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Hunter-gatherers in the Congo Basin are using smartphones to track poaching and logging.

CITIZEN SCIENCE

Amateur experts

Involving members of the public can help science projects — but researchers should consider what they want to achieve.

BY TRISHA GURA

Equipped with smartphones, computers and do-it-yourself sampling kits, lay volunteers are tweeting about snowfall, questing for comets and measuring the microbes in their guts. They are part of a growing group of 'citizen scientists', networks of non-scientists who help to analyse or collect data as part of a researcher-led project. They learn about science and get a chance to participate, but the scientists involved stand to gain too. "There is huge amount of spare attention out there and a huge desire to do something real with it," says Christopher Lintott, an astronomer at the University of Oxford, UK, and chair of the Citizen Science Alliance, which hosts projects and advises researchers.

There are indications that in the past five years or so, citizen science has become more popular with researchers — and more likely to translate into a legitimate, publishable research project. It offers a means of doing substantial, thoughtful public outreach, and of tackling otherwise intractable, laborious or costly research problems.

But recruiting non-scientists comes with complications, including finding the right technical tools and partners to organize and execute projects with potentially thousands of data collectors. And scientists must ensure that the data are sound. Researchers thinking about entering the citizen-science fray should contact established associations for guidance and consider what they want from the end result — is it outreach alone, or something more?

It is difficult to measure the growth in citizen science accurately, in part because many ventures overlap with science-education efforts, but projects are definitely becoming more common. The Citizen Science Alliance began with one project in 2007 and has now hosted more than 20. The alliance has received 200 proposals for possible projects in the past year alone, and launched 10. A similar organization called SciStarter now boasts more than 450 projects. Citizen Science Central — co-founded by Rick Bonney, an ornithologist at Cornell University in Ithaca, New York, who in 1995 coined the term citizen science — lists 162 projects.

Some have given rise to peer-reviewed publications. Jake Weltzin, an ecologist at the University of Arizona in Tucson, is executive director of the USA National Phenology Network, which runs a project called Nature's Notebook. Citizen scientists track how climate affects the timing of life-cycle events in plants and animals. Weltzin's group jumped from one publication in 2007 — when citizen science elsewhere meant asking for access to people's computer-processing power to work with huge amounts of data — to more than 100 now. "This is a whole new way of doing science," says Weltzin. "Being able to think about and collect data at a continental scale."

STRENGTH IN NUMBERS

Citizen science can help researchers to address previously insoluble problems. For example, Justin Halberda, a psychologist at Johns Hopkins University in Baltimore, Maryland, wanted to study how cognition develops as people age. He originally thought that he would need to gather data from tens of thousands of people of all ages over the course of years, a feat that would be financially and logistically impossible for one research team with a limited budget.

So he reached out, asking volunteers to play a sort of video game that measures number sense — the ability to estimate how many items there are in a collection without actually counting them. The game involved watching yellow and blue dots flash briefly on a screen, then estimating whether there were more yellow or blue. Over the course of a few months, more than 13,000 individuals — ages 11 to 85 — took the test, and Halberda's team analysed the results.

The researchers not only built up a general description of people's number sense, but also unveiled a surprise: individuals don't achieve the best precision in number sense until ▶

they are about 30 years old, much older than most previous studies had suggested (J. Halberda *et al. Proc. Natl Acad. Sci. USA* **109,** 11116–11120; 2012). Before citizen science, "no scientist would have been able to generate these data", says Halberda.

REACHING OUT

Citizen science can also educate and engage. Philip Brohan, a climate scientist at the Met Office Hadley Centre in Exeter, UK, and his colleagues build up data sets using weather records from nineteenth-century ships. The logs are handwritten, so they cannot be digitized automatically. The team set up an online project called Old Weather, in which citizen scientists pick a ship and read the logs' accounts of epidemics, people falling overboard, getting stuck in ice and, of course, the weather. While following along, readers transcribe the information into online forms, which Brohan's team analyses.

The project has been a huge success; readers get caught up in the accounts, as if they were diaries of the ship's voyage. "People fall in love with the ships," says Brohan. The weather has become just one part of a larger tale — but that part yields the science. Since the launch of Old Weather in October 2010, at least 16,400 citizen scientists have entered more than one million log pages to produce 1.6 million weather records, the basis for five atmospheric analyses.

Expanding on this kind of success, researchers are now using citizen science to improve their funding applications. Agencies often ask for some measure of how a research project will affect the lay public: the US National Science Foundation (NSF), for example, requests a description of a project's "broader impact" for many of its grants, including early-career development awards. Citizen science is a great way to meet your broader-impact requirements, says Weltzin.

MECHELLE MEIXNER

Jack Meixner tracks juniper phenology in Texas as part of a citizen-science project on pollen.

It can also get the public involved in research that can inform environmental or governmental policy. In one case, citizens helped to collect data on noise levels near a scrapyard in the London district of Deptford. Citizen scientists showed that the operation violated noise limits, and the UK Environment Agency revoked the scrapyard's licence.

In perhaps the most avant-garde example of citizen science, members of communities in the Congo Basin are set to aid land and animal conservation. Jerome Lewis, a social anthropologist at University College London (UCL), was working with pygmy hunter-gatherers in Rwanda and other areas in the region when they told him about poachers killing animals and loggers destroying natural resources, such as sacred trees. Collaborating with Muki Haklay, a geographic information scientist at UCL, Lewis sought a way to help, and to document the damage for policy-makers. At first, it seemed that citizen science was not an option, because the hunter-gatherers could not read or write — let alone access the Internet.

But Haklay's team designed smartphones with satellite-navigation systems and icons such as pictures of trees or traps. Community members carry the phones into the forests and press the relevant icon when standing in front of a landmark such as a sacred tree that could be targeted by loggers. The data streams back to Haklay's team, which creates a map and report. These are shared with logging companies, which then decide whether to leave particular landmarks standing. A similar project to deal with poachers will launch this April. Data such as the locations of snares will be shared with policy-makers to attempt to reduce the killing of endangered animals. As an added feature, the phones come with a thermoelectric battery charger, which can convert heat from campfires to electricity. "If we find a way to go to the extremes of citizen science," says Haklay, "we can do all kinds of really interesting stuff."

WHAT TO WATCH FOR

Citizen science might appear to be all upside and little downside — a way to get others to do cheaply what researchers cannot or do not want to do. But that thinking can lead to trouble. "Citizen science is enormously expensive in terms of time and effort managing people, websites and databases," says Brohan (see 'A call to arms').

People management is one of greatest challenges, says Andrea Wiggins, a social scientist who studies citizen science at the University of New Mexico in Albuquerque as part of DataONE, an NSF-funded project aimed at increasing the availability of Earth and environmental data. "You don't necessarily know who is on the other end of a data point," she says. It could be a retired botany professor reporting on wildflowers or a pure amateur with an untrained eye.

As a result, it is difficult to guarantee the quality of the data. Scientists have to design their projects and protocols for anyone to follow, and must perform regular quality control. Lintott and his team do exactly that as part of a project called Planet Hunters, in which citizen scientists sift through data from NASA's Kepler spacecraft

GETTING STARTED

A call to arms

Launching a citizen-science project involves a few essential steps.

First, come up with a question that takes full advantage of a network of amateur data-collectors. It could be getting citizen scientists to track changes in rain acidity over time by measuring the weathering rate of marble gravestones in particular graveyards. The results could indicate changes in pollution and climate.

Next, seek guidance from people who have already built these kinds of projects, such as the Citizen Science Alliance (www.citizensciencealliance.org).

Network or correspond with individuals who are adept at marketing to educators and using social media to develop a project that is user friendly, easy to follow and attractive to many citizen-scientist recruits. Groups such as Citizen Science Central provide an online toolkit (go.nature.com/e1jjm5), and DataONE has a guide to data management for citizen-science projects (go.nature.com/xfpdmh).

Invest in project design by, for example, creating a website, turning tasks into games, marketing and publicizing the project on social media and testing it on potential participants.

Plan to spend a lot of time and energy. It may take months or years to generate data for publication. Until then, the citizen-science effort may simply be another full-time responsibility.

Think about creative sources of funding, from private foundations to individual philanthropists or even corporations that want to support science education. Jason Osborne, co-founder of the citizen-science project Paleo Quest, reached out to teachers and then pitched an educational model for boosting interest in the sciences to corporate donors. "You can fund the research by funding the education," he says. T.G.

to search for transit events — brief dips in the brightness of stars that occur when planets pass in front of them. To track how well citizen scientists can spot transits, and to measure the sensitivity of the system to different kinds, the Planet Hunters team inserts fake planet signals alongside the genuine data and measures how good people are at detecting them. In another quality-control measure, multiple users do the same task on the same data, so that mistakes are averaged out. And because users log in to use the system, the researchers can track which citizen scientists are best at which tasks and then give extra weight to results from the best performers.

The sheer scale of the projects can create quality-control challenges. The eBird project at Cornell uses citizen scientists to document the presence, absence and abundance of species across the United States. It receives 25 million observations a month, which are reviewed by a team of 500 volunteers, handpicked for their experience. Each reviewer must sift through 4% of the observations to validate them, in essence looking at hundreds of thousands of observations. Project organizers are currently thinking about new ways to manage the big data sets, by either reviewing less or automating more.

"You are getting the information that you need at the same time that you are getting people involved."

Scientists also have to face the challenge of recruiting volunteers and keeping them engaged. "The science has to be romantic, in a way, so that people want to support the research behind it," says Jason Osborne, president and co-founder of Paleo Quest, a citizen-science organization focused on palaeontology. Projects have to be interesting, tangible and involve discovery, he adds. In an offshoot of Paleo Quest called SharkFinder, for example, Osborne and co-founder Aaron Alford identify layers of rock riddled with shark fossils and take large samples from river swamps and other remote environments. The researchers then distribute the samples in kits to US classrooms. Any fossils that students discover are sent to the University of Maryland in College Park, where palaeontologists led by Bretton Kent verify the findings. The project currently samples fossil formations along the east coast of the United States, but Osborne hopes to expand his sampling work to Panama and other countries. "You put Panama in the kit, and kids are like, 'Wow, I have a piece of Panama on my desk, and I am looking for fossil remains'," says Osborne, noting that kids also love handling prehistoric fossils. "There has got to be that kind of wow factor." And if they discover a new species, Osborne's citizen scientists might be named on a publication — or even be given the opportunity to name the species.

Whatever a volunteer's motivation — even if it is just the joy of participating — scientists have to understand and nurture it. For Old Weather, Brohan's team came up with a ranking system. Citizens receive the title of cadet when they join. After transcribing 30 pages of logs, they are promoted to lieutenant. The person who transcribes the most pages on a ship becomes the captain. Social media and online forums let the participants talk to each other.

Another way to keep volunteers engaged is to identify the best and invite them to do more. Scott Stevens, a research associate at the Cooperative Institute for Climate and Satellites in Asheville, North Carolina, works for a project in which citizen scientists classify images of storms. His team discovered that one-quarter of the data were coming from a handful of 'power users', who had classified more than 20 images each. In fact, a single citizen scientist contributed a full 7% of the activity on the website, more than the next five power users combined — and greater than all the least active half of the user base.

"Both these one-hit wonders and the super-users are important to us," says Stevens, whose team wants to create something like Brohan's ranking system to reward the best and most committed. As projects evolve, organizers can contact those super users and invite them to participate at a higher level, perhaps by helping to analyse data or to manage groups of other citizen scientists.

Finally, there is the challenge of getting citizen-science data through peer review. But that barrier is diminishing. "I have never come across a furious reaction against the idea of this," says Lintott. "You just have to test your model as you would had you written a new computer code."

Publications using data from citizen science are becoming more common, and even encouraged. Researchers at Princeton University in New Jersey, for example, have used data from Nature's Notebook to expand a model of the timing of leaf-bud bursting from the Harvard Forest area in Massachusetts to the entire eastern seaboard of the United States. The team published its expanded model this year (S.-J. Jeong *et al. Geophys. Res. Lett.* **40,** 359–364; 2013). Not only did peer reviewers welcome the citizen-science data, but one actually gave advice on how to use the citizen-science model more effectively, says Weltzin.

If all goes well, citizen science is a way to communicate science, engage in outreach and accomplish research aims. "You are getting the information that you need at the same time that you are getting people involved," says Weltzin. "It is like playing Whack-a-Mole with all hammers out. You meet all of your objectives at one time." ■

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SEQUESTRATION

Staff cuts likely

US universities and research institutes will remain in stable financial health despite federal budget cuts, but staff reductions are likely, says a report by Moody's Investors Service, an international credit-rating agency based in New York. In *The Sequester Series: Limited Impact on US Universities and Related Not-for-Profit Organizations*, published on 28 March, the agency notes that universities and research institutes will see an overall 5% cut in federal funds this year. The report is meant to reassure investors in the higher-education sector, but says that lay-offs, mainly of non-tenured researchers, could be needed to manage the cuts. Institutions are likely to increase their focus on interdisciplinary research and extramural collaborations to increase revenue and share costs, says Edith Behr, vice-president of Moody's.

EUROPEAN UNION

Easier migration

Foreign researchers and students would find it easier to stay or work in the European Union (EU) under a proposed law. Legislation now in the draft phase would ensure that EU member states issue decisions on admission applications within 60 days; would permit researchers and students to move between states for 6–12 months or for the entire study period for Marie Curie or Erasmus Mundus fellows; and would let students and researchers stay in the EU for up to a year to find a job or start a business. The European Parliament and the Council of the EU are reviewing the proposal, which could be adopted by early 2016. Current regulations are "very fragmented", says Michele Cercone, European Commission spokesman for home affairs. "This will fill a gap."

MEDIA

Online journal club

A US medical journal is the first to use the Journal Club Live online platform, which lets participants discuss papers with their authors in real time. *Fertility and Sterility* has streamed two sessions of Journal Club Live on YouTube and will run a third in May, says platform developer Steven Palter, the journal's new-media editor. Invited panellists take part in a video chat and YouTube viewers submit questions. Panellists and viewers for the first two sessions came from the United States, India and Spain. "This opens the discussion into a global collaboration," says Palter.