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**‘All Must Have Prizes’:**

**Citizen Science and the Environment**

Professor Carolyn Roberts

Good evening ladies and gentlemen, and welcome to my final lecture on an environmental theme for this academic year. Again, I express my thanks to the Frank Jackson Foundation for supporting the Professor of Environment role (only the second new Professorship at Gresham College since 1597), and to ask you to note that they have kindly extended my term for a further year. So, next academic year I will be exploring some more controversial environmental debates, framed by views on the ‘post truth society’, fake news, alternative facts and hoaxes.

Today, I want to talk about ‘Citizen Science’, and the role that it might play in addressing some of our environmental challenges. But first, please let me indulge my passion for Alice in Wonderland by providing a metaphor.

Alice, if you recall Lewis Caroll’s story, is sitting with a wet and bedraggled group of animals who have fallen into the lake of her tears. The Mouse recites the history of William the Conqueror which is apparently the driest thing he can manage, and is shouted down by the others, whereupon the Dodo suggests that the meeting adjourn for the immediate adoption of more energetic remedies. After a protest from the Eaglet and everybody else that Dodo’s language is incomprehensible, and eschewing any explanation (‘why the best way to explain it is to do it!’) the Dodo marks out a circular track, and starts a Caucus-race, in which everyone participates. They begin running when they like, and let off when they like, so that it is not easy to know when the race is over. However, after they have all run for about half an hour, and are dry, the Dodo suddenly calls out `The race is over!’ They then all ask, `But who has won?' Eventually, the Dodo announces that `EVERYBODY has won, and all must have prizes'.

Without this wishing this to sound like some form of Sunday sermon, let’s just pick up the salient points here. We have an environmental catastrophe, a flood, affecting everyone. The background to the disaster is not understood, although several of the characters realise that Alice is broadly responsible for it (by crying), even though she did not understand the implications of what she was doing. One aspirant leader (the Mouse) is shouted down because his suggested solution is boring and ineffective. Another character then suggests, albeit in almost incomprehensible language, that by doing something broadly competitive, they will all benefit in the long term. There is a course for the event, but there are no rules, no targets and no agreement on when the proposed activity (running around the lake) will be finished. They all nevertheless join in, and when the damage has been repaired, they are told that they have all won, and that all of them will have prizes of some sort.

Let’s not extend the metaphor too far here, but I think you get the message. This is a pretty good allegory for the ways we are addressing some environmental challenges today. Boring incomprehensible language about possible answers to challenges, rather shambolic arrangements for activities in which the citizens of Wonderland are supposed to join in, a bit of competition, but a lack of agreement on when the solution has been reached. Not being ‘expert’ like the Dodo, they don’t necessarily understand what they are doing. But it works, more or less. Part of the reason that it works is that everyone participates, because even without full collaboration, they all benefit and perhaps they enjoy it; we are not told.

Recently, we have seen an upsurge in the prominence of scientists in the media. In some cases this is because of a lack of confidence in abilities – too much ‘expert’ opinion, according to some politicians. But scientists themselves have been seeking greater prominence. The slides here tell their own story. Last month, for instance, scientists marched in cities across the world, including London, to promote science. The messages they sought to convey were about the crucial role of science in decision making, the importance of innovation, and the need to establish some form of ‘reality’. Alongside the medics and the physicists (‘Science saves lives’, and ‘Up and Atom’, environmental scientists were well represented – climate science being particularly prominent. ‘Climate change is not a Chinese hoax’, says one of the placards. The placards themselves, actually, were models of good scientific procedures (‘What do we want? Evidence-based science. When do we want it? After peer review’), and also testified to scientists having a sense of humour, I think.

There were also placards disputing ‘who’ scientists were, or could be: ‘Science is for everyone (although it needs decolonising)’ and on the personal characteristics of scientists ‘My Mummy is a scientist. Scientists are badass’. And this more succinct placard ‘Nerds’ with some arrows pointing at the assembled crowd. But for environmental scientists, perhaps it is this placard that best captures the balance of opinion in its play on words ‘If you are not part of the solution, you’re part of the precipitate’. Everyone can be a citizen and a scientist, if sufficiently nerdy perhaps, and citizen science needs to be part of the solution.

Just to tease this out a little, at its most basic, Citizen Science is ‘people power’, where volunteer non-scientists are used to report on particular phenomena such as the date of grape harvests, or cherry blossom flowering dates. To this extent, ‘science’ has long been the province of the amateur or ‘citizen’. Eighteenth century clerics with time on their hands, and Edwardian ladies looking for a pursuit beyond the taking of tea, have recorded natural phenomena such as daily rainfall totals, and the presence of particular species such as orchids or butterflies, for centuries. The earliest geologists, people such as Mary Anning, who dug out and sold Jurassic coast fossils, and made some interpretation of them, were complete amateurs, of course. Even when I was undertaking doctoral research on river channel erosion in cities, back in the 1970s, I found a man in Preston who had recorded the river level at a particular bridge every day for fifty years, whilst on his way to work in a factory on the top deck of a bus; even without the weekend observations, it was data worth having, for me. Was the man a scientist manqué, I wondered?

This definition of citizen science is very simple. However there are others, some of which suggest that the role could be much more significant in driving people to be ‘part of the solution’. Irwin, for instance suggests that Citizen Science is a precursor to opening up science policy and policy debate to the general public: when people are well informed through personal engagement, they are better able to participate in democratic processes. The suggestion is, therefore, that Citizen Science is not just a neutral term concerning specific activities such as data collection, but an altogether broader and deeper concept. It raises the possibility of the science responding more explicitly to public concerns. The graph of cherry blossom dates in Washington DC shows very graphically the policy connection that comes from some citizen science; blossoming dates have been getting notably earlier since the 1960s, as observed and recorded by ‘everyman’, and one would think that this must prompt thoughts about climate change, as well as the increasingly unreliable method of setting the start and end dates of the National Cherry Blossom Festival.

Citizen science is hence not a new phenomenon, but it has evolved very quickly over the last thirty years or so, and in the environmental sciences over the last five or ten. The first noteworthy citizen scientist of the twenty first century was probably the Dutchman Hanny Van Arkel, who whilst volunteering to analyse the thousands of images emanating from the Hubble telescope, identified a new type of celestial body – a quasar ionisation echo, or bright streak. In addition to that, there are still citizen science programmes hunting for aliens. A decade later, CERN and the University of Oxford are asking for ‘Higgshunter’ volunteers to search for the Higgs boson, or technically a baby Higgs boson with a slighter longer lifespan, by examining images from the Large Hadron Collider, to see if they contain anything weird or unexpected; the human eye-brain combination is very good at doing this. Findings are then flagged up to the scientists running the project, and are being used to improve the algorithms for machine recognition. As everywhere else, we humans may be out of a job soon, but 20,000 people have so far been involved. There are 60,000 images to analyse, and only 20,000 done, so I assume this is a somewhat painstaking task.

We environmental scientists have been a little slower on the uptake than the physicists. There are examples of citizen science from the 1970s, but relatively few. In 1987, the Audubon Society in the USA drew on the labour of over 200 volunteers across the country to collect, analyse and submit data on the acidity of local rainfall samples. Although the analytical method, using litmus paper, was accurate only to 0.5 of a pH unit (and the collection often involved old Cola bottles, which must have led to massive contamination problems in the event of any residue), the information was deemed good enough to demonstrate that acid rainfall was associated with industrial activity, and was widespread. The Society then used this as a lobbying point for the governmental agencies. Greater emphasis is being placed today on scientifically sound practice, and there are often goals for public education, something to which I will return later.

The other influence on what has been a recent meteoric rise in the practice of Citizen Science, is the massive improvement in the accessibility of technology. Global Positioning Systems, satellite images, mobile phones, the internet, flying drones and other technologies have become cheap enough to be deployed by almost anyone. If we just consider the carrying capacity of drones, for instance, with cameras or microphones, interesting possibilities open up. The example or case study shown here, concerns drones, potentially in the hands of amateur scientists, being used to survey songbird populations, by dangling small digital recorders 60m over woodland. I have a video extract that explains the advantages….

You will note that the study itself being done by Gettysburg College, Pennsylvania, which is an academic institution although not a research intensive one. There are also some disadvantages to using drones here, and some concerns about the quality of the data, but in theory citizen scientists could collect data that could subsequently be analysed by scientists, and generate information to inform bird conservation policy. In this instance however, the song of the key protected species the Mourning Dove, is not well captured.

The example here is of citizens collecting environmental data, albeit in this instance with specialised kit. However, if we return to the issue of definition, the European Commission Green Paper on Citizen Science, produced in 2013, developed the proposition much further. Several elements appear in their definition:

Citizen Science is "the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. While adding value, volunteers acquire new learning and skills, and deeper understanding of the scientific work in an appealing way. As a result of this open, networked and trans-disciplinary scenario, science-society-policy interactions are improved leading to a more democratic research, based on evidence-informed decision making”.

I want to draw your attention particularly to the words in purple, referring to raising new questions, and co-creating a new scientific culture. It is potentially about collaboration, and ‘citizens’ framing and steering research. There is an educational ambition, and an expectation that participation will be enjoyable. The definition goes on to raise the further possibility (words in red) of more democratic scientific research, based on evidence-informed decision making. Those are ambitions for engagement well beyond the mere provision of scientific data to scientists. Moreover, the ambition is increasingly being adopted by the academic world, driven in the UK, in part, by the increasing demands of the Research Excellence Framework. Demonstrations of ‘impact’ from research, are important. A new open access online journal ‘*Research For All’*, co-sponsored by University College London and the National Co-ordinating Centre for Public Engagement has been published, which anyone can read freely, including Citizen Scientists.

Having explained a little about the background to Citizen Science in environmental and other disciplines, I want to turn my attention now to the realms of environmental science, and look at some examples of what has been, and is being, done. If you feel so moved, you could become involved in any of these projects. For convenience, I am splitting them into the broadly environmental, but classical elements of earth, fire, water and air.

First, let’s turn to citizen science and the earth, including ecology. A very straightforward example is the ‘Lost Ladybug’ citizen science project, based in Cornell University in New York State in the USA. The research project started in 2000 as a survey of what in the UK we would call ladybird populations. In 2006, two ten year olds discovered the extremely rare nine-spotted ladybird and from 2008 the National Science Foundation provided funding. To date, groups of citizens, particularly school children, have collected, chilled, counted and photographed 34,000 of these attractive insects, nationwide. The photographs are sent to Cornell for analysis, but participants get a taste of the thrill of zoology and the project mission is “to help children become confident and competent participants in science, identifying personally with science, so that we develop a generation of adults who are engaged in scientific discussions, policy, and thinking”. The data is also of interest because the nine-spotted ladybug has been in rapid decline since the arrival of alien ladybug species which, it was thought, would have some agricultural benefits. It seems that they did not. However, it has also demonstrated that the species was not extinct as some had feared. The question of data accuracy, in particular, remains open. John Losey, the creator of the project, has argued that the cost-effectiveness of citizen science data can outweigh data quality issues, if properly managed; that is a key issue.

Citizen Science projects also record larger animals, either in the field as at Glacier National Park, Canada where mountain goats, bighorn sheep and raptors are recorded by amateurs directed by Park staff. The recording of grizzly bears is apparently best left to specialists! Despite the rigour, not to say hostility of the high altitude environment, the project is less interactive than some others, and the data is not really displayed for general education. What is said is that ‘for citizen scientists, the rewards are a sense of stewardship, a greater awareness of the park's resource issues, and an expanded insight in ecological research methods. For the park, citizen science provides a wealth of baseline data that increases our understanding of priority wildlife and plant species. It also enables us to begin addressing the growing list of research and monitoring needs in spite of personnel and funding constraints.’ These are important issues of emphasis, to which I will return.

Turning to the Southern Hemisphere, and a different form of observation, Weddell Sea Seals are being counted by Citizen Scientists (‘from the comfort of your couch’), in one of a set of live projects that use the web to broker interactions between citizens, species and scientists. In this case, volunteers are being used to count seals appearing in 300,000 satellite images in key areas of the Southern Ocean where human overfishing of the Antarctic Toothfish is suspected. The Toothfish is a delicacy in Chile but the seals are partly dependent upon that food supply. The website offers up images which may be zoomed in on, and a click records the presence of a seal spotted from a great height. The records generated so far are estimated to have replaced eleven years work by a trained scientist. Whether it is possible to sabotage the system with multiple clicks on nothing, I have not investigated.

You can do a similar thing with penguins (and their chicks and eggs) too, depending on your species preference, working with Oxford University. In this case, static video-cameras are being used to monitor populations of various penguin species, and their place as top predator again makes them a good indicator of overall ecosystem health. There has been no shortage of volunteers to do this work, as we shall confirm later with other elements. Snapshot Serengeti uses hidden cameras based in Tanzania, but in this instance, volunteers are prompted to choose a potential type of animal that they see on the millions of images: ‘it looks like a giraffe’ for instance. Classification is fairly basic. If your tastes are more for the coldblooded and you have an hour to spare, you can assist the Natural History Museum in evaluating earthworm populations and soil health in the UK, or you can receive training as a member of an angling organisation to undertake kick sampling of stream beds to identify flies, as indicators of river health.

The flies project involved volunteer training, but a more complex operation is involved in the Bat Detective project. In this case, the scientists coordinate the collection of sound recordings, and thousands of citizen scientists use the spectrograms and some software to separate out bat calls from other noise, classify particular species and submit their findings. There is considerable judgement to be exercised as the bats emit different sounds when feeding, resting, flying and so on, and not all known species have been recorded. The project is based in the UK where some bats are known to be threatened with extinction, but specific programmes globally have been undertaken, for example the map shows results from the island of Madeira.

If we pause for a minute to consider the nature of these Citizen Science projects, and specifically the extent of volunteer engagement, there are clearly different levels of engagement. Haklay, and indeed others, have suggested a spectrum of possible participatory levels, from Level I, crowdsourcing, where people collect data, or allow their home computers to be used by scientists for processing large datasets. An example of that might be the ‘Lost Ladybug’ project, which is high on the level of excitement associated with the hunt, but where observers are not involved in judgements or analysis. The extent of engagement increases through Levels 2 and 3 where there are progressively higher levels of autonomy and judgement expected from participants, for example the seals and the bats projects, to Level 4. This top level is truly collaborative science where the projects themselves are co-produced by teams of specialists working with citizens, but projects of this nature have proved challenging to frame, and to deliver. The nearest I have been to this myself, was a project looking at communications between scientists and Local Authorities on the Rover Severn catchment, with a focus on flooding. It was called Project FOSTER, for reasons that may be obvious to a UK audience. For those of you who are not familiar with the nursery rhyme, ‘Dr Foster went to Gloucester in a shower of rain. He stepped in a puddle right up to his middle and never went there again’. The Local Authority people in Gloucestershire and surrounding counties set many of the parameters of the project, including what they wanted to know about flooding in order to be able to manage it effectively, and together we explored the optimum ways of developing mutual understanding of the issues and challenges.

Having pointed out the different levels of engagement 1-4, I think it worth noting that quite a few so-called citizen science programmes are lectures, not dissimilar to the Gresham series, but not usually with active involvement of the ‘audience’. Those, as you will be aware, have a different purpose, and are not actually ‘Citizen Science’. They are designed to spark an interest, and perhaps lead you to explore further in other contexts.

Returning to our elements, let us move on to ‘fire’, or specifically temperature-related Citizen Science projects. There are perhaps fewer of these than there are ecologically-related projects, but they do illustrate different characteristics. Some involve citizen volunteers spotting natural fires on satellite images, and reporting them to the authorities, in a similar way to the seals project. Also in this category, we might include postings of comparative photographs from volunteers recording such things as the position of glacier snouts in successive years – using the volunteers’ energies to access rather inaccessible locations. However, probably the largest example of Citizen Science in this realm is Oxford University’s Climate*Prediction*.Net programme directed by Professor Myles Allen. The home computing power of thousands of volunteers is being crowdsourced to run computer models that simulate the climate, producing millions of predictions of temperature, rainfall and the probability of extreme weather events in the face of increasing levels of greenhouse gases. The software is downloaded to your computer and the output trickles back to the University, typically over a period of days, or up to a month, to inform what are known as ‘ensemble’ climate models. Hundreds of thousands of runs of climate forecasting models are made, each slightly different from the others, but each plausibly representing the real world in the next hundred years. The totality is too large even for supercomputers, so each ordinary computer tackles one part of the larger problem, and the results are grouped together to show the range of possible outcomes. Volunteers are not involved directly in the synthesis of the data, although there is an educational aspect in explaining what is happening, but the number of participants is very large indeed. A more advanced course is sold to potential volunteers.

Clearly this work has a political context, but the other ‘climate’ element I want to show you is taking place in a highly charged environment. South Sudan is suffering from conflict, food shortages and drought. Using satellite imagery, volunteers can tag permanent dwellings (such as tukuls or circular-shaped homes) and the tents which suggest people are on the move with their herds of livestock. FEWS NET then uses this data set more accurately to assess the level of food insecurity in South Sudan. It is a worthy endeavour, but given the sensitivity of the data there are issues about the accuracy, precision, representativeness and so on, of the conclusions. Lives will depend on the policies that emerge from the exercising of judgements of volunteers, as to whether what they see is a permanent or temporary dwelling. It is also worth reflecting, as for all Citizen Science projects, about the costs and benefits of this approach in the longer term. Big questions such as whether volunteers should ‘steer’ such a programme, or whether the programme is diverting resources away from aid on the ground, raise their heads.

Turning to the element of water, the theme of water pollution monitoring by citizens is very common, but less usual is a Citizen Science project to determine the status of urban rivers, specifically their form and general habitat status rather than the detail of the chemistry of the water. Run out of Queen Mary College here in London, the project evolved and now forms the basis of some of the Environment Agency’s work on river habitats. Local citizen groups are trained to use logging sheets to look, for instance, at the background to proposed river restoration projects.

At a larger scale, FreshWater Watch is testing rivers and ponds for nitrate and phosphate content, contaminants arising largely (not wholly) from intensive agriculture, in the UK and elsewhere; you will note a bias towards Europe, but some African coverage, for instance. However, they also have a specific programme in the Thames area, from which the complex pattern of results is shown here. Interpretation is unlikely to be job for volunteers, except in a general sense. This is a hands-on project where volunteers collect and analyse the samples using basic chemistry tests, and there is a potential for error in the methodology. When it starts to generate comparisons across countries, as seen here (the long blue bars show exceedances of nitrates, and the orange ones for phosphates; the UK appears rather poor on both), then the issues of bias in sampling start to arise as these samples are taken mainly from ponds. Ponds in the UK are unlikely to be representative of the wider hydrological context, so interpretation and policy action emanating from this analysis might be suspect. The volunteers nevertheless enjoy the process of walking and working in a team, I am certain.

There are other projects that utilise more specialist services, this one on marine litter utilising the skills of volunteer divers, and written up in the Institution of Environmental Sciences Journal, a very accessible publication that I can thoroughly recommend and which is free online to everyone.

Finally, on water, at least one project in Oxford is running in a fully commercial form, to collect data from citizens using the Internet of Things to link together cheap sensors installed by volunteers on their property, using spare bandwidth in the television part of the EM spectrum. The Oxford Flood Network is suggested to fill in the data gaps between Environment Agency monitoring, as part of a ‘Smart City’ programme that would operate in times of flooding to provide information on what is happening very locally. The quote is interesting, as the founder of the company is keen to do this ‘without permission’, and it has resonances with the ‘urban explorers’ who venture up the sides of buildings and into tunnels to take photographs, again without permission. How the outputs will be sold, and to whom, is not yet clear.

There are projects that cross my ‘elemental’ boundaries, too. This one in the Peak District, ‘Moors for the Future’, has Citizen Scientists mapping habitats, groundwater levels, bees and butterflies, mammals and other wildlife on the ground. The volunteers are supported with monitoring guidance sheets, and the data is publicly displayed after collection, building up maps of habitat and habitat change. Sphagnum moss is a particular theme of interest, as a good indicator of hydrological conditions. WeSenseIt, a German project also covers multiple watery interests, but focuses on how the different sets of participants can be connected together effectively to ensure that policymakers are appropriately informed by Citizen Science.

Finally, and very quickly in this overview of a few projects, I want to mention the final ‘element’ air. Some people here will be aware that I lectured on air quality some months ago, and since then (not as a result, I don’t think) the subject has jumped up the political agenda in the UK, and internationally. I do not propose to cover that shift now, but I will just mention one Citizen Science programme that is being promoted for Kickstarter funding at the moment. This involves citizens purchasing a small sensor called SPRIMO that will apparently monitor the air by enhancing your mobile phone, and as well as giving your personal data about your exposure to pollutants, and collating data into a map based on many participants. Now, the potential for this being useful is considerable because standard monitoring systems are expensive, and air quality in cities such as London varies over very short distances. As I am sure most of us now know, it is generated principally from diesel vehicles, and peaks around major roads. However, the problem with this sensor is that it is going to be very inaccurate as a spot measurement, and also that it measures only gaseous parameters (I am unable to establish which ones) but not the tiny PM2.5 particles that cause most of the damaging health impacts. This project is currently seeking investment, and I am not an investment advisor but…

Let me now review what we can learn about Citizen Science. Firstly, why do scientists wish to engage volunteers in research (assuming that this is where research projects originate, which may itself be a questionable assumption in future realms)? Citizen teams may be cheap, well distributed across the world, able to capture multiple points of sampling (in space and time) and willing to take on physically challenging activities. Some scientists may have genuine educational and outreach commitments, and some are driven by their research leaders to engage with the public in some way. A report on this has been produced recently, that produced a template for scientists to evaluate whether or not their research might benefit economically or in other transparent ways from public participation. But there could be other potentially more sinister and hidden motives: power and influence, financial gain from sales or courses, and occasionally theft of ideas. Mary Anning, our 19th century geologist in Lyme Regis, for instance, as a woman was never permitted to present papers at the Geological Society, and was poverty stricken almost throughout her life, whilst the benefit of her labours and researches accrued largely to Anglican clergy ‘scientists’. She wrote in a letter: “The world has used me so unkindly, I fear it has made me suspicious of everyone.” Who could blame her?

On the other hand, why to citizens want to be Citizen Scientists? Motives can be divided broadly into two arenas: self-directed, and altruistic, although no doubt for many Citizen Scientists there is a mixture of both. On the self-motivated side, they may have a wildlife passion, be seeking education or personal development, be looking for a purpose in life, or just wanting fun and friendship (a sort of scientific dating agency). Some may be seeking financial reward or a surrogate, such as winning points in a competitive game. Altruistic motives include contributing to science, or supporting a cause or their local area. The extent to which they achieve these potential outcomes does, of course, depend on the participatory level of the project, and here is no doubt that most projects operate only at Levels 1 and 2 of the hierarchy, even our bat call analysts and urban river classifiers do not participate in setting the research agenda, though their training and skill level may be high. Crowdsourced data collection, or lending a computer to a project may yield some personal benefits, but perhaps not deeper understanding of scientific principles.

A recent report by Reading University has elaborated on the motives of scientists and citizen participants, producing a diagram that attempts to capture the balance of motivations for different types of sample project. In Scenario A, scientists are involved in the monitoring and citizens in the recording- our Songbird and drones project, for instance. Scenario B is a project where the citizens have an immediate interest in the data and the project’s impact on the local area, whereas the scientists have an interest in the educational aspects. The WaterWatch programme on water quality might be an example, or the worms project done in people’s gardens. The size of the bubbles represents the size of the interest. One would hope that ‘personal satisfaction’ was significant in every case, and even ‘fun’, though that latter appears not to be a criterion. There are other possible scenarios, of course, which can be judged from the websites of the different projects.

In evaluating the potential costs and benefits of Citizen Science projects, some fundamental principles of science have to be borne in mind too. The goals of scientific enquiry are to be objective, and universal. In some cases of Citizen Science, it is clear that objectivity is relatively difficult to achieve. People may be tempted to record a Weddell Sea seal when there really is not one present, for example. The Citizen Scientist really wants there to be one there. Our monitoring of the mass human migration following drought and war in Sudan is another example where it will be hard to ensure objectivity. Participants may have axes to grind, reflected consciously or unconsciously in what they record, or the accuracy with which they record it. They either hope to show that people are moving and a disaster is impending, or possibly they do not. The people wanting to win the points to become ‘Top Citizen Scientist’ in FreshWater Watch, might also have other motives for recording things, which mitigate against objectivity.

Universality may also be a problem, though perhaps no worse than for any other way of generating environmental science findings. Some sites, and indeed some species of animals - the cute ones - attract more interest than others. Some places are more accessible, including the Thames Basin, for instance, as opposed to the Highlands of Scotland or Central Africa. People are keen to be involved in research on ladybirds and goats, and even on the travel distances of garden snails that devastate their vegetable plots, and murmuration patterns of birds (those swirling crowds of starlings) as reported recently on the media in the UK. But they are not so interested in researching rats or bacteria one suspects, even though those are key elements of ecosystems.

At the worst, it has been alleged that Citizen Science can damage science research. At one level there are concerns from scientists about redirecting funding away from ‘core’ science, and disadvantaging trained scientists who can use sophisticated equipment, personally ensure the quality of their data, and communicate effectively (perhaps). At another level Goeschl and Juergens (2012, University of Heidelberg) suggest that improved Citizen Science monitoring can also have immediate and adverse effects on environmental quality. They suggest that if reporting (of localised pollution incidents, for example) by citizens’ increases, costs for industries and regulators will increase, whereas the social or environmental benefit does not necessarily increase accordingly. Put simply, regulators and industries become overwhelmed by addressing the breaches of compliance with water or air quality standards that are identified by citizens in specific locations that happen to be of particular interest to them. They become less efficient at delivering overall improvements in environmental quality. I have to say that this research itself is not expressed in a manner conducive to citizen engagement – one slide here sums up a particularly impenetrable part of it – but they may have a case.

Summarising simply, the potential disbenefits of Citizen Science are legion, and every project needs careful evaluation even if on balance the involvement of citizens in science appears to be of immediate advantage in cost saving or coverage of research areas. However, when considering the broader positive impacts for society, Bethany Brookshire writes: "If citizens are going to live with the benefits or potential consequences of science (as the vast majority of them will), it's incredibly important to make sure that they are not only well informed about changes and advances in science and technology, but that they also...are able to...influence the science policy decisions that could impact their lives.” Citizen science offers an opportunity to involve people more effectively with environmental policy decisions, avoiding some of the worst excesses of policy uninformed by evidence. As the placards in the science March in April suggested, ‘It’s time to react’ to environmental challenges. Even bearing in mind the mental and physical sweat, involvement in Citizen Science can be enormous fun too, for scientists and citizens. Let’s just do it.

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