How Two Billion Smartphone Users Can Save Species!

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Insights

- Animal and plant populations are declining and becoming extinct at an alarming rate.
- HCI specialists have the expertise to work with biodiversity citizen-science projects across the world.
- This data can be used by scientists to record changes in species populations and distributions, enabling us to take action to save species and protect the world we live in for future generations.

What are some of your happiest memories of being in nature? Perhaps, as a kid, you watched swallows skimming over a glistening lake or skimmers by the sea? Or maybe one summer you found a tiny humming bird's nest in an elderly relative's backyard? Whatever precious memories you have, stop for a moment and ask yourself: What if your children and grandchildren won't have awe-inspiring experiences like these? How would you feel?

The populations of many plant and animal species are shrinking or going extinct at an alarming rate because of habitat loss, pollution, and climate change (Sidebar 1). According to the Center for Biodiversity, the rate of extinction has risen from the estimated

base rate of one to five species per year to be 1,000 to 10,000 times higher [1]. The World Wildlife Fund makes the shocking prediction that the wildlife population in 2020 will be 67 percent less than it was in 1970 [2].

But what can we do about it? While this topic may not seem relevant to HCI specialists, it presents compelling challenges for HCI research, practice, and education, and for raising awareness. By encouraging more citizen volunteers to become involved in collecting biodiversity data using well-designed technology, we can help save species and their habitats. These efforts will also protect and enrich the lives of us humans. By accepting our role in tackling wicked problems like habitat loss and using our design methodologies

1 HOW BAD ARE HABITAT LOSS, POLLUTION, AND CLIMATE CHANGE?

We humans take what we need to feed, house, protect, and indulge our growing populations. Our destructive effects on the planet are evident every day:

- Rubbish dumps of non-biodegradable polystyrene, plastic bottles, and old cars are a blight on the landscape.
- Mountaintop mining scars the countryside, destroys habitats, and changes the land's contours.
- Toxic runoff from farming and manufacturing kills life in lakes, rivers, and the oceans, creating dead zones.
- Floating islands of junk trap ocean wildlife.
- Housing developments and other human infrastructure block wildlife migration corridors.
- Climate change is causing the ice caps to melt.
- Vast areas of coral are bleached by rising sea-water temperatures.

We are in the new geological age of the Anthropocene, which is the first age in the history of our planet that has been substantially influenced by human activity, particularly the burning of fossil fuels [17,18]. Consequently, species are becoming extinct at an unprecedented rate compared with that of pre-Industrial Revolution times.

to support saving species, we make HCI design even more relevant than ever. Design methods that increase participants' sense of ownership and responsibility, such as research through design [3] and crowdsourcing design with technology users [4], are particularly promising methods for developing effective smartphone apps and websites.

Approximately 7.2 billion humans live on planet Earth. A portion of this population is expected to own or share more than 5 billion cellphones by 2019 [5]. Two and a half billion of these phones will be smartphones. Phone ownership is increasing rapidly in many countries, including China, India, and Brazil, as well as in some African nations. For example, 44 percent of Kenyans now own smartphones

2 INCREASE IN SMARTPHONE OWNERSHIP IN KENYA

Forty-four percent of Kenyans owned a smartphone in 2016, up from only 27 percent in 2014 [19]. Even though technology is expensive and access to the Internet is limited in many places, a surprising number of Kenyans own, share, or rent mobile phones for connecting with family and friends, running their businesses, and accessing information. More and more, Kenyan citizens are also becoming concerned about climate change, loss of biodiversity, and environmental stewardship [20].

(Sidebar 2). This increase in smartphone ownership paves the way for more citizens to be involved in data collection, provided they have well-designed apps and websites.

Recording biodiversity data is important because it enables scientists to examine the well-being of animal and plant populations. Using this data, scientists can investigate how these populations react to habitat loss and climate change. Typically, biodiversity data collected using smartphones can include photos, comments, numerical data, video, and sound, together with metadata (e.g., time, date, and geo-location logging). Many strategies are used to entice the public to contribute, but there is potential for HCI specialists to do much more. In this article, I describe the role of technology in biodiversity citizen science and suggest ways that HCI specialists can become more involved.

CITIZEN SCIENCE

Millions of people across the world are eagerly joining projects as partners with scientists to collect, analyze, document, and archive scientific data and plan projects—a process known as citizen science [6] (Figure 1). But citizen science is not new; it has existed in various forms for a long time. For example, Darwin was an early citizen scientist, and annual bird counts have been conducted in North America, Britain, and Europe for decades.

What is new for citizen science today is that digital technologies enable human crowdsourcers to collect,

analyze, and disseminate huge amounts of data more quickly than ever.

Smartphones are particularly potent data-collection and sharing devices that are being used in many citizen-science projects. However, even though citizen science is becoming more well known, HCI specialists have played a surprisingly small role in the design and use of technologies in citizen-science projects and communities (Sidebar 3). But with HCI know-how, smartphones can be even more effective tools for citizen science. While there are some large projects that engage millions of volunteers (Sidebar 4), there are also thousands of small projects with limited resources for technical development. Many of these small projects are doing important scientific work for research, advocacy, and conservation, and would benefit from HCI expertise, particularly user-experience (UX) design knowledge.

WHAT CAN HCI SPECIALISTS DO TO HELP?

As the functionality and robustness of smartphones increase with each new launch, there will be new design challenges and opportunities for HCI specialists. Games and gamification—the inclusion of gaming elements into apps—are hot topics. Citizen-science community development is another important research area where HCI knowledge and skills could be helpful. More computationally intense methods such as sentiment analysis, machine learning, and machine vision are also being explored. In addition, we need to keep hold of the basics: *Who* are the users, *what* will they do with the technology, and *where* will they do it? These and other issues are described below.

Different users with different needs. Technology that supports the needs of different types of volunteers will help to broaden participation in citizen science. Currently, the majority of citizen-science volunteers are middle-aged, middle-income, educated white people [7] (Figure 2). Some projects also appear to attract more women than men. More diversity among volunteers would potentially increase the effectiveness of citizen science as well as raise awareness.

People differ in their technology needs. More and more, citizens of all ages are demanding well-designed

Figure 1. Citizen-science volunteers collecting data.

Figure 2. Typical group of citizen-science participants.

technology. For example, reports indicate that millennials—the generation that grew up with home computers and the Internet—are less likely to question their own abilities when they encounter tech problems [8]. Unlike their parents and baby boomer grandparents, many millennials tend to assume that technology should work, and if it doesn't, then the fault lies with the designers, not with them. In contrast, some older volunteers prefer to use paper data-collection sheets. Typically, project leaders or other volunteers then transcribe this data so it can be recorded in a database.

Social engagement. Research indicates that volunteers are drawn to biodiversity citizen science by their enthusiasm and personal interest in nature. They want to learn more and to contribute to local, national, and international projects. Volunteers' reasons for long-term involvement differ somewhat from their reasons for initially joining. A sense of community paired with interaction and feedback from scientists are all strong motivators for continuing involvement in a project. Being acknowledged and appreciated by scientists is also a key ingredient for long-term volunteer participation. Return contributors play a big role in helping to develop communities of members that support each other [9]. In addition, return participants generally become more proficient in collecting data, which helps to ensure data quality. HCI specialists have the skills to develop technology and tasks that encourage long-term volunteer engagement and community development.

Taking and sharing pictures is fun! Smartphone manufacturers are especially eager to improve the cameras on their phones, because they know how much users enjoy sharing pictures. Better functionality is extending what citizen-science projects can do with smartphone cameras. For example, underwater photography with smartphones is becoming a hot topic (Sidebar 5).

Billions of pictures stream across the Internet and cellular networks every day. Some of these pictures are en route to citizen-science project sites; others go to social media networks like Facebook, Instagram, Flickr, and Twitter, where HCI specialists with expertise in machine vision and visual search can then extract them. These pictures can then be reviewed for inclusion in aggregator sites like the Encyclopedia of Life (eol.org), a large repository for documenting biological diversity. Further, important data may be captured accidentally. A similar argument is discussed below regarding the capture of serendipitous pictures by *Pokémon GO* players.

Experts in photography may also provide tips to help volunteers improve the quality of their photos for citizen science. Similarly, information specialists can aid in the design of species guides (Sidebar 6).

The use of low-cost, easy-to-use attachments for taking pictures through telescopes has been common practice among birders for years, but there may be opportunities to improve the design of such attachments. Similarly, researchers are exploring the development of inexpensive macro lenses, which resemble contact lenses and fit over smartphone cameras.

Taking and sharing pictures is fun, but being in nature has calming and emotionally grounding benefits, as discussed by Richard Coyne in his 2014 *Interactions* cover story [10]. Just watching nature films is known to have a calming effect. Wildlife films may attract wildlife enthusiasts to contribute to citizen science or to become ecotourists, who pay to contribute to citizen-science projects when they take

3 HOW MUCH INVOLVEMENT DO HCI SPECIALISTS HAVE IN CITIZEN SCIENCE?

While several HCI researchers publish on sustainability (e.g., ACM LIMITS workshops) and ICT4D (information and communications technologies for development), there are only a few papers on citizen science. For example, a search for the words *citizen science* in the titles of full papers accepted for CHI 2016 and CSCW 2016 returned only two papers for CHI and one for CSCW. Citizen science has featured more prominently in other parts of these conferences. For example, a workshop was hosted at CSCW 2017 in Portland, Oregon, but the HCI community can play a much bigger role in citizen science. Improvements in global infrastructure may also help to make this possible. For example, groups like GSMA Mobile for Development aim to bring together mobile operator members, the wider mobile industry, and the development community to deliver mobile services to underserved people (<http://www.gsma.com/mobilefordevelopment>).

4 EXAMPLES OF CITIZEN-SCIENCE PROJECTS

Zooniverse.org is a large, successful open source crowdsourcing Web platform for citizen science that supports a wide range of projects, covering the arts, climate, history, languages, science, astronomy, biology, nature, and more. The nature projects hosted on Zooniverse include Snapshot Serengeti, in which participants help to classify animals captured on millions of camera traps (snapshotserengeti.org), and Bat Detective, in which participants work with scientists to classify the calls of different species across the world (batdetective.org).

eBird.org, and its sister Merlin, an app for beginner birders, were developed at the Cornell Lab of Ornithology. eBird now supports thousands of volunteers, among them established scientists, highly skilled serious amateur birders, and novices. In May 2015, more than 9.5 million observations were contributed from across the world. Sophisticated data analysis and visualization tools are available that enable these contributors to explore bird-migration patterns and other topics of interest. eBird also feeds its data into aggregator sites such as the Global Biodiversity Information Facility (GBIF) so it is available for scientists to access more easily.

iNaturalist.org, an app for collecting biodiversity data, recently celebrated logging 3 million nature observations consisting of media (photos, audio, and video recordings) with their metadata (time, date, and location data). iNaturalist is a testament to the imagination, creativity, hard work, and passion of three master's students from the University of California, Berkeley's Information School, who launched it as a capstone project. Since then other staff have joined the project, which is now housed at Caltech in California. A growing number of volunteers and projects across the world contribute data to iNaturalist.

Project Budburst (budburst.org) is a phenology project. Phenology is a science that studies the relationship of weather and climate on recurring annual phenomena including changes in plant life and bird migrations. Project Budburst invites volunteers to track these changes across the seasons from year to year. For plants these include the time of leafing, flowering, and fruiting phases of specific plant species.

iSpotNature.org, based at the U.K. Open University, is also a platform for collecting biodiversity data, but unlike iNaturalist, it is embedded in university classes and has an explicit educational mission. In addition, individuals who are not taking classes are welcomed into the iSpot community. (iSpot's sophisticated reputation system is discussed elsewhere in this article.)

Zooniverse.org

eBird.org

The iNaturalist app and its leaderboard.

Budburst.org

The iSpot quiz.

An example of iSpot's reputation rating system.

Many other projects are listed on scistarter.org and citizensciencecenter.com.

vacations in exotic locations.

Challenges and competitions are fun for some but not for others.

Games and gamification can be enticing for volunteers, and they are interesting research topics for some HCI researchers. (Sidebar 7 contains examples of citizen-science games.) Opinions about how much citizen-science volunteers like gaming run the gamut. Some volunteers don't want to be distracted from the topic by games, while others enjoy being challenged [11].

Regardless of where you fall on the hate-love spectrum of citizen-science games, most of us were intrigued by the *Pokémon GO* craze that swept North America and Europe last summer. A July editorial in the science journal *Nature* published at the height of *Pokémon GO* mania noted that “millions of people have spent the past week walking around. Ostensibly they are playing *Pokémon GO* and hunting for critters in an augmented ‘reality world’ ... but they are spotting other wildlife too” [12]. Like the *Nature* editorial author, scientists were quick to realize that games like *Pokémon GO* might serendipitously pave the way for new participants to become citizen scientists. Pictures snapped by *Pokémon GO* players could, by chance, harbor evidence of newly discovered species previously unknown to science. They might also provide evidence of the presence of certain organisms in new areas where they were previously not seen. This in turn might signal evidence of climate change.

Increasingly, app developers are including game attributes in their designs. Gamifying apps add challenge and competition while also retaining the core element of a project's scientific mission. For example, iNaturalist.org motivates contributors by challenging them to get a place on the project's leaderboard (Sidebar 4). The thrill of being listed as one of the top 500 contributors is captivating for some participants. Currently, the person in first position has contributed more than 45,000 observations of almost 6,000 different species. In contrast, the volunteer in the 500th position contributed 1,220 observations of 629 species, which is still pretty impressive! Getting listed on this board requires hard work and is no easy feat. iNaturalist also has other leaderboards that rank contributors over different

5 WATER-RESISTANT SMARTPHONES: A PATHWAY TO UNDERWATER PHOTOGRAPHY

Manufacturers of several smartphone brands boast that their phones can now be submerged for 30 minutes or more. Apple says the “iPhone 7 dramatically improves the most important aspects of the iPhone experience. It introduces advanced new camera systems. The best performance and battery life ever in an iPhone ... Splash and water resistance” (<http://www.apple.com/ca/iphone-7/>). The ability to photograph without concern for splashes means that citizen-science volunteers can make more observations in and near water without worrying about damaging their phones.

Waterproof casing has been developed to encourage underwater photography at shallow depths; YouTube videos share best practices. For those who want to be especially careful, there is even a YouTube video that painstakingly demonstrates how to wrap a smartphone in plastic wrap to keep water out! These developments might open up opportunities for HCI developers, especially those working in maker labs, who are interested in exploring ways of using smartphones for underwater photography and other kinds of data recording.

time periods for different activities, for example, the most species submitted in November 2016 or the most observations in 2015, and so on.

iSpot (ispotnature.org; Sidebar 4) offers quizzes that encourage participants to test their knowledge of seven different groups of organisms: plants, mammals, birds, fish, fungi and lichens, invertebrates, and amphibians and reptiles. Participants can select the difficulty level of the questions on a 1 to 5 scale. When stuck on a question, a participant can ask for help up to three times during the quiz.

HCI specialists interested in researching the impact of games and gamification on volunteer participation can address a host of different research questions: What kinds of games and gamified apps motivate what types of volunteers doing what kinds of tasks? How should games and gamified apps

be scaffolded to help users improve their skills? How transferable is knowledge about established games like *World of Warcraft* to citizen-science games? What can we learn from studying *Pokémon GO* about volunteers' relationship with local places and how they interact socially?

Science requires quality data, so research is needed about how games and gamified apps affect data quality. How, for example, does the quality of data collected in iNaturalist compare with that collected in iSpot, which does not have leaderboards and instead encourages contributors to earn explicit reputation badges? iSpot badges are determined and awarded by clever algorithms based on the following attributes: the number of observations a volunteer submits, the amount she helps other participants to identify the organisms that they

6 PHOTO-TAKING AND INFORMATION DESIGN KNOW-HOW

HCI specialists can develop tutorials and other techniques to assist volunteers in taking better photos; for example, by providing advice on avoiding obvious pitfalls like taking pictures into the sun or in heavy shadow. Similarly, explaining the value of taking bursts of pictures of moving subjects, as well as of shooting from different angles, can train volunteers to collect more useful data. The extra detail contained in these pictures can be helpful for identifying species. Encouraging volunteers to use video so that sound is available to identify birds is also useful. Several large citizen-science projects, such as iNaturalist.org and eBird.org, already offer tutorials, but projects with limited resources might appreciate input from HCI and information specialists.

Increasingly, species-identification guides are provided by large projects like iNaturalist. Smaller, under-resourced projects might appreciate help from information design specialists and with usability testing, or with finding links to other useful resources. These activities might make good class projects for beginning HCI students while also benefiting the citizen-science projects. Organizing such activities would require the HCI professor to make contact with citizen project leaders, which might also lead to important long-term relationships.

7 GAMES IN CITIZEN SCIENCE

Jacob Sherson's lab (scienceathome.org) is developing games that encourage participants to push boundaries to identify new research directions. These games focus on quantum physics, chemistry, engineering, psychology, economics, and cognitive science.

Examples of biodiversity citizen-science games include *Citizen Sort* and *Questa*. Citizensort.org is a suite of three games, *Happy Match*, *Forgotten Island*, and *Living Links* that involve players in sorting organisms and other activities. *Happy Match* invites players to classify moths. *Questa* (questagame.com) invites children to learn about biodiversity in their neighborhoods, parks, or schoolyards by searching for organisms. The children have to provide evidence for their reports, which are then checked against a database of possibilities and recorded. Points are earned for successfully contributing to quests. Another example of a game for learning about nature is *Chirp USA!*, an app that tests players' recognition of bird songs and calls.

Chirp USA! app quiz for learning bird songs and calls.

8 TYPES OF SENSORS

Mike Sharples and his colleagues provide a useful classification of sensors into four categories [21]:

- motion sensors that measure acceleration and rotation using a three-axis coordinate system
- environmental sensors that measure ambient conditions such as changes in light, temperature, pH, etc.
- position sensors that measure physical location, such as GPS and the proximity of objects
- body sensors that measure heart rate and fingerprints, etc.

The British Open University's citizen-inquiry research project provides an example of how sensors are used by school-age students to explore science phenomena. Some examples of the students' projects include using sensors to record sunlight, noise levels, and barometric pressure at different locations. They then relate their findings to other phenomena such as bird behavior and changes in the weather. These projects require an Android app called Sense-it, available at Google Play (play.google.com/store/apps/details?id=org.greengin.sciencetoolkit). This app contains a toolkit for citizen-science inquiry-based science learning that allows participants to explore, record, and share data. A website, nquire-it.org, offers suggestions of missions that can be investigated using Sense-it. Teachers and individuals can also develop their own missions.

Sense-it explore and record screens.

find, the level of her formal training in ecologically related courses, and her status within the iSpot community [13] (Sidebar 4).

Smartphones with sensing devices.

Sensors are used extensively in environmental science for monitoring

air and water quality, noise, sound, and vibrations, but they are underexplored in citizen science. This is starting to change and will continue to do so as sensor technology, smartphone battery life, and Wi-Fi and cellular networks improve. Sidebar 8 describes

the different functions that sensors can perform and provides an example of how children can use sensors for learning about environmental science.

One reason that sensors have not yet been widely used in citizen science is that the locations where they would be most useful are often out of range for Wi-Fi and cellular networks. However, in addition to research on improvements to these networks, some researchers have found short-term workarounds to alleviate this problem. For example, human-relay systems require citizen scientists, in collaboration with scientists, to carry their phone data from their project sites to access points, where the data can be uploaded to another system. This uploading process occurs via specially developed middleware [14]. Sense-it (Sidebar 8) adopts another approach. It works outside of Wi-Fi and cellular network ranges, and then the network and phone sync when back in range. Further research is needed to find other long-term solutions to this problem.

Another exciting citizen-science opportunity is to link a broader range of sensors to mobile devices by Bluetooth for monitoring water quality or atmospheric pollution, or to link with citizen weather stations and monitoring posts (e.g., wxqa.com). HCI researchers have a role in improving the quality of citizen-provided sensor data by removing gross errors and correcting instrument bias [15].

The sensors on smartphones could also act as controllers for other devices, such as drones. Even though there are ethical and political concerns about using drones stemming from the military's use of them for surveillance, drones are valuable for recording pictures and related data in places that are otherwise difficult to access. For example, drones can be used for examining vegetation changes in heavily forested areas like the Amazon basin, and for tracking elephants and poachers across vast areas of savannah. There is a role for HCI researchers interested in the privacy issues associated with using drones in citizen science and in other types of data collection using technology [16].

MOVING FORWARD

This article began with pessimistic news about the plight of species and the impact of climate change, but

the future could be more optimistic. The Paris Climate Accord represents a significant step by nearly 200 countries toward mitigating the worst impacts of climate change. It encourages countries to take action to prevent global warming from rising more than 2.0°C/3.6°F above pre-Industrial Age temperatures. HCI specialists, along with others in the general public, can strive to ensure that all the countries involved in the Paris Climate Accord honor their commitments. Our engagement and political awareness is needed to make this happen. By working collaboratively with citizen-science projects throughout the world to co-create knowledge and design technology, we can all become better informed. For those new to citizen science, Sidebar 9 offers a few suggestions for getting started.

We HCI specialists have a duty to use our skills and knowledge to steer technology design, development, and usage to help save the species with which we share planet Earth. In doing so, we will help to ensure a safe, enriching, and awe-inspiring natural environment for our children and grandchildren. Collaborating with scientists and joining citizen-science projects is one way to help achieve these goals.

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RESOURCES FOR GETTING STARTED

A North American citizen-science association (citizenscience.org), which welcomes members from across the world, hosts a biannual Citizen Science Conference that is an excellent venue for finding out about citizen-science projects and networking in a relaxed and friendly environment. Similar groups exist in Europe (ecsa.citizen-science.net) and in Australia (hcsna.gaiaresources.com.au/wordpress). Scistarter.com lists hundreds of projects from across the world that you can explore. Finally, an article by Greg Newman et al. presents a thoughtful perspective on the impact of technology on citizen science [22]. Even though it was published almost five years ago, it is still relevant today. A recent paper by the author of this article discusses a broader range of topics for those who want to read more [11].

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