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Citizen Science in the Marine Environment, Scoping the Future – Part One

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1. Introduction

Since the founding of Porcupine, citizen science (CS) has been at the core of its activities (Woodward 1976) and its role in furthering the understanding of marine species and natural history. Earll *et al.* (2023) documented a number of the achievements made by citizen science since its inception in the UK, therefore, with Porcupine approaching its 50th anniversary it is timely to consider what the future of citizen science holds for work on marine natural history.

A great deal has been achieved in terms of understanding marine natural history over the last 50 years.

Our ability to collect and access information has improved massively, aided by the digital revolution and includes:

• The production of a number of marine atlases, one of the aims of early Porcupine members, e.g. molluscs and seaweeds;

• Online resources such as the National Biodiversity Network (NBN) highlight the distribution of our more common and better recorded marine species whilst the Marine Life Information Network (MarLIN) adds information on species traits and biotope character;

• The production of an international marine species checklist (WoRMS), which is in common usage;

• A description of the predominant biotopes (habitats & communities) occurring in our coastal and deeper seas (https://mhc.jncc.gov.uk/);

• New generations of published identification guides in colour;

• Marine ecology is now at the heart of many marine environmental assessments in relation to new development to take account of marine protected areas e.g. offshore renewable energy.

We need to fully recognise what we have achieved in order to set our thoughts on our future efforts.

Over the last 50 years, citizen science has come of age and developed enormously so that its aims and methodologies are now widely recognised across many environmental settings and by a wide array of national and international bodies. These are exciting times with lots of opportunities and ideas in development and it seems highly appropriate to explore these more fully.

This paper draws upon the backdrop of marine citizen science in the UK, a recent conference – *Marine Citizen Science Week* – sponsored by Natural England in March 2025 and the inputs of Porcupine delegates at the St Andrews conference not least on the social aims of citizen science.

This paper describes:

• What characterises Citizen Science? International and European Drivers – Models – Guidance (Section 2)

• The fundamental aims of citizen science – Scientific and Social aims – Questions being posed (Section 3)

• What are the marine environmental thematic topics covered by Marine Citizen Science? (Section 4)

• Citizen Science Methodologies – Current Challenges (Section 5)

• Some Aspects of Citizen Science relating to field work (Section 6)

• The Future of Marine Citizen Science: Porcupine's role - Emerging Trends & Opportunities (Section 7)

The aim of this paper is to start scoping how Porcupine members see citizen science so that they can play a full part in its future development.

2.What characterises Citizen Science? International and European Drivers – Models – Guidance

2.1 International and European Drivers

Whilst citizen science was once seen as the poor relation of traditional science, it would be fair to say that it has now come of age. Today citizen science is widely recognised internationally by institutions like UNESCO (2021) who describe it thus:

'*Furthermore, citizen science and citizens' participation have developed as models of scientific research conducted by non-professional scientists, following scientifically valid methodologies and frequently carried out in association with formal, scientific programmes or with professional scientists with web-based platforms and social media, as well as open source hardware and software (especially low-cost sensors and mobile apps) as important agents of interaction. For the effective reuse of the outputs of citizen and participatory science by other actors, including scientists, these products should be subject to the curation, standardization and preservation methods necessary to ensure the maximum benefit to all.*'

The European Citizen Science Association (ECSA) 10 Principles (2015) further help to describe how citizen science is seen and what it has become (Table 1).

Emma Lowe: 'When thinking about the future of CS, the ECSA principles should be a guide. Do all projects meet these principles, are the principles suitable for marine projects? Based on a global review of 74 marine projects, Kelly (2020) suggests these principles are appropriate.'

In addition to this background a number of other points are worth emphasising including:

i) *Traditional and Citizen Science*

Traditional or official science, funded by Governments, via research councils, agencies or corporate investment to researchers in universities, institutes or consultants is a model that is well established. In many instances however, there is *no* 'official' research on key environmental issues and the role of leadership in this context is often provided by environmental Non-Governmental Organisations (eNGOs) or academic societies. To put this more directly if there were no citizen science there would be no information.

ii) *Science with a Purpose*

Citizen science is now often framed strongly around the purpose of the project. The stronger the reasons the better the participation, e.g. action to address issues including biodiversity, environment (pollution), climate change.

iii) *Communication - the fundamental feature of citizen science*

A really significant difference between citizen science and traditional science is the absolutely fundamental role of two-way communication between project leaders and the people undertaking the project. No communication, no feedback, no citizen scientists (see Fig 1 below). Traditional scientists are becoming more aware of the value of citizen science and the importance of communication. In contrast there has been a growing trend since 2015 for Government, agency and consultancy research reports either not to be published widely or published under rules of commercial confidentiality. Citizen science research *has* to be communicated widely.

iv) *High levels of public participation at extensive geographical scales*

One of the major advantages of citizen science in comparison with traditional science is that by engaging large numbers of the public it is possible to gain huge numbers of observations (samples) at an extensive geographic scale. In 2025 600,000 people took part in the RSPB's Big Garden Birdwatch (BGB) across the UK in one weekend. There is no equivalent to this scale of assessment being available using traditional science.

v) *Continuity*

Some of the most successful citizen science projects are based on the benefits of continuity – development year on year – with their

Table 1: The European Citizen Science Association (ECSA) 10 Principles (2015)

Citizen science is a flexible concept which can be adapted and applied within diverse situations and disciplines. The statements below were developed by the 'Sharing best practice and building capacity' working group of the ECSA, led by the Natural History Museum London with input from many members of the Association, to set out some of the key principles which as a community we believe underlie good practice in citizen science.
1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leaders and have a meaningful role in the project.
2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the professional scientists and the citizen scientists benefit from taking part. Benefit may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes area.
6. Citizen science is considered a research approach like any other, (scientific project), with limitations and biases that should be considered and controlled for. However, unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.
7. Citizen science project data and meta-data are made publicly available and where possible, the results are in an open access format. Data sharing may occur during or after the project unless there are security or privacy concerns that prevent this.
8. Citizen scientists are acknowledged in the project results and publications.
9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright intellectual property, data sharing agreements, confidentiality, attribution and the environmental impact of any activities.
September 2015, London
From: http://doi.org/10.17605/OSF.IO/XPR2N

benefits accruing cumulatively. Much greater thought needs to be given to the issue of continuity with regard to marine citizen science projects.

2.2. Models of citizen science

Marine citizen science evolved significantly in the UK in the early 1970s (Earll *et al.* 2023) and was based on a simple organisational model developed by Frank Perring at the Biological Records Centre (BRC). Figure 1 illustrates the traditional *organisation led* citizen science model which highlights the role of the lead organisation – in particular in defining the question to be answered - the importance of communication and the diversity of audiences involved with making projects a success. The question setting, engagement and communication process was usually led by an eNGO, club or society and participants and members would be encouraged to send in their records, often on preprinted record cards to the organisers who would provide feedback and publish the results.

A number of models are set out below with differences in overall structure and emphasis including the following components:

- Leadership style: Corporate to individual;
- Scale of outreach to participants expected: Extensive to reduced;

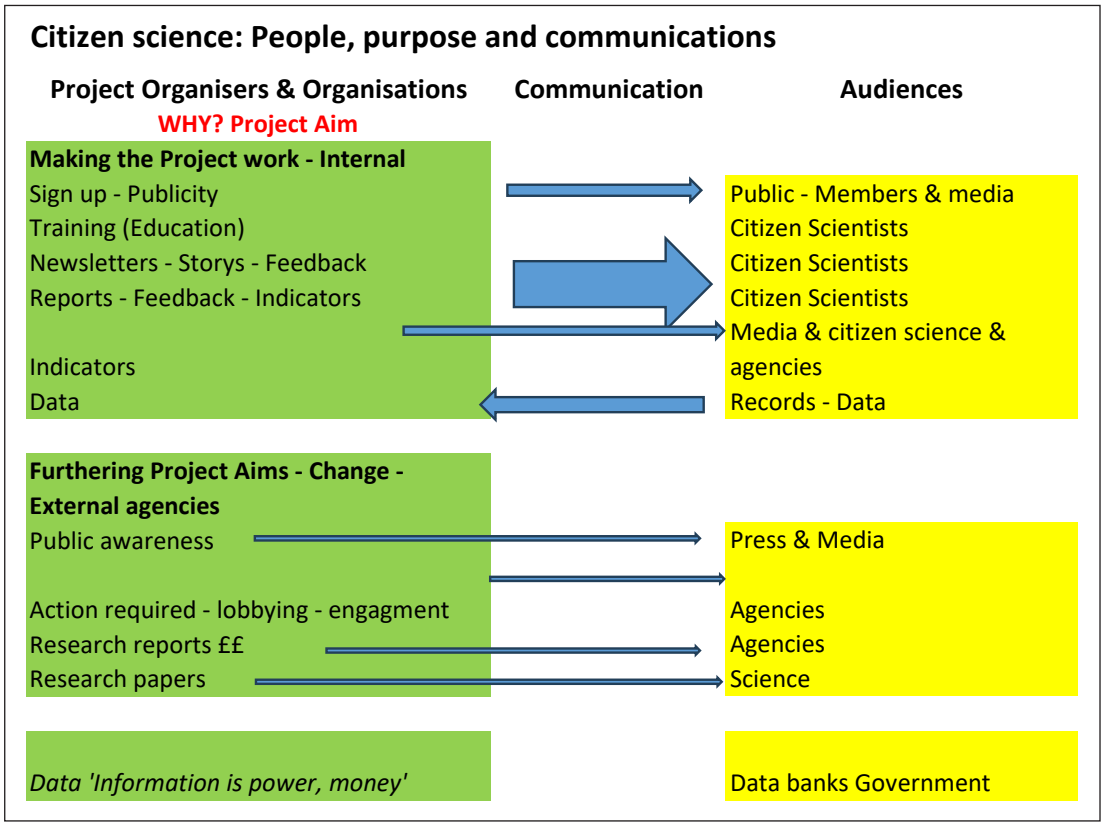

Fig 1: Citizen science and the relationship between organisers, the importance of communication and audiences, including CS participants

• Geographic scale of outreach: National, regional, local;

• Proactive projects and reactive projects to responding to *ad hoc* records;

• Scientific v social aims.

Emma Lowe 'On models of Citizen Science include those proposed by Bonney (2009) who suggested three categories:

i) Contributory projects where volunteers are involved primarily in data collection in a project designed by scientists;

ii) Collaborative projects which are also designed by scientists but offer additional opportunities for volunteers to be involved post data collection in activities such as data analysis or communication of findings;

iii) Co-created projects where scientists work together with volunteers to design a project and provide opportunities for the public to be involved at all stage of the scientific process.

Shirk *et al*. (2012) further suggest the inclusion of two more categories: contractual projects where communities ask professional research to conduct a specific investigation but play no role in data collection themselves and collegial contributions where non-qualified individuals conduct research independently with varying degrees of recognition by professionals. Community-based monitoring projects can also be identified by their governance structure either *Consultative, collaborative and transformative* as highlighted by Conrad & Hilchey (2011).

There are now many variations on the traditional CS model, facilitated in many ways by the digital revolution involving the mobile phone, using apps, digital photography and online recording systems. A number of variations are set out below, including:

i) Environmental NGO-led projects

Environment NGO-led projects driven by the desire to fill gaps in understanding of important species, communities or issues often at a national scale. Many of these projects are designed and lead by scientists albeit that they are based in eNGOs rather than universities or agencies.

Alistar Lyndon 'A good example of the eNGO model would be the BTO wetland bird surveys (WeBS counts) which are coordinated monthly across the UK and go back decades –this, along with RSPB BGB, are examples of NGO-led (so largely membership-led) exercises involving individuals across a wide area without necessarily any person to person contact – the common thread is the national organisation.'

ii) Hybrid projects between eNGOs and Government agencies

Hybrid projects between eNGOs and Government agencies where Government funding enables national scale projects and outputs to be channelled to desired outcomes such as putting information into data banks e.g. RSPB BGB or Seasearch.

iii) Community-led projects

A more recent variant on this is the development of *community-led* projects such as those being driven by the recent upsurge of interest in freshwater pollution. These projects are often run at a more limited geographic scale in relation to catchments, counties, estuaries or stretches of coast.

Alastair Lyndon 'Community-led citizen science which has a more local geographic focus, often based on connection to the locality (history, heritage, familial connection, social networks), the common thread being the community itself and its place/location. Such local community-led projects can, nevertheless, be connected across wide scales through over-arching bodies such as Coastal Communities Network (CCN), although there is often some disparity in what each group is aiming to achieve, resulting from differing local priorities. This poses a challenge in providing a coherent body of information at the large scale from community efforts.'

iv) Recording *ad hoc* observations

People interested in marine biology will often make *ad hoc* observations of interesting, novel species and communities and also of events during their activities. These are *ad hoc* records in the sense that there is no formal project or organisation which enables these observations to be recorded systematically. In the pre-digital era, the Underwater Conservation programmes (later to become the Marine Conservation Society) used a record card for *ad hoc* records which had the standard headings for location, date etc but left the observation field blank. The Observation scheme record cards (1000+ from the period 1978-1994) are now archived at the Marine Biological Association (MBA); three reports were published (UCS 1978,1986, 1987). The Observation scheme was also linked to a photographic project where participants sent their photos in for identification and cards were completed using these images. The mobile phone has also enabled *ad hoc* observations to be made more easily. Examples include:

- Social media platforms like Facebook have groups of people who are interested in particular species and share images of species e.g. nudibranchs or other seabed life, but there is no attempt to capture the information being shared systematically.

- iNaturalist, which encourages the observer to verify observations made but also once this process is complete automatically transfers records to data banks. Bernard Picton made the point that iNaturalist has a huge benefit in enabling people to communicate and make contacts across different countries with the ability to record spontaneous sightings of species rather than as part of an overall project.

- South-West Marine Ecosystems is a project which records annual change at a regional scale and it has routinely been used to publish verified *ad hoc* observations (Earll, 2024).

- Alastair Lyndon 'Seagrass Spotter app (https://seagrassspotter.org/) has been running for approximately 10 years and allows systematic retrieval of *ad hoc* seagrass location records globally using smartphone pics and GPS positions.'

v) Work undertaken by individuals

Porcupine has always supported the work of individuals – experts by experience – working both within organisations and independently. This category relates to many Porcupine members. This work, often of a very high standard, has made many contributions to marine biology and natural history. Often these individuals are key to specialist communities of expertise but without any overt wish to

engage or build a larger participation base or to run projects as such.

2.3 Guidance on methodologies

With the growing recognition of citizen science in the UK by the nature conservation agencies, guidance on methodologies has become more widely available covering CS in general and marine topics in particular. There is also a growing literature on the theory and application of CS to the marine environment. This section lists some of the key guidance publications available:

• NatureScot has provided a really good website https://www.nature.scot/citizenscience identifying a wide range of supportive material.

• A NatureScot handbook covering a diverse range of topics in relation to marine themes and projects https://www.nature.scot/funding-and-projects/community-led-marine-biodiversity-monitoring-project/marine-monitoring-handbook)

• The NERC Centre for Ecology & Hydrology and Natural History Museum – Choosing and Using Citizen Science – A guide to when and how to use citizen science to monitor biodiversity and the environment https://www.ceh.ac.uk/sites/default/files/sepa_choosingandusingcitizenscience_interactive_4web_final_amended-blue1.pdf)

• The NERC Centre for Ecology & Hydrology (CEH) and Natural History Museum (NHM) have produced a CS Best practice guide: https://www.ceh.ac.uk/our-science/citizen-science/citizen-science-best-practice-guide

• Roy *et al.* (2012). Understanding citizen science & environmental monitoring. Final report on behalf of UK-EOF. NERC Centre for Ecology & Hydrology and Natural History Museum. Natural History Museum, London, UK. Emma Lowe 'Mostly terrestrial but mentions that 14% citizen science projects at the time of the review focused on marine or coastal environments.'

• Data Archive for Marine Species and Habitats (DASSH) Online Citizen science guidance https://www.dassh.ac.uk/citizen-science/best-practice This looks like a really helpful guide to explaining how citizen science interacts with data requirements of data banks.

• Natural England commissioned work funded by the marine Natural Capital Ecosystem Assessment Programme (mNCEA) from 2022 resulting in a number of reports on marine citizen science projects (Tillin *et al.* 2022); problems with publication have meant that these reports are difficult to access. Further useful reports are in the pipeline and Katrin Bohn should be contacted for details (Katrin.Bohn@naturalengland.org.uk)

o Evaluating the Multiple Benefits & Values of Marine Citizen Science March 2025 by Michael J.O. Pocock, Rachel M. Pateman, Miranda Bane, Sarah Laptain, Erica Walsh, Rhys Archer.

o Frameworks for collaboratively monitoring nature and the environment – A guide for users.

o Marine Framework for collaboratively monitoring nature and the environment – in preparation - Natural England https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=21728

3. The fundamental aims of citizen science – Scientific and Social aims – Questions being posed

One of the key emerging developments of citizen science is that the primary aim of the project can be social rather than scientific. That is to say the social benefit is the main aim rather than the scientific output. This paper describes and acknowledges the social dimension of citizen science – see below - but is written from the perspective of science being the primary aim of the projects described.

3.1 Scientific aims – overview

This section develops some key points about the type of science being undertaken by citizen science. As Tansley put it, *'Every kind of scientific investigation has two stages – the descriptive and the analytical. We must first know clearly what the phenomena are – the things or processes we propose to investigate; and thus we must carefully observe and accurately record before we can proceed to find out how particular phenomena come about.'* Tansley (1945).

i) Description - 'Survey'

Many of the citizen science projects conducted in the past 50 years have been undertaken to map the basic distribution of marine species simply because those distributions were not based on recent data. Fifty years on we should be in a much better place in understanding distributions and ecology of our common marine life and be able to interrogate data banks to help us understand what we might expect to find when we visit sites around the UK.

ii) *Hypothesis testing – testing predictions*

You can explain anything after the event, i.e. what you found on your survey, however, science, once it has passed the descriptive phase, is very much about testing ideas. A good deal of science is based on previous observations, descriptions and clear understanding of key ecological details. Framing citizen science projects in a way to test predictions of what we expect to find based on what we know (or think we know) would be instructive, not least in assessing change over time periods. Data systems should be able to feedback such information based on decades of data.

iii) *Documenting trends - Monitoring*

Many marine citizen science projects document trends by year on year projects that are undertaken using the same methodology. The Beachwatch litter surveys conducted by the Marine Conservation Society are based on a worldwide methodology and have tracked litter pollution annually for over 30 years in the UK. The BTO garden bird watch uses a standard monthly protocol from over 11,000 observers to track the population changes in 40 of the more common garden birds highlighting both increases and declines on a national scale.

Whether citizen science can be used for monitoring marine species in the marine environment to the standard required by nature conservation agencies is open to debate, however issues of methodology and standardisation are also similar for professional monitoring teams. Given the ongoing financial constraints imposed by Governments on agencies it may well be that citizen science efforts are better than no assessments at all. Standardised methods – protocols – would seem to be a basic requirement for all monitoring studies. The basic lack of any data in the recent Tees crustacean mass mortality begs many questions of how less complex / eDNA routine monitoring of marine environmental health could work.

3.2 What are the questions marine citizen science is addressing?

Why? So what? What is the purpose of marine citizen science projects? What is the story to tell after the project is complete? The stronger the reason behind the project, the clearer the communication task and the easier it is to 'frame', to explain the purpose of the project. This can encourage recruitment *and* communicate a story when reporting the results to the participants. The following is a selection of questions posed by historic and recent citizen science projects which fall into a number of distinct categories:

Biodiversity:

- Conservation, restoration and recovery: marine protected area (MPA) assessments.
- Species ecology, protection, and management: Depth and geographic distribution of kelp, basking sharks, flapper skate – egg case hunts, seals, non-native species.
- Conservation measures: Measuring kelp depth profiles to support inshore MPA designation.
- Understanding change over time – monitoring – e.g. garden bird watch BTO, South-West Marine Ecosystems.
- MPA site assessments – e.g. Seasearch.
- The use of citizen science data to report annual change e.g. South-West Marine Ecosystems https://swmecosystems.co.uk/.

Pollution:

- Beached bird surveys.
- TBT and imposex in dogwhelks – and their absence from the seashore.
- Marine litter and plastic monitoring e.g. MCS Beachwatch.
- Water Quality – e.g. Catchment

Monitoring Cooperative https://monitoring.catchmentbasedapproach.org/– Rivers Trust.

• Using under-boulder surveys to monitor crab, echinoderm and fish species – in response to the Tees Crab mass mortality event.

There seems to be an obsession amongst people currently working in CS about data and data flows, whilst at the same time ignoring the reasons that motivate people that drive their engagement. Bill Gates (2025) puts this in perspective: '*This year marks 25 years since we started the Gates Foundation. Back then, we had a simple but ambitious goal: help more children survive and thrive. But at the time, even the most basic question—why are so many children dying?—didn't have a clear answer.' That's why I believe our most transformative breakthrough from the past two-and-a-half decades wasn't a single vaccine or invention. It was better data…*' (https://gatesventures.emlnk1.com/lt.php?x=3DZy~GDKKnKhEH8uyd-8h.Od3X2mjtD3jPZhYnnEUIKZ58Cszky.zeJs1I2iitE~jvYwZHfE). The ambition and motivation was to help more children survive and thrive – that came first and drove his projects not collecting data.

3.3 Social aims and dimensions

The social dimension has always been a key part of citizen science, not least among membership groups like Porcupine and specialist groups working together with a shared interest in birds, cetaceans, molluscs and algae. For many people the reward – the key benefit – is simply being on, near or in the sea. Social benefits were often seen as a secondary benefit and much less valued. The trend that is emerging strongly now is that citizen science projects also have very strong and clear social objectives, to the point where these are the primary objectives of running projects.

Emma Lowe puts it this way, 'The social side of CS is a must have not a nice to have. We do not have CS without participants and projects need to be wary of asking too much without a plan for supporting volunteers. How many projects are developed with a scientific query in mind and then fail because of the lack of volunteers? There needs to be inbuilt training, support and feedback provided to volunteers no matter if they are new or well known to the project. A training plan would also go a long way in encouraging use of data by others who may be sceptical on CS.'

Alastair Lyndon puts the importance of the social dimension as follows, 'we need to be clear that science and social science are not separate silos, but they should work hand in hand to achieve project outcomes and also provide multiple channels for communication and advocacy both inside and outside the project.

The points highlighted below illustrate some of the long-standing social dimensions and then moves on to those topics which are becoming key social objectives in citizen science projects. Given this change in priorities it would seem appropriate to also consider different linguistic frames other than citizen science.

Social dimensions include:

Friendship - all sorts of relationships have been built through communities of common interest in field work and membership meetings e.g. Porcupine, Seasearch.

Communication - modern citizen science requires a very clear understanding of various communication channels, including social media, working with difference audiences - volunteers, agencies and the media (Figure 1). Whilst professional qualifications in communication are now well understood scientists often lag behind in understanding the many facets that are essential to effective communication.

Language is powerful (Linguistic framing - Lakoff https://en.wikipedia.org/wiki/George_Lakoff - the power of language to frame what we are doing is vital. The Porcupine conference at which this discussion was facilitated highlighted several examples:

• Richard Birch: the language of science can be a barrier – a form of academic 'nepotism' – or patronising to the public. We need to open out the communication of scientific publications for more general consumption.

• Emma Lowe, Framing: My comment at the time was about framing – using the

phrase *community* science rather than *citizen* science. Language is powerful. An explanation of using community rather than citizen science is given by McAteer & Flannery-Power (2022)

- Chris Rickard: Shark and Skate Scotland dropped the 'citizen' part of their name.

- Alastair Lyndon: Framing: Show us your mussels – a very appropriate and direct title of a citizen project on the distribution of the common mussel *Mytlius edulis* in the Firth of Forth.

Motivation and recruitment of citizen scientists 'McAteer *et al.* (2021) highlights that people tend to fall into four categories of citizen scientist, namely, volunteer activists, conservationists, professionals and hobbyists. What they each get out of volunteering will differ. Whilst the value of labelling individuals by their volunteer type is open to debate, if we try to understand more about the types of volunteers drawn to a project it will be useful in project development, in recruitment strategies, communicating results and understanding social outcomes.' *(Emma Lowe)*

Social legacy *Alastair Lyndon* pointed out that 'The main legacy of projects may be the creation of communities and increase in social engagement.' The creation of the Marine Conservation Society from the Underwater Conservation programmes of the late 1970s is a perfect example of such a 'social' legacy resulting from citizen science.

Communities of practice Given developments with virtual meetings and social media it may well be that Porcupine can play a more active role in facilitating specialist groups – communities of practice https://en.wikipedia.org/wiki/Community_of_practice - that look at particular taxa.

Projects with a stronger set of social objectives often relate to:

Wellbeing Projects which encourage people in to the environment and onto the seashore e.g. the Rock Pool Project https://www.therockpoolproject.co.uk/, have been increasingly recognised as being beneficial to health and the ideas around social prescribing have arisen from this. No doubt, over time, there will be a clearer breakdown of the issues and demographics that help us understand issues of wellbeing and CS.

Emma Lowe 'There are positive and negatives here. Yes, there is increasing evidence to support that 'time in nature' is beneficial for wellbeing and health but counter to that is volunteer fatigue which links back to recruitment and retention of volunteers.'

Ocean literacy and the promotion of environmental awareness in order to promote pro-environmental thinking and to greater levels of ocean literacy. The first ocean literacy strategy developed by the Marine Conservation Society led by Ffion Mitchell-Langford collaboratively with many Welsh agencies is an example of how this field is developing, https://www.mcsuk.org/news/uks-first-ocean-literacy-strategy-launches/.

Advocacy, activism and community empowerment

Three points illustrate the role of CS in broadening of advocacy, activism and empowerment beyond the traditional eNGO role:

i) *Activism by project participants*. In many settings, not least in the field of water pollution, citizen science initiatives are seen as closely linked to environmental and ocean advocacy – activism *by the project participants*, not just the project organisers.

ii) *Community empowerment*. There is work being carried out to support community decision-making and empowerment. But the future of CS needs to consider how to do this effectively, taking account of the wider issues, without expecting communities to do too much. (*Emma Lowe*)

iii) *eNGO lobbying & activism by organisations* Non-governmental environmental groups have always used information from citizen science to lobby and advocate for change to environmental policy.

Ethics 'Another point to consider is the ethics of using the data collected. As volunteers help collect data, they have a valid stake in the ownership of the data and how the data is used. Ensuring full transparency

of what happens to the data would seem appropriate but how many projects have a strategy in place to ensure this? There are also questions to be asked on how to acknowledge volunteers, particularly in the case of academic papers. What is the threshold for co-authorship for citizen science volunteers? We need to recognise that volunteering is a transaction, citizen scientists give away their time for free and those leading projects should find ways to give back to their volunteer base. Showing participants through actions that their contributions are valued would also give volunteers a sense of ownership and improve retention of volunteers.' (*Emma Lowe*)

Social science, project recruitment and education 'It is really important to acknowledge that the social aspects, particularly of community-led projects, are a highly effective recruitment tool for increasing engagement with the scientific aims, especially for children and those with a non-science background, who can be scared off by the assumed technicalities and maths awareness that 'science' is often perceived as requiring. Through Edinburgh Shoreline (https://edinburghshoreline.org.uk/) and Restoration Forth many people who did not engage directly with science-based elements of the project initially have become engaged after involvement through social/arts/heritage aspects, which have then exposed them to the scientific aspect and helped them realise the 'science' is not scary or beyond them and they can contribute effectively. This links closely to the 'Limpetarium' and 'Maerl Immersion' presentations from the 2025 Porcupine St Andrews Conference.' (*Alastair Lyndon*)

4. What are the marine environmental thematic topics covered by Marine Citizen Science?

The marine science community categorise the way they describe and study the marine environment in a systematic way. Table 2 illustrates the sets and subsets of this classification in terms of the thematic topics covered. A number of key points can be made about this classification:

i) There are two main categories of thematic topics:

- Natural systems/natural capital topics: oceanography, plankton, seashore and seabed, fish, coastal birds, turtles, seals, cetaceans. Single species, species groups, biotopes and multi-species site assessments
- Management topics: Plastic pollution and marine litter, water quality, site assessment for development or MPAs

ii) Thematic topics - the basis of statutory, regulatory and policy requirements. The sets and subsets of the thematic topics outlined in Table 2 are also used to assess the various regulatory and policy requirements. Work underway on the UK marine science, policy and regulatory landscape is building a coherent view of this relationship.

iii) Scientists and methodologies - It might seem obvious but it is clear that the scientific methodologies to study thematic groups are often very topic specific, and the community of scientists working on these themes are often highly specific to those topics. In relation to citizen science this means that methodologies and data requirements will be closely linked to professional marine scientists working on these topics.

iv) Citizen science and thematic topics - As was amply illustrated by the programme content of the Porcupine St Andrews (2025) conference Marine Citizen Science covers the full range of taxa, biotopes and a number of 'management' issues. Earll (2024) described how marine citizen science covering all the major natural system sets is being used by South-West Marine Ecosystems (https://swmecosystems.co.uk/) to describe annual changes in the marine environment.

v) Recognising Bias - Given how individuals view their specific interests in marine biology and CS projects it is not surprising that there is often a bias in the perspectives of what constitutes marine citizen science. This bias is real. It is important for Government and its agencies to fully understand the broad scope of the thematic topics covered by marine citizen science.

vi) Natural England Marine Framework - Natural England is working on a table of thematic topics. This exists in draft, but it is unclear when it will be published.

Table 2: Citizen Science and Thematic Topics, Sets, Sub-sets and Notes for Natural and Management Systems

Thematic Topics - Sets	Topic Subsets	Notes
Natural Systems		
Oceanography	Chemical – nutrient fluxes, salinity, sewage pollution	Porty Water Collective (fb and Instagram) Surfers against sewage (SAS) www.sas.org.uk
	Physical – storms, rainfall	
Plankton	Phytoplankton	Algal species (blooms)
	Zooplankton - Gelatinous	Jellyfish, salps; MCS Jellyfish survey https://www.mcsuk.org/what-you-can-do/citizen-science/sightings/jellyfish-sightings/
	Zooplankton	
Seashore	Coastal habitats (terrestrial)	
	Estuarine species	
	Estuarine habitats	Example: saltmarsh, restoration projects e.g. managed realignment
	Marine intertidal species	Intertidal seagrass (CLP Nature Action, Fife) The Shore Thing; CoCoast (Capturing our Coast)
	Marine intertidal (biotopes)	e.g. under-boulder communities; Edinburgh Shoreline https://edinburghshoreline.org.uk/; The Rockpool Project www.therockpoolproject.co.uk
Seabed	Sublittoral plant – species	
	Sublittoral animal species	e.g. oysters, restoration projects Restoration Forth consortium = various community groups
	Sublittoral biotopes	e.g. kelp, maerl, seagrass. (Restoration Forth consortium = various community groups); https://sussexwildlifetrust.org.uk/helpourkelp
		Moray Ocean Community (MOC); MaCCOLL
Fish	Agnaths	
	Elasmobranchs	Sharks and rays The Shark Trust; Great Eggcase Hunt https://www.sharktrust.org/greateggcasehunt, Basking shark observations https://www.sharktrust.org/basking-shark-project
	Teleosts – pelagic – water column	
	Teleosts – demersal – seabed, benthic species	Examples: Sturgeon https://uksturgeonsightings.org/?page=Home, seahorses https://www.theseahorsetrust.org/
Turtles	Turtle strandings and at sea	http://www.ukturtles.online/

Birds	Estuarine species - waders	BTO WeBS counts
	Coastal breeding species Rock (e.g.kittiwakes, auks) and sediment (e.g.plovers, terns)	Chesil Little Tern project (and others e.g. Langstone Harbour)
	Marine species & Seawatching e.g. Shearwaters & petrels	
Seals & otters	Grey & Harbour Seals, otters	Cornwall Seal Research Trust https://www.cornwallsealgroup.co.uk/
Cetaceans	Toothed whales	Dolphins & sperm whales; Hebridean Whale and Dolphin Conservancy; Manx Whale and Dolphin Watch; Orca Watch – The Seawatch Foundation & ORCA https://www.seawatchfoundation.org.uk/orca-watch-2025-volunteer-scheme/
	Baleen whales	Forth Marine Mammals; South West Marine Ecosystems Hebridean Whale and Dolphin Conservancy; Manx Whale and Dolphin Watch
Multiple marine species	Cornwall Wildlife Trust (CWT) Strandings network https://www.cornwallwildlifetrust.org.uk/what-we-do/our-conservation-work/at-sea/marine-strandings-network CWT Seaquest https://www.cornwallwildlifetrust.org.uk/what-we-do/our-conservation-work/at-sea/seaquest-southwest	Individual animals, cetaceans and seals and wrecks of marine life stranded. Seaquest – Timed observations of mobile species from fixed vantage points
Freshwater		SmartFly river monitoring and Riverfly Monitoring Initiative(supported by Freshwater Biological Association
Management Topics & Human activities		
MPA & Proposed development sites		Baseline recording by Seasearch divers
Water Quality		Catchment Monitoring Cooperative https://monitoring.catchmentbasedapproach.org/ – Rivers Trust
	Chemical contaminants	
	Nutrients – land based sources	
	Organic enrichment: sewage. Inc. storm water overflows	
	Oil pollution	e.g. Beached bird surveys - RSPB
Litter & Plastic Pollution	Plastic pollution	e.g. Beachwatch – MCS, and multiple collection projects

5. Citizen Science Methodologies – Current Challenges

The previous sections of this paper describe key aspects of methodology and this section explores some of the current issues facing marine citizen science. Many of these topics are relevant for both CS and professional marine science.

i) Data systems overview

At the St Andrews Porcupine conference (2025) several conversations on data arose and Charlotte Bolton has agreed to write an article for a future Porcupine Bulletin on the current arrangements concerning data systems. The article will signpost the data landscape and help us understand how we should be engaging with the various systems and describing how these fit together. The points made here, which have been discussed with Charlotte Bolton, relate to CS – data issues in general including:

• Are there preferred data systems for records of all the diverse range of marine thematic topics e.g. seaweeds, birds and cetaceans? (Table 2).

• How are existing data systems supposed to work for *mainstream projects* e.g. Seasearch or Shoresearch?

• How are data systems supposed to work for *ad hoc records* – which arise routinely via social media?

• Are these systems fit for purpose?

• Does NBN work effectively for marine? On at least three occasions in St Andrews NBN was mentioned with negative connotations

• In moving to citizen science projects which test what we already know, will data banks be able to make such predictions accessible e.g. site, or regional species lists?

• What access should project organisers or ordinary recorders expect to existing records?

• Should there be an 'access test' for users wishing to submit records and to gain access to the records?

Charlotte Bolton 'The Quality Assurance (QA) step should NOT be underestimated, and the importance of appropriately experienced verifiers will be emphasised in my data article. The NBN annual awards now recognise this through a specific verifiers award. An awful lot of CS projects fail because of misidentification, thus downgrading the entire project on the basis of "dodgy data," and a lack of appreciation of the importance of QA.'

Data Archive for Marine Species and Habitats (DASSH) has recently published an interactive report on citizen-science/best-practice from their data perspective (DASSH, 2025). This information looks really helpful but it does not seem to have been shared more widely until very recently (April 2025).

ii) Logistics of citizen science events - safety – codes of practice – risk assessments

Citizen science in the marine environment can be challenging in a variety of ways depending on whether projects are near, in or on the water. In this respect the marine environment poses very different challenges in comparison with, for example, an armchair participant in Garden Birdwatch. Organisers have always had to address a range of issues in terms of safety and risk assessments and insurance and these are now widely accepted. The circumstances of these differ in terms of whether citizen science is being done in organised groups or whether, as is often the case, recorders are working in their own way and independently. Would more guidance for marine citizen science project organisers covering these issues be helpful?

iii) The current challenges facing diving

In its halcyon days of large, club based sports diving in the UK and light touch regulation of scientific diving in the 1970s and 1980s the participants in citizen science were members of sports diving clubs diving under their own volition and organisation – in other words – not organised by the citizen science organisation. Safety, risk insurances etc., were covered by their sports diving organisation. Diving has always faced issues of safety and insurance but currently these issues are being voiced more strongly and routinely and challenged by regulatory bodies. This topic arose in the St Andrews meeting inputs in terms of:

• Fewer sports divers taking part in citizen science (Bernard Picton)

• The grey area between professional and citizens science diving projects (Alistair Lyndon)

• Issues arising from deeper diving (Tim Clement)

iv) Identification guides

With both new and old technologies, and the growing impact of digital photography, there will be a continuous need to develop guides that enable citizen scientists to identify what they are seeing. There is thus a need for colour guides that work on live animals *in situ*, as well as online tools for laboratory identification after specimens have been preserved. The development of more sophisticated eDNA approaches to identification is a challenge to support in environmental field work contexts.

v) The impetus of new technologies

The speed with which 'new' technologies are being developed and applied to marine science opens up many new ways that citizen scientists can contribute, such as:

vi) eDNA Ground truthing – for example using citizen scientists as sample collectors over large geographic scales

vii) Artificial Intelligence (AI) to monitor individuals in populations e.g. skates, rays and seals

viii) Routine use of videos from GoPros and similar cameras

ix) Use of drones

x) Reviewing camera footage (e.g. baited camera traps) from long deployments

These technologies will provide new insights into our understanding of marine natural history and will provide a wealth of material for presentations and papers. How these technologies will impact on citizen science remains to be seen.

6. Some Aspects of Citizen Science relating to field work

Porcupine's habitual activities relate to field meetings covering intertidal and sublittoral ecology and which coincide with some wider issues discussed below which arise from these activities and relate to citizen science as a whole.

6.1 Field meetings – 'bioblitzes' of multiple species at sites

Jon Moore 'Organisations have developed the bioblitz idea of intensively exploring the species and biotopes of a particular site. Porcupine has an extensive list of field meetings and publication relating to these sites [https://pmnhs.co.uk/meetings/previous-conferences]. Records from these meeting have been uploaded via Marine Recorder on to the NBN. Projects such as Seasearch and Shoresearch have also been accumulating species records. We have been doing this for over 50 years and should by now have a pretty good understanding of the distribution of a large number of intertidal and shallow sublittoral species around the UK. One might now question the purpose of additional site visits (section 3.2), beyond the enjoyment of participants for finding and recording in places they hadn't been to before.

Answers to that question can point to the additional knowledge on distribution of species for which there are relatively few records (due to rarity, small size, cryptic nature and/or tricky identification), on distribution of species that are vulnerable to change (i.e. at the edge of their biogeographic range) and on the local abundance of species of interest (e.g. of conservation priority or sensitive to anthropogenic impacts). Once entered into NBN these data are available to anyone to be searched and analysed, now or in the future. Additionally, the simple act of putting a bunch of marine life enthusiasts together on a shore always results in questions, ideas, inspiration and education.

Nevertheless, the limited structure or protocols applied to typical bioblitz surveys creates data that rarely attract much attention. The length of the species list can be impressive, but without any particularly clear purpose or question as a focus so that anyone who wasn't part of it might say 'so what?'.

In recent years Porcupine has developed its

field meetings to provide more structure and purpose. Advance preparation has included collation of existing records for the nominated site / area, discussion with individuals who know the site and its habitats and understanding the skills and interests of the expected participants. This typically generates questions (e.g. why no records of x?), target lists of species and possibilities for knowledge exchange between participants. Recent meetings have requested participants to look out for particular species (e.g. ones close to the edge of their range and likely to be affected by climate change), pay particular attention to certain habitats, give show and tells on particular taxa, provide instruction on survey techniques and equipment and demonstrate new cameras.'

6.2 Protocols for specific taxa and biotopes

To provide a clearer purpose for work in the intertidal and sublittoral it would be helpful to have more focussed methodologies – with detailed protocols - aimed at answering particular questions, not least so that the results – feedback – can be given to citizen scientists more directly. Citizen science in the intertidal environment, despite easy access to an interesting environment, has had a very patchy history. Discrete protocols to assess particular taxa or biotopes – rather than the entirety of the shore populations - could be one way to both maintain interest and develop the consistency of results that nature conservation agencies require for their monitoring. Four examples:

i) **Recording barnacles**

Herbert (2025 PMNH Bulletin No 23) describes his work on the Alderney Porcupine field trip comparing the results of surveying common barnacle species between samples taken in 1956 and 2024. For this he used a recognised abundance scale from Crisp & Southward (1958) in a study that looked at the changes in these species in relation to potential climate change impacts.

ii) **Single species protocols**

***Mytilus* in the Forth**

Alastair Lyndon 'The Firth of Forth shoreline is divided up into 1 km squares covering the whole area. Volunteers select a square from the Edinburgh Shoreline website (the allocation of squares is viewable, so that new surveyors don't pick an already allocated square). They are then asked to walk the shoreline in their square searching for mussels (*Mytilus edulis*) around low tide; record position (using What Three Words app), take a photo, measure the min, and max length of mussels seen and whether they have barnacle encrustation or not. This information is then uploaded via a website form. This is aimed at mapping distribution and size structure of the Forth mussel population over a wide area and a short time period to assess current status in the context of an apparent decline.'

iii) **An intertidal under-boulder protocol?**
In 2023 there was a mortality event at the mouth of the Tees and adjacent coastal areas when only crustaceans died. No monitoring science was available to explain what normal crustacean populations were like in the area, and the post-event science was unable to explain the cause of the mass mortalities. The development of an intertidal under-boulder protocol which could be undertaken by citizen scientists is being discussed as a way of providing routine background information on a variety of crustacean, mollusc, echinoderm and fish species. Few, large and conspicuous species are involved and the results could be communicated quickly in terms of the environmental health of particular sites in a standardised way.

iv) **Sublittoral kelp population protection and recovery**

In 2021 Sussex Inshore Fisheries and Conservation Authority (IFCA) received support from Government and passed a byelaw which sought to protect inshore kelp forests from damage by mobile fishing gear. Since then the interest in the distribution and recovery of kelp species has risen enormously among conservation groups in the UK. The first sports diving project in the UK was organised by David Bellamy in 1968 – Operation Kelp. A protocol to survey the depth distribution of common kelp species would both provide an insight into the status of these keystone

species whilst also helping support other conservation measures.

6.3 Verification through large numbers of samples

Quality assurance and quality control are key aspects of CS however the very scale of CS projects can help with this. One of the major opportunities of citizen science is that large numbers of pairs of divers or small groups studying a seashore (as with the Porcupine field meetings) can be viewed as separate samplers of a particular 'site'. If such samples are combined it is possible to get a clear picture of the species diversity of the site including common and rarer species, and a measure of 'abundance' as a function of the number of time species / biotopes were recorded by the different sampling groups. This process was used to test various scenarios by pairs of divers at the marine station at Millport (Earll 1983). This process also has the virtue of helping to integrate expert inputs, verify records and highlight misidentification outliers.

6.4 Plankton studies and citizen science

In a PMNHS article Elizabeth Beston (2024) describes The Plankton Project highlighting making more people aware of the marine environment and plankton is a key part of her thinking. The 'Plankton Manifesto' https://unglobalcompact.org/library/6242 covers this on an international scale. Recording plankton has not been a common activity for citizen scientists, but there are now a number of people including Julian Cremona (Pembrokeshire) and Andrew Powell (Dorset) routinely making records. There is considerable scope to collaborate to see if plankton studies can become a more routine part of marine citizen science activities.

7. The Future of Marine Citizen Science: Porcupine's role - Emerging Trends & Opportunities

7.1 The future role of Porcupine in Citizen Science

In March 2025, Natural England funded a conference called Marine Citizen Science Week. Two events ran simultaneously in Plymouth and Whitley Bay and involved 40+ organisations. Porcupine was not formally involved or represented. One of the outputs of this conference was a call for there to be an organisation which supported marine citizen science in the UK. The Coastal Communities Network act as a support group and exists in Scotland – see References.

The thing that binds Porcupine members together is a strong shared interest in marine natural history and seeing species in the marine environment. Porcupine has a long history of promoting marine citizen science. Any role Porcupine might take in any future national organisations is open to debate. Porcupine can continue to provide a valuable support to furthering CS in the marine environment through:

- *Bulletin* articles highlighting both specific projects and discussions of more general issues of topical interest e.g. data, and new technologies
- The PMNHS conferences are closely linked to the *Bulletin* but provide a platform to discuss the issues raised in this article, such as data, the role of protocols to assess and report thematic topics, the role of eDNA etc.
- By providing a platform for different voices especially on thematic topics relatively new to citizen science, such as plankton observations (Beston, 2024). Porcupine could encourage more formal communities of practice to consider taxa such as nudibranchs or plankton. Given the ease with which iNaturalist operates Porcupine could formalise some of these groups.
- Field visits could also provide a test bed for developing protocols that provide specific outcomes and guidance which would be of wider interest and application.

7.2 The Future of Marine Science: Emerging Trends – Opportunities

This paper sets the scene for more detailed articles on a range of topics in marine citizen science. This article is by no means complete – hence the 'Part One' of the title. The trends and opportunities of citizen science in the marine environment is changing rapidly.

- There is a clearer picture of the role of citizen science in the context of traditional science and a wider recognition by international and

regional forums of the role CS can play. This recognition includes guiding principles e.g. ECSA.

• There is a clearer understanding of the underlying models which can be used to take projects forward and harness information collection, as well as a growing level of helpful guidance and publications on many aspects of citizen science.

• Citizen science in terms of its scientific aims is similar to science in general and we should be moving on from the descriptive phase of applications to help resolve higher profile environmental questions in relation to biodiversity, environment, climate change and resource use.

• The growing recognition of the social and societal elements of citizen science is raising the profile of CS projects, not least through higher profile social objectives of projects.

• There is now a growing awareness of the different models of citizen science and their value. Whilst traditional organisation led models prevail, community-led projects are also becoming commonplace. There is a need to have greater awareness and clearer pathway to gaining and utilising *ad hoc* records of marine species and events from social media sources.

• There should be a wider recognition of **all** the major thematic topics in the way marine citizen science is framed and promoted, recognising the topic specific methodologies.

• There are a wide range of methodological issues, not least new technologies, that will provide topics for discussion and future developments.

• Field work continues to pose challenges in terms of the scope of species records to be collected and the need for protocols for certain taxa and biotopes.

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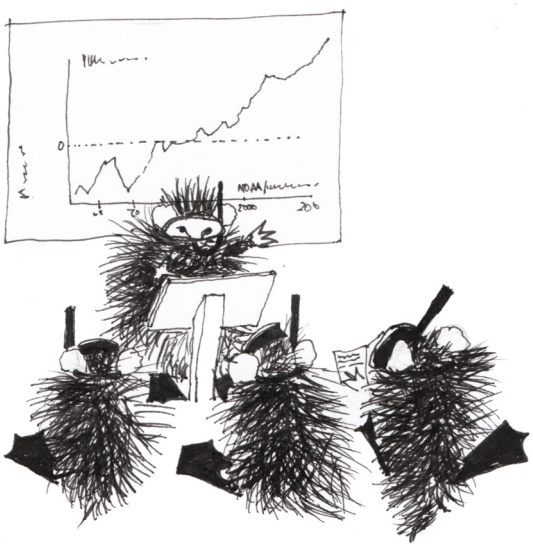

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