytical and reporting purposes. The interview protocol incorporated questions that reflected our theoretical framework i.e., questions related to a project's organizational aspects (number of people actively involved in project coordination, decision making mechanisms), coordinators' perceptions and experience of the pandemic and response strategies for mitigating the pandemic's effects on the project taken.

c. Analysis of interview data

Interview data were analyzed by following a Qualitative Content Analysis (QCA) approach [34]. QCA relies on the creation of a coding frame, a hierarchical structure of codes (main categories) which aim at classifying all data as instances of a set of aspects related to the research questions. Our coding frame consists of three main categories capturing (a) the effects of the pandemic on participation; (b) coordinators' perceptions and experience of the pandemic and; (c) crisis management aspects of the pandemic.

V. RESULTS

Composition of clusters

In order to examine whether the composition of clusters was driven by other factors not taken into consideration, chi-squared tests between cluster membership, discipline and launch year were performed. Results showed no significant association between cluster membership and discipline ($\chi 2$ (24) = 23.118, p=.513) or cluster membership and year of launch ($\chi 2$ (24) = 31.715, p=.134), which suggests that differences between clusters represent only differences in the number of contributions per participant (ratio).

How did the pandemic affect participation in online CS projects?

As demonstrated in Figure 1, while the number of citizen scientists and their contributions grew between 2015 and 2018, a significant decline was observed in 2019 both in the number of citizens (-50.57%) as well as in the number of contributions they made (-50.40%). However, this trend changed in 2020 since more citizen scientists participated in Zooniverse projects and made more contributions. Interestingly, the increase of citizen scientists in 2020 (10.27%) resulted a larger increase in the number of contributions observed (48.14%). Although this tendency is on par with 2016 (21.97% more citizens, 65.92% more contributions) and 2017 (103.89% more citizens, 212.59% more contributions), it also highlights how the pandemic led to changes in the average number of contributions per participant i.e., a 10% change in citizen scientists resulted four times more contributions.

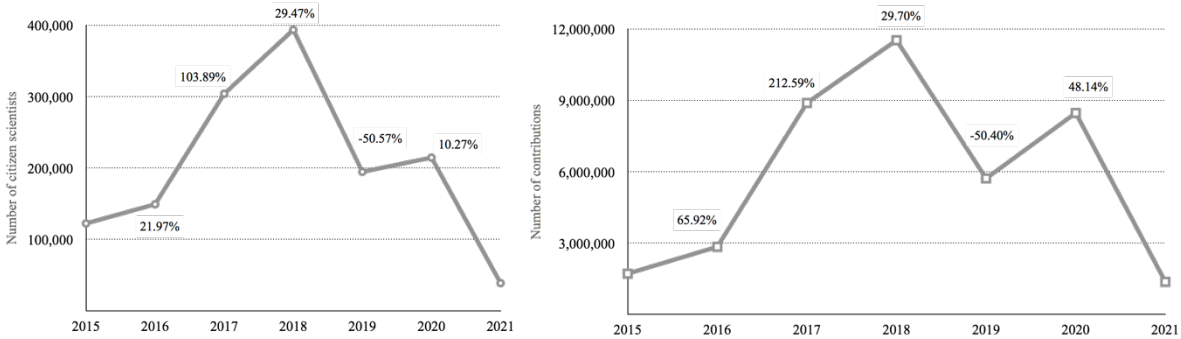

Figure 1: Changes over time (*N*=239, listwise) in the number of citizen scientists participating in Zooniverse projects (left) and the number of contributions (right). Percentages indicate changes from the year before.

Changes in the number of citizen scientists during 2020 was one of the main topics identified in our interview data as well: all coordinators confirmed that they experienced a stream of new volunteers who registered at the start of the pandemic. However, as suggested by the interviews the influx of new citizens was not the only mechanism driving changes in the number of contributions. Some coordinators ascribed the support provided to citizen scientists or the ease of registering at an online CS project as some of the factors that led to changes in contributions. For example, while explaining her team's actions during the pandemic, the coordinator from "Penguin Watch" said:

> *"Beyond the increase demand, we have also seen an increasing number of new volunteers engaging with our research through word of mouth initiated due to the extra volunteer support we*

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provide. Some volunteers have also expressed the will to continue volunteering passed the need for their projects or to continue despite the slow reopening worldwide, mostly due to the easy access of the project. Online citizen science projects, particularly with Zooniverse, have a low barrier to entry e.g., no requirement to sign up, get somewhere, flexible schedule, permanent dataflow."

Other coordinators, made links between citizen scientists' demographic characteristics and/or the psychological need of disconnecting from the new reality the pandemic had brough. For example, the coordinator from "Measuring the ANZACs" mentioned:

"Some volunteers... had a lot of time during the pandemic while others didn't e.g., parents working from home, taking care children. Our project had always I think older people as citizen scientists, in terms of the volunteer's base, 50s, 60s, 70s... [...] but definitely we have a lot of older folks and... I think this is one of the very common stories of the pandemic, it's that it sort of increased inequalities in a way... so people who had a lot of time on their hands, [now] had a lot of time on their hands… The thing that was mentioned to me at various points (they'll send me a personal message on Zooniverse)... they said this is been really nice, just taking a break and not thinking about the pandemic, particularly in the regions of Northern America and Europe... People needed that mental break..."

A more detailed picture of the pandemic's effects can be obtained by examining the number of monthly contributions for projects that were launched before 2020. As observed in Figure 2, the pandemic acted as an accelerator which increased participation in all projects, although not to the same extent. For example, when comparing February 2020 with March 2020, the number of contributions in "Penguin Watch" increased by 710%, in "Manatee Chat" by 42%, in "Beluga Bits" by 8% and in "Measuring the ANZACs" by 3,068%. When comparing March 2019 and March 2020, the number of contributions in "Penguin Watch" increased by 202%, in "Beluga Bits" by 93,728% whereas "Manatee Chat" witnessed a decrease by 32%.

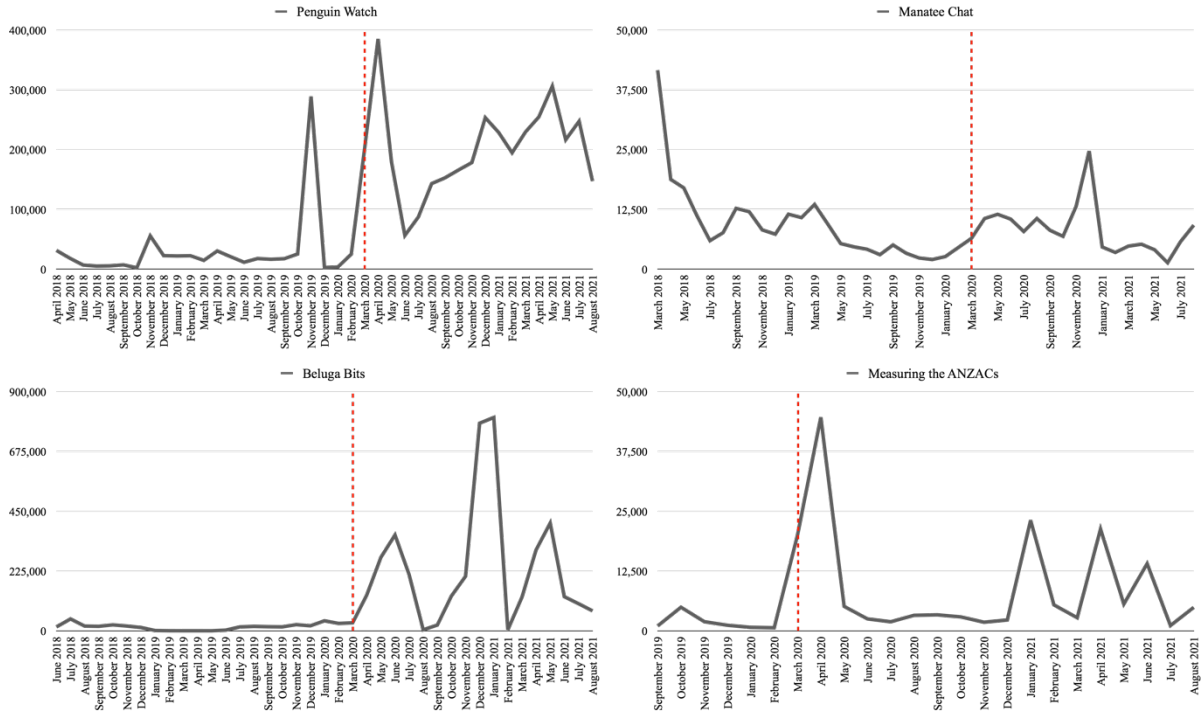

Figure 2: Graphs showing the number of contributions (vertical axis in each graph) per month for projects that launched on 2019 or earlier. In each graph, the start of the pandemic (March 2020) is depicted with a red dotted vertical line.

Figure 2 reveals that changes in contributions were only temporary: for most of the projects included in our case study, the increase in participation lasted for a short period of time, ranging from two to three months; an acknowledgement also made by many coordinators.

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For instance, the coordinator from "Manatee Chat" commented:

"…once lockdowns were initiated, we actually saw an uptick in citizen scientists participating in online projects. But this uptick was temporary and did not last once the lockdowns were eased."

How was the pandemic perceived and experienced by CS coordinators?

In terms of the way coordinators perceived and experienced the pandemic, we identified five main topics in our interview data: the pandemic as an opportunity and a threat; the need for in-person engagement with citizen scientists; the importance of technology in CS; the role of CS in promoting scientific literacy and; the need for recognizing citizen scientists' contributions.

a. The pandemic as an opportunity and a threat

All coordinators acknowledged that they treated the pandemic as an opportunity due to the foreseen increase in participation. For example, when asked about her view of the pandemic, the coordinator of "Penguin Watch" acknowledged that:

> *"Our citizen science being online, the pandemic represented an opportunity to further engage youth groups -stuck at home during the pandemic - with our research and the need to conserve the south pole region."*

On a similar note, when asked about his initial reaction of the pandemic, the coordinator from "Measuring the ANZACs" replied:

> *"I was very conscious right away that there was this sort of opportunity with people being at home... it's a destruction, even though it's about the war... [our project]. The other aspect of our material from WWI is that there's... quite a few... you do see evidence of the influenza pandemic in there... so, we very much saw it like... this is an opportunity, we can engage people!"*

Likewise, the coordinator from "Wild Mont Blanc" reported that:

> *"We quite rapidly thought that it would be an opportunity because it is a citizen science program you can do at home, on your couch and it's easy... Whereas the other projects we have, you have to go outside... so, we knew that some of our participants… wouldn't be able to do all the monitoring we've asked them for... because of the lockdowns... So, for the [mentioning another project] we had a bad feeling but for Wild Mont Blanc we knew it was an opportunity."*

The recognition of the pandemic as an opportunity for increased participation seems that speed up also the decisions for launching a project. For example, the coordinator from "Aurora Zoo" pointed out:

> *"...it was also the Easter holidays in the University and I had suddenly less distractions and more time... and we realized that there would be a lot of people suddenly at home, with time on their hands, so it seemed the perfect time to launched the project. We'd even already preparing it for quite some time so..."*

The coordinator from "UK Tides", a project that was launched during the second year of the pandemic, offered a view related to the increased opportunities for working collaboratively or attending international meetings remotely. He explained:

> *"I think... Early on […] we were putting together various reports with people from all over the European [Union]/ it made it easier to have Zoom calls or whatever […] beforehand you had to go and book a room in your office to have a video conference and these were always you know... in short supply... It made it a lot easier to talk to people... And the other aspect was international meetings as well... various big international meetings that, the ones I didn't have the opportunity beforehand because you know... to pay for travel... because the meetings were kind forced to kind of... forced to do things remotely... you could join in and they found that a lot more people were participating... particularly from less developed countries as well... there's been a kind of big benefit from that point of view..."*

The view of the pandemic as a threat was less elaborated in our interview data but it clearly highlighted several aspects of managing a CS project. One topic that emerged from our analysis is related to practical issues the pandemic resulted such as, travelling for research meetings (related to the CS project) or collecting and uploading data in the Zooniverse platform. For instance, the coordinator from "Aurora Zoo" commented:

> *"…the citizen scientists did a lot of classifications of our data and finished it off... and I couldn't get access to more data to put in the project... because it's all stored in the [university] office and I couldn't get to the office to get that (it's on data tapes) ... so, I had to wait..."*

A similar experience was also reported from the coordinator of "UK Tides":

> *"Probably one of the main difficulties we had is actually getting access to the original books [which were scanned to produce the data] because they were stored in the basement of our building and we didn't have access to the*

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building for a long time..."

b. The need for in-person engagement

Another topic that emerged from our analysis pertained to the fact that although crises such as the pandemic could result an increase in participation, an important dimension for maintaining the levels of engagement is the establishment of in-person relationship with citizen scientists. While elaborating on his overall experience with the pandemic, the coordinator from the project "Measuring the ANZACs" noted:

"We needed to sort of restart our relationships with schools and university lecturers in New Zealand... 'hey we're back, up and going' ... every time we've done in-person workshops in New Zealand we got a sustained boost for 2-6 months... All events like this were cancelled. So, there was an in-person component which we weren't able to do... which was a pity... My view is... online is great, you can find an audience but the... relationships, the synergy between offline engagement and personal contact can be really important for the success of some projects, particularly smaller projects. […] the pandemic for me... really did bring home the sort of the limitation of online only engagement with people."

c. The importance of technology

The view that technology plays a crucial role in CS, was implicitly mentioned by many coordinators however, when the coordinator from "Beluga Bits" was asked whether the pandemic highlighted certain aspects related to managing a CS project, she replied:

"I think some of the biggest things that I have been reflecting upon the last year are... that it [the pandemic] maybe underscores the value of technology and the internet when it comes to... putting out a project and getting people involved, I think... a lot of projects are online now, but I think something like the pandemic has really highlighted the value in having that technology and access to those technological aspects to stay involved in a project but also to run a project successfully… without... the internet, without virtual meeting platforms... how do we get our project out there, how do we train people to help us collecting the data? So, I think from my perspective, looking over the course of the pandemic, these were tools that we were already using but it really highlighted how incredibly valuable they are..."

d. The role of CS in promoting scientific literacy

While commenting on the important role of technology for the successful implementation of CS projects and having witnessed first-hand the increase in the people engaging with CS, the coordinator from "Beluga Bits" reflected upon the role of CS in relation to promoting scientific literacy:

"…even from the perspective of science literacy […] I think having CS out there and accessible... it's probably a great way to… really promote science literacy and get people involved again in science, involved in that process of thinking and feeling more positive about research and science in general..."

e. The need for recognizing citizen scientists' contributions

The final topic identified in our data, pertains to the need for recognizing (in one form or another) citizen scientists' efforts in analysing data. Many coordinators mentioned that -especially- during the pandemic, it was very common for students to be assigned the task of volunteering a certain number of hours in a CS project, as part of their curriculum. Some of them stated that the action of calculating the number of hours a student volunteered is a very difficult task because Zooniverse does not have that kind of function embedded. This was an issue that the coordinator from "Penguin Watch" touched upon:

"For us, the pandemic has highlighted the need to give back to the citizen scientists in a more concrete way. While Zooniverse doesn't provide volunteer certificates or hours verification, an easy way to give back a little something to your volunteers, we have had to start this process for the new volunteers we get from schools, universities, and Duke of Edinburgh's Awards. We have also been working on developing some education materials to improve the understanding of our volunteers as to why their help is important and what our research is intended for. Unfortunately, this is also resource intensive and is often not recognized as a priority to researchers with limited time, funding, and training in public engagement."

How did CS coordinators react in counterbalancing the pandemic's potential effects?

In relation to the governance features and structural characteristics of the projects included in our analysis, these were of a small size; on average, 4.6 people were actively involved in each project's implementation. Decision making was described by all coordinators as a flexible and collaborative process, involving on average three people. None of the coordinators reported factors that had or could hinder their ability in decision making. In terms of

responding to the pandemic, two strategies were identified by the interviewing process. The first type relates to the motivation for enhancing and maintaining the engagement of citizen scientists: in view of the temporal character that the increase in participation had, some coordinators took actions aiming at engaging citizen scientists in a more sustainable way. For example, the coordinator from "Manatee Chat" mentioned:

"We tried to engage people during the lockdowns by doing a blogpost highlighting our projects for new citizen scientists as something to do during the lockdowns and self-isolating. We also introduced a daily quiz that ran for a month during the lockdown, which we later turned into a permanent weekly quiz feature on our platform."

Although engaging citizen scientists was a well-recognized need for the prosperity of a CS project, undertaking such actions was not always an easy task. Further to the obvious restrictions in holding in-person events, some projects simply did not have the capacity to manage the increased number of participants, not even in an online manner. The coordinator from "Penguin Watch" referred to this issue:

"Our researchers have always been good at volunteer engagement, and we often organize educative webinars, design education materials and provide volunteer certificates. We also have a forum with three amazing moderators who regularly engage with volunteers' questions or general comments on the images and penguin research. However, with the pandemic, the need for these has skyrocketed and we have been struggling to find the balance between the will to engage with our ever-growing pool of volunteers and our own shortfalls e.g., time and funding."

The second strategy pertains to purposefully releasing smaller sets of data instead of larger ones or releasing them all at once: due to the increase in participation, many coordinators reported that a way to maintain citizen scientists engaged and counterbalance the increased participation was to upload even smaller sets of data to be analysed. This was acknowledged either as a future plan or as an already implemented action. For example, the coordinator from "Measuring the ANZANCs" mentioned:

"We have tended to release groups of about 100 soldiers [set of data] at the time... One thing that I've been considering is to have smaller groups of soldiers that we put out at a time and so essentially taking advantage the fact that every time you say "we've got a new bunch", people are like "oh, great this is new and interesting" and they just try keep that momentum going... That is something that we are definitely going to do in the future..."

This strategy appears to be associated with a project's overall goal: if a project was not aiming at analysing data in a short period of time, then this approach was also ensuring that most of citizens would have the chance to engage with all the data. The coordinator from "Tag Along with Adler" referred to this:

"What we did was break that [set of 1000 images] into 100 images per set, so that at any time only 100 images are on the platform for people to engage with... And we partially did that due to research that shows a lot of crowdsourcing and citizen science platforms do have super-users, so people who do every data set and they want to look at every image and they are very committed… […] for a project like ours that was not necessarily just looking to process through things... […] So, our plan was to release them in 100s so that overtime super-users could still be a part of the project..."

VI. DISCUSSION AND CONCLUSION

While the increase in participation during the recent pandemic is an effect that has been reported in the literature, empirical studies in the area concern outdoors [21, 22, 23] rather than online CS projects. Participation analytics from Zooniverse projects coupled with input from project coordinators demonstrate that restrictions posed during the pandemic (especially in lockdown periods) resulted in a relative high increase of contributions. Although no clear links could be established, our findings suggest that this increase is associated with an interconnected set of factors including the investment of more time by existing citizen scientists, the influx of new ones, the easiness of registering to an online CS project, the support offered to participating citizens as well as their demographic characteristics.

In terms of their perceptions and experience, coordinators acknowledged the pandemic as being more an opportunity rather than a threat. More importantly, the interviews highlighted a number of challenges that have been prominent in the pre-pandemic literature but were probably enlarged due to the increased participation: the need to recognize the efforts and maintain engagement with citizen scientists, the role of CS in promoting scientific literacy and the importance of technology in initiating and supporting online CS projects.

The need to recognize citizen scientists'

efforts and contributions has been emphasized in literature [35]. To this effect, our data point that the specific type of recognition required is that of personal recognition. This type of recognition pertains to acknowledging a citizen scientist's contribution in the form of a thank-you letter, a public mention or a certificate of participation [36]. Consequently, the notion of formal recognition of citizen scientists' efforts seems to be a required condition for CS projects and platforms to adopt in the near future. Likewise, given the utilisation of CS as a method for enhancing or complementing science education in schools [37], the need for implementing formal mechanisms in acknowledging (in this case) students' efforts in a CS project seems to be also vital for engaging future citizens with science. To this end, it is obvious to us that providing a formal recognition of citizen scientists facilitates engagement with CS.

In relation to engagement, our results demonstrate that the current increase in participation was only temporary and given that no in-person events could be held, as soon as restrictions were eased, participation decreased. As such, engaging citizen scientists through motivating means to which participants' recognition is an essential component, appears to have a positive impact on a project's management and scalability strategies. In parallel, the literature provides various viewpoints in relation to maintaining citizen scientists' engagement [38, 39, 40], and our data suggest that an additional efficient strategy is the release of a project's data in small sets rather than uploading them all at once. This approach could help to counterbalance both the effect of super-users [41-42], as well as to maintain citizen scientists' engagement over an extended period of time.

Finally, our findings point towards the role technology plays in implementing online CS projects as well as CS' potential in promoting scientific literacy. Although the latter is a claim that has attracted a lot of diverse views [43, 44], the connection between technology and specifically online CS seems to be an area that has been overlooked. Although it has been emphasized that online CS projects are characterized by technological affordances which can potentially facilitate citizens' scientific knowledge and information and communication technology (ICT) skills [45], less is known about the ways technology can ideally maintain citizen scientists' engagement over extended periods of time [46].

VII. LIMITATIONS

It is acknowledged that the limited number of projects that form the study's reviewed cases deriving from a single platform constitute a constrain towards generalisation on the effects of COVID-19 on online CS participation. We, however, attempted to reduce the sampling shortcoming through methodological tools so as to achieve representativeness of the cases that came to inform the study's research concerns. As such we are of the opinion that the current study contributes to the knowledge base on effects of crises situations on citizens' participation in CS endeavours and as such, facilitates reflection on the required mitigation measures.

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