Citizen scientists: school students conducting, contributing to and communicating ecological research – experiences of a school–university partnership

Pen-Yuan Hsing and the MammalWeb citizen science project

Abstract Started in north-east England in 2015, MammalWeb aims to improve our knowledge of British mammals through the use of motion-sensing camera traps. Fundamental to the project is the involvement of local communities and individuals who act as citizen scientists. They contribute to the collection and analysis of the camera trap photographic data. Here, we jointly describe our experiences as a partnership between Belmont Community School and Durham University. School students became citizen scientists and ecological ambassadors who took part in research and designed outreach materials for their local community. We discuss what we learned and the resulting mutual benefits.

Providing opportunities for students to experience authentic science in an academic research environment has been suggested to have positive impacts (Holman, Hickman and Leevers, 2016). They include developing learning and research skills and transferable proficiencies such as independence, self-esteem, resilience, decision-making and communication skills (European Commission and SOCIENTIZE Consortium, 2014: 51; Holman *et al.*, 2016; Archer, 2016: 23). Students' attitudes towards science are observed to improve and, as they become aware of STEM (science, technology, engineering and mathematics) career options, more consider pursuing a science career (Jones *et al.*, 2016: 54; Holman *et al.*, 2016). Such improvements are often more marked in students from traditionally under-represented groups (Jones *et al.*, 2016; Holman *et al.*, 2016). In addition, although practical work in general is not associated with any increase in science test scores (Organisation for Economic Co-operation and Development, 2016; Hamlyn, Matthews and Shanahan, 2017), higher science test scores have been noted for students who designed and implemented experiments than for their peers who did not (Jones *et al.*, 2016; Hamlyn *et al.*, 2017). As such, the Wellcome Trust and the Nuffield Foundation fund the publication of practical science activities (www.nuffieldfoundation.org/practical-work-science), and the Institute for Research in Schools (www.researchinschools.org) connects school teachers with national research programmes in the UK. In addition, a survey of 4000 14- to 18-year-olds at state-funded schools in England identified that 58% would like to do more practical work, which rose to 76% of those on a single-science programme (where students take an examined course combining biology, chemistry and physics and achieve one result at the end), and 53% would like to hear more about scientists' research (Hamlyn *et al.*, 2017). This suggests an appetite among students for more practical experiences.

Giving students the opportunity to become citizen scientists, where they become involved in the scientific process and actually contribute to research, is a means of enabling people to become active co-creators of authentic science (Irwin, 1995; Bonney *et al.*, 2009; European Commission and SOCIENTIZE Consortium, 2014: 51). Indeed, academic research is increasingly turning to citizen science for aid in data collection, classification, or even analyses (Kosmala *et al.*, 2016). While crowdsourcing data collection is just one form of citizen science, it potentially makes research more democratic and reduces the lag time between discovery and education (e.g. the Foldit project, Khatib *et al.*, 2011).

Here, we present an example of student citizen scientists, who, through a partnership between Belmont Community School and Durham University (both in Durham, in north-east England), contributed to a university research project while engaging their local community in the science. Belmont Community School (www.belmontschool.org.uk) is a co-educational state-funded secondary school for 11- to 16-years-olds, and Durham University (www.durham.ac.uk) is a highly selective collegiate research university, consistently ranked in the top 10 in the UK, and top 100 worldwide.

North-east England has the lowest student participation in higher education in the UK (Higher Education Funding Council for England, 2017: 25), and we wanted this partnership to (1) expose students to real-world science at a university and become aware of STEM career options; (2) let teachers gain experience to reignite a passion for their subjects and increase confidence and knowledge when discussing university research in the classroom; (3) allow researchers to crowdsource their science and broaden the impact of their work.

We believe our citizen science approach to a school–university partnership not only fulfils those goals but also empowers school students – through enhanced science learning and outreach – to be engaged citizens.

Citizen science ecological monitoring

The ecology-based citizen science project, MammalWeb (www.MammalWeb.org), was initiated in 2015 by ecologists in the Department of Biosciences at Durham University and the local Durham Wildlife Trust (https://durhamwt.com). This was in response to gaps in the monitoring of British wild mammals (Croft, Chauvenet and Smith, 2017) and as an investigation into whether the success of citizen science surveys for other taxa (such as the UK annual Breeding Bird Survey: www.bto.org/volunteer-surveys/bbs) could be replicated for mammals.

Mammals are elusive and often nocturnal, making them difficult to track. As such, the project uses motion-sensing camera traps to photograph different mammals as they pass. These cameras are set up and monitored by more than 70 citizen scientists representing local communities and schools. The citizen scientists upload the resultant images to the online MammalWeb platform where anyone with an internet connection can register to help classify the animals (Figure 1). As of March 2020, more than 310 000 image sequences and video clips have been submitted from 1250 sites, representing 225 camera-years of cumulative monitoring. Of those, over 216 000 image sequences and videos have been classified at least once by the 747 active classifiers on MammalWeb. We aim to aggregate input from multiple users for each image into consensus classifications on which further ecological analyses can be based (Hsing *et al.*, 2018). These records are then submitted to repositories including the Environmental Records Information Centre for the north-east of England (ERIC North East: www.ericnortheast.org.uk). MammalWeb's growing dataset could enhance understanding of our natural heritage by allowing analyses of wildlife diversity and its changes across space and time, which is important in light of rapid global environmental change.

In addition to quantitative analyses, data (in the form of classified camera trap photos) collected by MammalWeb

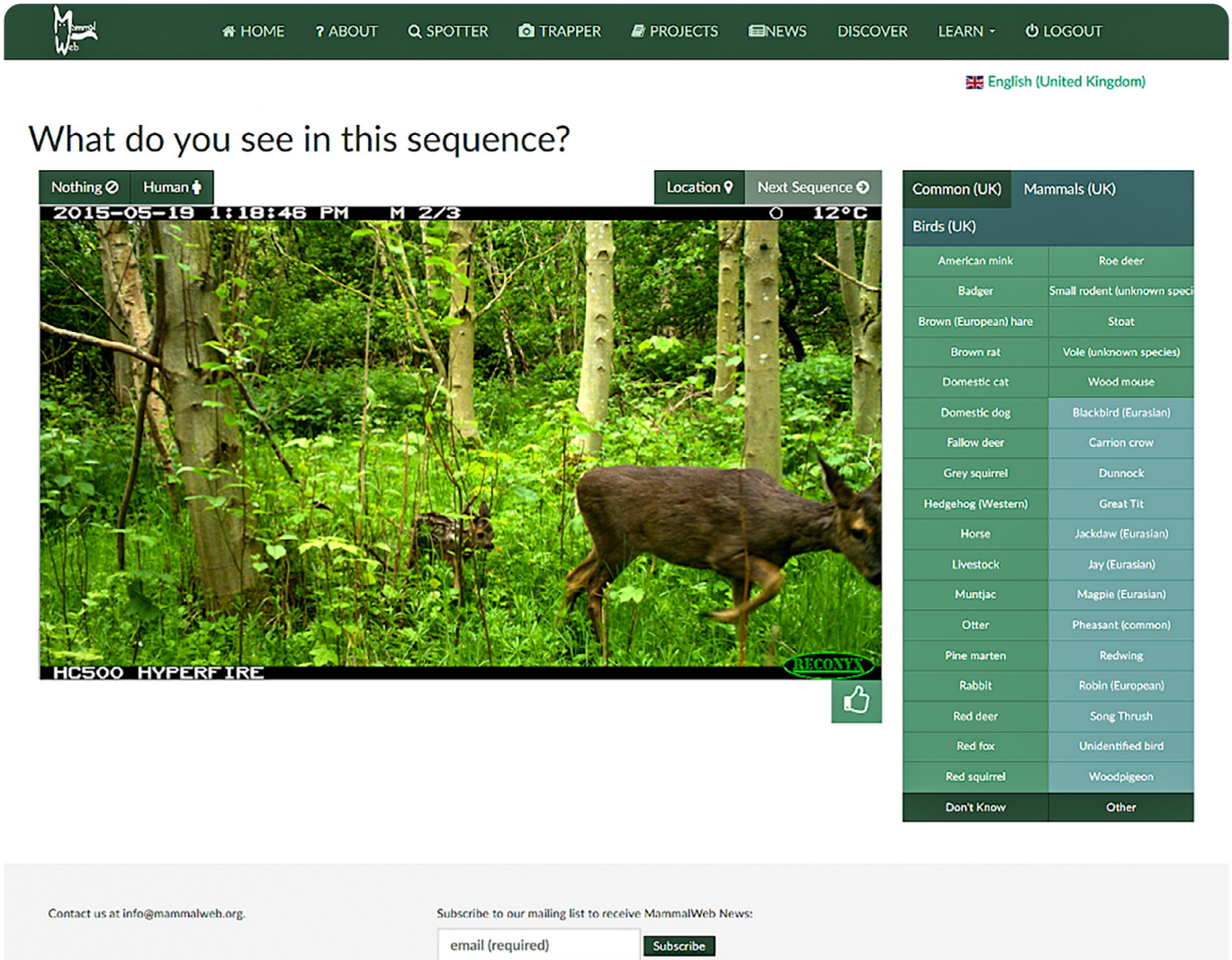

Figure 1 The MammalWeb web interface for camera trap photo classification; users choose from a scrollable list of options to indicate which animals they think are in each image

Figure 2 A non-native raccoon (*Procyon lotor*) as imaged by a motion-sensing camera trap operated by a MammalWeb citizen scientist

Figure 3 Student citizen scientists deploying motion-sensing camera traps in Rainton Meadows Nature Reserve

citizen scientists has led to civic engagement with tangible management outcomes. For instance, one of us (Roland Ascroft) used camera traps on a reclaimed colliery site at New Brancepeth (in County Durham, England), gathering over 74 000 images by autumn 2018. In addition to submitting these images to MammalWeb, he found 12 species of wild mammals, including roe deer (*Capreolus capreolus*), which reproduce annually on site. These results are now informing the planning of a local nature reserve in the area.

On another occasion, a series of camera trap photos revealed the presence of a raccoon (*Procyon lotor*), which is not native to Britain, in nearby Sunderland (Figure 2). Since MammalWeb citizen scientists follow a camera trapping protocol that includes careful recording of metadata (such as the precise date, time and location of camera deployments), the UK Department for Environment, Food and Rural Affairs (Defra) used MammalWeb data to locate the raccoon and transferred it to a local zoo.

Through the partnership between Belmont Community School and MammalWeb, we hoped that students would experience contributing to tangible scientific outcomes like these, and, more importantly, take ownership of sharing this experience with their community.

Student citizen scientists

Schools have worked with MammalWeb researchers in deploying camera traps and classifying photos. For example, the Durham Wildlife Trust engaged with four schools at primary and secondary levels on the project who viewed it as valuable engagement for the students in terms of the natural environment and technology curriculum. However, in collaborating with Belmont Community School, we built a deeper, sustained relationship, both for long-term ecological monitoring and in providing distinct experiential learning opportunities to a team of ten year 9 students (ages 13–14). The goal was to train, support and empower the students as seed 'ambassadors', who not only contributed to data collection but also conducted their own ecological outreach within their community.

Throughout the academic year 2016, MammalWeb PhD student, Pen-Yuan Hsing (supported by Durham University's outreach specialist, Dr Lorraine Coghill, and Belmont School's science teacher and lead practitioner, Mrs Julie Ryder), made bi-weekly visits to the school. These after-school, extracurricular sessions were initially focused on widening participation in the research, enabling the young people to gain an understanding of real-life science, including basic training on the deployment of camera traps for wildlife monitoring (Figure 3). This followed the camera trapping guidelines published on the MammalWeb website, which were informed by past citizen science camera trapping projects (e.g. McShea *et al.*, 2015). The students were encouraged to consider factors including location, set-up and security, thus developing ownership over the trapping. In tandem, they researched local wildlife and investigated already-captured images on the MammalWeb platform. Supported by an Outreach Grant from the British Ecological Society (www.britishecologicalsociety.org/funding/outreach-grants), the team visited a range of potential camera trapping sites beyond the school's immediate location to broaden the students' exposure to nature. This included the Durham Wildlife Trust's Rainton Meadows Nature Reserve (County Durham, England) where, crucially, the students took control and ownership of camera trap deployment. Other field trips included one to camera trapping sites at the Durham University Botanic Gardens. All activities were planned and conducted in accordance with health and safety regulations at Belmont Community School.

What the student citizen scientists learned

This section is an edited account written by the students – who are co-authors of this article – regarding their experiences deploying camera traps at the Rainton Meadows

Nature Reserve, where they obtained approximately 1000 wildlife photos.

Finding a location for camera traps

During the first visit to Rainton Meadows, we scouted the reserve for suitable locations for deploying our two camera traps. To ensure scientifically useful photos could be obtained for MammalWeb, we set the following criteria for the environment in which we positioned the camera traps:

- Avoid places with substantial human activity that could disturb the monitoring and where thefts of cameras were known to occur.
- Consider which animals we were likely to observe in the area.
- Ensure the camera's field of view is not obstructed by foliage or low branches.

We selected a location in the woods near a stream and not viewable from the pedestrian paths. Evidence of animals was spotted nearby, including bones, faeces, tracks and birds' eggs. The cameras needed to be low to the ground because we believed most mammals here were small, and the cameras' limited range meant placement was important. Although the cameras are water resistant, we placed them under the canopy of trees to minimise exposure to the elements.

Setting up a camera trap

Camera traps require a strong and freestanding object to attach to (usually a tree or fence post). In our case, this was a strong tree about 3 m from a stream. Considering the height of the animals likely to be in the environment, we placed our camera traps just below knee height.

To test the cameras' positioning, we initially set them to do a 'walk test'. While in this mode, a small red light on the camera flashes when an object moves in front of it, which identifies when a picture would be taken. Once satisfied with the cameras' angles, we armed them to take real photos. We then attached the cameras with a cable lock to the tree trunk.

The camera traps we used (Reconyx HC500) employ an infrared motion sensor that triggers when an animal passes by. We set the camera traps to take three images in quick succession on each trigger ('burst mode'). The camera resets within a minute after a trigger and is ready to take more pictures. We left the camera for three weeks.

Expected findings

During the period of research, in the weeks leading up to the day on which the camera traps were set at Rainton Meadows, we used information from previous sightings and our knowledge of the type of environment found there (relating to the habitat certain species require to live) to predict what types of animals we would be able to photograph. Some examples of the species we predicted to find were: rabbits (*Oryctolagus cuniculus*), deer, hedgehogs (*Erinaceus europaeus*), grey squirrels (*Sciurus carolinensis*) and small rodents (e.g. rats, mice).

Collecting the camera trap

After collecting the cameras, we uploaded their images onto a computer in order to observe our findings. We were delighted to discover that a large number of animals had been photographed, some of which were predicted beforehand. Multiple photos of rabbits, hedgehogs and grey squirrels were captured on both of the cameras as well as some birds (Figure 4). In addition, we were excited to find that multiple images of a red fox cub (*Vulpes vulpes*) were taken on several different occasions (Figure 4). Even though it was known that red foxes lived in Rainton Meadows, it was surprising to find them captured on camera. The data can be used to predict the paths of the foxes, what times they use these routes and the activity they may be partaking in at these times.

Students as ecological ambassadors

Crucial to the project was the ambition to encourage the students to become ambassadors for their research and engaging their own community. As such, later after-school sessions focused on facilitating the students' planning and design of ecological outreach. This took a student-led approach with school and university staff facilitating the process through a series of games, activities and training sessions that encouraged the students to develop their communication skills, taking different 'audiences' into consideration and exploring different engagement techniques.

The students decided to concentrate engagement efforts in three areas: (1) the development and delivery of interactive activities suitable for community events; (2) the development of educational materials for schools and public; and (3) the production of a short video to illustrate the project.

Commencing with the Belmont Easter Community Fair in March 2016 (Figure 5), the team (in self-designed T-shirts) ran a stall of activities aiming to engage visitors with their MammalWeb research and findings about local wildlife. The students demonstrated camera trapping and got people engaged in classifying images on the MammalWeb platform. They found that an animal poo

Figure 4 Animals observed with camera traps set up by Belmont Community School students; clockwise from top left: rabbit, grey squirrel, red fox, and hedgehog – these photos have been uploaded to MammalWeb for classification by other citizen scientists; the greyscale images were taken at night or in low-light conditions using the camera's infrared flash

identifying game (using models of wildlife scat samples on loan from the British Ecological Society) was particularly successful in engaging people of different ages, while their mammal Easter egg hunt absorbed younger children. The team adapted their activities and have since contributed to several community events, including engaging over 2000 people in one day at Durham University's public Celebrate Science festival in October 2017 (Figure 6). In addition to demonstrating the use of camera traps and running the poo game at this festival, the students showed and explained an activity they developed where

Figure 5 Student ecological ambassadors at the March 2016 Belmont Easter Community Fair

Figure 6 Student ecological ambassadors engaging visitors at the Celebrate Science festival in October 2017

participants learned about animals through using stamps representing their tracks. Evaluation from the festival highlighted the students' contributions, with several visitors naming it as their favourite activity, and multiple comments stating that it was '*great to see young people who are so knowledgeable and enthusiastic about science*'.

With support from the British Ecological Society, we worked with a local professional filmmaker to document these experiences, as well as presenting the MammalWeb citizen science project to a wider audience. The resultant 10-minute video is shared in full (https://vimeo.com/237565215) and in 1.5-minute versions (https://vimeo.com/237771257). The video and photos in this article are shared under the Creative Commons Attribution-ShareAlike 4.0 licence.

Lessons learned from citizen science collaboration between schools and universities

The core group of ten students who worked on the project were initially motivated by a general interest in wildlife and a desire to see animals in their natural habitat. After nearly 2 years of working on MammalWeb-related outreach activities, the key outcomes reported by this group of students were:

- Considerable surprise about the diversity of wildlife to which they were previously 'oblivious'.
- Excitement about participating in outdoors experiential learning, finally 'learning outside the classroom'.
- Satisfaction from contributing to a real and on-going citizen science project with broad impact.
- Enjoyment from doing the above in their local community.

Through conversations with Mrs Julie Ryder, teachers at Belmont School noted:

- Involvement in the Mammal Web project raised students' awareness of the valuable contributions young people can make to research. The increased understanding of the distribution of animals in the local area has been shared with the school and the families of those involved, spreading the information through the local community and well beyond the core group of ten students.
- Links made with Durham University – allowing students to contribute to research – have opened up the idea of education beyond school and the prospect of studying science at university.
- The students involved developed a real teamwork approach to solving problems, and showed that they are confident leaders who can interact with adults and students across the school and the wider community.
- Students have an increased enthusiasm to pursue science-related subjects beyond school, having broadened their experience of science-related work. They feel confident to take an active part in a range of community projects.
- Involvement in projects linked with Durham University is a vital part of the extracurricular provision they can provide for our students. Opening a window of opportunity for their students to work with the university is crucial if they are to increase the aspirations of their students.

From the perspective of researchers at Durham University:

- Crowdsourcing the collection and processing of data is just one form of citizen science, but it is helpful to researchers whose time and resources are limited.
- When ecologists work with multiple schools, they can expand the geographical reach of their surveys. Also, if there is buy-in from teachers then school partners can sustain ecological monitoring over longer periods of time when compared with individual volunteers, building long-term capacity.
- Citizen science projects such as MammalWeb – through education, outreach, and empowering citizen scientists – demonstrate the broader impact of research at universities.
- In the UK, universities are subject to evaluation by the Research Excellence Framework (REF; www.ref.ac.uk) with broad implications for funding. Citizen science projects allow scientists to demonstrate the impact of their research outside academia, which is one of the criteria in REF, while simultaneously collecting important data.
- Durham University has a stated goal of working more closely with the local community. MammalWeb is a successful case study of how Durham University researchers have achieved this with local citizens and students by joining them as co-creators of science.
- Working in partnership with young people and teachers provides a different perspective on the research, opening up new ideas and opportunities.

The project required a dedicated team to coordinate, and did experience delays and changes from the initial plans. From our experiences, we would advise the following if embarking upon a similar project:

- Identify dedicated key contacts from the school and the university. Many universities have outreach specialists whom a teacher can contact to initiate this process.

- Take time to understand each other and get to know what everyone wants to achieve. Be honest and understand what can be achieved, including discussing barriers and limitations (and possible ways to minimise them) such as time, staffing, budget and resources.
- Agree how to communicate and maintain regular contact. Keeping each other updated and informed of changes to staffing and activities ensures that the programme can be adapted to suit all parties.
- Carefully consider time implications. Running something like this does take additional time. We deliberately arranged our activities as an alternative science club in order to reduce time pressures, and we were able to pre-provide all documentation (e.g. risk assessments) to facilitate field visits.
- Be aware of scheduling issues. The time pressures and academic schedules of schools and universities do not always align. Include substantial buffer time to deal with delays.
- Be flexible. New opportunities can arise (such as our participation in the Easter fair) and unforeseen circumstances (such as sickness) can hamper involvement.
- Think carefully about the how the project is set up - it is important that the students can take ownership of the project and feel confident and empowered to contribute to discussions and take action (within the limits of the project). It is important to emphasise regularly that the project is a collaboration between all participants, that it involves real research and is not just a classroom exercise, and that their input is key. All involved adults should be made aware and supported with this too to prevent a more didactic approach, which alters the group dynamic and can impede full participation.
- For both the students and the wider group of citizen scientists contributing to MammalWeb, a major motivator is that they are conducting ecological research directly connected to their communities. This suggests that for a large-scale research project to involve schools, it is important to investigate and emphasise local relevance in order to sustain interest.
- Consider what additional partners could contribute. For example, the British Ecological Society supported the external visits by the school group (which we were not able to fund internally), but was also keen to provide additional resources and training opportunities. Organisations such as the Institute for Research in Schools also promote the integration of academic research in primary and secondary education.

Conclusion and future plans

We believe the MammalWeb citizen science project exemplifies the fruitful partnerships that can be formed between schools and universities. The mutual benefits and, in particular, the observed impact on the students as active, motivated and more confident learners, are felt to outweigh the time and organisational commitment required. The students are already working on developing the project further and the school has activated new programmes for other groups with different organisations.

Aspects of this project's findings have been presented at international conferences of the European Citizen Science Association, the British Ecological Society and the Ecological Society of America. Insights gained from the crowdsourcing of data collection and classification have been published in a peer-reviewed ecological journal (Hsing *et al.*, 2018). In addition, MammalWeb worked with the Great North Museum: Hancock in Newcastle, England, on a schools' outreach partnership with a network of 50 schools. We hope to develop MammalWeb into a wider educational network for ecological monitoring to fill the gaps in mammal monitoring. Interested parties can contact us (email: info@mammalweb.org) to discuss possible collaboration.

One challenge is how to integrate real-world science – such as the MammalWeb citizen science project – into the formal school curriculum if after-school extracurricular activities are not feasible or not desired. We believe that MammalWeb can complement the biology curriculum and develop numerical skills (e.g. statistics on species diversity, abundance, or temporal change) if data analyses are done as well. The design of camera traps and the MammalWeb web platform can tie into technology and computer science curricula. We are currently developing activity guides for educators with this in mind, and some educational resources are available via the 'Learn' item in MammalWeb's top navigation menu.

This partnership has also prompted broader contact between other schools and Durham University. For example, the Ustinov Global Citizenship Programme at the University ran an engagement event between postgraduate researchers and local teachers to develop joint programmes for school students. This has already led to several masters and PhD students (with subjects from psychology to social sciences) visiting those schools to engage young learners in the cutting-edge research being conducted at Durham University. We hope the MammalWeb case study can serve as a template for implementation of other successful school–university partnerships, the benefits of which may be far-reaching.

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