Listening to the Forest and its Curators: Lessons Learnt from a Bioacoustic Smartphone Application Deployment

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ABSTRACT

Our natural environment is complex and sensitive, and is home to a number of species on the verge of extinction. Surveying is one approach to their preservation, and can be supported by technology. This paper presents the deployment of a smartphone-based citizen science biodiversity application. Our findings from interviews with members of the biodiversity community revealed a tension between the technology and their established working practices. From our experience, we present a series of general guidelines for those designing citizen science apps.

Author Keywords

Bioacoustics; biodiversity; citizen science; community practices; mobile; participatory sensing; tradition; tension.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces - Interaction styles

INTRODUCTION

Debates concerning our environment often center on the threat people pose to the biological diversity of our planet. A raft of national and global initiatives has emerged to highlight the importance of biodiversity and the threat posed by the extinction of species. A critical part of many of these initiatives centers on gathering detailed information about the diversity of our natural world and the status of the variety of species involved. Initiatives such as the IUCN red list (www.iucnredlist.org) maintain a detailed record of species under threat. Core to this is the undertaking of surveys of our natural world to capture evidence of species and to understand the nature of the particular population. The scale involved in capturing the biological diversity of our planet is vast. The need to capture information about species is becoming ever more critical given the rate with which natural habitats are disappearing. This is particularly important as environmentalists need evidence to inform environmental policies and to argue for programmes of intervention.

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The scale of the task at hand and its societal importance makes biodiversity a natural candidate to exploit the growing trend of citizen science. Initiatives such as Galaxy Zoo (www.galaxyzoo.org) or Folding @ home (http://folding.stanford.edu/) have utilized digital technologies to recruit volunteers from the general public to tackle critical scientific challenges. Volunteers have been provided access through a growing number of internet tools to catalogue galaxies, transcribe handwritten texts and help in the folding of protein structures. The increasingly ubiquitous nature of smartphones that offer sophisticated sensing capabilities has opened up the possibility of moving these volunteer citizen scientists out of the home and into the field allowing the general population to be engaged in undertaking the species surveys so critical to biodiversity and consequently conservation.

This paper presents the development and deployment of a smartphone-based citizen science biodiversity application. The application seeks to recruit members of the general public to find evidence of a rare cicada in the UK that might already be extinct. The challenge of finding evidence for the cicada is that its distinctive chirp is at a frequency that is only just audible to the human ear. However, it is within the range of the microphones in most smartphones. Hence, it is possible to record, process and detect a cicada's song directly on the phone; with location determined by the GPS.

We discuss findings from a set of studies that involved interviews with employed biodiversity professionals and volunteer amateur naturalists as well as observations of a biodiversity event where the app was launched to the general public. In addition to commenting upon the application itself, our studies highlight the distinctive challenges that emerge as citizen science goes mobile and engages with scientific endeavors in the field. Although offering considerable potential advantages in terms of scale and engagement with the public, the turn to citizen science in biodiversity also raises tension in terms of the nature of the scientific endeavor, and its current culture and practices. We elaborate some of these key tensions and suggest a

number of general guidelines for those involved in the development of citizen science applications.

BACKGROUND

While citizen science is a relatively new term, the tradition of public participation and collaboration in scientific research goes back centuries. Indeed much of this has focused on capturing information about the natural world. The National Audubon Society's Christmas Bird Count (http://birds.audubon.org/christmas-bird-count) was established in 1900, and continues even today, with amateur and professional bird watchers joining forces in cataloguing bird species. There are instances of recording even earlier than this, as during the 17th century farmers, hunters, clergymen and other members of the public actively contributed in collecting and classifying various nature datasets for research purposes [3,18].

Today, citizen science has been able to take advantage of internet based technologies. Citizen scientists work remotely on large-scale data sets that are increasingly becoming a key feature of scientific investigation in the natural sciences. For example, Galaxy Zoo engaged the public in examining images of galaxies and classifying their basic characteristics. While the bat detective project (www.batdetective.org) asks volunteers to identify potential bat calls in audio surveys collected by researchers. Other projects have gamified aspects of such classifying tasks to make them more appealing to a wider audience, motivating and educating the public involved in the project [1]. Web-based communities have also been formed to support socialising and sharing between citizen scientists such as eBird [24] and Key To Nature [17].

Advancements in mobile and ubiquitous technologies have allowed a move away from domestic desktop interaction, and enabled people to contribute valuable new datasets by engaging with their environment *in-situ*. Participatory sensing approaches enable people equipped with sensors or their own mobile devices to collect information from their environment as part of their everyday activities and interpret it within context [5,6]. Environmental impact has been a particular focus for participatory sensing with the general public tracking and measuring climate change and pollution [2,8,19].

Existing work in participatory sensing for sustainability has shown positive results in making people more aware of, and actively engaged with, their environment. It has also shown the importance of the *in-situ* experience and how it can contribute to the interpretation of the collected data [6,12,20]. Education has also played an important role, with environment-visiting based work such as Ambient Wood [21], Ubigreen [11] and e-Science in schools [23] using mobile devices/sensors to educate participants about the environment. These systems emphasize managed groups [4] openly exploring, and reflecting on the physical space [13,21]. In distinct contrast, Citizen Science has emphasized using an anonymous crowd to survey/analyze data. Work related to this has revealed a number of challenges in terms of privacy, storage, dissemination and interpretation of the data. Paxton and Benford [20] stress the "*complex balance between the various needs, limitations and the preferences of both the users and the sensing tools"* and how this can affect both the experience of the user as well as the quality of the data interpretation. In considering this, along with the capabilities of mobile phones today, we can see that participatory sensing lends itself to the field of biodiversity monitoring, in terms of supporting the recording and classification of species.

Bioacoustic Participatory Sensing

One of the main benefits in the use of mobile phones for biodiversity is in the use of their microphones as a sensor [14]. In many respects this can serve as an ideal tool for species surveying. As would be expected, acoustic sensors typically focus on species with *recordable* and *predictable* vocalizations, such as amphibians, insects and birds [26]. With an ongoing trend in the increased adoption of smartphones by the public, there is a move toward utilizing the onboard microphone for recording purposes. There are already projects which make use of microphones, such as CrowdSense@Place [7] for the classification of places based on sound and NoiseTube [16] for assessing noise pollution. Much of this work relies on server-side post processing of the recordings using software such as the Extensible Bioacoustic Tool (XBAT) [10]. Equally, with the computational power available on smartphones, there exist possibilities for localised classification of acoustics. This type of automatic detection for surveying has been described as the '*ultimate'* smartphone application [15], and as a paradigm shift for many ecologists [26]. In the following section we describe a smartphone application that seeks to bring about such a shift.

CICADA HUNT MOBILE APPLICATION

The New Forest cicada (*Cicadetta montana s. str.)* is the only cicada native to the UK. The prevalence of the species is currently in question as the last *unconfirmed* sighting of the cicada was in 2000. Along with a general decline in the species there are three problems, which make surveying for the cicada particularly challenging for professionals.

1) The New Forest cicada lives underground for seven to eight years as a larva, before emerging and taking on its adult form for just four to six weeks between May and July. Unlike periodical cicada, its emergence is not synchronized, and thus, this significantly decreases the number of cicadas present during the already small and tight timeframe.

2) The size of the New Forest is approximately 600km^2, making it impossible for a small number of experts to effectively cover the area during the few sunny days when the males sing.

3) The cicada sings at a frequency of 13-14kHz, which is at the limits of hearing for most adults. This makes

one of the primary means of in situ identification of insects by experts unusable (i.e. listening).

These difficulties in coverage, detection and a narrow season motivated the surveyors to explore the possibilities of a technological solution. Through a series of meetings with core stakeholders (expert entomologists and members of the New Forest National Park Authority), the use of participatory sensing was agreed upon as a viable and effective technological medium for promoting and assisting in the survey of the cicada; particularly given the untapped ~13 million day-visits per year to the New Forest National Park.

Design and Development

The pervasiveness of smartphone ownership underpins their appeal as a participatory sensing tool in the forest setting. Furthermore, through trials it was found that the microphone in a typical smartphone was sensitive enough to pick up the frequency of the cicada. To assist in the process of acoustic classification, an algorithm was developed to accurately distinguish and specifically detect the New Forest cicada [27]. Given the onboard computational power available on smart phones, it was also possible to run the (typically server side) classification algorithm locally on the device in real time. This classifier is based on a hidden Markov model, which is fed the ratio of two key frequencies extracted through the Goertzel algorithm as a single feature vector (for more details see [27]). It was trained using recordings from Slovenia where the same species of cicada is still abundant. The classifier also has the potential to detect common species of Orthoptera, including: wood cricket, Roesel's bush cricket and a field grasshopper.

An interesting constraint during the design of the app was the difficulty in trialling it in-situ. For this reason, a number of circuit board 'electronic cicadas' were developed to emit a constant acoustic square wave between 15kHz–18kHz to imitate the cicada's song. These were used during preliminary field trials of the application which were subsequently used to iteratively inform the design of the mobile application.

The final design (called 'Cicada Hunt') included a sonogram, which was used to visualise the algorithm, taking inspiration from the popular music application Shazam (www.shazam.com) and drawing on a user's likely familiarity with it. The sonogram was thus visualised in a circular way, as opposed to the more commonly found horizontal format. The sonogram displayed the real-time fluctuations relating to the audio's frequency and amplitude. This detail was not only intended to act as a means of education for users about frequency and sound, but also to speak to professionals who frequently make use of sonograms. Interaction with the application was designed to be as simple and lightweight as possible, in order to serve

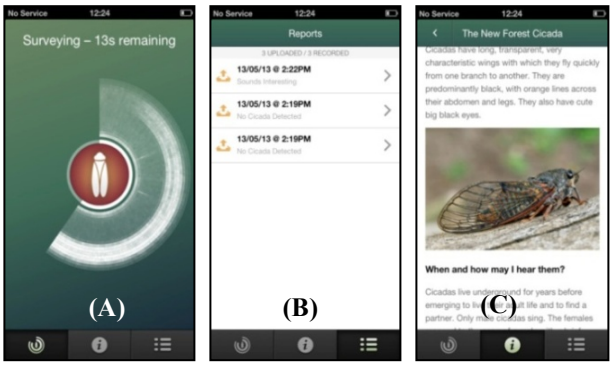

Figure 1 'Cicada Hunt' mobile phone application

many different types of users. To use the app, users press the cicada icon (see Figure 1 (A)) to start a survey, which records and analyses the next 30 seconds of audio in the environment.

If a cicada is detected, the users are informed and a report consisting of the location, time, and audio, is uploaded to a server. In the case of a negative record, a report is also being sent with the location, date and time but without any sound file. Users can review the record of their sent reports on the app (see Figure 1 (B)) and can also access information about the app itself (instructions, project), the cicada species and habitat, and the New Forest National Park in general (see Figure 1 (C)). Access to all users' records is provided through a password protected dashboard on the project's website.

A typical feature of a participatory sensing application is the use of a map to indicate where surveys have been conducted. This can help with motivating surveyors to fill in the recording gaps on the map and also to create a sense of community. However, during pre-development discussion with the stakeholders, this was not perceived as a desirable feature as it was anticipated that it might encourage users to wander off the tracks and venture deep into the forest (to fill the gaps). This is a particular problem, as the cicada and ground nesting bird seasons coincide. For this reason, this feature was consciously excluded from the application.

Deployment and Use

The application was launched on both the iOS app store and the Android Google play store during May 2013 (search for 'Cicada Hunt'). This was intended to coincide with the emergence of the cicadas. The app was promoted through significant news press coverage and with a launch event during a Bioblitz. Over a period of 3 months, more than 4,000 surveys were conducted, and 1,500 unique downloads to phones; unfortunately no cicada was found. The top ten users accounted for almost ¼ of all surveys, suggesting a key group of power users (see Figure 2). While these usage statistics provide some indication of the level of use of the app, they say little about who used it and what the issues involved in using the app might be.

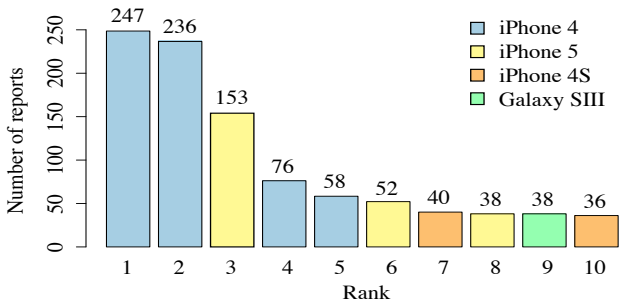

Figure 2 Top ten anonymous power users and their devices

Method

In order to build a richer picture of app use, we carried out a number of in-depth interviews with a range of employed biodiversity professionals and volunteer amateur naturalists. Participants were selected based on the types of biodiversity activities they engage with. We focused on those that carry out surveying, store and manage data, and make strategic decisions regarding forest management. Participants were approached through the New Forest National Park Authority (NFNPA) and local surveying groups in Hampshire and Sherwood. Interviews were carried out at locations where participants conduct their activities (i.e. during the bioblitz, at the New Forest National Park Authority and at the Sherwood Forest Trust). A total of 15 participants were interviewed (~1 hour), with 8 male and 7 female, aged between 23-72. Interviews were conducted over a 3 month period. Participants are grouped by role and location:

1) Forest Managers, NFPA [**FM1**, **FM2, FM3**]
2) Ecologists, NFPA [**E1**, **E2**, **E3**, **E4**]
3) Biological Data Managers, NFPA [**D1**, **D2**, **D3**]
4) Community Managers, Sherwood [**CM1**, **CM2**]
5) Rangers, Sherwood [**R1**, **R2**]
6) Ecologist, Ceredigion [**E5**]

Ecologists and rangers are active fieldworkers who directly conduct surveys of the environment. They carry out similar curation-based tasks, but each specialises in a particular species including: birds, bats, lizards, dragonflies and pond life. The remaining roles are typically adopted by ecologists later on in their careers. For example, biological data managers who receive the data from surveys, storing the information in databases and managing how it is shared internally or across local authorities. Forest and community managers focus on strategic decisions related to cultural and natural heritage, landscape and habitat preservation, and public engagement activities. During the interviews, our focus was the utility of a citizen science approach to the scientists involved, how the application was received by domain experts (professionals and amateurs) and how it might be used for surveying and educating the public. Interviews were transcribed in full, and an inductive thematic analysis was carried out. The data was iteratively coded at a low level, and grouped together to reveal themes.

The interview results were augmented with a number of short participant-observation studies during a public biodiversity event in the New Forest (Bioblitz). Bioblitzes are outdoor events where members of the public meet-up with professional naturalists to intensively survey as many species as possible over a 24 hour period. The aim is to both engage the public with nature and collect genuine survey data. Approximately 60 people, mainly young families and older amateur naturalists, took part during the event. The event was held in an open field in the New Forest, with pop-up stalls providing different nature related activities for children and for signing up to organised surveys. We observed a number of these intensive surveys over the 24 hours including: moth, bat, plant, bird, seashore and pond surveys (see Figure 3). Each event saw small groups (up to 10) guided by a professional naturalist, conducting real surveys of the species over a few hours. This gave us the opportunity to better understand some of the existing practices of surveying, but to also examine how they are used to engage members of the public. The cicada app was also officially launched to the public during the event from a stall which provided free Wi-Fi. This gave us the opportunity to observe and discuss the use of the application in-situ.

Through the interviews and the actual deployment of the cicada mobile application the tension between engaging and inviting citizens to the forest, and protecting the habitat of the species under consideration came to the fore. This tension underpinned the previous decision to exclude the map style interface traditionally associated with participatory sensing approaches. As we began to unpack this, we found that the app was surfacing critical issues about the use of citizen science for biodiversity. However, before we consider these issues in detail, it is worth understanding the nature of the biodiversity community.

THE BIODIVERSITY COMMUNITY

The biodiversity community includes both biodiversity professionals and amateur naturalists who play an active role in the work of the community. Biodiversity professionals are involved as part of their job with the natural environment. Their daily work entails a variety of activities depending on their specific role but, in general, they engage with monitoring and preserving natural habitats and the species that are part of those. Some of them might be forest rangers; others might be ecologists, scientists (entomologists, botanists etc) or heritage specialists. Most of them share their time between being out in the field observing and collecting information about species, and deskwork analysing that information, creating reports and disseminating them for purposes of planning, policy making and educating.

Amateur naturalist is a term used by the biodiversity professionals to describe members of the general public that engage in species surveys and other biodiversity activities.

Figure 3 Bio Blitz in the New Forest National Park

Amateur naturalists self identify with the term and distinguish themselves from the professionals despite the fact that sometimes they are just as knowledgeable as a result of their long-term engagement with species recording. Very often, they are locals, residents near a park area that work closely with the county recorders in regular, organized group surveys or people who just record things on their own while walking the dog.

The biodiversity community, both professionals and amateur naturalists, share an affinity and sense of wonder for the natural environment that motivates them to engage with its preservation. In many cases this seems to have been instilled in them from a young age. Many of the professionals that we interviewed vividly described memories of their childhood with family walks in the forest and the excitement of seeing and getting to know more about the species:

"From an early age with my parents and they instilled that kind of… the wonder of nature and the world is such a diverse place and people are so diverse [...] and they take it for granted. To understand it is just beautiful and it changes, day to day, season to season [...] you always learn something new no matter where you went." CM1

Protecting the natural environment is of utmost importance for this community. Biodiversity professionals identified two activities as vital in achieving that: conducting surveys and educating the public; in particular children. Instilling a love of nature, biodiversity and its preservation in the younger generations is of great importance for all professional and amateur naturalists:

"I'm in to what I do because of my dad. You know, a natural interest from a young age. I went out with him and I fell in love with nature, but a lot of kids these days don't have that […] you need to get them while they're young to kind of nurture that interest and that passion." R1

"If I have enthused, you know, 5 kids really into it, really excited, for me that makes my job worthwhile." R2

Survey as a Tool of Data Collection

The emotional attachment to their work is also reflected in the professionals' view of surveys and the tools used for surveying. Despite the advances and availability of technology in this digital era, professionals tend to conduct

Figure 4 Amateur naturalists surveying species on paper

surveys using pen and paper, and ID books (see Figure 4). Several reported using a camera or audio recorder and a GPS to define location, but equally admitted to avoiding using digital devices when possible as they lack the romanticism of the old ways. Pointing at a smartphone, one of our participants said:

"There is nothing romantic about this, you can see the records but you cannot feel them as you would with the ones in your nature diary." E1

In the same context, another referred to the feel of their field guide:

"You have your field guide that you have had for years and you know, you kinda know the pages because of the way you have twisted them? It's things like that isn't it?" R2

Amateur naturalists conduct surveys in the same way, often with even less digital support unless this is done in the context of a joint organized survey with the professionals. After a survey is complete, the collected records usually have to be transferred into a digital form so that they can be disseminated, checked and archived in county and national databases, and planning, management and policy making offices or other relevant organizations. Not only is this process tedious, but it is also clear that people are not particularly inclined to share data:

"You suspect there's an awful lot of useful data out there, but some people umm don't like sharing it […] it's easy for them to put in a note book and then it's more hard work and perhaps not so much what they want to do is to then get those records into the biological record centres." E2

"[Another heritage group] been surveying for 40 odd years, and they've got a fantastic database but they won't let us see it." D3

Checking the work of volunteers

Accessing, disseminating and checking survey records is also challenging with respect to the volunteers. Biodiversity professionals and amateur naturalists both stressed a distinct lack of consistency among the recordings of volunteers:

"When you get some data in, from some people that will be very meticulous, to the letter and ya know […] and then you get really sketchy data, and to try to put the two lots of data together… was

quite difficult, so I think maybe the apps might help a little more uniformity and that data reduction." E3

This fuels a general suspicion of data collected by volunteers and the extent to which it can be used for biodiversity purposes:

"There needs to be some clear scientific vetting, to say that that is a confirmed record or a possible record, so we have certainty over the presence or not of a species." CM1

This is obviously highly problematic and while standardizing data collection techniques (including the use of digital entry systems) and intensive training sessions can address these issues, the concern remains about not knowing who has done the survey:

"It could be anyone. I think the thing is when you're dealing with individuals, people are going to each do things to a greater or lesser level." E3

However, recruiting volunteers willing to be trained makes a challenging task even more difficult: "*finding groups that want to come out and do surveys is a challenge in itself*" (CM1) which often results in compromising with less accurate data or more verification work from the professionals' part.

In addition to providing data, surveys are also increasingly used as a means of public engagement. Recruiting the general public to participate in surveys is as much about enthusing them and promoting awareness about particular habitats and species as it is about scaling data collection.

Surveys as a Tool of Engagement

As mentioned earlier, getting the public engaged with and enthused by the natural environment as well as educating them on the dangers it is facing and how these can be addressed is a significant part of biodiversity conservation. To increase the numbers of survey volunteers and nurture a long-term engagement, day-long or weekend events are organized where professionals, amateur naturalists and the general public get together to learn and conduct species surveys. Social media is also starting to become more popular in supporting the organizing and publicizing of these and other biodiversity activities.

Scepticism for the use of the digital *in capturing data* was evident when biodiversity professionals and amateur naturalists spoke about doing surveys. However, this is replaced by enthusiasm when the digital serves as a *means of engagement*. Digital technology is seen as a way to entice and engage new (in particular young) people into the tradition of nature conservation and surveying:

"The younger generation do everything digitally don't they?" E5

"It is like social media […] I don't mind some aspects of it, but some of it I would rather do without, but unfortunately it is a very powerful tool for interacting with large audiences […] things will move on, gradually technology, people's aspirations and interests, and we will be left behind." R1

Still, concerns remain about the extent to which social media is used and what this might mean in terms of people's experience of the natural world.

"I do think that we need to be careful that we use it as a means to an end, rather than an end itself. So social media is great, but if we have everybody sitting at home just looking at pictures of the New Forest, then I think that's not right, to properly love something, to get a connection with something, then we do have to try and realise that umm firsthand experience […] ya know going and seeing a tree or witnessing butterflies in a meadow, those are the important things." FM1

Several still see technology engagement and the engagement with the natural environment as clashing; the latter should be about *being in nature* and *being with each other in nature*. Discussion on the use of the app brought this into sharp contrast:

"Personally I don't really like it as much as you physically going out there having a natural interaction, but I think unfortunately given the fact that time has moved on, technology has moved on, it is the 21st century now, things have changed, you do need some other approach if you want to appeal to new people." R1

"People have said things about umm being in wild places being an escape from technology, and an escape from always being in communication with people and that they feel technology stands between people somehow as a barrier between people." E5

Having presented the ways in which biodiversity professionals and amateur naturalists view public involvement and the role of the survey, it is clear that the turn to digitally mediated citizen science might raise a number of issues for this community. In the following section we discuss their reactions to the cicada app.

OLD PRACTICES AND NEW TOOLS

With a more grounded understanding of the existing motivations, practices and traditions of expert users, we can now explore and better appreciate the ways in which the cicada application was received during the deployment and follow-up interviews. As the Cicada Hunt application moved from its initial design to a deployed real world application it brought into focus the underlying sensitivities within the community and the tensions surrounding the involvement of the public in biodiversity surveys.

Disturbing the Forest

As the Cicada Hunt application was deployed, the distinct nature of the environment emerged as a critical issue. The environment itself is a fragile entity which needs preservation as much as the cicada does; indeed the two are interdependent. As the nature of the interaction with the environment became clearer, so did concerns about the possibility that untrained citizens using the app might disturb or interfere with the habitats:

"I suppose the danger with the app is that you are actively encouraging people on to sensitive habitats, which might not be visited in the normal course of their visit." FM1

This issue was particularly significant given the open and rather accessible nature of the environment itself:

"The New Forest is in this special situation because it's open access throughout and […] people can penetrate quite deeply into areas which are reasonably tranquil and undisturbed. Now they have the perfect right to do that, so there's no real way you could stop them even if you wanted to." FM1

As well as offering a potential benefit, the Cicada Hunt app was seen by biodiversity professionals and amateur naturalists as offering both a positive promise and a significant threat. Many were torn between sharing their passion for the environment and the potential impact the app might have:

"The concern I have, a lot of people have, is the sheer number of visitors who come to the forest, but my personal feeling is if people come to the forest because they want to observe, study, enjoy the wildlife, that's great." FM2

As well as the potential for physical damage, the concern focused on the extent to which the experience of visiting the new forest would alter:

"On one hand, it would be really exciting if loads of people do it, but on the other hand someone else might be oh god there's thousands of people wandering around with their phones, and that might cause disturbance." E2

Managing How the Forest is Shared

The concern surrounding physical impact was matched by concerns about the digital sharing of information about the forest. Many felt that over-sharing of information and 'knowing too much' about what is in the forest can also cause damage. Reactions drew upon previous systems and stories of the use of other biodiversity apps to illustrate the potential damage to the forest:

"There is a lot more advantages to the apps than there are disadvantages […] there are positive things, it is just that occasionally they can be used for the wrong purpose […] I suppose with the iSpot thing, you take a photo of a flower and you upload it, you don't really think about it do you, until someone goes and digs it up (laughs) […] it is a shame but unfortunately there are people out there, abusers, it's just about sensitivity." R1

Sharing detailed information was viewed as important when recording data about rare and sensitive species. However, people were concerned in some instances that public sharing of this information may result in the capture or killing of dwindling species:

"They had this very rare fern and they publicized it and collectors came in and collected the fern and it lost its AAA status." R2

"If you show people where sand lizards are on a site then people will go and collect them […] so there's quite a kind of concern of how the data collected will be made available to people." E4

Some of these even focused on the public's negative reactions to specific species, requiring particular discretion about the publicity of information:

"There's a lot of sensitivity with the public availability of data with adders because that can be a sort of contentious issue, some people don't like knowing that there are adders around because they are concerned, mis-placed concerns in my opinion […] if someone could find where all the adders were hibernating, they might go there and kill them, which has happened before." E4

The need to control dissemination about the environment engendered a strong sense of ownership of finds and data. This was further amplified by the need to keep data for either publication or exploitation:

"There is a delay because it is quite often […] we will want to keep that information because we were to publish it in a scientific report, so there is often a time lag between me releasing that information before I have written the paper." E1

Coordinating Activities in the Forest

The forest is also viewed as a managed physical resource that is subject to a range of surveys for different purposes. The need to think how these different activities are coordinated led to a further concern on how public endeavours might interfere with ongoing surveys.

"The other side of sensitivity is because umm I think others are doing surveys, ya know the physical ground survey for the cicada […] it would just be sods law if umm they'd found a new, ya know a suitable habitat they were just doing, and suddenly yeah just lots of people going through it and disturbing it." E2

"I know this study is out now, actually going in tandem with […] a parallel scientific contract being led by the forestry commission to look in certain areas where they think they've found, and you wouldn't want […] any conflict between those. What you want is to, umm, complement." FM1

Automating the Citizen Scientist

Another set of issues focused on the automatic classification of the cicada as part of the app. As people trialled the app, the level of involvement of the person holding the sensor was debated. Many saw the benefits of the automation as simplifying the process. The emphasis on the app as a treasure hunt was seen as a good way to engage the general public with surveying:

"Something that is automatic can be fun, that you can, it is almost like a game really […] it can give you the confidence if you are starting out […] to say 'I heard' or 'I saw' and what certainty that you can put to that." R2

The automation was also viewed as a reasonable way to standardize the data collection process without having to train volunteers, offering the opportunity to ease recruitment tensions:

"There are elements of training in my job. It is not as much as it should be, and it is not to high enough standards that I think you can totally guarantee you know someone using the field guide. I

think that is the bit that the app provides, that extra insurance of the quality of the records." CM1

"This automated collection of where the person is, when they've done that, where the record is […] it cuts out possibly what might be barrier to somebody taking part in the survey." E2

"If people could go out and survey using some technology which would mean they don't have to have like an incredibly detailed knowledge […] I think that can be quite an empowering thing." E4

The ability to capture sound at a distance was also appealing with respect to interaction with the species:

"The fact that you don't have to physically find something is good from a sort of non-invasive view." CM1

Although some viewed the automation positively, concerns were raised about the impact on learning and loss of skill. This is an important consideration, given the role of surveys in educating people about biodiversity:

"There could be an element of laziness, that, you know, not gonna take it any further, that you just rely on the app to identify it for you, rather than drilling down into it." CM1

"It makes it more accessible for everybody as a hobby […] cause for me that is the only way really that you start to learn, cause you hear a sound and it finds it automatically… I don't think you learn quite as much, it is not like experiential learning." R2

Many of these concerns echoed the issues of personal attachment to the environment and the drive to share enthusiasm for the environment with the public:

"that would be good, that would be very useful… maybe too useful, maybe it takes all the excitement out of pouring through your text books and looking through various possibilities." FM2

"I've found sort of learning those songs for myself to be a really life-enhancing thing ya know, I can now go for a walk and it feels like I'm kind of experiencing nature in another dimension as well, not only the things I can see but the things I can hear as well." E4

Validation of Results

The importance of verification became an area of scepticism for some experts with respect to the cicada app. They argued that while Cicada Hunt may be automated, there still remains a need to have a human expert verify any app-confirmed detection of a cicada. They also felt that the application may help narrow down the search for the cicada, but it cannot (yet) replace a human expert's identification:

"If the app was to find something, then there would need to be some follow up, you wouldn't just say 'yeah that's fine' and walk away." D1

"You're still always going to need an expert with the skills to identify it […] you can't just send a whole load of people out with this app and say 'yep, we've found it here, here and here'. It's got to have someone still to go out and check." D2

"I wouldn't want to just rely on [the app] because there's always an exception to any rule isn't there?" E5

Dealing with Disappointment

The framing of the app as a Cicada Hunt also raised comments. Due to its rarity, it was always highly unlikely that users were going to detect the species. This meant that users were likely to experience a significant number of consecutive 'fail' results. This can de-motivate public users, particularly given the effort required to visit and walk around the forest compared to other desktop based crowd sourcing systems:

"To get a report that says nothing found, it just leaves… it could leave people feeling a little cold and empty." CM1

"It's highly likely you're not going to find something. That will put people off, you know there's only so many times 'I still haven't found one', 'I still haven't found one', before you'll just give up." E5

The challenge is how to develop a system that enhances the users' experiences and encourages them to persist.

DISCUSSION

Cicada Hunt wishes to harness the potential of citizen science and participatory sensing to re-discover and protect a rare species. However, as the application was deployed and grew in use, significant issues surfaced surrounding the use of citizen science approaches to tackling biodiversity. In particular, a rather fundamental tension emerged where it became clear that because of its fragility and rarity the species was both supported and endangered by the use of the application. Biodiversity professionals and amateur naturalists recognized the potential of the technology but were concerned about the need to create a balance between widespread searching and the need to educate and protect:

"It is that constant battle though isn't it? It's like, how do you inspire people […] you've got this amazing plant or amazing species that is here but then it's at the risk of people abusing it, so you can't share nature with people. It's that, do we share it or do we keep it secret? Which a lot of people do keep sites secret, but then a lot of people will never get that advantage to experience something pretty, ya know, amazing biodiversity wise, so it is that kind of weighing it up, where is the line?" CM2

"You want to make it available so you can have interactions shared as experiences and there are places where the people would have that experience but at the same time you don't want it because it is sensitive and it is an endangered species." R1

Other participatory sensing projects have faced a number of challenges with respect to the situated nature of the activity [5,20] yet the cicada application reveals one more. Unlike the sensing of polluted air or traffic patterns, the very sensing of the cicada can contribute to, instead of resolving, the problem that created the need for participatory sensing in the first place. It can also endanger other species in the forest that might be rare. The fragility of the cicada and its habitat creates a new challenge for participatory sensing and citizen science that emerges as a result of the nature of

the science. The use of citizen science within biodiversity requires us to collect data in *fragile environments,* about *endangered species* and alongside a community of users who have *established practices* to achieve the same goal.

Our core contribution lies with explicating how use of the crowd plays out in practice when surveying endangered species in a fragile environment. We reflect on this with three lessons learnt that arise from citizen science for biodiversity.

The Danger of Scale: Citizen Science traditionally recruits large anonymous crowds to work online to aid scientists. Such open ended large scale recruitment of inexperienced participants becomes problematic when surveying involves visiting fragile habitats at risk from footfall and direct engagement.

The Need to Curate the Crowd: The challenge is how to curate the crowd both *physically* and *digitally* to protect the environment. Visiting experiences (e.g. [21]) often encourage open inspection of natural settings, but this was a point to be avoided in our case requiring a physical curation of crowd activities. Citizen science emphasizes sharing information with others. However, in fragile environments, controlling information disclosure is often a priority for the curators suggesting the need for digital curation of the crowd.

Recognition of Emotional Engagement: This community has a deep emotional connection with nature and a detachment from technology is cited as an important aspect of this. Consequently, engagement with nature through technology is met with skepticism. This raises a cautionary note for cases where the digital mediates engagement with nature or where digital data collection is foregrounded; and suggests the need for a more mindful and situated approach to the design of technology that understands the broader socio-political framing of environmental issues [9].

To assist designers of this class of biodiversity citizen science application, we propose a series of guidelines in light of the above lessons.

(1) Curating through Technology: A tension exists between recruiting the public to survey and protecting fragile environments. To address this, systems might support physical curation by proactively responding to footfall by guiding users via GPS to protect fragile zones and segmenting areas to allow different forms of surveys to coexist based on the experience of the surveyors.

(2) Managing Disclosure: The sensitive nature of survey results requires disclosure to be carefully managed. The types of data shared and with whom should be carefully considered in order to better protect the environment. This focus on digital curation extends beyond existing approaches to Citizen Science which tend to emphasise open-ended sharing.

(3) Reframing the Survey: There is a need to frame Citizen Science in a way that is considerate to fragile environments. We suggest including interactions with the crowd *before*, *during* and *after* the survey. *Before,* the crowd might be taught about the environment and how to proceed when in it. *During* data collection, the crowd can be proactively managed with feedback on their movement and the environment. *After* the crowd has experienced the forest, the collected data should be managed accordingly to protect the environment.

(4) Promoting Discussion: Citizen Science offers the opportunity to promote discussion and reflection on broader environmental and sustainability issues [4]. This may take the form of social media [25] or even build upon the use of narratives in pervasive sensing systems (e.g. [22]).

CONCLUSION

Cicada Hunt aimed to educate and engage members of the public in assisting the re-discovery and conservation of an endangered species simply by performing short audio surveys with their mobiles phones while visiting the New Forest. The in situ deployment illustrated a number of issues that are critical to how such applications can be both beneficial and problematic to the preservation of species and the environment in general, which highlights the need to reconsider their design and potentially the role of citizens altogether. What is involved in using technological devices within a physically sensitive context or in educating the general public to the standards of the professionals arises as the critical debate for biodiversity citizen sensing applications. This calls for a closer coupling between the tradition of biodiversity surveying, educating citizens and the design of such technologies with respect to the fragility of our environment.

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