Advancing Citizen Science

for Coastal and Ocean Research

Position Paper 23

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Advancing Citizen Science for Coastal and Ocean Research

European Marine Board IVZW Position Paper 23

This position paper is a result of the work of the European Marine Board Expert Working Group on Advancing Citizen Science for Coastal and Ocean Research (WG Citizen Science - see list of WG members on page 104).

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Foreword

The participation of the general public as a means of collecting large amounts of data on a given scientific subject has been in use in terrestrial research, and to a lesser extent in marine research, for some time. Citizen Science, however, goes far beyond this, sitting firmly in the realms of co-creation, co-exploration and co-management. It is a research methodology which, if used correctly, offers huge potential to, not only further scientific knowledge and understanding, but also to educate and empower society, to develop and implement policy, and to inspire future generations.

The ocean is generally perceived as vast, unknown and unconnected to the daily lives of ordinary citizens. This challenge is being addressed by the ocean literacy movement which seeks to inform people of the role of the ocean in their lives and how their lives impact on the ocean. “Marine Citizen Science” stands at the interface between ocean science and ocean literacy. It is a means by which science and society can work together for mutual benefit, through a partnership between marine scientists and the general public. Given the vast scale of the ocean and the obvious limitations in terms of numbers of scientists active in marine research, there is enormous potential to harness the enthusiasm of interested citizens to contribute to the collection and analysis of data and the delivery of knowledge and information. However, this must be done with a clear understanding of both the potentials and constraints of Citizen Science, which is an area of research in itself.

In a European context, the recent growth of Marine Citizen Science is timely. The focus of policy and research is now, more than ever, directed towards understanding the changes that are occurring in ocean systems, appreciating and mitigating the impacts of these changes, and achieving sustainable blue growth. Marine Citizen Science has the potential to not only influence the environmental impacts of society through behavioural education and knowledge, but also to empower citizens to engage constructively in the development and implementation of truly fit-for-purpose and evidence-based maritime policy.

The development of Marine Citizen Science and increasing the extent of its usage cannot be achieved by one level of stakeholder alone; it requires uptake and action from stakeholders in science, policy and civil society at all geographical scales, from local to international. Taking a European perspective, this paper aims to provide new ideas and directions to stimulate further advancement of Marine Citizen Science. While addressing a wide readership in general, the paper targets policy- and decision-makers, citizen science coordinators and the scientific community in particular. The paper takes a broad perspective, using lessons from other fields and the experience of the experts. It seeks to identify opportunities and barriers, illustrate best practice, and sets out a list of high-level strategic recommendations for the future development of Marine Citizen Science in Europe.

On behalf of the EMB membership, I would like to extend my sincere thanks to the members of the EMB Citizen Science expert working group (Annex 2) for their dedication and hard work in producing this comprehensive paper. Particular thanks must go to the working group Chair, Dr. Carlos Garcia-Soto, and Co-Chair, Dr. Gro van der Meeren, for their leadership, drive and enthusiasm, ensuring delivery by the working group of a high-quality paper and a valuable and timely addition to the EMB position paper series. I gratefully acknowledge the efforts of working group member Jane Delany in editing and refining the final document text. My thanks also go to the EMB Secretariat, in particular to Veronica French, Paula Kellett and Niall McDonough, who worked very hard and efficiently to support the work of the group and finalization of the paper. I am hopeful that this paper will provide the impetus for a new level of coordination and growth in Marine Citizen Science in Europe. This can be a powerful tool in generating new knowledge of ocean, seas and coasts which will be essential for a more sustainable use of these precious environments in the future.

Jan Mees
Chair, European Marine Board IVZW

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Executive Summary

Citizen Science is an approach which involves members of the public in gathering scientific data and, in more advanced cases, also involves them in the analysis of such data and in the design of scientific research. Benefits of this approach include enhancing monitoring capabilities, empowering citizens and increasing Ocean Literacy, which can itself lead to the development of environmentally-friendly behaviours. There is a long history of citizen participation in science as a general concept. However, the process of studying and understanding the best ways to develop, implement, and evaluate Citizen Science is just beginning and it has recently been proposed that the study of the process and outcomes of Citizen Science merits acknowledgement as a distinct discipline in its own right.

Considering the vastness of the ocean, the extensiveness of the world's coastlines, and the diversity of habitats, communities and species, a full scientific exploration and understanding of this realm requires intensive research and observation activities over time and space. Citizen Science is a potentially powerful tool for the generation of scientific knowledge to a level that would not be possible for the scientific community alone. Additionally, Citizen Science initiatives should be promoted because of their benefits in creating awareness of the challenges facing the world's ocean and increasing Ocean Literacy.

Responding to this, the European Marine Board convened a Working Group on Citizen Science, whose main aim was to provide new ideas and directions to further the development of Marine Citizen Science, with particular consideration for the European context.

This position paper introduces the concept and rationale of Citizen Science, in particular regarding its relationship to marine research. The paper then explores European experiences of Marine Citizen Science, presenting common factors of success for European initiatives as examples of good practice. The types of data amenable to Citizen Science are outlined, along with concerns and measures relating to ensuring the scientific quality of those data. The paper further explores the social aspects of participation in Marine Citizen Science, outlining the societal benefits in terms of impact and education. The current and potential future role of technology in Marine Citizen Science projects is also addressed including, the relationship between citizens and earth observations, and the relevance of progress in the area of unmanned observing systems. The paper finally presents proposals for the improved integration and management of Marine Citizen Science on a European scale. This leads to a detailed discussion on Marine Citizen Science informing Marine Policy, taking into account the requirements of the Aarhus Convention as well as the myriad of EU marine and environmental policies.

The paper concludes with the presentation of eight Strategic Action Areas for Marine Citizen Science in Europe (see summary below with details in Chapter 4). These action areas, which are aimed not only at the marine research community, but also at scientists from multiple disciplines (including non-marine), higher education institutions, funding bodies and policy makers, should together enable coherent future Europe-wide application of Marine Citizen Science for the benefit of all.

Strategic Action Areas

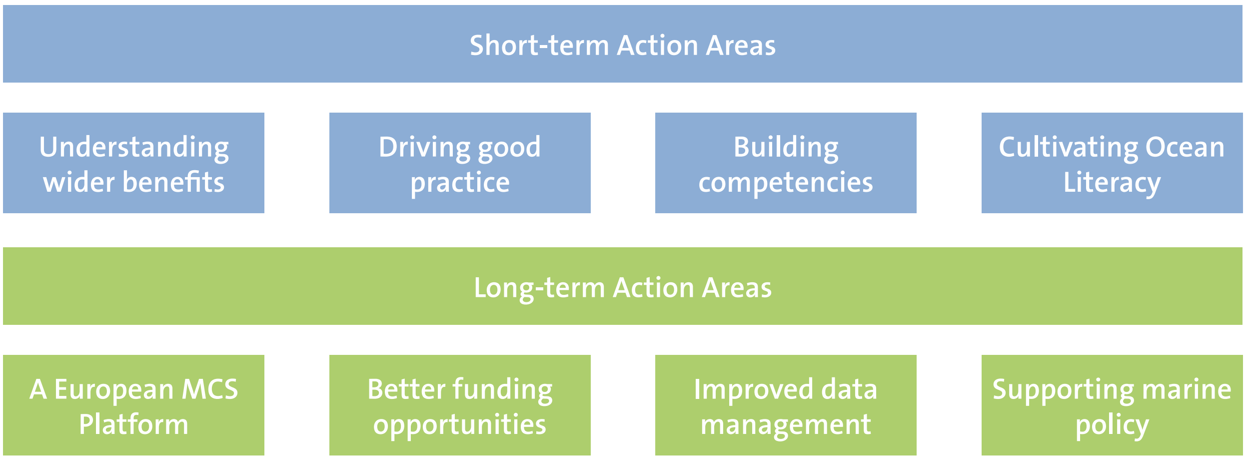
The eight proposed strategic action areas can be summarised as:

Shorter-term action areas:

1. Driving good practices at European level
2. Understanding the wider benefits of Marine Citizen Science for marine research and policy
3. Cultivating Ocean Literacy
4. Building competencies across multiple disciplines

Longer-term action areas:

5. Launching a European Marine Citizen Science platform
6. Empowering Citizen Science to support marine policy
7. Improved funding opportunities
8. Facilitating efficient management of citizen-generated data



Strategic action areas for progressing Marine Citizen Science in Europe

1
An Introduction to Marine Citizen Science

Credit: © John Rafferty Photography / Marine Photobank

There is an ever-growing need to further knowledge and understanding of global ocean systems, and hence to gain insight into the impacts that climate change and other natural and anthropogenic influences have had, and will have. Given the sheer geographic scale of the ocean and coastal areas, and the wealth of information they hold, it would be impossible for marine scientists to gather all these data alone. Involving citizens in marine science research can offer a means of overcoming these issues, while at the same time furthering education and Ocean Literacy amongst the general public. This chapter will introduce the concept of Citizen Science and present the rationale for its use in marine scientific research.

1.1 What is citizen science?

Citizen Science is a term used to refer to scenarios where members of the general public, typically in collaboration with professional scientists, collect and/or analyse data relating to the natural world. In marine applications this could involve data from coastal areas, open sea areas, including information on the water itself and on the wealth of life found there.

The Citizen Science formula is simple: to give people a structured way to record their observations and share them with scientists. It does not end here, however; Citizen Science is a process where citizens can become an integral part of the sharing of results and findings within the wider community and the interaction is very much a two-way process. Some of the benefits include enhanced monitoring capability, empowerment of citizens and increased environmental awareness. Considered a relatively new field, the process of studying and understanding the best ways to develop, implement, and evaluate Citizen Science is just beginning (Shirk *et al.* 2012), and it has recently been proposed that research on the actual processes and outcomes of Citizen Science merit acknowledgement as a distinct discipline (Jordan *et al.* 2015).

Putting the theory of Citizen Science into practice relies on cooperation between a range of experts and non-experts, which involves interdisciplinary public engagement, education and data collection (Jordan *et al.* 2015). The interaction between public participants and scientists for the purposes of scientific research can take varying forms, ranging from contractual projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results, through to more interactive approaches where public participants contribute data and may also be involved in project design, analysis and the dissemination of findings (Shirk *et al.* 2012).

The review by Thiel *et al.* (2014) of 227 peer-reviewed Marine Citizen Science studies, demonstrates that volunteer-generated data has contributed information about population dynamics, health and distribution of marine organisms, harmful algal blooms (HAB) and jellyfish blooms, marine litter, and has supported long-term monitoring programmes of Marine Protected Areas (MPA's). Examples of successful Marine Citizen Science projects in Europe include the Italian programme 'Occhio Alla Medusa', during which a new species of jellyfish was discovered; it attained high

Chapter 1 cover image: Green crab (Carcinus maenas) on the Irish Coast media profile (featured twice in Time magazine - (Time 2009; Time 2010)- including once as a cover story), along with a number of scientific publications (e.g Boero *et al.* 2009; Boero 2013). Other examples of projects are highlighted throughout this paper, with a non-exhaustive list of Marine Citizen Science initiatives in Europe provided in Annex 3. There are instances of synergies between marine projects, such as Citclops, My Ocean Sampling Day (MyOSD) and Coastwatch Europe, where mutual benefits are derived from the enhanced profile and greater reach that partnering brings, with a consequent multiplier effect for results than can be achieved.

1.1.1 Rationale

The value of Citizen Science lies in its ability to contribute to scientific knowledge, the benefits for education, its societal value and its value for policy making (Science Communication Unit - University of the West of England, 2013).

Citizen Science is able to make significant contributions to marine science where the available human resources limit professional scientific activities, i.e. where there are limited numbers of marine scientists; and thus capacity, to carry out scientific studies. Considering the vastness of the ocean and the diversity of habitats, communities and species, proper understanding of this realm requires intensive research over time and space. This recognition should lead to increased consideration of Citizen Science as a powerful tool for the generation and spread of scientific knowledge (Thiel *et al.* 2014). It is, however, noted that a Citizen Science approach may not be suitable for every scientific study. Pocock *et al.* (2014) present a decision support framework to help guide those considering this approach.

Citizen Science initiatives should be promoted because of the benefits in introducing the day-to-day working lives of scientists - their motivations and challenges, creating awareness of the threats facing the world’s oceans, and increasing Ocean Literacy. Concerns have been raised about current gaps in Ocean Literacy, the importance of marine systems to life on earth, the impacts of climate change and the part that humans are playing in creating such change (e.g. Gelcich *et al.*, 2014). Many excellent Marine Citizen Science projects have awareness-raising and education at the forefront of their aims. However, the balance of addressing such aims with those of producing quality scientific data should always be considered, or the activity is purely educational, and not Citizen Science in its true sense (Pocock *et al.* 2014).

A Citizen Science project can contribute to the changing of attitudes and behaviours, bringing about stewardship for the marine environment. Participation and collective sharing of goals can serve to promote community spirit and build social capital. Society benefits if it is one in which science, protection of the natural environment and social cohesion are valued. A recent EU report on environmental Citizen Science (Science Communication Unit - University of the West of England 2013) summarised the key challenges and opportunities facing Citizen Science as a whole, as seen in Table 1.1.

Table 1.1 - Summary of the key challenges and opportunities provided by Citizen Science (Science Communication Unit - University of the West of England 2013)

KEY CHALLENGES AND OPPORTUNITIES PROVIDED BY CITIZEN SCIENCE	
Challenges	**Opportunities**
Recognition of scientific value	Timely data from disperse sources
Maintaining scientific rigour and data quality	Power to address large knowledge and funding deficits
Involvement of Citizen Scientists representing a broad spectrum of society	Educating public about environmental policy issues such as biodiversity
Political and financial guarantees for action on findings	Participatory democracy

Credit: Petra ten Hoopen

Fig. 1.1 Family sampling at My Ocean Sampling Day 2015

In order to bring these challenges and opportunities into guiding good practices for Citizen Science projects, the European Citizen Science Association (ECSA) developed ten principles of Citizen Science (European Citizen Science Association 2015):

1. Citizen Science projects actively involve citizens in a scientific endeavour that generates new knowledge or understanding;
2. Citizen Science projects have a genuine science outcome;
3. Both the professional scientists and the Citizen Scientists benefit from taking part;
4. Citizen Scientists may, if they wish, participate in multiple stages of the scientific process;
5. Citizen Scientists receive feedback from the project;
6. Citizen Science is considered a research approach like any other, with limitations and biases that should be considered and controlled for;
7. Citizen, Science project data and meta-data are made publically available and where possible, results are published in an open access format;
8. Citizen Scientists are acknowledged in 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 activity.

As alluded to in the above principles, and as laid out in the Aarhus Convention (United Nations Economic Commission for Europe 1998), citizens have a right to participate in environmental decision-making and hence to be involved in advising, developing, and implementing marine policy. Citizen Science participation can be a channel through which citizens exercise this right. Bottom-up initiatives and policy development, supported by scientific evidence, and addressed by local communities to tackle local issues in a way which is appropriate for their needs, can enable the development of more successful and sustainable outcomes. By facilitating members of the public to address issues that directly affect them - at local, national and global scales - it provides opportunities to influence decision-making about these issues. As Citizen Science comes of age, its focus should be turned increasingly to addressing those global challenges for which data is so urgently needed.

1.2 Why there is a specific need for Marine Citizen Science

The benefits of Citizen Science are well documented in the burgeoning academic literature on the topic and have been outlined in the previous section.

Our seas and ocean provide the vast majority of the available living space on the planet. There is a widespread reliance of global society on the marine environment. More than a third of the world's population live in coastal areas, even though these account for less than 4% of terrestrial land. Our ocean system is one of the most diverse, productive and yet highly threatened ecosystems on Earth (Laffoley & Baxter 2016). It has been disproportionately impacted by anthropogenic activity and associated climate change effects. Ocean warming represents more than 80% of the change in the energy content of the earth's climate system over the last four decades with concomitant changes to global climate, precipitation, salinity and hydrodynamics. This hydro-climatic forcing, coupled with overfishing, pollution, habitat loss, increased connectivity and invasive non-native species (INNS), has led to profound changes in marine ecosystems with an unprecedented loss in native species and habitats.

There is already a plethora of initiatives pertaining to the marine environment, to which members of the public have contributed (Thiel *et al.* 2014), a number of which have achieved significant global coverage though novel approaches, appealing initiatives and the use of technology platforms. However, there can also be difficulties in achieving initiatives on this scale. Citizen Science from the marine domain has lagged behind its terrestrial counterpart (Roy *et al.* 2012; Theobald *et al.* 2015), and relative to wider spatial and long-term integration of terrestrial initiatives, it is often piecemeal and fragmented. There are several reasons why this may be so.

The most obvious is that the majority of the marine system is inaccessible to the majority of people and while some projects have overcome this by bringing offshore habitats and issues into the public realm, it stands that nearshore, coastal and intertidal habitats predominate marine participation projects. The figure below, from (Thiel *et al.* 2014), presents the relative proportions of Citizen Science studies relating to different marine areas.

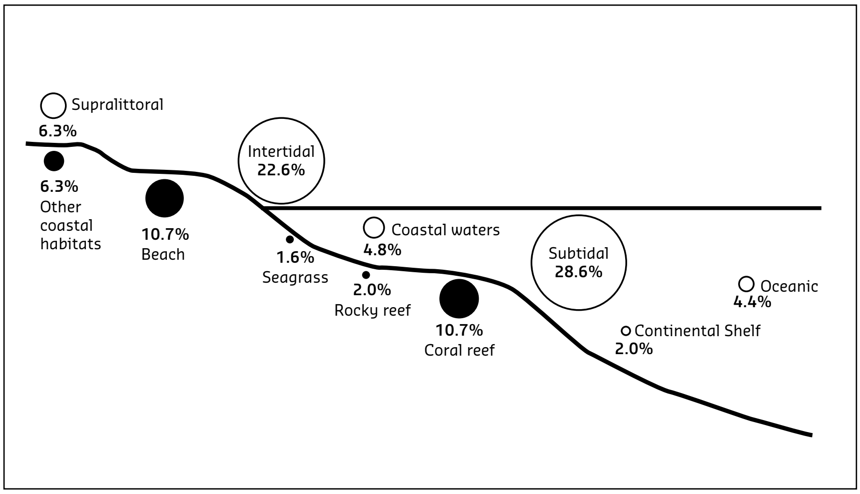


Fig. 1.2 Relative proportions of marine studies with volunteer participation in particular habitats and depth ranges (Figure 4 from Thiel *et al.* 2014).

The second factor may be due to the lesser extent to which a community of naturalists and recorders already exists for marine life in comparison to terrestrial flora and fauna. While specific species or objects such as fish, seabirds, shells and marine mammals have captured the imagination of “amateur” naturalists for generations, many taxa have garnered less attention. This can be attributed to two challenges that are not so apparent in terrestrial environments. The first is the aforementioned inaccessibility; the second is that there is not such a tradition of sharing knowledge and observations amongst those who do have access to these environments, such as the commercial sailing and fishing communities. In fact, in these sectors, the commercial advantage that such information could provide is undermined once it is shared and hence it may not always be forthcoming (Maurstad 2002). This may be why there have been fewer high impact studies on, for example, the impacts of climate change supported by volunteer data in marine contexts. Citizen Science initiatives can, of course, take steps towards overcoming these hurdles by providing training (e.g. in taxonomy) and highlighting the mutual benefits of sharing traditional knowledge.

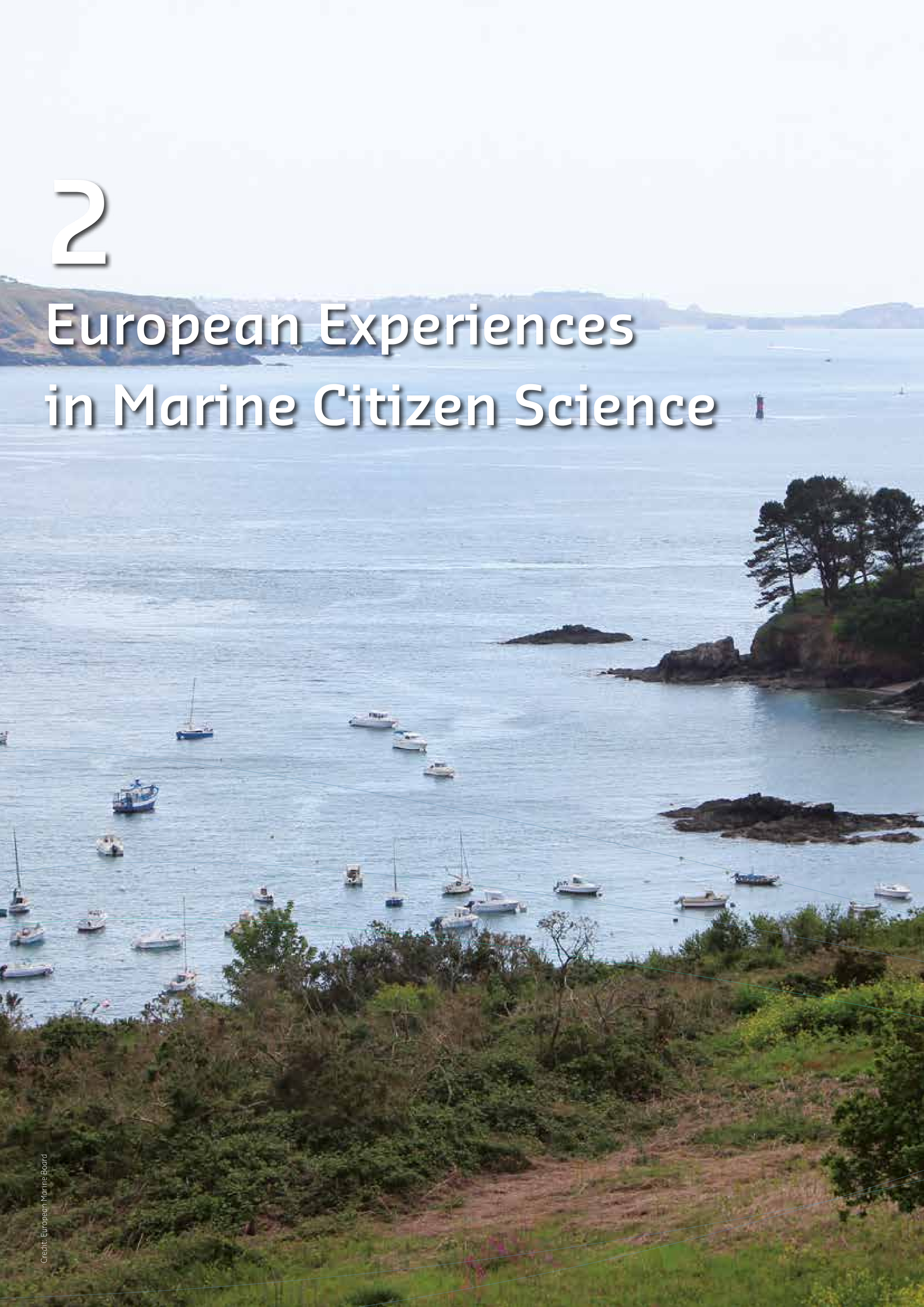
Marine systems pose their own unique challenges: they are open systems with more variable productivity; they have less clearly defined boundaries of territory and ownership to demarcate areas of stewardship; and their greater inaccessibility makes them less easy to monitor than a land-based habitat. Despite this relatively lower prevalence of marine compared to terrestrial projects, there is arguably a greater urgency for building capacity and embedding Citizen Science approaches into mainstream monitoring of marine systems and issues. The call for Marine Citizen Science to be seriously considered at the highest political level arises from three key drivers:

a. Global change and consequent impacts to marine systems;
b. The evolving international marine governance and management landscape and the opportunity to ensure that Citizen Science approaches are built in to new policy frameworks;
c. Need from volunteers: negative perceptions of marine environments, perceptions of powerlessness to enact change, the need for greater advocacy and stewardship and reported evidence of the desire amongst citizens to participate.

If we are to effectively plan for adaptation and/or targeted remedial action, it is essential that we are able to appropriately evaluate the rate and extent of ecological impact and have robust predictive capability for future change. Governments are also committed on national and international levels to achieving quantitative targets in conserving biodiversity and ensuring its benefits are distributed equitably. Failure of countries to achieve the Convention on Biological Diversity (CBD) 2010 targets led the 10th Conference of the Parties to the (Secretariat of the Convention on Biological Diversity 2010) to adopt a revised plan for tackling biodiversity loss, which included 20 stronger, more comprehensive, explicit and measurable targets for 2020 (the Aichi biodiversity targets; United Nations Environment Programme (UNEP) (www.cbd.int/sp/targets)). However, policy makers will not know if these goals are met without robust and representative systems for monitoring the changing state of nature. Evidence is additionally required to evaluate the efficacy of particular conservation strategies. Long-term and spatially diverse data sets are vital to our understanding of how such changes are occurring and to distinguish natural fluctuation from anthropogenic-induced impact. There is, however, a significant deficit in the monitoring of marine habitats to inform how new legislation may be implemented; for example, the provision of data to underpin a network of Marine Protected Areas across Europe has been lacking. Alternative approaches to evidence gathering that draw on interdisciplinary expertise are likely to gain increasing attention in the years to come and developments in Citizen Science are thus timely and highly relevant.

2

European Experiences in Marine Citizen Science



Credit: European Marine Board

Marine Citizen Science offers great potential as a research approach. However, it must be used wisely to ensure that it can be efficient, effective and sustainable. This chapter will detail common factors of success in Marine Citizen Science projects, present methods for analysing projects and consider the types of data suitable for Marine Citizen Science applications and the requirements for data quality control. It will also discuss the role of unmanned systems and other technology in Marine Citizen Science, investigate social aspects and propose methods of coordinating projects in a common way.

2.1 Approaches, challenges and best practice in Citizen Science projects

A consensus has not yet been reached on what makes a successful Citizen Science project. A simple working definition is: success is when citizens are satisfied and useful scientific data has been obtained to answer scientific questions. This definition requires both satisfaction and usefulness to be measured and quantified. It pointedly distinguishes between a 'successful project', and those which create useful scientific data, but in a manner which leaves citizens feeling frustrated or unengaged, or in contrast, that has brought enjoyment and value to citizens but has not contributed to scientific knowledge. The great variety of Citizen Science models intrinsically means that not all will have every success factor in common.

There are a number of typologies, reviews of best practice and guidance documents on how to establish, and manage a successful Citizen Science initiative. It is not the intention of the authors to exhaustively review these, but instead to pull out widely upheld core elements that determine success, and to reflect on approaches particular to the marine environment. In doing so, extensive reference is made to the publications of Bonney *et al.* (2009), Shirk *et al.* (2012) and Pocock *et al.* (2014), but there are, of course, many other excellent reviews.

Chapter 2 cover image: View of coast near Brest, France

COASTWATCH EUROPE

Coastwatch Europe is a non-governmental organisation based in Ireland. Founded in the late 1980's, Coastwatch aims to protect coastal areas by raising public awareness of their value and demonstrating practical ways to save them, and is hence a long-term contributory monitoring project.

Coastwatch aims to address a wide scope of environmental issues that have evolved along with the project and its expansion into other European countries, and which currently include biodiversity, seafloor integrity, eutrophication and litter. The initiative also campaigns for improvements to environmental policy and the implementation of legislation.

The mainstay of Coastwatch is its annual survey in which participants are invited to survey a pre-agreed 500m stretch of coastline, answering a range of questions on their observations in a formal questionnaire, and to submit relevant pictures they may take. Additional testing kits are available for survey coordinators to submit data on environmental parameters.

Participants are directed towards partner projects and supplemental information they may wish to gather at the same time. Survey data can be uploaded online, via an app or by post to the organisers. Pre-survey training events are available to participants and preliminary results are posted online shortly after submission, with subsequent analysis and outcomes posted in due course. Participants are kept up to date with policy and legislative developments via the website and the group's social media outlets.

Coastwatch actively disseminates its work at conferences, workshops, information days and through regular press releases. The group, and its findings, have had a significant impact on a number of causes including the Irish plastic bag tax, as well as informing a number of scientific publications across Europe. Participants have identified a number of new seagrass beds (*Zostera spp.*), honeycomb reefs (*Sabellaria spp*) and other priority features of conservation interest, translating into engagement and stewardship for the natural environment.

http://coastwatch.org/europe/

Credit: Brendan Cooney

Fig. 2.1 Coastwatch surveyors near Irish honeycomb reefs

2.1.1 Project approaches and identification of best practice

Bonney *et al*. (2009) suggested a 9-step process for developing a Citizen Science project. We adopt a modified version of these headings as a basis for considering design, and the subsequent evaluation of success of projects, incorporating concepts and frameworks by other authors as we do so.

1. Choose a scientific question
2. Form an interdisciplinary team
3. Develop, test, and refine protocols, data forms, and educational support materials
4. Recruit participants
5. Train participants
6. Accept, edit, and display data
7. Analyse and interpret data
8. Disseminate results
9. Measure outcomes

Choose a scientific question

A key aim of any Citizen Science project is to generate scientific knowledge and understanding. A contributory factor for success of a Citizen Science project will be that the identified scientific question can yield valuable (and thus publishable) scientific data, and eliminating poor objective setting at the outset is thus essential. It will direct the formulation of methodologies and help to shape the ways in which the volunteers will contribute (McNie 2007; Sarewitz & Pielke Jr. 2007; Tulloch *et al*. 2013; Bonney *et al*. 2014). Environmental monitoring initiatives can also be effective Citizen Science projects, but there needs to be a well-understood cause-and-effect pathway from the issue to what is being recorded (Pocock *et al*. 2014).

There are particular types of question that are best answered using a Citizen Science approach. Citizen Science is particularly helpful in answering questions that have a large spatial or temporal scope: for example surveying marine litter (Nelms *et al*. 2017); the mapping and monitoring of species ranges across extensive geographic areas (e.g. Boero *et al*. 2016); or the documentation of large-scale changes in rare or patchily distributed species (Ward-Paige *et al*. 2011; Ward-Paige & Lotze 2011). A decision to be taken at the outset about whether or not the particular question identified is really best tackled using Citizen Science (Pocock *et al*. 2014). Section 2.2 presents the types of data that are amenable to Marine Citizen Science.

The project will, of course, only be successful if it can attract and retain the engagement of citizens. Hence, the appeal of the question and the accessibility of the data collection process are paramount (see Section on recruitment and retention of participants below). The aims of the project need to be shared and agreed with everyone involved, both scientists and citizens.

Form an interdisciplinary team

In describing this step in the project process, Bonney *et al*. (2009) refer to the team of 'experts' with professional skills required to lead and deliver a successful project from a 'top-down' perspective. They discuss the scientific expertise, the engagement or educator expertise, the technological and statistical skills, and the ability to effectively evaluate outcomes.

Shirk *et al.* (2012), however, bring together different explorations of the degree to which members of the public contribute to the scientific process, and present a framework for considering projects according to the level of volunteer participation. The citizens can thus be considered very much a 'part of the team' in the development and implementation of a Citizen Science project; the degree to which they participate will vary across the various project models. The 5 models are:

- *Contractual* projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results;
- *Contributory* projects, which are generally designed by scientists and for which members of the public primarily contribute data;
- *Collaborative* projects, which are generally designed by scientists and for which members of the public contribute data but also help to refine project design, analyse data, and/or disseminate findings;
- *Co-Created* projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all aspects of the research process;
- *Collegial* contributions, where non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals.

The step of identifying the aims of the project, for example, is a creative process, and in some cases it may be suitable to co-develop these with the intended participants, or a subset of these. Shirk *et al.* (2012) refer to the interests ("the hopes, desires, goals and expectations") of the citizens and the scientific community collectively as 'Inputs' (see Figure 2.2 below). Several authors (e.g. Haklay 2015) have commented on the value of each of these 5 models or approaches to Citizen Science, and highlighted that no one approach is necessarily better than another. A successful Citizen Science project will, however, always ensure that citizens are adequately informed about the range of ways through which they can get involved (objective setting, choosing of methods, data collection, data analysis, manuscript writing, dissemination and profile raising), and will consider the appropriateness of volunteer input to each step of the project design; where such direct input is unfeasible, the considerations of volunteer needs should be carefully considered.

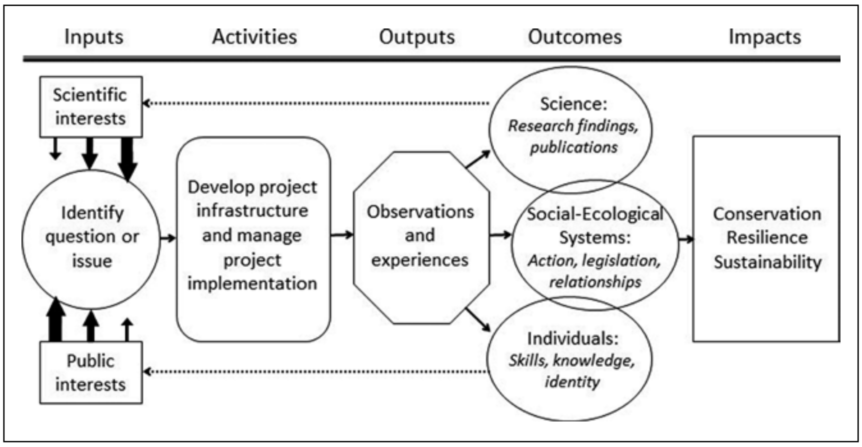


Fig. 2.2 A framework for public participation in scientific research projects. Projects must balance inputs from scientific interests and public interests, but each project negotiates that balance differently (as represented by input arrows of different sizes). Projects also exhibit different outcomes for science, individuals (researchers or volunteers), and social–ecological systems, which may relate to the particular balance of inputs. Note feedback arrows: certain outcomes may reinforce certain interests—and therefore particular design emphases—as initiatives evolve over time. Quality public participation depends upon sufficient attention to public interests in the input stage, to identify questions and structure activities most likely to yield outcomes relevant to those interests. Adapted from Shirk *et al.* (2012)

Develop, test, and refine protocols, data forms, and educational support materials

The breadth of methodologies employed in Marine Citizen Science projects is dictated by the scientific questions being answered, the locations or environments in which the study is taking place, the nature of the citizens involved in the study, and the funding or technology which is available. The dedication of the scientists who support the scientific aspects of the project is crucial for success. A successful project will be able to identify at the outset a clear timeline of required data collection that will adequately address the question set; setting a finite end to the data collection is advisable to alleviate volunteer frustration at not seeing outcomes or an endpoint materialise. Where a long-term time-series is the method of choice, the value of such data should be clearly communicated to participants and regular feedback of trends and changes presented. The proposed method should be workable in the locations of study without any adaptations needing to be made.

It is valuable to test the intended data collection method on a representative pilot group before it is launched. The target sector of society should be clearly identified and either the broad, or unique, needs of that group carefully considered.

It is important to manage the expectations of the participants; the value of absence records must be communicated to avoid under-reporting of negative results. Engagement and perseverance can be maximised using carefully designed protocols. For example, where particular sites are required to be surveyed for scientific rigour and completeness of survey, yet such a survey design is predicted to persistently yield 'absence' records for certain sites, (e.g. such as particular headland observatory posts for a national cetacean survey) the frustration of volunteers assigned to these headlands can be avoided, by clearly outlining expectations, and by coupling the survey activity with other tasks where a positive result is almost guaranteed. Participants could additionally take regular observations of sea state, water colour and transparency, current direction, or note bird sightings.

Flexibility is required, and it is good practice for both scientists and citizens to be open to the possibility that mistakes may be made, to acknowledge when these have occurred, and to adjust the proposed methods in a mutually agreed manner.

PLANKTON PLANET

Credit: Claire Sollinger

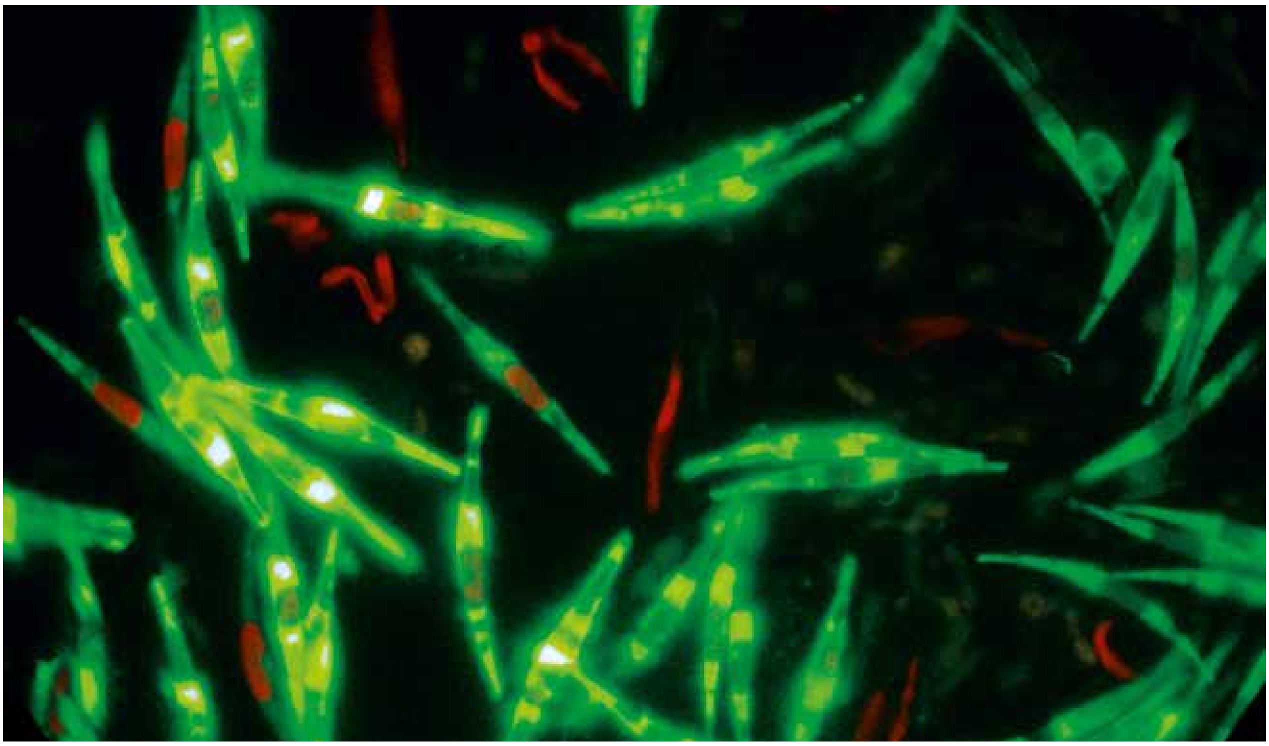
Plankton Planet is a recently established and ongoing Citizen Science project initiated by researchers from the CNRS (The National Centre for Scientific Research) in France, together with the Tara-Ocean expedition teams. The project aims to mobilise citizen sailors, known as 'Planktonauts,' to provide continuous samples of plankton from all over the world to biological oceanographers. Planktonauts are asked to assist for a few hours a week. At present, 20 sailing vessels are involved in a preliminary study aiming to improve methods and analyses approaches.

Plankton, a term used to identify all organisms which drift with the currents, are the foundations on which the entire food chain within the ocean is built and are responsible for around 50% of the earth's primary production. Plankton react quickly to changes which may arise through pollution or climate change, or indeed from natural causes. The current lack of understanding of plankton biodiversity and evolution is a barrier to modelling the functioning of the biosphere and hence the prediction of global environmental change. The samples collected will allow for information to be gleaned on current plankton biodiversity and changes over time and space, and therefore enable scientists to predict the evolution of plankton in future ocean conditions.

Participants are provided with free training and are also equipped with sampling equipment and a Planktoscope, a miniature microscope adapted for mobile phones. The participants collect samples and also take images using the microscope and these images are then shared within the Plankton Planet network so that members can identify the organisms present, and hence the nature of the project is contributory to generate new science. The samples are sequenced and all of the results will subsequently be shared with the participants and the public. The aim is to develop long-standing national and international consortia.

Around 200 samples have been collected to date and results are currently been checked for quality and bias. A scientific paper is also currently being prepared.

http://planktonplanet.org/



Credit: Jean-Paul Cadoret / Antoine Carlier, Ifremer

Fig. 2.3 *Phaeodactylum tricornutum* phytoplankton

Recruitment and retention of participants

The success of any Marine Citizen Science project will require the ongoing involvement of citizens and the degree to which they consider the project enjoyable and of value. Success measures can be considered by looking at Attention, Accessibility, Relevance and Satisfaction.

Attention

Reaching out to potential contributors requires an appropriate strategy. Citizen Science projects need to catch the attention of potential participants amongst the vast amount of information constantly available in everyday life. This can be done successfully through personal interaction. However, this is demands a lot of resources and therefore limits the number of successes if Citizen Science participants are all addressed on a one-to-one basis. Interaction with professional societies (e.g. through water sports associations or organisations such as the sea scouts) or (non-governmental) organizations can act as a multiplier and is therefore recommended. Professional media coverage and prominent or celebrity advocates of Citizen Science projects are other ways of reaching the attention of larger numbers of potential participants. One good strategy can be to have concerted activities (such as Ocean Sampling Day) that activate a higher number of participants on a specific day (or within a short time frame) and therefore help the project to reach media and hence public awareness (e.g. the international Coastal Clean Up project (www.oceanconservancy.org/our-work/international-coastal-cleanup). The rise in social media platforms and their common usage can be exploited to provide a relatively simple means of reaching large numbers of potential participants through indirect networks, and using targeted language and handles. Another possible approach is to have a project linked to a specific location such as a museum or aquarium, where all visitors are also invited to participate.

Accessibility

The lower the hurdles to participation, the higher the participation, and thus success, rate of Citizen Science projects. Prominent examples are recent Citizen Science projects that make use of smart phones and specially designed applications (apps) as their primary approach. Websites or printed questionnaires are other examples of low-effort participation. If nothing has to be purchased or specifically built to participate in a Citizen Science exercise, the accessibility is higher and therefore external (e.g. budgetary) constraints are minimized. As offshore habitats are inaccessible to most members of the public, coastal and estuarine projects are naturally more common for Citizen Science initiatives (Thiel *et al*. 2014). Exceptions do however exist, for example in the crowdsourcing of satellite image screening for wreck portions of the missing Malaysian Airlines flight MH370, using the Tomnod project platform (www.tomnod.com/campaign/malaysiaairsar2014/map/15exny5d), or the plankton identification project Plankton Portal (www.planktonportal.org) on the Zooniverse platform.

Relevance

The willingness to participate in a Citizen Science project depends on the perceived relevance of the topic. Regardless of what is required from the participant (e.g. installing an App on a smartphone, reading instructions, signing up to a website), an initial effort is required, and they are only likely to make this effort if the topic is relevant to them. This can include economic relevance for the individual (water quality monitoring at your waterfront property) or its societal status (contribution to a community effort in marine debris monitoring). The benefit has to be clearly defined and highlighted by the project co-ordinators. This reflects the consideration of Shirk *et al.'s* (2012) collaborative design of project 'Inputs', to consider those that are relevant to both the public and the scientific/conservation management community. It was the experience of the Italian 'Occhio Alla Medusa' project that the public and coastal authorities deemed the investigation of jellyfish distribution and abundance to be a priority (Boero *et al.* 2016; Boero 2013), and put it to the scientists to address. Intertidal rocky shores can present a habitat of relevance given their proximity to the residents of many coastal communities, and thus an integral part of their local landscape.

Satisfaction

Communication with the citizen community is crucial to eliminating or minimising dissatisfaction with the project. It is important that participating citizens are able to gain a clear picture of why the scientific question should be answered and the expected short-term and long-term impacts that addressing this issue, and hence their contribution, will have. While certain projects only require once-off participation, others benefit from the skills developed as a citizen contributes repeatedly, over time. This can be achieved through having clear visibility of their individual contribution to the project, for example through the presentation of collected data and reports. Success within the project has to be visible, the status of the project has to evolve, and individual advantages need to be granted. Keeping citizens interested in the project requires a dedicated feedback strategy that needs continuous development. The project will benefit from having the participants feeling that they have an ownership of the results and outcomes, and they can see how their contribution fits within the "bigger picture", why their input is important, and how their results are being used. Engendering ownership of the data and giving due acknowledgement are crucial aspects of successful Citizen Science projects (see Section 2.4).

Train participants

Simplicity is one key to the success of mass participation Citizen Science projects. As the complexity of the protocol increases then adequate training and support in accessible formats and language styles will be needed. 'Training' encompasses a range of possible provisions that must be appropriate to the scientific questions and methodologies which the citizens are required to undertake and there needs to be careful consideration of whether such resource implications are justified. The benefit to the citizen community of skill development in its own right should not be undervalued and is often an aim of the project. Frequently though, it can be more a matter of confidence building than actual skills development and 'training' can focus predominantly on ongoing 'support'.

In developing training and resources, the specific nature of the participants, and the degree to which they have been previously exposed, or not, to the scientists should be considered. Despite no anomalous records arising from a pilot study, a high number of false *Zostera* seagrass records were returned for Coastwatch surveys early after its launch (see box on page 18), with the majority of sightings transpiring to be green macroalgae. The discrepancy between the pilot group and the early project-stage surveyors was determined to be in the level of face-to-face training provided; the identification of previously un-encountered species was difficult to do solely from photographic guides and text descriptions, and the project design was hence revised. Once provided with the appropriate level of field-based training, the identification guides acted as an effective *aide memoire*, and as a tool for volunteers to further train others. Investment in appropriate training and materials paid off.

Results, interpretation and dissemination

The primary output of all scientific studies is publication in the peer-reviewed scientific literature. Marine Citizen Science is no exception. Through the process of peer-review, the validity of the findings is ensured, but so too is the credibility of the citizen-based approach and the value of volunteer contributions is highlighted as a consequence. The publication itself can become a measure of project success, and metrics such as citation rate and journal impact factor demonstrate its standing and ranking in academic circles. Dissemination and sharing of findings should include all contributors, participants and wider society; thus a variety of dissemination avenues should be employed. Open access is changing the relationship of scientific data with society, yet the language of academic publications can alienate many of those who have contributed generously of their time and accessibility may still be difficult. Good practice points to the use of feedback celebration events, blogs, newsletters, reports, website posts, workshops, films and photographic exhibitions amongst others.

Credit: Michelle Cronin

Fig. 2.4 Harbour seals (*Phoca vitulina*)

Dissemination activities are not limited to the end of the project; they should be carried out through the whole project as far as possible. In projects where individual observations or records can be uploaded instantly or within a short time frame on a website, for example, and made visible to all participants and/or the general public, part of results sharing has already been achieved. The timeframe for feedback of outcomes should consider the volunteer's retention and engagement, and strive to do so while participants can still clearly remember the work carried out. In projects such as Marine Conservation Society's Beachwatch survey (http://www.mcsuk.org/beachwatch), the Italian 'Occhio Alla Medusa' (see box on page 58), The Marine Biological Association's 'Shore Thing' (see box on page 42), the UK-wide Capturing our Coast (see box on page 27), and Ireland's Coastwatch Survey, volunteers are rewarded with an immediate visual indicator on an interactive map that their records have been uploaded and received; data verification and analysis may take time and the full impact of their contribution may not be able to be reported until a later date, but such short-term acknowledgement is important. Citizens also need to be convinced that they can trust the data and that entries are genuine. The Citclops project (see box on page 49) invites participants to take pictures of sea surface water colour and categorise it; it is important to the project and the trustworthiness of the data that photographs of alternative surfaces are quickly identified and removed.

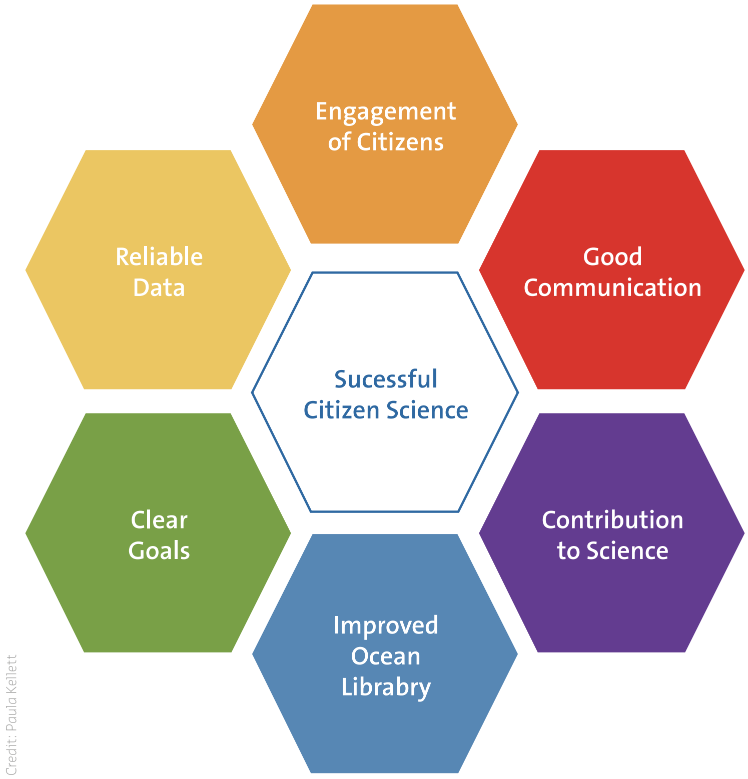


Fig. 2.5 Factors of success in Citizen Science projects

Although predominantly undertaken by professional scientists, the analysis of data does not necessarily mean the exclusion of citizens from this process. Citizen Science is a unique opportunity for scientists to introduce citizens to what they do, how they go about generating knowledge, and the processes involved in that. Explaining the processes involved in collecting raw data, and processing, analysing and interpreting it, is a great way to do this, as it can be a fascinating process to those seeing it for the first time. The participating volunteer community is, of course, a diverse one; recognising the diversity of skills and expertise is an important aspect of the success of Citizen Science projects, and some participants may have analytical skills relevant to this stage of the project (Haklay 2010). Citizen Science projects tend to produce coarse data sets that can present significant challenges for analysis and interpretation (Bonney *et al.* 2009) and this is considered in Section 2.3 on quality control.

It is important to appropriately acknowledge the input of citizens, both as individuals and as a group. Participants give their time and usually do so *gratis*. Due acknowledgement in relation to significant findings or efforts by individuals is particularly important and should be considered in the same manner in which those of a professional scientist would; several publications have included all contributors as authors. Where this is unfeasible, recognition in other ways can be embedded. Citizens like to see their results in publications to which they can relate and acknowledgement on project websites and in media attention can address this.

Citizens need to know that the project has a system which caters for those who want to ensure that their names and other personal details are held confidentially. Due consideration must be given to data protection and the legal requirements of such provision in the host country. Academic and research institutions in most European countries now appreciate the requirement for a full 'ethics' review of a project before launch, including the treatment and acknowledgement of participating volunteers, and the appropriate protection of their confidentiality. Non-Governmental Organisations (NGOs), such as the Earthwatch Institute (http://eu.earthwatch.org) with global reach and decades of experience in supporting volunteers in environmental science, now represent a resource of international standing in the area of volunteer engagement ethics. A comprehensive discussion of the ethical considerations of volunteer engagement can be found in the studies of Riesch & Potter (2014).

CAPTURING OUR COAST (COCOAST)

CoCoast is a UK-wide Citizen Science project, funded by the Heritage Lottery Fund, which was launched in 2016. The project is coordinated by 7 academic, research and conservation hubs spread around the UK.

The main aim of the project is to further understanding of the abundance and distribution of marine life around the UK through a monitoring approach. These data will then be used as a baseline to highlight the impacts of climate changes as well as other environmental and human factors. Citizens can participate by adopting a 'package' of 8 species, from a total of 65 available, thus becoming competent in identification of a tractable set of species; this serves to build their confidence, and ensures reliable data is independently returned.

A unique feature of the project is the opportunity for volunteers to participate in addressing scientific hypotheses through manipulative experimental approaches. Using the network of research labs around the UK, replicated studies across environmental and latitudinal gradients maximise the value that can be derived from intertidal explorations of phenology (seasonal breeding patterns), interactions between native and invasive species, and the impacts of climate-derived disturbance. The information gathered will contribute to more effective management of marine systems and the potential for Citizen Science data to contribute to policy is being explored.

In its first year alone, the project recruited over 4000 Citizen Scientists, making this one of the largest coastal Marine Citizen Science projects of its kind. For those without coastal access, web-based opportunities will also be available. Survey results from participants can be uploaded online. Training and field support are provided to the participants to ensure high-quality data gathering and maintain engagement and this is furthered by the provision of engagement events and home study materials.

It is the intention that the project and the data gathered will lead to a number of scientific publications. The website and social media outlets are also used to communicate with participants and others to celebrate success and to provide feedback.

www.capturingourcoast.co.uk/

Credit: Megan Evans, CoCoast

Fig. 2.6 Conducting a CoCoast survey

This box identifies the questions that Citizen Science Project managers and coordinators should ask, answer and address in order to ensure that a project is being run as effectively and successfully as possible.

KEY QUESTIONS TO ADDRESS

Opportunities

- What is the novel idea?
- What is the novel approach?
- What advantages does the project have (knowing the environment, knowing stakeholders, knowing a recruiting pipeline)?
- What are the expertises within the group?
- How could the project become interdisciplinary?
- How could the legal aspects of the project be addressed?
- Are there dedicated scientists who accompany the scientific aspects of the project?
- What unique or lowest-cost resources can the project draw upon that others can't?
- Are there enthusiastic volunteer Citizen Scientists who are willing to contribute?
- What good opportunities can be identified based on the citizen network created?
- What interesting (climate or environmental) trends have been highlighted?
- Can outreach events be targeted towards new findings?
- Can changes in technology broaden the goals or scope of the project or make them achievable in a shorter timeframe?
- Can changes in government policy related to the field under study facilitate the project?
- Can changes in social patterns, population profiles, lifestyle changes etc. boost the project?
- What is the legacy of the project?

Challenges

- Are the results of scientific interest?
- Can the results be integrated into ecosystem management or policy development?
- What could be improved in order to recruit more citizens for participation?
- What should be done better when training citizens?
- How could the project be effectively advertised?
- Are the data of sufficient quality to answer a scientific question (and generate a scientific publication)?
- Do the involved scientists achieve scientific publication at an appropriate level and time scale?
- What kinds of deliverables are more effective for citizens and for marine scientists?
- How can citizen engagement be maintained throughout the project, at the end of the project and beyond?
- How can high-cost technologies be supported without dedicated funds?
- What obstacles does the project face?
- Is changing technology threatening the project within given timeframes, e.g. 1, 3, 5 or 10 years?
- How can the quality of the fieldwork and results be assessed?
- How can shortages of funding at the end of the funding period be overcome?

2.2 Types of marine data amenable to Citizen Science

Original data collected by citizens may consist of counts and measurements (numerical data), notification of given categories (presence/absence, colour) or descriptive observations, images and other documentation. Contributions by Citizen Scientists can be based on incidental observations as well as on standardised surveys and monitoring protocols. These can include:

- Ongoing presence/absence reporting;
- Organised snapshot records at set times and in set format;
- Measurements which require instruments or materials and training;
- Chance sightings or unusual observations ideally with photographic evidence;
- Dedicated scientific exploration programmes with citizen participation;
- Interactions with traditional knowledge holders.

By increasing public involvement in a project, the pool of data can be geographically extended and a regional or even global coverage of observations can be achieved. However, there is still a strong bias towards studies in the most accessible habitats such as beaches and shallow water areas (Thiel *et al.* 2014) and towards the most visible or attractive taxonomic groups. Seabirds, mammals, turtles and fish have been observed for decades, even centuries. However, studies on invertebrate or microbial communities, as well as analysis of image material and oceanographic data in general require more familiarisation, background knowledge and training measures for interested citizens. Exceptions do however exist for example in harmful algal bloom (HAB) studies involving Citizen Scientists. Examples of marine science data and information that are amenable to for Citizen Science are presented below.

Credit: Valerie Craig / Marine Photobank

Fig. 2.7 Cooperating with traditional knowledge holders can generate valuable results

Credit: ImagDOP

Fig. 2.8 Divers conducting a survey

2.2.1 On land and along shorelines

- Online identification of organisms and features etc. from image banks and archives
- Microclimate monitoring
- Monitoring of beach morphology changes
- Reports on shoreline changes (sand, water level)
- Reports on stranded organisms (fish, cephalopods, gelatinous organisms, marine mammals) during periodic visits to the shoreline
- Monitoring of fresh fish catches for invasive species
- Beached seabird observations
- Mammal and turtle observations
- Reports on stranded litter and organic matter (wood, flotsam)

2.2.2 In shallow waters

- Surveys of shallow water hotspots by diving clubs or other watersports associations
- Long-term monitoring programmes of Marine Protected Areas
- Monitoring of changes in protected benthic communities
- Reporting on anthropogenic damage to shallow water communities
- Coral and artificial reef monitoring
- Night observations of shallow water biodiversity
- Invasive species observations
- Studies of diverse but accessible habitats
- Extensions of fish and seafood databases by divers and anglers

2.2.3 In the open sea

- Sampling from ships of opportunity
- Mobile applications to determine water colour, reflectance, clarity
- Collaborations with eco-volunteer organisations for survey and sampling
- Use of drones for observations of mammals and floating debris or coastal and intertidal habitats
- Ferry boxes for underway sampling
- Use of tethered underwater robots

OCEAN SAMPLING DAY AND MY OCEAN SAMPLING DAY CAMPAIGN

Micro B3 (Marine Microbial Biodiversity, Bioinformatics, Biotechnology) was an EU FP7 funded project which ran from 2012 to 2015.

As part of the outreach activities of the this much wider project, Ocean Sampling Day (OSD) was first held on the summer solstice in 2014 and was repeated in 2015 and 2016. Ocean Sampling Day is a simultaneous ocean sampling campaign whereby samples of coastal seawater and associated environmental variables are collected on a single day across the world to gain a snapshot of microbial communities and monitor this over time. Stemming from this, My Ocean Sampling Day (MyOSD) encourages Citizen Science participation in this event to not only greatly increase the scope of the database of results, but also to engage, empower and educate citizens. Within the German Science Year Seas and Oceans 2016-17, the project focussed on German coasts and also included rivers.

Marine bacteria are known to be the most important environmental engineers, as through their biogeochemical action they are able to ensure that the marine ecosystem remains functional and habitable. The health of the ocean and the ocean's response to climate change are very much dependant on these microbes. Nowadays, information on microbial genetics is not only further understanding of the ecosystem and its functioning, but is also allowing for exploitation of these genes in biotechnology and biomedicine.

On the day of the 2015 event, useable seawater samples were collected at 191 participating locations across the globe using specially designed and distributed kits, filtered onto cartridges and then sent to laboratory facilities in Germany for DNA extraction and next-generation sequencing. In 2016, more than 1000 citizens participated in MyOSD. Oceanographic data, metagenomic information and physical samples of scientists and citizens are stored in long-term repositories; Information and data for 2014 are available online at www.ebi.ac.uk/metagenomics/projects/ERP009703 and https://doi.pangaea.de/10.1594/PANGAEA.854419 for 2015. Data of subsequent years will follow after data curation.

All three events received significant press coverage, and the work of the Micro B3 project as a whole has led to over 120 peer reviewed publications, with a number being a direct result of OSD and MyOSD including (Kopf *et al.* 2015; Schnetzer *et al.* 2016).

www.microb3.eu/
www.microb3.eu/osd
www.microb3.eu/myosd
www.my-osd.org

Credit: Prof. Dr. Frank Oliver Glöckner

Fig. 2.9 The MyOSD sampling kit

2.3 Citizen Science data quality control and modelling

Credit: Ángel Muñiz Piniella

Fig. 2.10 Intertidal survey

A challenge for Citizen Science is the concern surrounding the rigour and validity of the data (Bird *et al.* 2014; Bonney *et al.* 2014; Tulloch *et al.* 2013; Bonter 2012; Dickinson *et al.* 2010; Silvertown 2009). These criticisms arise from potential biases in survey effort, including under-detection of species or the non-random distribution of effort, issues of scale and inconsistencies over time (Bird *et al.* 2014; Tulloch *et al.* 2013; Crall *et al.* 2010; Crall *et al.* 2011). A good Citizen Science project will build in quality assurance and data robustness analyses at the outset of project design. This will confirm that they are delivering on their objectives of adequate training and support, and the confidence that the scientific community will subsequently gain in the data ensures its usefulness and uptake. Addressing this issue also demonstrates to the participant the robustness of the data that they and the value of their contribution (see Satisfaction and Retention in Section 2.1.1 above).

The range of methods employed include (i) providing close training and supervision; (ii) cross-checking for consistency with existing literature; (iii) cross-checking with scientists' own observations; (iv) quiz style questionnaire at end of survey; (v) simplifying the tasks asked of the public and/or adapting the research questions; (vi) database management; (vi) filtering or subsampling data to deal with error and uneven effort; and (vii) technologies and statistical techniques to identify signals of change in noisy ecological data (Riesch & Potter 2014; Bird *et al.* 2014; Newman 2012; Crall *et al.* 2011).

2.3.1 An ideal case

In an ideal scenario, data are collected by volunteers that are all trained for this specific task, are motivated to do so with care, and report all data without error or censure. If the sampling scheme follows systematic and fine resolution coverage of space and time, the resulting data set can be of high quality, perfectly comparable to data collected by an expert. The main difference with a scientific programme dataset is the large number of volunteers (non-professionals) who participate, each one submitting a comparatively small number of observations, with the whole generating a large amount of data. This introduces a trade-off between the number of participants which adds to the heterogeneity and the favourable signal-to-noise ratio that comes from large datasets yielding strong patterns that are easy to interpret (Bonney *et al.* 2009). The heterogeneity is inherent to Citizen Science and there are several ways to limit it. Training, even via a simple tutorial, can reduce the variability between volunteers (Holt *et al.* 2013). When volunteers are only a vector for the device that collects the information, for example a picture that is immediately transmitted by a smartphone with automatic geolocation, date and time logging, (see Section 2.5), there is little room for error and heterogeneity only arises from the way the picture is taken (e.g. focusing, framing). It will be the same for other physical measurements such as noise levels, temperature etc.; homogeneity of the devices ensures homogeneity of the data, independently of the volunteers.

2.3.2 Data representativeness and heterogeneous sampling in space and time

Even with accurate individual observations, a frequent characteristic of Citizen Science data is the absence of a planned sampling scheme on a geographic scale, so the observation density over both space and time is more representative of observer density than of the targeted data points themselves. Spatial analysis of data will require interpolation methods to fill the biggest data gaps. For species distributions, it can be easily corrected if the effort of observation is simultaneously recorded (i.e. it is essential to report absence as well as presence), transforming the raw data into relative abundance for each species (Bird *et al.* 2014). For purely opportunistic observations, consisting of heterogeneously distributed presence-only data, there are no good solutions, and strong assumptions need to be made. This is what is undertaken by methods such as the Ecological Niche Factor Analysis (ENFA) method which uses environmental covariates, or Maximum Entropy Method (MaxENT), which generates pseudo-absences to fill the gaps and hence enable the analysis of presence-only data (Kramer-Schadt *et al.* 2013; Renner *et al.* 2015). The absence of correction for heterogeneous opportunistic observations may lead to important and significant biases and hence spurious conclusions on long-term trends or spatial patterns of species distribution. For example, a seasonal increase in the number of observers may lead to the conclusion that there is a seasonality in the relative abundance of species. A convenient way to address such issues involves pooling opportunistic data with controlled data (e.g. scientific survey data based on a strict protocol, or presence-absence data with trained observers and a stratified sampling scheme) when available (Pagel *et al.* 2014), and use the latter in a global model to calibrate the purely opportunistic data. This can help to extend and increase the density of coverage, fill the gaps and reduce monitoring costs (Giraud *et al.* 2016).

Credit: IMR

Fig. 2.11 Data collection using canoes in Norway

RED *POSIDONIA* MURCIA

posidonia murcia
RED DE SEGUIMIENTO DE POSIDONIA OCEANICA

Seagrass meadows are recognized as being marine habitats that provide important ecological services and functions to coastal marine ecosystems, including primary production, water quality, biogeochemical cycles, biodiversity, shore protection, hydrodynamics and local fishery resources. In the Mediterranean Sea. *Posidonia oceanica* is the most productive and extensively distributed species, but its decline has been reported in many locations due to the impact of human activities (illegal trawling, coastal works, urban and industrial waste, aquaculture, desalination plants and invasive exotic species). As a consequence, these seagrass communities were included in the EU Habitats Directive Annex I and hence their conservation is a priority target. Their sensitivity to environmental change reveals their excellent properties as a biological indicator, which has been extensively used in long-term monitoring networks established along the coasts of many countries (France, Spain, Italy, etc.) for evaluation of the Mediterranean marine ecosystem Conservation Status.

"Monitoring network of the Mediterranean seagrass *Posidonia oceanica* in the Murcia Region (Southeastern Spain)" is a Citizen Science project run by the Spanish Oceanography Institute (IEO) and funded by the Aquaculture and Fishery Department of the Murcia's Regional Government (CARM) and the European Fishery Fund (EFF). The scientific monitoring activities are performed by IEO researchers in collaboration with the Subaquatic Activities Federation of the Murcia Region (FARSM), diving centers and volunteer divers. A monitoring network was established in 2004 in the Murcia region to quantify and analyze long-term trends in *Posidonia oceanica* meadows. The project is run by 17 sampling stations distributed along the Murcia coast which are annually visited by scientific and volunteer divers to measure a set of basic seagrass descriptors that allow for the determination of long-term trends of this habitat. A key aspect is the determination of its current conservation status and future trajectories. Volunteer divers participating in underwater activities are previously trained by members of the scientific staff to ensure the reliability of measurements and their use for scientific purposes.

The basic data obtained are directly applied to ensure compliance with European Directives related to the protection and management of biodiversity and international networks dedicated to the control of the effects of global climate change on Mediterranean marine ecosystems. Additionally, work will be undertaken to update the mapping of the seagrass habitats in all Spanish marine regions to elaborate the "Spanish Atlas of Seagrasses", whose content will be crucial for the design and implementation of monitoring programmes requested for the EU's Marine Strategy Framework Directive and in Marine Protected Areas, and also for the "National Inventory of Natural Heritage and Biodiversity".

www.facebook.com/redposidoniamurcia

Credit: Juanma Ruiz

Fig. 2.12 Divers survey seagrass for the Red *Posidonia* Murcia project

2.3.3 Observation errors, data cleaning and data validation

Errors or uncertainty in the transmitted data, such as the misidentification of species or imprecise measurements of size or abundance, should also be considered. For such errors that are characteristic of a lack of training of the volunteers, many Citizen Science programs have implemented validation protocols, with a group of experts who validate the data. Such procedures are based on previous knowledge and can be assisted by the submission of pictures to accompany the data. However, when the volume of collected data increases, for example more than one thousand every day, these resource intensive approaches become unfeasible and alternative solutions have to be implemented. These may include computer image recognition by learning methods (Joly *et al.* 2016) or a democratic system of online validation by the volunteers themselves. Such data cleaning processes may lead to the loss of large amounts of data, meaning that a large part of the volunteer's work may be go unused. Considering that data with large uncertainty may still always contain some information of use, another approach is to weight each datum using a truthfulness index that can depend on the results of an automatic learning approach, but also on what is already known about the volunteer that collected the datum. A good knowledge of the participants is necessary in such approaches (level of training, preference, behaviour), which is possible only if their fidelity is known and they each collect a sufficient amount of data.

Credit: Gro I. van der Meeren

Fig. 2.13 Briefing volunteers

Considering errors in the identification of species, this issue is particularly problematic if the data are already collected and no picture has been recorded. More information on the confusion matrix is needed to correct the induced biases because confusion is generally not symmetric and may be complex. This can only be done using previous experiments comparing expert identifications with volunteer identifications on test data (Oswald *et al.* 2003).

In conclusion, most data quality problems can be addressed if they are properly anticipated. The simplest and probably most effective measure is the training of participating volunteers. A second way is to efficiently manage the pool of volunteers to co-build shared objectives, as discussed in Section 2.1, and obtain self-coordination of the group to globally optimize the data collection while maintaining motivation and a sense of fun in the activity. This can be done by communication and networking. Finally, when data have already been collected, it remains a challenging task of data/statistical modeling in order to (i) reduce the variability and eliminate outliers or more trivial errors; (ii) reduce the potential bias; and (iii) aggregate data from different sources to obtain a global consolidated dataset. Data science is an active research domain and has already seen some first promising results in the context of Citizen Science applications (Fithian *et al.* 2015).

2.4 Social engagement, social impact and education

2.4.1 Social engagement

Central to relevant and rigorous Marine Citizen Science is the notion of social engagement and, in particular, participation. Participation is about collaboration, empowerment and direct active engagement with scientists, volunteers, community members and citizens through the different stages of Citizen Science work. Participation is about speaking and listening to individual citizens on their own terms. Participation goes significantly beyond just asking citizens for their opinions or what might be called ‘participation by consultation’. It gives citizens a voice about change and ownership, and responsibility for solutions to influence their welfare, their concerns and interests. Citizen Science research is interactive; it is ‘with’ and not ‘by’ or ‘on’ citizens. As can be seen in Figure 2.14 below, social engagement means moving away from simply informing or consulting towards collaborating with and empowering citizens:

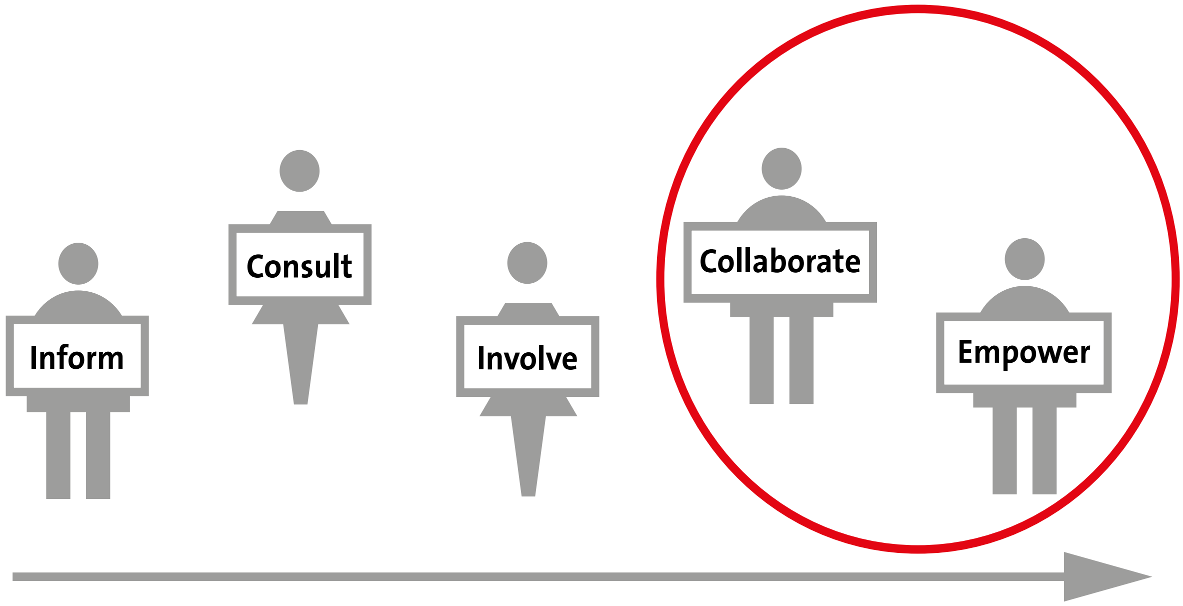


Fig. 2.14 Levels of participation in Citizen Science. Adapted from McHugh et al. (2016) and Davies & Simon (2013)

2.4.2 Why is social engagement and participation important?

Social engagement, direct active participation by individuals and communities, is the foundation for effective and efficient Marine Citizen Science. Active participation to define issues contributing to data collection and potential solutions is more empowering because it reflects the values important to the individual and increases control. Participation provides the necessary dialogue, interaction and mutual learning to manage and “resolve highly complex issues” (Alexander 2002, p.111), such as influencing human behaviour and the choices we make concerning the ocean and our seas.

The goal is to work out why potential Citizen Scientists do what they do at present, such as displaying environmentally-aware behaviours and sentiments, and their values and motivations, and use this understanding to develop a Citizen Science offering that is equally appealing but with positive personal and/or social outcomes. An in-depth discussion on the social science research behind this in the context of the microplastics issues is presented in Pahl & Wyles, 2017. This citizen-orientated approach is central for Marine Citizen Science to co-create successful research, initiatives, projects and studies and build through a well-grounded understanding of citizens, their needs and wants and the people engaged in it.

A highly participatory approach to Marine Citizen Science facilitates multiple stakeholders from various sectors and settings to simultaneously work together. It helps different groups with varying opinions and experiences reflect diverse social systems, contexts, content and actors underlying the work needed for Citizen Science. This collaborative process ensures citizens are no longer "objects of projects" (Brenkert 2002, p.21) but individuals to be reached out to and engaged in "scoping the possible causes of and solutions to problems" (Lefebvre 2013, p.8).

2.4.3 Marine Citizenship

Citizenship is a programme of rights and responsibilities that involves all members of a community or state to work towards a common goal, but the common goal must be communicated clearly to those citizens. McKinley and Fletcher (2012) lay out a justification for their concept of a 'Marine Citizenship', the idea that individual members of a state have the right to the outcomes of the government level policy goal of a 'healthy and productive marine environment', but concurrently have a responsibility to contribute to the achievement of that goal. For Marine Citizenship to be effective in the delivery of commitments to marine environmental protection, the individual citizen needs to have: (i) an awareness of the scale and challenge associated with the threats to the marine environment at local and global levels; (ii) genuine concern for these issues; (iii) an appreciation of the extent to which their own behaviours, and the behaviours of those around them, can stem the progression of these threats; and (iv) a motivation to change their behaviour, and to facilitate change in others, to lessen impact on the marine environment.

Attempts to tackle environmental concerns by simply providing information about an issue are an over simplification of the behavioural processes involved and likely to fail (Schultz 2011; Barr & Glig 2007). Psychological and sociological research over recent decades has investigated why there is often a difference in what people believe is the right way to act towards the environment, and how they actually behave (Thøgersen & Olander 2006; Toomey & Domroese 2013). There are many factors - social, economic and cultural influences, values, emotions - that can influence choices and an individual's readiness to overcome hurdles to lasting change (Kollmuss & Agyeman 2002; Hawthorne & Alabaster 1999).

Participation in science, and in environmental conservation, lets citizens observe and develop their own positive solutions and this potentially can have far-reaching impacts on environmental behaviours. Co-created projects (see Shirk *et al.* (2012) and Section 2.1 above) offer the greatest level of contribution and citizen-proactive collaboration. But even contributory models of Citizen Science provide opportunities for the participant to develop skills that empower them in other aspects of their lives and equip them for environmental citizenship. Involvement also provides access to scientific knowledge and to an understanding of the research process.

CITIZEN SCIENCE AND THE THIRD AGE

Citizens in the EU and indeed most other regions of the world are living longer and in better health than ever before. The next two decades will see the “baby boomer” generation retiring and a resultant demographic shift towards a more active older generation. However, rather than seeing an aging population as a financial threat, it can also be seen as a great achievement.

Increasing involvement of older citizens in voluntary work and cross-generational issues is an opportunity as well as a necessity for society. In 2012 the European Year for Active Aging and Solidarity Between Generations addressed the oncoming challenges and sought methods for improvement. Participation in Citizen Science projects is a potential method for enabling the ongoing participation in society by the older generation, as well as ensuring cross-generational interaction and solidarity.

The concept of lifelong learning is of growing significance and has recently seen the rise of related initiatives such as the University of the Third Age movement, associations of academic education for senior citizens, senior academies and an increase in interest for voluntary work in museums. This all points to an increase in interest being expressed in research-based education and discovery. Citizen Science projects offer both active involvement and an insight into modern research and current developments. In this, both educational institutions and senior citizen organisations can provide possibilities. For Marine Citizen Science projects in particular, the participation of the older generation offers mutual benefits and a wealth of potential. Questions raised by senior citizens are generally based on their rich and varied life experiences, long-term observations or familiarity, and professional expertise from other subjects. Some seek explanations where marine issues interact with personal life as well as public issues, for example in relation to seafood and marine resources, local phenomena and pollution issues. Conversely, others seek participation in activities where they can interact with younger generations, or out of concern for the future, especially if this is linked to children or grandchildren.

The benefits for senior citizens are numerous and include:

- Active involvement in marine science and informing marine policy
- Intellectual stimulation from research-based learning
- A feeling of appreciation and pride in participation and achievement
- An opportunity to address challenges facing the next generations
- An opportunity to keep in contact with evolving technology (mobile apps, internet, networks)
  An opportunity to stay engaged and mentally fit, regardless of health restrictions

The benefits for science are also significant and include:

- Active dialogue about marine issues with a growing part of society
- Increased potential for data collection and analysis
- The added benefits of life experiences and professional skills
- The opportunity to create mediators between research and society, and across generations

2.4.4 Social impact

The social impacts of Citizen Science, and specifically considering marine-based projects, can be both concrete and "soft". In terms of tangible impacts, these may be felt both by the Citizen Scientists and also other members of the communities and of society who are not directly involved. Examples might include a cleaner beach environment following a clean-up task and a study regarding marine litter, better water conditions following a campaign, or improved preservation of a nature hot-spot following the identification of a new or threatened species of flora or fauna. Improved education and changes in behaviours as a result of participation in a Marine Citizen Science project may likewise indirectly impact on the wider community through interaction with the Citizen Scientists (Hartley *et al*. 2015). This means that the positive societal impacts of Marine Citizen Science projects can be felt by a much wider range of people than just the numbers of direct participants, meaning that the benefits may be much more significant than initial assessments within the project may suggest. In terms of the "softer", more intangible social impacts, these can include benefits such as improved community spirit, which again may not have been a specific objective of the project but will, nevertheless, have positive societal impact. This again may benefit both participants and non-participants alike.

2.4.5 Assessing social impact

Assessing and measuring the social engagement and participation that facilitates Marine Citizen Science programmes and initiatives (Mulgan *et al*. 2013) becomes complicated as there is no single guide, template or universally agreed set of impact metrics. Social impact measurement deals with the 'processes' of Marine Citizen Science, where aggregate statistics no longer suffice as impact tools. Instead, the priority is to "record, describe and analyse the processes of engagement and change within the intervention so as to help make sense of outcome results and to help others learn from the intervention's experience" (Stead & McDermott 2011, p.199).

Therefore, to "improve" rather than "prove" change (Stead & McDermott 2011), social impact serves multiple roles such as:

- Monitoring and evaluating activities and processes
- Showing linkages between audiences and activities
- Determining if activities and processes are being implemented as planned
- Determining if activities and processes are meeting their desired values
- Allowing for benchmarking and comparative assessment
- Providing a trigger to modify efforts if they are not adequate
- Promoting continuous learning
- Encouraging collaborative relationships
- Providing feedback loops for continuous communication
- Systematically monitoring progress
- Reflecting on successes and shortcomings
- Identifying future legacy contributions

For Marine Citizen Science, a Participatory Impact Assessment Framework (Figure 2.15) is a timely and fitting model as it emphasizes systemic measurement – measuring activities and processes, in addition to traditional measurements such as inputs and outputs – producing a bigger picture, a systems view of Marine Citizen Science. The participatory impact dimension stems from the interaction and connectivity between the formative and summative level measurement dynamics over the duration of a Marine Citizen Science programme or initiative.

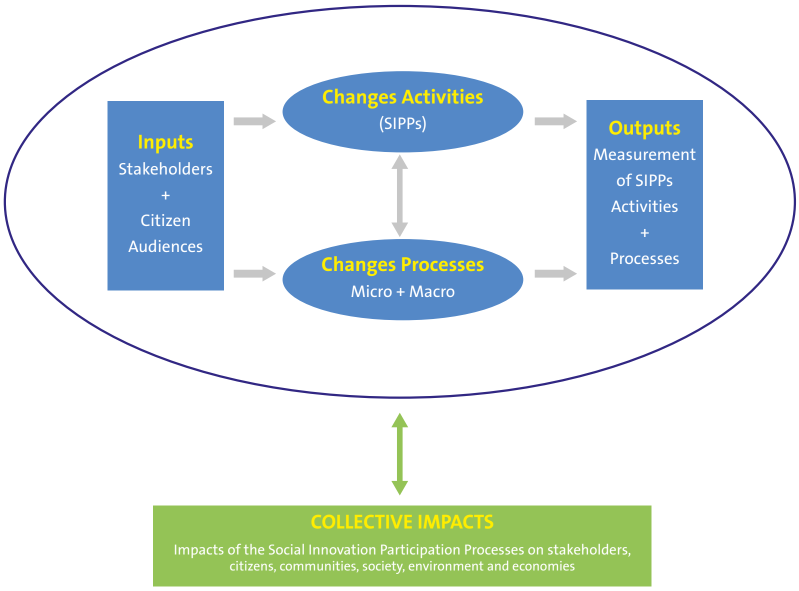


Fig. 2.15 A participatory impact assessment framework for Citizen Science. Adapted from (Ertl *et al.* 2006)

A Participatory Impact Assessment Framework for Marine Citizen Science is a forward-moving assessment. Measuring impact is not always easy, but it should not be treated as an afterthought or a last line of defence. Impact measurement for Marine Citizen Science assesses isolated impact metrics (snapshot in time measurements for inputs and outputs) in addition to participatory impact metrics to better understand attitudes, knowledge, behaviours, values and actions. This requires the continuous monitoring and measurement of inputs, activities, processes and outputs, to create an overall picture of Marine Citizen Science, and grasp the social and cultural implications of social impact.

Furthermore, acknowledging the power of learning and feedback is essential to the proficient measurement of social impact. Marine Citizen Science programmes and initiatives facilitate multiple interactions between people, communities and their oceanic environments. The inclusion of feedback loops between Citizen Science researchers and citizens creates reflection points throughout the lifetime of a project. These can be used to monitor the effectiveness of the Citizen Science structures and processes, assess the way in which relational systems and activities are operating, and judge the degree of progress toward the shared goal. To this end, it is paramount to monitor and track the Participatory Impact Assessment Framework through three distinct stages as set out in Table 2.1.

Table 2.1 – Three Marine Citizen Science approaches to assessment. Source: Bayliss-Brown et al. (2015)

	DEVELOPMENTAL FRONT-END ASSESSMENT	FORMATIVE ASSESSMENT OPPORTUNITIES	SUMMATIVE REMEDIAL ASSESSMENT OPPORTUNITIES
CITIZEN SCIENCE PRINCIPLES	Co-design	Co-create	Co-deliver
COLLECTIVE IMPACT ASSESSMENT FRAMEWORK	Citizen Science project is exploring and in development.	Citizen Science project is evolving and being refined.	Citizen Science project is stable and well-established.
WHAT'S HAPPENING?	Partners are assembling the core elements of their Citizen Science initiatives, developing action plans and exploring different strategies and activities. There is a degree of uncertainty as to what will work and how. New questions, challenges, and opportunities are emerging.	Citizen Science core elements are in place and partners are implementing agreed upon strategies and activities. Outcomes are becoming more predictable. The Citizen Science initiative's context is increasingly well-known and understood.	Citizen Science activities are well-established. Implementers have significant experience and increasing certainty about "what works". Citizen Science is ready for a determination of impact, merit, value, or significance.
STRATEGIC QUESTION	What needs to happen?	How well is it working?	What differences did it make?

At a basic level, developmental front-end assessment, formative assessment and summative remedial assessment allow for a combined and tracked measure of social impact, providing answers to 'what-is-happening' and 'how and why change is happening' in the Citizen Science system. The inclusion of these 'how' and 'why' questions speaks directly to the assessment of social impact as it determines and observes the progress of Marine Citizen Science, provisioning for developmental changes to efforts, activities and processes, if necessary, to improve the research and social impacts of programmes and initiatives.

From this perspective, the Participatory Impact Assessment Framework with its underlying social impact measurement resonates with Marine Citizenship and Public Perceptions Research (PPR) in reaching unity of thought. Participation in Marine Citizen Science views social impact as parts of an overall system, rather than reacting to present outcomes or events and potentially contributing to further development of the undesired issue or problem. The "sum of the whole is greater than the sum of the parts" and "the parts cannot be understood if considered in isolation from the whole" (Phillips 2000, p.44).

CITIZEN SCIENCE, CHILDREN AND EDUCATION

There are a number of examples of Citizen Science projects that are aimed specifically at children and which are also linked with core curriculum subjects. Two European examples are presented here.

Shore Thing builds upon the work done by the MarClim project (www.mba.ac.uk/marclim) running long-term ecological research of UK coast species to quantify the effects of climate change on species range distributions. Shore thing encourages students to survey rocky shores recording the distribution and abundance of climate change indicators and non-native species using two protocols: transect survey and effort-based search. The latter records presence and absence (important when monitoring impacts of rising sea temperatures and range changes in species) of 22 species. By joining this project, students have the opportunity to (i) record the distribution and abundance of climate change indicators and non-native species around UK shore; (ii) provide data to help monitor the impacts of rising sea temperatures; and (iii) take part in "real" science. The data collected by the students are made available to a wider audience via the National Biodiversity Network. By engaging schools and citizens in marine conservation through fieldtrips, Shore Thing strengthens the connection between education and marine research. This project can be used to teach several topics such as biology, environmental studies and even geography. Moreover, it provides strong support for teachers to implement this innovative project into their practices (e.g. teacher training, survey protocol, teaching resources).

www.mba.ac.uk/shore_thing

Credit: ©Jack Sewell (Marine Biological Association)

Credit: Mikael Olsson

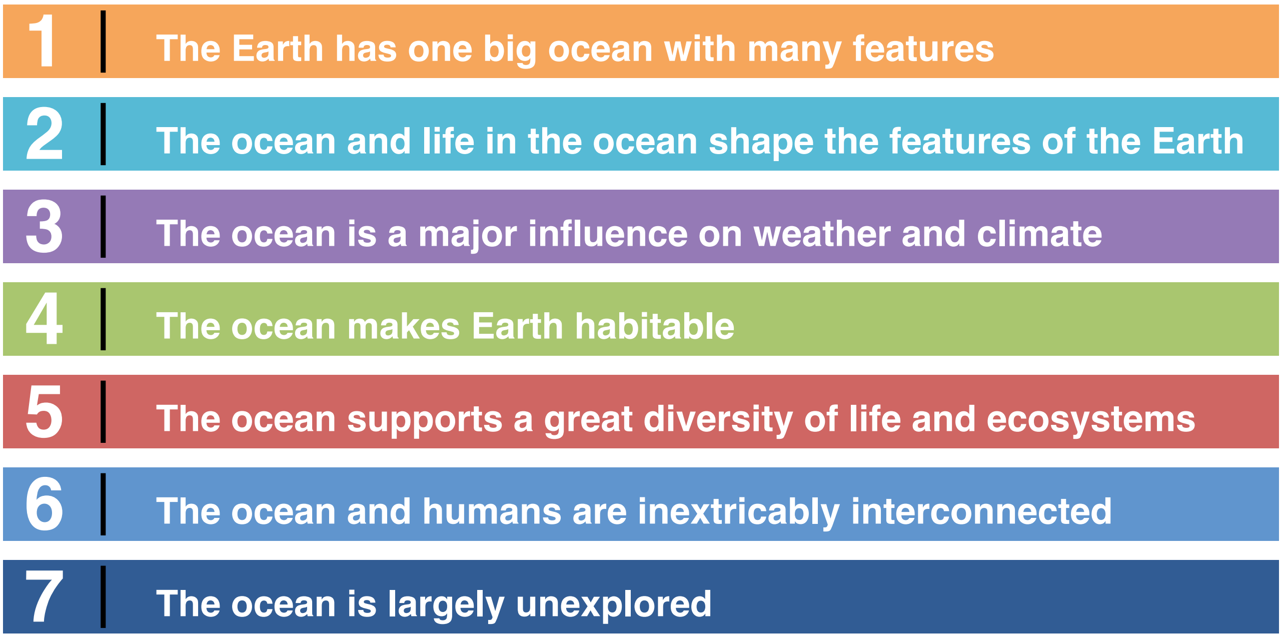
Fig. 2.16 Left: The Shore Thing, Right: Virtue project

The Virtue project is run by the University of Gothenburg and the Maritime Museum & Aquarium in Gothenburg and aims to stimulate interest in science among students of all ages through exploration of their local marine environment. The idea is simple: clear plastic discs are mounted on a plastic pipe rack and placed in different aquatic ecosystems for various lengths of time to monitor colonization of species (biofouling). The students will analyse biofouling on the discs and register the findings in a database (Virtuedata.se) or on paper, which enables students to compare and discuss their results. Virtue provides ample opportunity to take an inquiry approach to one's work; practice in setting up experiments; carry out measurements in the field, classroom or laboratory; and interpret and report on the results. Virtue promotes teacher collaboration as it connects different subjects (e.g. biology, mathematics, physics, chemistry, arts and languages) and offers online educational support (e.g. data sharing platform, species group identification guide) and the possibility of international school collaboration.

http://science.gu.se/english/cooperation/virtue

2.4.6 Ocean literacy and education

The term Ocean Literacy refers to the understanding by citizens of the two-way dynamic relationship between the ocean and the human population: the appreciation of the influence of the ocean on people and that people are influencing the ocean. Its definition, essential principles and fundamental concepts were developed from 2005 by fruitful interactions between 100 stakeholders from academia and research institutes, US national scientific agencies, private foundations and the National Geographic (www.oceanliteracy.net). Further partners include informal science institutions, educator communities, government agencies and NGO's. The resulting seven Essential Principles of Ocean Literacy encapsulate a multidisciplinary prospective to study, utilize and preserve the ocean's ecosystem functioning; it is upheld by the partners that all members of society should have an understanding of these principles by the time they leave secondary education. A lack of knowledge of these core principles is deemed to a significant barrier to the development of Marine Citizenship. The seven Essential Principals are:



Credit: Geraldine Fauville

Fig. 2.17 The seven essential principles of Ocean Literacy

The development of the concept of Ocean Literacy emerged initially from the US, and in Europe the movement first gained ground in Portugal. Since the early eighties, researchers have employed various methods (focus groups, written survey, observations, telephone survey) to explore the level of familiarity of respondents (both school pupils and adults) with marine topics. The longitudinal study run by The Ocean Project (The Ocean Project 1999; The Ocean Project 2009) reveals that American public's knowledge and awareness of ocean-related topics remains low. The situation seems similar in Europe. Large scale pan-European (Gelcich *et al.* 2014; Potts *et al.* 2016 - 10,106 and 7000 respondents respectively), regional sea level (Ahtiainen *et al.* 2013) and national surveys (Boubonari *et al.* 2013; Chilvers *et al.* 2014) have been carried out on public perceptions of marine impacts, concerns and priorities relating to these, awareness of marine species, habitats and the ecosystem services derived from marine environments. These studies demonstrate that the level of concern regarding marine impacts depends on how much the respondents have been informed about threats to the marine environment, and that pollution and overfishing are two areas prioritized by the public as requiring particular attention (Gelcich *et al.* 2014; Jefferson *et al.* 2014; Potts *et al.* 2016).

CITIZEN SCIENCE AND TRADITIONAL KNOWLEDGE

Traditional knowledge, Citizen Science and other scientific information are core elements in understanding, protecting and managing the coastal zone. Humans have lived in and used intertidal and shallow water areas for thousands of years, learning to use indicators and to understand local peculiarities and patterns, which occasional scientific tests and models may miss. Traditional knowledge is sometimes recorded and local libraries and maritime museums can be good sources for this kind of information. However, direct interaction with the local population including fishers, gatherers, bait diggers, harbour masters and boat builders can also be a very valuable approach. For those seeking traditional knowledge directly from the knowledge holders, it is essential that this source is valued and acknowledged as being equal, though different, to any other type of scientific insight.

As has been discussed before, there may be valid reasons, such as commercial interests, why this traditional knowledge is not commonly shared openly. However, by working together, scientists and traditional knowledge holders can engage in meaningful dialogues that will not be detrimental to either. In building a relationship based on trust and transparency, issues such as traditional knowledge holders feeling that the sharing of their knowledge is taken for granted and simply "mined" with no returns, or information being withheld or selectively shared, can be avoided. The key to success in such endeavours is good communication, careful project design and appropriate monitoring schemes. Adherence to a simple and clear code of conduct for all parties will also ensure transparency and foster trust.

In short, scientists need to cultivate and promote ethical ways in which to involve traditional knowledge holders and share information in order to generate public participation and buy-in for management plans, legislation and its implementation.

Credit: Marnie Bammert ©MSC/Marine Photobank

Fig. 2.18 MSC-certified fisheries in Hastings, UK

Over the last decade, the publication rate on knowledge and perceptions of the public in relation to marine issues has grown steadily from an almost non-existent level in the early 2000s. Through the Sea Change Project (www.seachangeproject.eu), funded under the EU Horizon 2020 programme, a much more in-depth understanding of the current status of, and barriers to, achieving widespread and high quality marine awareness has been developed. The localized nature of certain issues and perceptions has been identified, but so too have the broader challenges that are specific to promoting marine environmental knowledge.

In order for citizens to become engaged participants in marine environmental issues, Ocean Literacy is essential. Formal education in schools offers the opportunity to reach large sections of the European population and the seven principles can usefully constitute the focus of ocean science education at school. Rooted as it is in both science and environmental education, ocean science education can serve as an important bridge between these two fields (Gough 2002; Wals *et al.* 2014). Two examples of ocean-related education projects being included in school curricula outside Europe are provided by Nicosia *et al.* (2014) and Eastman *et al.* (2014). However, in Europe to date, environmental and science education focus strongly on the terrestrial environment, while ocean topics are less well regarded (Gotensparre *et al.* 2017). As part of the Sea Change project, a pan-European consultation of stakeholders addressed barriers and potential solutions to teaching 12 to 19 year olds about the ocean. A meta-analysis of the eight national reports constitutes the first mapping exercise of this issue and will potentially be an important step towards understanding the challenges for ocean science education.

In order to tackle these challenges, associations with specific remits for the promotion of marine education excellence have adopted a holistic approach, addressing hurdles from both top-down and bottom-up perspectives. The European Marine Science Educators Association (EMSEA), the National Marine Educators association in the US (NMEA), the Canadian Ocean Network for Ocean Education (CaNOE) and the Asian Marine Educator Association (AMEA), each have their own specialisms and cultural relevance. In Europe, EMSEA provides training and teaching material to support marine educators and acts to raise educators' awareness of marine issues. The Association is collaborating with European decision-makers in order to embed Ocean Literacy in formal educational programs.

The engagement of young citizens at this crucial stage of the development of their value system is likely to lead to better informed stewards of the marine environment and development of a lasting 'Marine Citizenship'. Greater levels of awareness regarding the societal and environmental challenges associated with 'marine', and the role of research and science in addressing these, may contribute to the promotion of environmental and marine science research as a career pathway. In turn, Ocean Literacy, knowledge exchange and engagement in environmental research have the potential to directly combat the growing trends of post-truth, dissemination of unfounded rumours and negation of scientific thinking (e.g. climate scepticism). Direct participation in gathering factual evidence may help to improve confidence in facts and actions based on the opinions of experts, and reduce manipulative and emotively driven reactions.

Citizen Science projects can play a significant role in enabling and furthering Ocean Literacy. As a deliverable, they often provide educational materials to schools, universities, public institutions and online. EU projects such as Sea Change (www.seachangeproject.eu), ResponSEAble (www.responseable.eu), and Sea for Society (www.seaforsociety.eu) have focused interdisciplinary research capacity to explore how scientific research can be made accessible. Allowing young people exposure to the scientific research process at first hand ensures they appreciate both the limitations and the potentials of science.

CITIZEN SCIENCE AND FISHERS

While a typical Citizen Science project is based on participation by volunteers, collaborations between scientists and trained citizens, usually stakeholders, have proven to be a very valuable source for obtaining data otherwise out of reach for the scientists alone.

The marine science community of Norway, a small country with an exceptionally long coastline and a huge exclusive economic zone, is unable to monitor all of this area alone. However, more than 80 % of the population live within 10 km of the coast and have access to probably the highest number of recreational boats per capita in the world. Collaboration with stakeholders, which has been developed over a number of decades, had led to an improvement in the information and databases such that they cover a much larger area and a much wider range of species, rather than being limited to only a few commercially significant species.

In recent years, recreational anglers and divers have been invited to report their landings and observations through catch diaries, sample and measure all catch, report on recaptured fish and lobsters in tag-recapture studies, and collect marine litter such as ghost traps and gear. The service provided by the recreational anglers and divers is rewarded through economic incentives, and in the case of the commercial, fleet, fisheries quotas. The data being provided are of great importance for fisheries and environmental management and also for policy making related to coastal ecosystem and stock protection. Some typical projects which seek the direct participation of stakeholders include:

(i) Collaboration with fishers to register selected catches, based on gear, area and season. Old logbooks can also be a valuable source of information. The commercial fishing community are trained in species recognition and the monitoring procedure required to obtain scientific data of equal quality to standard scientific survey data. This could involve them reporting on their total catches including all sizes of the target species and bycatch of non-commercial species (Institute of Marine Research 2013), comparison of catch per unit effort studies (Woll *et al.* 2006), landings of litter, etc. Such data are used in several stock assessments and is important for improving management, stock protection and the tracking the trends in income.

(ii) Tag-recapture programmes with awards for delivery of tags along with data on the catch site, water depth, date, and biological measurements of the animal. All recaptures are entrusted to commercial or/and recreational fishers and have resulted in new and important information which is now used in stock assessments, fisheries management and fisheries policy-making, e.g. escaped farmed salmon (Skilbrei 2010); and Greenland halibut stock and movements.

(iii) Collection of catch diaries created by recreational anglers. Such collaborations have resulted in new and highly important information regarding the actual extent of recreational exploitation (Ferter *et al.* 2013) (e.g. the actual total catches of lobsters by recreational fishers (Kleiven *et al.* 2012)). This information is now being used in ongoing management revisions for non-commercial fisheries in Norway. Besides these Norwegian cases, studies in other countries are based on similar collaboration, e.g. (Lloret & Font 2013; Diogo & Pereira 2014). A review on lessons learned in such studies was published by Dedual *et al.* (2013).

(iv) Log books from professional fishers: Current and historic logbooks from the commercial fishing community can be a very valuable source of information over a long temporal period and have been used in examples such as (Britten *et al.* 2014).

2.5 The role of technology in Citizen Science

Citizen Science approaches can benefit from technological innovations and many depend on their availability. Enabling technologies include information technology (IT) infrastructures and mobile human-machine-interfaces (HMI, e.g. in the form of software applications or short apps) as well as sensors and platforms. There are inspiring examples for the use of technologies in all of these areas for seas and ocean research. While technologies are certainly not mandatory, there is a large potential for them to address a number of new parameters, assist in quality control and acceptance of data, help with visualization and interpretation, and enable free access to data for a more extensive societal reach. Technology has vastly increased accessibility: (i) of the citizen to the scientist, and the ease with which the citizen can return collected data; and (ii) of the natural environment to the citizen and the ease with which the citizen can collect and engage with ocean data. It is this factor that is purported to have been the greatest driver in the dramatic expansion of Citizen Science over the last two decades.

Because technologies have public appeal and are considered ‘exciting’, their use in projects can increase citizen engagement; this is particularly true of the more novel and innovative elements (see unmanned systems below), if they are enabled to interact with the equipment directly. This could be done through direct interaction, online platforms to virtually control and pre-programme the equipment, online platforms to monitor the equipment, online means of analysing the data, or education initiatives to perhaps “sponsor” and have ownership of a particular piece of equipment.

It is, however, noted that concerns regarding the use of technology in Citizen Science projects have also been raised. Reliance on it can contribute to the exclusion of certain groups without access to such technologies and the steadily increasing number of smartphone apps can be overwhelming for users unfamiliar with such tools. That participants may focus more on the gadget and the game element, rather than the educational value or engagement with marine issues, has been also debated. Additionally, with increasing alienation of society from the natural environment, it is argued that providing routes to interact remotely and via technology exacerbates this problem, rather than alleviating it. An additional risk arises from a requirement to keep these tools continuously up to date (e.g. with respect to model changes and operating system updates) thus exceeding project resources. This sustainability is, of course, related to funding constraints, but can be mitigated if appropriate approaches are used throughout the design of the technology. On balance, the benefits greatly outweigh the challenges relating to project inclusivity, engagement with nature and marine issues, if the use of technology is carefully considered during the design stages (see Section 2.1).

2.5.1 Smartphones, apps, sensors and DIY

The observation of relevant marine ecosystem variables is closely related to the cognition of the observer. Environmental parameters, for example marine flotsam or species presence or abundance, are accessible from visual inspection. With mobile devices such as smartphones, human observations can be entered into an electronic log sheet, photo-documented, and guided by decision (identification) support software within the dedicated app. Metadata, such as position and time of measurement, can be automatically captured using embedded time and global positioning sensors, which are now standard in modern devices. The inherent capacities of a smartphone, such as its camera sensor and in-built flashlight, its knowledge of position and point in time, its graphical user interface and its telemetry options, can be enhanced and exploited to become a sensitive analytical device (Friedrichs *et al*. 2017). Beyond that level, even apparently simple water properties such as temperature or salinity require specific measurement equipment and thus can be a hindrance to Citizen Science initiatives if not properly managed.

A possible way to overcome this and to widen the marine parameter portfolio to cover more data types (Section 2.2) is the development of low cost sensors, which can be affordable and easy to purchase or build. The DIY (Do It Yourself) approach can be an especially powerful way to actively engage citizens in both the application and improvement of the sensor. Building a temperature sensor and connecting it to the smartphone can be realized with low costs and technical knowledge. Quantifying a water parameter such as chlorophyll a fluorescence, a proxy closely linked to phytoplankton abundance in the sea, can be achieved using self-assembled electronics in a mechanical housing printed using a 3D-printer, both controlled using a smartphone. Smartphones can also be used for data acquisition, by connecting them to external DIY devices with open-hardware platforms, e.g., Arduino, as shown for the KdUINO (Bardaji *et al*. 2016). For future smartphone generations, more inbuilt sensors are to be expected which could comprise ultraviolet or infrared illumination, have automatic detection capacities or contain highly sensitive pressure sensors.

The key to a sustained DIY approach is to open the electronic layout and mechanical construction information to the public, making it a sustained community effort (e.g. the Arduino user network or the 'maker-bot' community). Citizens, with an accessible level of technology skill, can pick up design information and details, modify them to suit other mobile devices and improve them; all such development is shared with, and acknowledged by, the citizens involved. Options involving the adaptation of globally available tools and household items require less technical knowledge; it is possible to build the water transparency measurement device, the iQwtr (http://bluelegmonitor.com/en/technology/iqwtr), from an IKEA™ storage box and some hardware store items.

The use of technical tools such as smartphones apps or portable measurement devices has a strong advantage in adding automated quality control to the data. This has already been demonstrated for terrestrial applications, e.g., bird monitoring supported by known distributions of species to flag unusual observations, and could be adapted for coastal and open ocean species. In the use of smartphones as a sensor, quality control measures can be added for each measurement, e.g. using built-in inclinometers to control device orientation, or cameras to evaluate illumination conditions. Compliance with international data standards increases the acceptability of Citizen Science data for international data repositories, such as SeaDataNet (www.seadatanet.org) or EMODnet (www.emodnet.eu) (Busch, Bardaji, *et al*. 2016). Such standardization of data leads to compliance of citizen and satellite data with rigorous scientific requirements, with examples including data on water colour (Busch, Price, *et al*. 2016) and temperature (Brewin *et al*. 2015; Schnetzer *et al*. 2016).

Engaging the large community of citizens that have access to sailing vessels or motor yachts offers high potential when tackling the data requirements of theopen sea. Underway sensing equipment, deployed in the water, in a flow-through system within the vessel hull or above the water, is capable of sensing a variety of marine environmental parameters and contributing to calibration and validation activities. Though there is a certain cost of procurement and maintenance associated with these systems, the target community is typically affluent and affording such equipment as supplementary equipment to their passion is not prohibitive, especially if mutual benefits and incentives can be demonstrated.

CITCLOPS

Citclops (Citizens' Observatory for Coast and Ocean Optical Monitoring) was an EU FP7 Framework funded project which ran from 2012 to 2015.

Anthropogenic and non-anthropogenic causes together can lead to harmful conditions within the marine environment and in these in turn can affect human society. Examples of this include harmful algal blooms and habitat destruction which can have societal, economic and health implications. A widely adopted scientific indicator for assessing the environmental status of marine waters is through their optical properties. Seawater colour, transparency and florescence can all be used as indicators of different aspects including sewage impact, dissolved organic matter, sediment load and gross biological activity.

Concerned about the ongoing conflict between conservation and exploitation of aquatic ecosystems, and the importance of including the interests of all stakeholders in the development of new policies to address this, the project sought to engage the wider public in gathering this optical data. By engaging citizens through active participation, not only would it be possible to create a broad database of results and develop a greater understanding of ecosystem processes not covered by conventional monitoring, but also greater education, understanding and a feeling environmental stewardship could be fostered amongst the participants.

In this project, a concept and smartphone app called "EyeOnWater" was developed, where citizens use their device's camera to take a picture of the water and then classify its colour using a comparison bars. Their picture, together with the conditions in which the picture was taken and their automatically-logged location (in an internationally standardised metadata format) are then uploaded to the website for everyone to view. The website also has a section for uploading water clarity data, typically measured using a Secchi Disk device, and a new section on Sea Lettuce colour observations. Three additional techniques to assess standard water properties were developed: KdUINO underwater buoy-based light chain to measure the attenuation of light in the water column, TRANsparency underwater Index based on Citizen camera pictures (TrandiCam), and SmartFluo, which converts a smartphone into a fluoro as in the Citclops project meter for measurement of algal pigments in water, by means of a 3-D printed housing. Data and metadata of Citclops are prepared in internationally standardised format that allows an easy uptake to, and open access in long-term repositories, such as Seadatanet, EMODnet or GEOSS.

The EyeOnWater app and website have continued operation beyond the end of the Citclops project, and to date have had over 1600 measurements worldwide, contributing to ongoing long-term and statistical analysis in conjunction with climate research. The work within the project has also led to 11 peer-reviewed publications.

www.citclops.eu/home
www.eyeonwater.org/

Credit: Shutterstock

Fig. 2.19 A DIY drone kit

2.5.2 Unmanned systems: new tools for surveying marine habitats

Autonomous vehicles, and more citizen-accessible drones, are increasing in both affordability and performance capability. Flying drones can be used for coastal monitoring (e.g. CoastalResilience (www.coastalresilience.org)) or as a marine sampling platform. Along with such applications come legal and ethical concerns, and the need to inform citizens on the proper use of such platforms, since they can penetrate prohibited areas or cause harm.

Aerial, underwater or sea-surface surveys of marine habitats, coastlines or coastal populations can provide accurate, human risk-free, and inexpensive solutions. They can also enable exploration and study of previously-inaccessible or dangerous locations. Long-term datasets constructed using drones will be of high conservation value and an efficient means of risk assessments for human impacts. Programmability for pre-programmed operations to known locations provides additional benefits. With time and some further development, they should become a standard tool in monitoring coastal systems and would be well suited for high-value Citizen Science input. Association between Citizen Scientists, citizen developers, educational institutions, industries and scientists would increase the scientific and social benefits.

Unmanned Aerial Systems (UAS)

This term refers to small drones which are remotely operated from the ground by the user. They can be controlled using smartphone or tablet applications, and in the future may become fully autonomous. Drones can provide cost-effective monitoring of the environment at spatial and temporal resolutions that are appropriate to the scales of many ecologically relevant variables. There is already a structured and active DIY drone community (www.DIYDrones.com) which could prove a valuable partner in Marine Citizen Science. Drones can carry various imaging and non-imaging sensors to provide data for monitoring protected and endangered species for wildlife conservation, data on the effects of climate change, coastal erosion and sea-level rise, information regarding marine debris and chemical pollution in remote locations, and observations on strandings of marine organisms.

While **Fixed-Wing UAS**s are currently not used directly by citizens, **Rotor-Based Copter Systems** have low operating costs and the requisite skills are within the reach of Citizen Scientists. Projects using such equipment could operate along similar lines to those which currently rely on citizens who own and operate their own yachts and water craft, or diving equipment. They are suitable for vertical profiling experiments and spatial surveys (i.e. photogrammetry and wildlife census, fine-scale remote sensing, coastal habitat and sea grass mapping, etc.). These systems can currently fly for a maximum of 20-30 minutes and have a range of around 5 km. In terms of Citizen Science projects these systems provide both spatial and temporal perspectives on ecological phenomena that would otherwise be difficult to study.

Autonomous Underwater and Surface Vehicles (AUV and ASVs)

Remotely operated oceanographic equipment return information on an ocean-basin scale, greatly enhancing our understanding of our ocean systems. They include Autonomous Underwater Vehicles (AUVs), propeller-driven submersibles or underwater buoyancy-driven gliders, and Autonomous Surface Vehicles (ASVs), one example of which is the Wave Glider (www.liquid-robotics.com), which is able to utilise wave and solar power to operate entirely without fuel for up to a year. In terms of Citizen Science applications, although such equipment may be prohibitively complex and expensive for use in such projects at present, their ongoing development is likely to make them an asset in the near future. Possibilities would be particularly interesting in options such as educational programmes where students could be involved in "sponsoring" a glider or floats, programming it for a mission and gathering and analysing the results. For larger AUV such as Remotely Operated Vehicles (ROV), the information and pictures that they could gather could be very popular for online Citizen Science data analysis projects.

Credit: NOC

Fig. 2.20 An AUV

Credit: David White, NOC

Fig. 2.21 A wave glider

The box below presents a non-exhaustive list of potential benefits from the application of enabling technologies within Marine Citizen Science projects.

BENEFITS OF APPLYING ENABLING TECHNOLOGIES

- Tools can be drivers for increased Citizen Science participation
- Positioning services, such as GPS, can provide a simple link between onsite measurement and location/object
- Mobile devices (e.g. tablets and smartphones) extend application possibilities beyond paper log-sheets of observations, to visualization, mapping and image analysis capacities
  Remote-controlled vessels or gadget drones provide access to remote areas (see Section 2.6)
- Low cost underway sensing systems could enable sailors to contribute to the global network of vessel of opportunity observations
- Open web interfaces and database structures enable the broadening of Citizen Science initiatives to handle a scalable, potentially large number of participants and entries
- Low-cost and DIY sensors can address water properties and other information not observable from pure visual inspection or camera application
- Game-interfaces can help to recruit human creative power and complex recognition skills
- Web-enabled devices allow for direct information access and upload as well as multi-directional communication channels, including social media
- Meta-analysis of social media activities can support monitoring and tracking of events and social impact of projects
- Usage of open access approaches and configurable toolboxes can speed up the development of specific solutions for individual Citizen Science projects, widen engagement and involvement, and foster their sustainability e.g. facing software updates and newly evolving platforms
- Compliance to standard data and metadata formats allows long-term accessibility of data in regular data repositories (EMODnet, SeaDataNet, GEOSS) and direct comparability between citizen and research data
- Automation of data quality control and long-term storage in international data centres can then support open access of data and meta-data

In conclusion, technology can positively support and advance Marine Citizen Science initiatives if embedded thoughtfully into the project design. Technologies act as an enabling tool and can be used to foster higher levels of participation, particularly if there is citizen involvement in the design of the approach and analysis of the results. To maximize the benefits derived, it is recommended that there is greater access to and sharing of expertise in technical support, tools and facilities across Europe, so that new ideas can be developed in a shorter time without a requirement for in-depth technological knowledge amongst project instigators. Such platforms could assist in demonstrating the use of different tools, address queries raised by citizens and authorities, and showcase inclusive stakeholder communication systems using new technologies.

2.6 Citizen Science and earth observations

Coast and ocean observations are essential to support applications in areas such as marine safety (sea ice forecasts, oil spill, ship routing), marine resources (time-series for hydrodynamic and ecosystem models), marine and coastal environment (water quality, pollution, coastal activities), and seasonal and weather forecasting. The need for clearer understanding of the impacts of climate change on global marine environments and ecosystems in order to inform the policies that will be needed to combat these impacts is making comprehensive earth observation and data collection approaches increasingly vital. This is discussed in more detail in Chapter 3. The strengths of remote sensing operations include extensive spatial and temporal coverage, access to remote or hard-to-reach areas (high seas, sea ice), and standardised data processing and management procedures. Weaknesses are usually related to large pixel sizes of images and a limited aerial re-visiting time of sensors (> daily), which inhibit documentation of small scale spatio-temporal changes. For optical remote sensing sensors, near shore areas are often corrupted by cloud cover, influence of land to pixels or bottom visibility (Busch, Price, *et al.* 2016).

The contributions of citizens to the field of earth observation, sometimes referred to as community remote sensing, can certainly support such operations. Data retrieval has the potential to deliver a positive cost-benefit ratio, and the inclusion of citizens in earth observations holds the potential to empower societies to take a more active role in decision-making.

Co-use of data from citizens and satellites is strongly supported by the use of standard oceanographic parameters, as these are directly comparable. Water temperature data from space and citizens were successfully compared in recent studies (Schnetzer *et al.* 2016; Brewin *et al.* 2015); water colour, transparency and algal fluorescence (e.g. Citclops project) are examples of complying products (Busch, Bardaji, *et al.* 2016). Such conformity of Citizen Science data with standard parameters is hence highly supportive for comparability to earth observation data (see Section 2.7). In addition, there are a number of parameters that do not directly comply with, but relate to, remote sensing products. One example is nutrient concentrations, which have an impact on algal proliferations, or pH.

The combined use of citizen and satellite data offers a number of advantages:

2.6.1 Increased spatio-temporal coverage of measurements

While optical remote sensing observations are often corrupted in coastal areas, this is the most commonly sampled zone in Marine Citizen Science projects. Often Citizen Science data covers areas where no *in-situ* or remote sensing data are available, as shown for 80% of citizen-derived data in the Ocean Sampling Day project (Schnetzer *et al.* 2016), or in a Citclops case study in the Ebro Delta (Busch, Price, *et al.* 2016). On the other hand, data samples from the ocean are not frequently accessed by citizens, except by leisure sailors or certain maritime professional groups. This spatial mismatch, however, may require new solutions and software for combining citizen and satellite datasets. Citizen data also hold significant possibilities for supporting remote sensing operations by aiding in the identification of temporal patterns that are not covered by more precise remote sensing data, which often display locations at the same local solar time (sun synchronous). Also, sporadic events such as algal and jellyfish blooms, mass mortalities and strandings, or oil spills can be detected by Citizen Scientists in a timely manner, where no space-borne data are available.

2.6.2 Support in data quality

Trends or seasonal averages of space-produced data can be used as background for citizen data, e.g. to verify their quality and/or to set citizen data within a larger context. The difference between Citizen Science and scientific data quality can be assessed by comparing both against remote sensing products, and can contribute to discussions on the robustness of Citizen Science data (Schnetzer *et al.* 2016). Conversely, water temperature measurements from Citizen Scientists comply well with *in-situ* systems, and may support quality control of space-borne observations (Brewin *et al.* 2015). It is noted, however, that in most cases, Citizen Science data will not reach a sufficient level of precision for quality control of remote sensing data at present. A clear description of Citizen Science tools, methods, and associated limitations aids in the determination of purposes for which these data can be used.

There are already a number of examples of compatible remote sensing and citizen datasets. These can be considered as a first step in the support of earth observation using Citizen Science. A full understanding of the potential citizen contributions has to offer to *in-situ* and remote sensing for the marine environment, or more specifically to marine safety, understanding and forecasting of environmental processes, and decision making, is still in its infancy. It is important to note that Citizen Science will not substitute traditional data retrieval and it is not a panacea to overcome all limitations of remote sensing observations. Extended research and case studies will, however, aid in exploring the added value of combined Citizen Science and earth observations.

SECCHI DISK STUDY

The Secchi Disk Study, which has been running since 2013, is operated by the UK charity, The Secchi Disk Foundation, and is funded entirely by sponsorship and donations. It is named after the white disk that was developed by Pietro Angelo Secchi in 1865 as a means for measuring water clarity. This study relies on the global participation of seafarers, including sailors, divers, anglers and the commercial fishing community, to generate and send data on water clarity. To date, data have been gathered from the Arctic to the Southern Ocean, and from the Pacific to the Atlantic, including in 2014, data from the Northwest Passage.

Secchi
SECCHIDISK.ORG

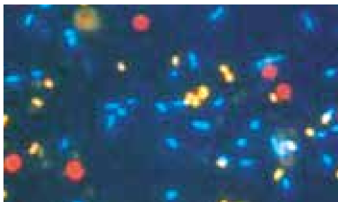
In areas of water away from estuaries and coastlines, water clarity is an indicator for the amount of phytoplankton present at the sea surface. Phytoplankton are photosynthetic, microscopic organisms and they are the ocean's main primary producers, and so they underpin the food chain to support other ocean life, including commercial fisheries. Phytoplankton are so abundant in the sea that they account for at least 50% of all photosynthesis on Earth and so they also generate at least 50% of the earth's oxygen, which is a product of their photosynthesis.

The sea surface habitat of phytoplankton makes them particularly sensitive to changes in sea surface temperatures. Recent, high-profile studies have suggested that rising sea surface temperatures, due to climate change, may have caused large-scale declines in global phytoplankton concentrations by affecting the supply of nutrients from deeper waters. The Secchi Disk study aims to collect as many data as possible about global concentrations of phytoplankton and their changes over time and space to understand the influence of climate change upon ocean productivity and generate new scientific knowledge.

A Secchi Disk is a simple white, 30cm diameter disk that is attached to a tape measure and weighted from below; citizen participants can either make their own Secchi Disk using household items or purchase one from the study. The disk is then lowered into the water until is just disappears from sight and this depth, known as the Secchi depth, is recorded using a smartphone app called Secchi and submitted to the study where it appears on the publicly accessible data map available on the website. The data can also be requested for detailed study. The first publications arising from the data gathered are currently in preparation.

The study has received significant global media attention over a range of formats including scientific publications, mainstream press articles and coverage in magazines on topics from popular science to leisure.

www.secchidiskfoundation.org/
www.secchidisk.org/
https://vimeo.com/194387410



Credit: CNRS/D. Marie

Credit: ©Secchi Disk Study

Fig. 2.22 Secchi disk equipment

2.7 European coordination of project management networks and data

The increase in opportunities for involvement in Marine Citizen Science initiatives at different geographic scales, from local beaches to international programmes, is a potential source of confusion for citizens. At best it may be a source of loss of interesting data through the fragmentation of information. At worst, it could lead to a lack of motivation amongst participants who were not clear on the best way to contribute.

The discrete and separate archiving of each individual Marine Citizen Science programme, means that each observation is dispatched into one of numerous different databases. An example of this is the multiplicity of observations on cetaceans gathered through many different channels with a high potential for overlaps and unnecessary repetition of work; this represents a waste of resources available. Despite these issues, the multiplication of programmes is a positive indicator of the continuous progression of citizen involvement in marine sciences, policy and conservation. However, this effort needs to increase in coherence both for citizens and scientists through common coordination in order to achieve its full potential.

The nature of the marine environment makes this even more important than for terrestrial projects. While there are certainly interesting projects using Citizen Science on large scales on land, the marine environment is, by definition, continuous, and any studies, involving citizens or not, can only benefit from a broader perspective.

2.7.1 Clarity for participants

The first step for bringing coherence to Marine Citizen Science is to clearly display the available opportunities to citizens. Individually, it is necessary that each initiative explains the questions and objectives underlying the programme, however these also need to be reported on a wide scale.

There are potentially two ways of clarifying the Marine Citizen Sciences landscape for the public: reduce the number of initiatives by excluding some of them and merging others or, more efficiently and justifiably, enable existing and future projects to work as a network where each participant finds the right programme for them, and each programme is therefore able to engage with the most interested and suitable participants. The first option is not viable; it would be unfeasible to dictate on what grounds a project should be excluded or required to merge, and by whom these decisions should be taken. Most programmes understandably want to keep their identity for funder-recognition reasons or because it is already known by the public. Therefore, the objective should be to guide the potential participant to the programme which best suits them in terms of: required time input; data collection method; level of citizen involvement in project development, analysis and results-generation, and any policy development; geographical location and access to the required environment (shoreline, inter-tidal region, open sea) or facilities (sailing, diving, fishing); and topic of research, using means such as Annex 3 and its sources.

2.7.2 Data management in Marine Citizen Science networks

The multiplicity of databases containing information from Marine Citizen Science initiatives could be considered an issue. There are strong arguments to merge and centralize such databases to make information more easily available for policy-makers, researchers and for the general public. However, the volume and varied formats of data produced makes efficient aggregation at the speed at which they are gathered, problematic. The fact that knowledge would be centralized in one organisation/database is also ethically questionable.

Citizen Science initiatives are intrinsically inclusive. This "openness" should be a core element in Marine Citizen Science. Accessible databases can be easily harvested for information: "data mining" means several databases can be studied at the same time and analysed together, tailored to particular research questions.

In some specific contexts, 'blockchain' protocols could be a potential tool for large-scale Marine Citizen Science projects and the sharing of data. Blockchain is a technology originally linked to the virtual currency, Bitcoin. It allows the validation of information exchanged within a network, and the identification of 'false' data. This is particularly powerful in the absence of a centralized validation entity. An embedded condition is that every exchange is signed, while encryption allows everyone to take part in the validation process even if contents remain private.

This system isn't necessary in a fully open data context, and can be replaced by a democratic, decentralized vote protocol, screening for errors coming from the nodes of the network. However, in the absence of a centralized organization is responsible for gathering together all private and confidential information, and who is trusted by the whole network, it would be pertinent and indeed required under data protection laws to ensure that the parts of each database which contain personal and confidential information are protected. The growth of the Web and social networks, with the ability to access and circulate scientific information, and the proliferation of smartphones, opens up new routes for large-scale cooperation between professionals and non-professionals.

Long-term storage in databases of international data centres supports data interoperability and re-usability beyond project lifetimes, which was recently identified as critical issue in Citizen Science during the Citizen Science and Smart Cities Summit (Schade & Tsinaraki 2016). An upload to international data centres requires consistency and comparability of metadata and measured parameters. This in turn is strongly supported by the use of common standards and vocabularies. One example for marine data and metadata treatment is SeaDataNet (pan-European infrastructure for ocean and marine data management) (www.seadatanet.org). In Citizen Science projects, it is highly advantageous to introduce standard metadata formats early in the data generation process, e.g., by use of emerging technologies (see Section 2.5). The aim is not necessarily to reach the highest precision level with Citizen Science measurements, but to provide a consistent data quality and description of limitations that define the boundaries of use for applications. Advantages of storage in international data centres include:

1. Support of interoperability for data and integration with scientific datasets (such as remote sensing databases)
2. Open access, availability and re-usability of data
3. Reduction of costs for data and metadata conversion and quality control
4. Unique identification of data collections with a Digital Object Identifier (DOI)

While uploading to international data centres is not feasible or reasonable for all types of Citizen Science data, it should be identified as a best practice for data management where possible.

OCCHIO ALLA MEDUSA

Credit: Alberto Gennari / Fabio Tresca

The occurrence and regularity of jellyfish blooms is one of the signs used to identify changes in the seas. Jellyfish species are better suited for survival in oxygen-poor, saltier and warmer ocean conditions than their competitor species and hence tend to thrive and increase in abundance in these conditions. It is thought that increases in CO_2 emissions and warming of the seas through climate change may be causing increased presence of jellyfish species worldwide (Boero *et al.* 2016). Overfishing is an additional cause of the prevalence of jellyfish in oceanic systems, along with increases in coastal artificial structures which provide space for settlement, and the transport of alien species in the ballast water of ships. Jellyfish blooms not only pose a physical threat to humans through the danger of stings, they can also have wide-ranging indirect impacts on tourism, fisheries, aquaculture, ecosystem equilibrium, and in clogging water inlets and equipment.

The 'Occhio Alla Medusa' initiative, which translates as 'Spot the Jellyfish', originated in 2001 as a result of a Mediterranean Science Commission (CIESM) workshop on jellyfish outbreaks (www.ciesm.org/online/monographs/Naples.html) (Boero 2013), was relaunched in 2008 and is still ongoing. The initiative is coordinated by the University of Salento in Lecce, Italy, although it has been operated in collaboration with a number of organisations over its lifetime. The aim of the initiative is to gather information about jellyfish distribution in the Mediterranean Sea and especially around Italy, whilst also involving citizens and raising awareness about the subject. The programme aims to develop a better understanding of the potential causes and mechanisms behind increased jellyfish outbreaks as well as to develop an understanding of the movement and populations of species.

The input from Citizen Scientists is significant and ongoing, with records of jellyfish sightings continually being submitted. The main focus of the second adaptation of this initiative was an eye-catching poster showing pictures of the main jellyfish species found in the Mediterranean Sea. The poster was designed with the help of an illustrator and a graphic artist, to make the poster itself a valuable possession, and has been very successful in engaging children and adults alike. The poster has been updated several times to include more species. Citizens can use this to help identify jellyfish species they observe and send records of sightings via email, website or app, to the initiative organisers. The sighting is then uploaded on a map of sightings after validation. The high likelihood of a sighting on any visit to the coast by citizens, coupled with acknowledgement of their contribution, have ensured ongoing engagement and hence substantial data-sets dating from 2009.

The project has attracted continual media attention throughout its operation, with new discoveries and information being presented in both national and international media outlets, most notably including two articles in Time magazine (Time 2009; Time 2010), once as a front cover story. Notable scientific successes include the discovery of a new species, *Pelagia benovici,* which is detailed in Piraino *et al.* (2014), meaning that the project is both monitoring current trends and also generating new scientific knowledge. Interest in the project has also been maintained through TV appearances, interviews and a variety of articles. The scientific contribution of the project has also been significant, with a number of peer-reviewed scientific journal publications arising from the results (Boero 2013; Boero *et al.* 2009; Piraino *et al.* 2014; Boero *et al.* 2016; Canepa *et al.* 2014).

(The website and app currently under renovation and development)

2.7.3 Going beyond: decentralization of Marine Citizen Science

Citizens don't work 'for' the scientist, but rather 'with' them, and therefore there are scenarios in which it is appropriate for the citizens themselves to propose research topics for study, or to analyse data. The value of this collaborative approach is discussed in Sections 2.1 and 2.4. As an example, the Astrolabe association is a pioneer in this method: its members are well versed in collaborative uses and open source technologies. They work closely with "fablabs" (fabrication laboratories, or small scale workshops for digital fabrication, equipped with computer-controlled tools, facilitating the public to manufacture items to suit their individual agendas) to develop cheap technologies to be adapted, for example, on sailing vessels owned by citizens to help them realize scientific observations. They broker collaboration between citizens who are engaged and keen to listen to proposals, and scientists who advise on how to address them.

Credit: Veronica French

Fig. 2.23 Different types of seaweed found on the Irish coast

Biolit (www.biolit.fr/?language=en) is a French Marine Citizen Science initiative studying brown algae and sea snails on the shore. It is led by the NGO "Planète Mer" in collaboration with the marine station at Dinard and the National Museum of Natural History. Volunteers are recruited and supported by local hubs all across France who organize training and events. There is a centralisation of data collection by Planète Mer through its website, the 'central node'. But the local representatives, or 'hubs', are situated in the field, are directly in contact with the citizens, and may participate in several different initiatives.

We can therefore consider networks of Citizen Science initiatives on different scales of size and complexity: projects where links exist between both nodes and hubs; and Open Databases, where data circulates between nodes. A model in which these networks and their associated databases are totally decentralized is conceivable, and data can be directly allocated between the citizen's hubs.

This paradigm would need to follow some standard conventions:

- Citizens need to have a clear view of what is available and how they can get involved in a way that suits them
- All data, not including personal and confidential information, need to be open and freely accessible by everyone in the network. This allows researchers to mine the databases in order to answer their questions, and policy makers to make scientifically-based decisions
- Dedicated researchers and/or technology specialists and managers need to be available to help design solid protocols in collaboration with the hubs and citizens
- Tools (especially websites and databases) need to be designed jointly or to pre-agreed standards, in order to be fully inter-operational and compatible.

2.7.4 Developing a sustainable economic model

A decentralized scheme raises another important question: how is it possible to maintain a sustainable economic model for Marine Citizen Science?

Four groups of stakeholders are considered:

1. Researchers
2. Organisations (including government organisations and NGO's) directly in contact with scientists
3. Organisations facilitating activity in the field with the participants (local hubs)
4. Participants or citizens

Researchers have greater access to funding sources, and are able to apply for dedicated grants through recognizable and sustained frameworks; as such, they may have the most secure position in the system. As regards 'bottom-up' research, the position can be more uncertain. There may be a role for national and international funding bodies to play in reviewing how their funding is divided, and considering the possibility of allocating some specifically to Citizen Science applications. Alternative funding sources such as local association budgets, charity schemes, crowdfunding and philanthropy could also be considered. It is particularly important that any Citizen Science project is properly able to disseminate information to a wide audience regarding the project and its aims, its results and findings, and its impacts. Large-scale projects such as CoCoast and Occhio Alla Medusa, in particular, have extensive outreach and dissemination goals which have been successfully achieved, supported by the acquisition of funding to enable this. The example set by these projects in terms of general best practice in management and dissemination, and in funding approache could be adopted elsewhere. It is proposed that any research project wishing to involve citizens should foresee the related expense and include these in project budgets, and that funding bodies could allow for greater flexibility in how allocated research funds can be used. There are always alternative possibilities for funding, as listed above, which straddle categories, although there are also sustainability issues to consider.

The hubs, operating in the field as the direct link with participants, are often local environmental education NGOs. They seek their own funding streams, but their work is often constrained by funding objectives. Since their work is essential in addressing local issues with, and for, citizens, local and regional authorities may be the best placed to ensure a more resilient source of funding in relation to citizen engagement, including Citizen Science.

Citizen science projects operate on the understanding that participating citizens are volunteers, and are hence not remunerated for their input. Indeed, the voluntary and unremunerated participation of citizens in Citizen Science initiatives is taken as a cornerstone of the approach and an element of participation is the 'giving back' to society or the environment that is frequently cited by volunteers as a reason for involvement. Taking a boat offshore, or undertaking a dive, is not cheap, however it is often accepted that the citizens offer these services to the project, and cover the costs themselves. Some NGOs offer "participative observation" on research or fishing vessels, where participants are required to pay for the privilege of participation, using the same model as eco-volunteering opportunities; whether this is Citizen Science in is truest sense is debated. In contrast, others ask private and commercial vessel owners to participate and to freely share boat spaces with others. Globally, the required financial contribution of participants to Marine Citizen Science projects should be maintained at a minimum, essentially to open participation up to as many people of possible, regardless of their financial means or income. While volunteers give their time and skills freely, many initiatives build in compensation (such as car mileage recompense, or provide lunches) to cover costs incurred during participation. The approach regarding compensation does however vary significantly, depending on the country in which the initiative is being organised, and there is not a universally accepted approach.

In the current European economic climate there is likely to be less funding available than previously, not only amongst citizen, local and regional authorities but also for research itself. For this and many other reasons, it is imperative that a strong case for Marine Citizen Science is made across all levels in order to ensure that the funds which are available are directed towards these initiatives and that the most efficient and appropriate use is made of those limited resources.

Credit: Ángel Muñiz Piniella

Fig. 2.24 Diverse flora and fauna species can be found along the coastline

3 From Citizen Science to Marine Policy

Credit: Gaynor Rosier / Marine Photobank

The Aarhus convention (2001) established the right of the public to be able to receive environmental information held by public authorities and, crucially, also established the right of the public to participate in environmental decision-making. This chapter explores the pathways from Citizen Science to marine policy but also outlines the challenges and shortcomings in current approaches and potential alternatives to current practice.

The opportunity to connect the individual with the policy process is increasingly cited as a potential benefit of those Citizen Science programmes which focus on societally relevant topics. Despite the obvious societal relevance of marine issues, to date this link has not been made as clear to the public to the same degree as has occurred for other areas such as health-related topics, and on the scale required given the urgency of the challenges associated with marine ecosystem health (see Section 1.2). Haklay (2015) presents a review of the contribution of Citizen Science to policy more generally, but this chapter focuses specifically on the marine policy context; the challenges and considerations are unique because of the distinctive nature of the marine environment, the complexity of the marine policy arena, and because of a more divergent relationship of the public with marine, compared to terrestrial environments. The authors do not intend to overstate the contribution of Citizen Science to policy, or imply that it could replace professional scientific evidence for policy and statutory environmental monitoring. However, opportunities to use Citizen Science to achieve positive outcomes for science, for the global marine environment and for society are being missed (Bonney *et al.* 2014) and the developmental point has been reached in the field of Marine Citizen Science when the significant effort, skill and goodwill of volunteers should be targeted to these ends (Henderson 2012).

This section discusses the two pathways in which Marine Citizen Science can help to inform the development, implementation and evaluation of marine policy; capacity and resources. This includes the potential of volunteer evidence to underpin and inform marine policy and marine citizenship; the democratic two-way exchange of understanding that better informs policy development and facilitates a better engagement with and understanding amongst the wider public of policy-relevant issues and democratic processes. This latter has previously been discussed in Section 2.4.

Chapter 3 cover image: Volunteer diver collecting data near Girona, Spain

3.1 Capacity and resources

3.1.1 Contribution of Marine Citizen Science to policy evidence gaps

Diamond's overview of global drivers of extinction propose the "evil quintet" of anthropogenic causes, namely: climate change, overexploitation, invasive species, 'land' use change, and pollution (Diamond 1989; updated by Brook *et al.* 2008). It is regarding these five globally relevant threats that academics, who work at the interface of Citizen Science and environmental science, believe research effort should be focussed, to explore the full extent to which volunteer data can contribute to scientific knowledge and understanding.

In the policy context, the value of Marine Citizen Science is derived from this delivery of scientific evidence to inform policy via the significant additional resource. This is especially pertinent given the escalating complexity of marine legislation and the requirements for extensive datasets collected over wide geographical areas to support evidence-based policy making. As an example, under the Marine Strategy Framework Directive (MSFD), the aim to achieve 'Good Environmental Status' (GES), in all EU territorial waters requires data on 29 associated criteria and 56 indicators that include biological, physico-chemical indicators as well as pressure indicators—including hazardous substances, hydrological alterations, litter and noise, and biological disturbance such as introduction of non-indigenous species. It is therefore understandable that alternative interdisciplinary and cost-effective approaches are now being explored with a new degree of prominence by governments, international bodies and funding agencies (e.g. EEA 2013; UNESCO 2013; SEPA 2014).

Reviews by Thiel *et al.* (2014) and Theobald *et al.* (2015) demonstrate the breadth of volunteer data and its contribution to our understanding of marine ecology, species distributions, oceanography and coastal geology, and Section 2.2 of this report further details the types of data provisioned by Citizen Science activity. These reviews, however, illustrate that (i) there are fewer studies in marine systems compared to those of terrestrial systems; and (ii) in marine contexts, that there is a bias towards the monitoring of biodiversity (and of charismatic species in particular), relative to other policy-relevant information with fewer studies on resource management or the characterisation of the physical environment. The appeal and relevance of topics to participants has to be central to the design of a Citzen Science project, but ways to make alternative themes acceptable and engaging should be explored. There may always be some issues that remain unsuitable for investigation by volunteers, but a greater breadth should be considered if the true potential of Citizen Science to directly address policy relevant evidence gaps is to be realised. Section 2.5 and 2.6, for example, discuss the degree to which technology has engaged citizens with physico-chemical data.

Data collected by several Marine Citizen Science projects have fed into particular policy goals, providing a contribution to the evidence base. Examples can be found across a wide range of policy themes. The Marine Conservation Society (MCS) beach litter survey (Nelms *et al.* 2017) was set up to fill an evidence gap on the amount of marine litter in the environment and how it changes over time, and similar surveys are routinely used across the world (e.g. for the United Nations Environment Programme, Marine Strategy Framework Directive, and Regional Seas Conventions). The volunteer-approach to data collection is valuable in the mapping and monitoring of species ranges across extensive geographic areas, thus providing evidence for policy goals in biodiversity, and also in the monitoring of invasive non-native species (INNS). It is particularly useful for rare or patchily distributed species; for example documentation of large-scale changes in world-wide shark species abundance has been used to inform marine conservation efforts (Ward-Paige *et al.* 2011; Ward-Paige & Lotze 2011).

The evidence base for policy development and management strategy is strengthened by information that comes from a diverse array of sources (Danielsen *et al.* 2005; Jay *et al.* 2016; Edgar *et al.* 2016), hence the justification for employing Citizen Science alongside other approaches. But even within volunteer programmes, the wide spectrum of project design and data types, as discussed in Sections 2.1 and 2.2, contribute to the overall power of such evidence-gathering tools. Exploring the full breadth of project types from 'contributory projects', through 'collaborative' and 'co-created' projects (*sensu* Shirk *et al.* 2012); or 'consultative' through to 'transformative' (*sensu* Couvet & Prevot 2015) to those initiatives where the research is largely or wholly directed by volunteers, known as 'Extreme Citizen Science' (Stevens *et al.* 2014), could in the future provide sources of information that remain underexplored in marine policy contexts. Citizen Science projects at the far end of this spectrum (Extreme Citizen Science) are not as yet realised for marine science research and hence policy pathways, but 'lay expertise' or 'traditional knowledge' (see boxes on pages 44 and 46) has long been recognised as a valued source of marine policy-relevant information (Dubois *et al.* 2016). Marine policy could also benefit from consideration of such alternative evidence sources and the inclusion of 'stakeholder' or 'traditional' knowledge, along with the facilitation of members of the public to contribute through Citizen Science. This in turn enhances trust, policy reputation and compliance.

Credit: J. Fontes, ImagDOP

Fig.3.1 Trained divers can assist with monitoring of shallow water fish species

3.1.2 Assessing the cost-effectiveness of Marine Citizen Science projects

If one of the quoted benefits, or drivers, of a Citizen Science evidence-gathering approach for marine policy is its financial cost-effectiveness, a realistic measure of that resource saving needs to be assessed. Undoubtedly, deploying large numbers of motivated people in a targeted fashion can save statutory agencies, conservation bodies or scientific teams a wealth of time, and access remote areas and geographic scales otherwise unimaginable in the required timeframes. However, from an evidence-gathering perspective, such volunteer approaches should not be utilised unthinkingly, but with a clear understanding of the overall benefits to the policy-programme in question, including those that relatively outweigh professional scientist approaches. In addition, adequate planning must be incorporated for training and support (where appropriate), tractable task design, clear objectives, and adequate and accessible data capture infrastructure. Furthermore, it is crucial to reflect on the overall benefits, in place of payment, for the participating volunteer. Users of Citizen Science approaches do, however, need to be aware of trade-offs which arise from using this approach. Aspects of cost-benefit analysis and cost-effectiveness are discussed in Roy *et al.,* 2012.

The funding required to establish and run a successful Citizen Science project will depend on what the overall objectives are (e.g. solely marine environmental data gathering versus wider interdisciplinary research additionally capturing experiences of participants), the design and complexity of the tasks (e.g. return of simple presence/absence data or whether face-to-face training and support is required), and the level of engagement of the volunteers (e.g. contributory or co-created projects).

Various attempts to capture the value of in-kind contribution of volunteer efforts for the environment (both terrestrial and marine), via their submission of policy- or scientifically-relevant data, have been published. In their review of biodiversity-focused Citizen Science projects, Theobald *et al.* (2015) estimate that between 1.36 million and 2.28 million different people volunteer annually in the 388 projects that they surveyed. Examining estimates of numbers of hours of volunteer time, they conservatively estimate that this translates to between US$667 million to US$2.5 billion annually of volunteer in-kind contribution, and highlight that this is an underestimate given their methodology for sub-sampling projects for the purposes of the review. The UK government (DEFRA 2011) estimated the value of volunteer monitoring of the UK environment at a level in the region of GBP£50 million annually. The contribution of volunteers engaged in biodiversity-related projects in France to delivery of the Convention on Biological Diversity (CBD) was estimated at between €0.67 and €4.41 million in 2010 (Levrel *et al.* 2010).

The type of in-depth cost-benefit analysis undertaken by Tulloch *et al.* (2013) of published Citizen Science bird monitoring schemes (Atlas and Breeding Bird Surveys), would be invaluable if done similarly for Marine Citizen Science, aiding enhanced design and clarifying the returns per unit effort of volunteers. The total value of the investment by volunteers (non-salaried) and coordinators (salaried) in collecting data for each Atlas dataset was on average US$10,133,500 (± $3,654,600se) and for Breeding Bird Surveys (BBS) (a more structured institution co-ordinated survey)

Credit: Julien, Marine Genomics Europe

Fig.3.2 *Amateur naturalists have observed seabirds for generations*

it was US$10,014,200 (± US$5,165,400se). Mean contribution of volunteers in-kind was US$1,097,300 (±US$279,800se) annually for an Atlas type survey, whereas it was US$431,100 (±US$65,600) for a BBS project, leading to the conclusion that the cost-benefit value in terms of scientific outputs was overall higher for the latter type of project. While numbers of papers published, and the amount spent per unit data returned are not the sole measures of success of a project, a more pragmatic view of the potential of Citizen Science projects to support scientific advice to marine policy is required. Studies such as those by Bertram *et al.* (2014) have attempted a cost-benefit analysis of environmental protective measures in the marine context, and there is now a growing literature on economic valuation of ecosystem services (e.g. see Sagebiel *et al.* 2016) including the value members of the public put on marine resources and services (e.g. Brouwer *et al.* 2016). Incorporating a realistic cost-benefit analysis of Citizen Science contributions to marine policy evidence gathering, coupled with associated wider intangibles such as increased advocacy and its benefits to the marine environment should be considered in future assessments of marine conservation and policy measures.

3.1.3 Barriers to the use of Marine Citizen Science in addressing marine policy evidence gaps

Despite the enormous possibilities that Citizen Science offers for collecting much-needed marine policy evidence, the degree to which this has been realised is quite low. Roy *et al*. (2012) estimated that from the 30 case study Citizen Science projects they looked at in detail (in terrestrial, marine and freshwater areas), only 37% had policy relevance. Not all Citizen Science projects set out to 'feed into' policy, and indeed not all projects need or should do so, but more could be meaningfully used in this way. Here, some of the barriers to the embedding of Marine Citizen Science data into policy, and the ways in which they could be overcome, are discussed.

Lack of clarity in aims and objectives

Not only is poor objective-setting a threat to any scientific study, in the case of a Citizen Science project, it can also be a threat to any intended contribution to policy support, and the relationships and networks which may have been built up to enable this. Undirected monitoring or inadequate hypothesis-setting can use up considerable resources and may frustrate or alienate participating volunteers who become dissatisfied with the way in which their contribution has been missused or missmanaged. Poor objective-setting can further create the illusion that adequate monitoring has been carried out where this is in fact not the case, compromising habitat conservation (Legg & Nagy 2006). The setting of the scientific question, aims and objectives should be treated with as much rigour in Citizen Science projects as for any other scientific study. Amassing great swathes of data can be appealing once an enthusiastic cohort of volunteers has been recruited, and undoubtedly serendipitous findings, not expressed as an objective from the outset, do occur when there is sufficient data to detect an unexpected occurrence or disturbance event that might otherwise have been missed. However, even authors who defend 'surveillance monitoring' (e.g. Wintle *et al.* 2010), stipulate that there must be scrutiny of the likelihood of delivering such unexpected benefits, over a targeted design.

Some projects proclaiming to be undertaking Citizen Science are wholly engagement initiatives. Increasing scientific literacy and reconnecting publics with nature and the marine environment are valuable, but solely in themselves do not qualify as Citizen Science (see Section 2.1). Others provide useful data to support ecological knowledge and 'pure scientific learning', without direct relevance to policy issues. All such drivers for establishing volunteer activities are entirely appropriate; not every volunteer project needs to support policy or conservation, but in such cases it is unethical and deceptive to the volunteer to imply that they do. Communicating clearly the aims, objectives, data pathways and usage, and managing volunteer expectations about what the data can achieve, is crucial to sustained engagement and trust, and effective uptake of data by relevant decision makers. Despite the claims of some Marine Citizen Science projects in non-peer reviewed reports and on project or organisation websites of having directly supported policy in some way (e.g. through the underpinning of Marine Conservation Zone (MCZ) establishment in the UK), there are cases where these claims are unfounded or at best difficult to substantiate.

Lack of publication

A fundamental barrier to the ability of Marine Citizen Science data to support marine policy is ensuring it is seen and accepted by the wider scientific community and policy makers. Publication in a scientific journal is not the sole measure of success of a project, but the impact of such data on legislation, conservation measures and scientific understanding can be prohibited without this form of visibility. It is possible for Citizen Science data to bypass academic literature and impact on management or policy directly, but opportunities to do so are more restricted. Indeed, Citizen Science, by its very nature, is a scientific study to enhance current knowledge and understanding, and therefore a lack of publication in the scientific literature means that this knowledge cannot be shared widely (see Section 2.1 on what defines Citizen Science). Not only is the opportunity of given datasets to impact increased by publication, but so too is the efficacy of the policy channels themselves improved for future projects, with the dissemination of best practice in project design. Lack of publication represents a threat to the project itself, as well as a missed opportunity for citizens to contribute to global challenges of environmental concern.

Theobald *et al.* (2015) undertook a comprehensive analysis of the publication rate of Citizen Science projects (environmental, but not restricted to marine projects), and found that while 97% of projects surveyed claimed to have the advancement of scientific understanding as an explicit primary goal, only 12% had peer-reviewed scientific publications to support this claim. Confusion was evident amongst project managers surveyed regarding what constituted peer-reviewed literature, potentially misinterpreting "peer" and/or "journal", and this has also been highlighted elsewhere (Shirk *et al.* 2012). Factors affecting the likelihood of publication using data derived from Citizen Science initiatives included: the spatial and temporal extent, with projects of wider geographical scales and of longer timeframes more likely to yield publishable data; the accessibility of the data to bodies external to the project; the provision of training for volunteers, with training in species identification skills being important, but not necessarily training in data collection methods. The higher likelihood of large-scale studies reaching publication stage may be because they are better able to measure change over space and time, and therefore quantify impacts of management and policy. Another possible explanation could be that scientists are more aware of older, more widespread Citizen Science projects, and thus more likely to use their data in publications; in other words, the reputation of the project becomes established within mainstream science. Nonetheless, the value of smaller, more regionally focused projects should not be dismissed, and also offer value through publication.

Another key issue identified by a range of articles (e.g. Theobald *et al.* 2015; Follett & Strezov 2015; Cooper *et al.* 2014; Tulloch *et al.* 2013) regarding publication, is the lack of explicit acknowledgement by some studies of their reliance on Citizen Science data. The value and impact of Citizen Science is therefore being underestimated, and the participants involved are being treated unethically. Such omissions may simply be a lack of realisation of the important role such acknowledgement can offer Citizen Science as a discipline in its own right, as well as to the individual citizens involved. If, however, this is fuelled by concerns about the ways in which the data will be perceived by the wider scientific community, then there are more fundamental


Credit: Aurélien Carbonniere

Fig. 3.3 People often perceive the ocean to be vast, unknown and unconnected

issues to consider; the concerns in this regard of younger researchers who have yet to become established should not be dismissed lightly (see discussions in Riesch & Potter, 2014). The increasing visibility and acceptance of such data sources should help to overcome this. Riesch and Potter (2014), and Cooper *et al.* (2014) call for authors to use the keyword "Citizen Science" in papers, so that the contribution of Citizen Science can be better tracked in future. In doing so, the likelihood of Citizen Science reaching its full potential to contribute to scientific evidence gaps and the support of marine policy frameworks may be better realised.

Validity of data

Challenges for Citizen Science integration into the accepted armoury at the disposal of the scientific community arise from concerns surrounding the rigour and validity of Citizen Science data (Bird *et al.* 2014; Bonney *et al.* 2014; Tulloch *et al.* 2013; Bonter 2012; Dickinson *et al.* 2010; Silvertown 2009). These criticisms arise from potential biases in survey effort, including under-detection of species or the non-random distribution of effort, issues of scale and inconsistencies over time. The increasing numbers of peer-reviewed publications that demonstrate that data collected by Citizen Scientists can be of equal quality to data collected by experienced researchers, mean that this scepticism should eventually be overcome. It is vital, however, that authors continue to clarify the quality assurance and data robustness analyses that they have employed to lend weight to these arguments. The range of methods employed are overviewed in Section 2.3.

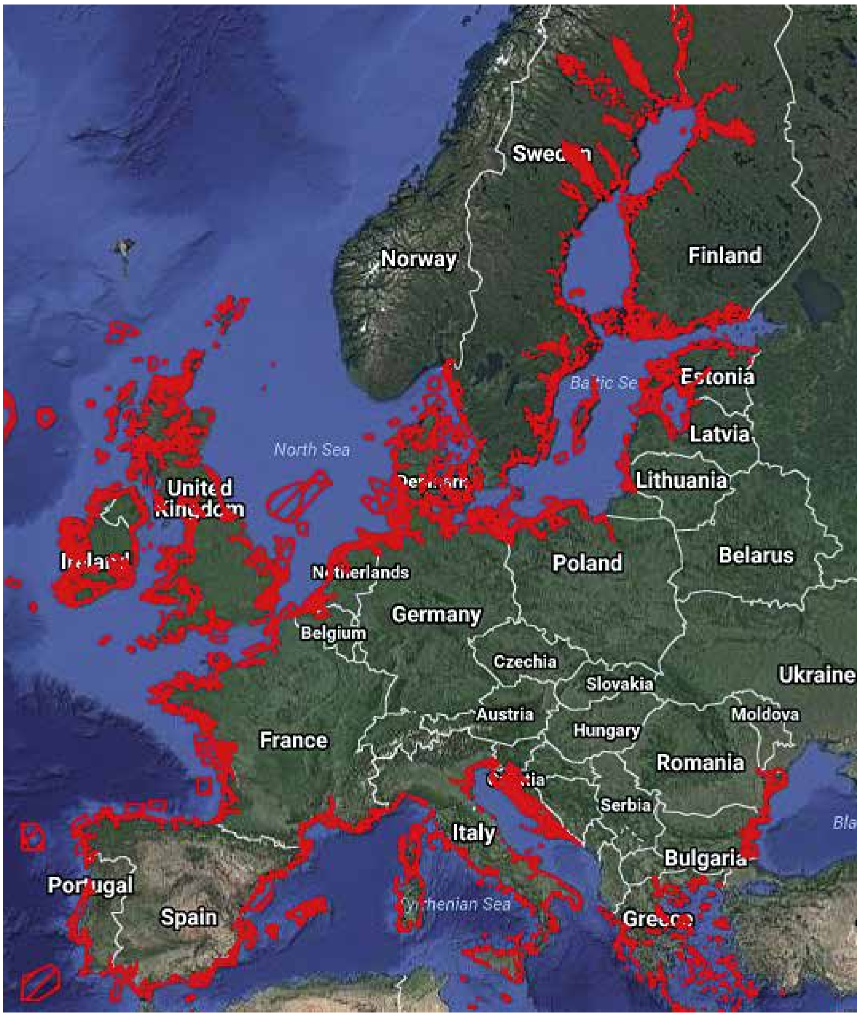
Complexity of the policy process

High quality Citizen Science data that map onto policy themes are available, but it is rarely feasible to follow the pathway through directly to its manifestation in a policy outcome. This can, in part, be because of the complexity of the policy development process. The creation of environmental policy is not straightforward; while it starts with consideration of scientific evidence, a number of policy options must be proposed, taking account of diverse societal viewpoints, issues of logistics, economics and cultural perspectives, with interplay in complex and unforeseen ways to produce 'social uncertainties' as they travel along the 'pipeline chain' from science to policy and practice. The links from foundational data to the policy decision-making endpoint can therefore become hidden, or may not be explicit. This lack of a causal relationship is exacerbated for Citizen Science, the usage of which within marine policy frameworks is very much in its infancy. If the aim is for Citizen Science data to become part of the long-term monitoring and evidence- generating effort, support needs to be garnered at international level to ensure longevity in co-ordination and information management of Citizen Science activity, and for the organisational structures and practices that deliver these. It will be essential for policy-makers and their officials to be made aware of the potential of Citizen Science to be part of the approach used for achieving policy goals, with an endpoint of providing appropriate support and resources to organisations that are running policy-relevant Citizen Science programmes.

3.2 Engagement of the public in democratic processes

3.2.1 The European marine policy context for Citizen Science

The European Union has adopted two initiatives to address criticisms of the otherwise fragmented nature of earlier provision to protect the marine environment: The Marine Strategy Framework Directive (MSFD - 2008) and the Maritime Spatial Planning Directive (MSP - 2014). Both of these Directives sit within the overarching EU Integrated Maritime Policy (IMP - 2007) and have synergies with other EU policies, *inter alia*, the Water Framework Directive, the Floods Directive, the Habitats and Birds Directives and the Common Fisheries Policy (CFP). One of the most important drivers for MSP and the MSFD is biodiversity conservation legislation, which forms part of the EU's international commitments under the Convention on Biological Diversity (CBD) and the World Summit on Sustainable Development.



Credit: EMODnet Human Activities: Environment

Fig. 3.4 Natura 2000 network of protected sites in Europe, from the Habitats Directive and the Birds Directive.

The policy landscape for 'marine' is still a young and emergent one in Europe. Relatively new instruments, such as the Directive for Maritime Spatial Planning, are subject to ongoing political and legislative changes that may significantly affect their future implementation. With the unprecedented decision by the UK electorate to withdraw from membership of the European Union ('Brexit') comes a period of great change for EU marine environmental protection, resource management and associated marine policy across Europe. Analysis of geopolitical risk in maritime contexts has so far been lacking, yet Suárez de Vivero and Mateos (2017) point to a compelling new urgency for such investigations in light of global changes that will have consequences for our marine biodiversity and resources. Such uncertainty produces a compelling need for even greater vigilance regarding the direction of policy development, regarding the developing frameworks for marine monitoring and the degree to which developments consider the end user in the policy process and facilitate their input. The degree to which Marine Citizen Science will contribute must be considered in this changing landscape.

3.2.2 Challenges for European marine environmental policy implementation

Several challenges to the effective implementation of European marine environmental legislative tools have been identified. Of most relevance to the themes in this document, is the criticism of inadequate 'stakeholder engagement' in policy-making. It is at the local and non-scientific front line that the individual experiences environmental challenges, yet they are not engaged in setting international research directions that direct policy, nor are they considered individually at the policy level. Solutions to marine environmental problems will only be successful when addressed with the end users in mind, but also when flexible enough to respond to changes to social-ecological systems, and a detailed understanding of complex societal interactions is therefore necessary in stakeholder engagement and public participation is explicitly outlined as a requirement in all major pieces of EU marine environmental legislation. Fletcher (2007) criticises the lack of guidance on the timing at which external contributors should be involved, how they should contribute and even that the very definition of 'stakeholder' in EU marine policy instruments is poorly defined.

This process of engagement with 'stakeholders' is underpinned by the Aarhus Convention. For social, ethical and democratic arguments it is imperative that the people most profoundly affected by a policy and its consequences should be involved in the creation of that policy. Science provides insight to inform policy, but the ultimate outcome of the best policy option is a societal decision, with stakeholders and policy makers collaborating to consider the scientific evidence alongside other socio-economic, logistical and value-laden drivers. This move towards participatory policy-making, with stakeholders making normative judgements about the way their environments are organised, and resources managed, has effectively occurred in terrestrial policy settings (Kidd & Ellis 2012), but the move to collaboration has arguably been slower for the marine arena and has not always run smooth (McFadden 2008). The complexity of marine governance issues is suggested to be a further hurdle precluding full participatory involvement. A further flaw inherent in the EU legislative instruments and resultant governance programmes, highlighted by McKinley and Fletcher (2012), is that they unambiguously do not address public behaviour, or have provision for the individual citizen as the vehicle through which policy is implemented. Section 2.4 discusses the societal value of participation and the promotion of a 'Marine Citizenship'.

3.2.3 Current understanding of marine environmental issues

A lack of knowledge is a significant barrier to the development of marine citizenship. Section 2.4 reflects on the growing number of studies emerging on public perceptions of, and attitudes to, marine issues. These studies demonstrate that the level of concern regarding marine impacts is closely associated with the level of relevant information, and that pollution and overfishing are two areas prioritized by the public for policy. The degree to which the European public perceives the immediacy of marine anthropogenic impacts, and the strength of their concern about a range of threats, is variably concluded in these studies as being moderately to highly concerned. Overall, the public is prepared to engage with considering multiple stressors synergistically in ocean impacts, but concerns about threats to marine environments were ranked lower than for other environmental issues (Gelcich *et al.*, 2014; Potts *et al.*, 2016).

The citizen is asked to take a personal responsibility for what is predominantly unseen, unknown, unfamiliar, and vast. This requires an understanding of the nature of threats to the ocean that are global, yet subtle, and complex. Even within an individual's own national waters, gaps persist in the understanding of the richness of marine life and of resources worth protecting. The UK public, for example, has deemed its offshore waters to be cold, barren and empty (Rose *et al.* 2008) and not as 'rich' as seas in other countries, with respondents tending to underestimate the presence of exotic and charismatic species (Jefferson *et al.* 2014). Conversely, less colourful or less impressive-looking species were perceived as more likely to exist in UK seas despite being unfamiliar. Visually demonstrable issues such as litter and sewage tend to garner far greater attention than invisible and more complex issues such as ocean acidification and climate change impacts.

3.2.4 Impact of personal and collective behaviours

Marine knowledge held by publics must be accompanied by a realisation of their own ability to do something to conserve biodiversity and minimise impacts to it. Long term sustainable conservation and management of marine biodiversity can only be achieved through wider societal buy-in to policy and management strategies, both in terms of regulatory compliance, but also on a fundamental level of attitudinal and behavioural change in terms of lifestyle choices. However, in an extensive European study, a majority of respondents (57% of over 10,000 participants) perceived individual actions to be ineffective in tackling marine impacts (Gelcich *et al.* 2014). Despite a pervading general sense of admiration for the marine environment and a desire to take a more active role in marine conservation a lack of clear information on how personal actions can bring benefits and contribute to solutions can lead to an individual ignoring or being overwhelmed by the problem (DEFRA 2009).

3.2.5 Overcoming hurdles to behavioural change

Understanding how individual and collective behaviour can affect environmental change is important, but it does not necessarily translate into enactment. Awareness-raising activities play a role in signposting the public focus to key issues, and getting people passionate about the marine environment. Social and mass media dramatically extended the reach of such initiatives: high-profile campaigns, such as those of the UK Wildlife Trusts, 'Petition Fish', Hugh Fearnley-Whittingstall's 'Fish Fight' and the Marine Conservation Society's many campaigns (e.g. sustainable fish, and 'Break the Bag Habit') bring particular issues home to a wide audience, presenting actions through which people can 'make a difference' by lobbying, or by changing consumer behaviour. These campaigns have had impressive success against a number of metrics, but research is still needed regarding the persistence of such positive activism. An extensive literature exists in the field of psychology, exploring evidence of 'behavioural spill-over', whereby there is an effect of an intervention on subsequent behaviours not directly targeted by the intervention; positive 'spill-over' examples have encouraging implications for the development of an individual marine citizenship, and for the outcomes of Marine Citizen Science participation, but there are incidences of negative 'spill-over' reported too (e.g. Truelove *et al.* 2016; Thomas *et al.* 2016; Thøgersen & Olander 2003). Lessons can be drawn from social marketing campaigns that identify a target behaviour for a specific audience, and tailor the language and context accordingly to maximise the impact for pro-environmental behaviours.

3.2.6 Citizen Science contribution to marine policy change

Enfranchisement of European publics to contribute meaningfully to the collective goal of healthy and productive seas is not a simple process. It require smultifaceted approaches, including (i) facilitating development of a sense of marine stewardship; (ii) opening up dialogue and empowering publics to contribute to the policy change process through scientific input; and (iii) reviewing the fundamentals of the policy instruments themselves, so that they better encompass individual considerations and values. Citizen Science projects can contribute to addressing these and additionally offer a social research platform from which motivations of volunteers and valuation of marine resources can be used to inform policy development and improve policy pathways.

Participation in Marine Citizen Science can achieve positive outcomes for policy change by encouraging a value shift towards taking personal responsibility for the marine environment; engagement presents opportunities to discuss actions and measures that can be adopted by individuals, but also to debate their value and relevance against wider strategies and behavioural themes. Building advocacy through Citizen Science can provide a powerful tool in the armoury of marine management and conservation.

Citizen Science projects 'package' particular issues in digestible formats, but additionally variably offer training, online supporting materials or signpost the participant to external sources of information on the topic. If the interaction is appropriately structured, this can represent a valued portal and 'gateway' for the engaged volunteer to further extend their knowledge base at their own pace.

The role of science in policy making is presented as the dispassionate arbiter and 'truth-sayer', yet science is often used as a 'tool of persuasion' to promote particular positions by interest groups or policymakers (e.g. Ozawa 1996; Sarewitz 2004; Yamamoto 2012), thus contributing to the alienation of publics and distrust for the evidence that underpins policy. Furthermore, there exists a body of social scientists who, rightly or wrongly, argue that science in practice is not the objective venture it claims, but rife with the imperfections and biases of human endeavour. Citizen Science, they argue, offers opportunities for members of the public to 'see behind the curtain' and appreciate fully what science entails. Regardless of stance, whether the motivation is in response to a need to build trust, to deepen understanding of the scientific process or to facilitate access as a basic human right, Citizen Science has at least the potential to place members of the public in settings where they experience for themselves what it is to be a scientist, struggling with the hurdles and complexity of data collection; it allows first-hand interaction between public, scientist and policymaker groups and facilitates reflection by the latter two on the relevance of their policy agenda or research direction.

For the future of policy-effective Marine Citizen Science, research is required to further explore public perceptions, clarifying what the public understand by ecological concepts and why they consider these to be relevant to marine health, what their environmental priorities are and how they wish their marine services and resources to be managed. Appreciating how varied public audiences are, will facilitate tailored engagement, and better design of tractable Marine Citizen Science tasks; but it will also accommodate more focused and effective dialogue between members of the public, the scientific community and the policy makers to achieve the desired endpoint of targeted policy change.

4

Developing European Marine Citizen Science: Strategic Action Areas

Credit: IMR

Realising the full potential of Marine Citizen Science in Europe will require concerted action by research organizations and research leaders, not only from the marine sciences, but also from diverse fields including computer science, law and economics. Research funding organizations can also promote and support a greater deployment of Citizen Science through national research programmes and strategies. Strong European-level coordination and support is required in order to promote exchange of good practices and to ensure that Citizen Science is contributing to the European Research Area. This chapter outlines 8 strategic action areas, grouped under shorter- and longer-term actions, for progressing Marine Citizen Science in Europe.

The sections below present the shorter- and longer-term actions needed to progress Marine Citizen Science in Europe, and these are summarised in Figure 4.1:

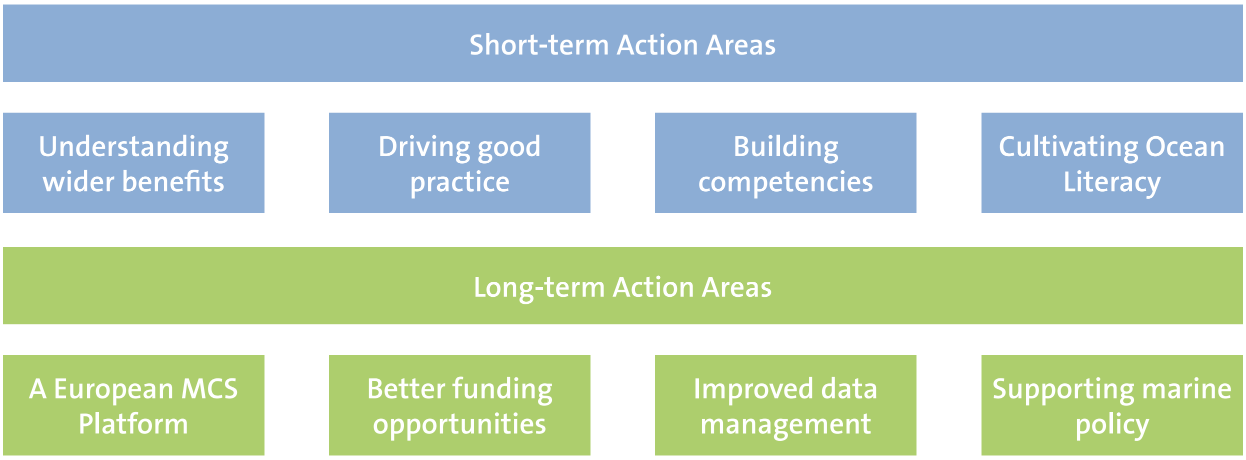


Fig.4.1 Strategic action areas for progressing Marine Citizen Science in Europe

Chapter 4 cover image: Children conduct a coastal survey in Norway

4.1 Shorter-term actions

1 Driving best practice at European level

Develop a framework and detailed guidelines for Marine Citizen Science initiatives in Europe to ensure that they are properly developed, managed and assessed. These should include ethics and baseline requirements, guidelines on data quality and recording, use of standard parameters and common vocabulary, details of how to incorporate initiatives into policy-making frameworks, and details of channels for citizens to access initiatives in bottom-up approaches. A forum for sharing should accompany these guidelines where Marine Citizen Science instigators, users and participants can share experiences, good practices and lessons learnt in order to continually improve the efficacy and standard of European initiatives and to ensure that mistakes are not repeated unnecessarily.

2 Understanding the wider benefits of Citizen Science for marine research and policy

Explore the knowledge gaps within marine science research as well as additional areas where Citizen Science can play a role to broaden the scope of Marine Citizen Science input. It is important to have an understanding of the true scale of potential offered by Citizen Science to ensure that this potential can then be met.

Create a better understanding of impact assessment and methods for quantifying the impact of Marine Citizen Science, taking this beyond simple participation and reach metrics and into the assessment of social and economic aspects. In this way, a more holistic view of good practices and factors for success can be realised.

3 Cultivating Ocean Literacy

Improve general awareness amongst the marine science community, policy makers and the general public regarding the importance and power of Marine Citizen Science, and the role and importance of marine research in general. Ocean Literacy is a powerful means to further the interest and participation amongst citizens, not only in research data gathering initiatives, but also in the development of research questions and marine policy. This will then lead to the advancement of Marine Citizen Science into projects which require greater involvement by citizens, towards extreme Citizen Science and citizen-led research.

4 Building competencies across multiple disciplines

The effective implementation of Citizen Science requires an understanding of best practice and particular expertise and competencies. It is imperative to enable the development of such competencies within Europe in order to fulfil the roles and tasks that have been identified. These include expertise in:

- Mediation and facilitation to act between the marine science and policy communities
- Citizen Science “Champions” who can bridge the gap between citizens and marine scientists
- Alternative funding sources and alternative financial models
- Dedicated cutting-edge data storage and management
- Digital and social media for outreach and education
- Website and devices technology including app development for initiatives.

4.2 Longer-term actions

5 Launching a European Marine Citizen Science platform

Establish a European Marine Citizen Science Platform that will become a central hub for information and expertise, incorporating the full "landscape" of initiatives from every country and clearly presenting this to the public through appropriate means. It would represent both EU Member States and non-EU European states. The Citizen Science portal (Vigie-Mer) being developed (in Open-Source) in France and due in mid-2017 could be used as a blueprint for a wider European Platform. The platform would have links to general Citizen Science bodies such as the European Citizen Science Association (ECSA) and national hubs or platforms, where these exist, in order to address issues such as local languages. It would provide an inventory of existing initiatives and could facilitate links between existing projects and foster the creation of new collaborations and new trans-national initiatives. This platform should also incorporate a technology component that will provide technical support, tools and facilities to initiatives across Europe. This will enable new projects and ideas to be developed and implemented faster without the need for relevant technical expertise among the initiative instigators. The platform could also report on project outcomes and successes, and promote the profile of Marine Citizen Science in general. Finally, this platform could act as a neutral space for scientists, citizens and policy makers to come together for discussion. Having a coordinated platform on a European level would create greater impact and a unified voice.

The platform could act as a forum for marine science researchers to explore and share successful strategies for citizen engagement, education and involvement. It could also enable strategies and recommendations for coordination and cooperation between local and wider-reaching initiatives in order to address aspects such as regional values, customs, cultures, specificities and language. It could further encourage cross-disciplinary and cross-sectoral collaboration in order to develop Marine Citizen Science research approaches that are effective as well as an efficient use of the resources available.

6 Better funding opportunities

Ensure that EU, regional and national funding mechanisms for research incorporate ways in which both the research and Citizen Science initiatives can be funded, as at present researchers will typically only receive funding for their direct research. Projects funded under Horizon 2020 and other EU funding programmes such as INTERREG and LIFE+ could benefit greatly from the use of Citizen Science. This should ensure appropriate financing for all players in the system, as outlined in Section 2.7, from researchers to local hubs. Financing mechanisms for both top-down and bottom-up management of initiatives should be considered and developed accordingly.

Additionally, explore alternative funding mechanisms for Citizen Science, including crowdfunding and philanthropy, so that a greater range of Citizen Science initiatives can be funded in a way that also directly engages the general public.

7 Facilitating efficient management of cCitizen-generated data

Develop open source data management, analysis and mining tools to ensure fast, reliable and effective generation of results and reporting. This is important not only for ensuring research results can be published quickly in order to maintain engagement with participants, but also to comply with the requirements of the Aarhus Convention on the rights of the public to access environmental data held by public bodies. Where the need exists, working groups for the furthering of research and development in key areas such as managing the data and databases from the multitude of initiatives should be coordinated.

Foster compliance of Citizen Science data with international data and metadata standards as these provide a certain level of consistency in data description, but also in data quality and inter-comparability with external datasets.

Create fit-for-purpose data storage and archiving solutions to ensure general access to the data by all, as well as sustainable current and future capacity. As the use of, and participation in, Marine Citizen Science in research grows, the volume of data gathered will multiply by orders of magnitude. Suitable data storage solutions will, therefore, be crucial in ensuring that all the data can be retained in an efficient and accessible way. This should be done in collaboration with existing international data repositories to ensure that a high standard of data management is retained. Such long-term storage in databases of international data centres, and accessible through EMODnet, SeaDataNet and GEOSS, allows data interoperability and re-usability beyond project lifetimes.

8 Empowering Citizen Science to support marine policy

Enable collaboration between marine science communities and marine policy makers to develop a better understanding of how Citizen Science can be used to co-develop policy and how it can be integrated into current and future EU laws and directives.

Using these findings, embed Marine Citizen Science into EU marine policy, for example in the monitoring aspects of the Marine Strategy Framework Directive and the Water Framework Directive and implementation of the Maritime Spatial Planning Directive. It could also be embedded in health policy, for example through EU initiatives such as Healthy Ageing. The Aarhus Convention established the right of the public to engage in environmental decision-making through Citizen Science and hence the provision of a scientific evidence base. The formal inclusion of Marine Citizen Science in research and policy would ensure that this right is upheld. Further opportunities could also be fostered through the funding of demonstrations on the complementary use of citizen data to support monitoring and decision making in a policy context.

Finally, while Citizen Science has considerable potential to support EU policy and environmental decision-making, it will also be important to foster international collaborations (with non-EU Member States) even though different policy and regulatory frameworks for environmental management will apply. This includes the important issue of fully open access to data as an underlying principle.

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List of abbreviations

AMEA	Asian Marine Educator Association
ARRS	Attention, Accessibility, Relevance, Satisfaction
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
BBS	Breeding Bird Surveys
CaNOE	Canadian Ocean Network for Ocean Education
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
CSA	Coordinated Support Action
CSP	Citizen Science Project
DEFRA	Department for Environment, Food and Rural Affairs, UK
DIY	Do-It-Yourself
DOI	Digital Object Identifier
ECSA	European Citizen Science Association
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EMSEA	European Marine Science Educators Association
ENFA	Ecological Niche Factor Analysis
EU	European Union
FU	Functional Unit
GDP	Gross Domestic Product
GEOSS	Global Earth Observation System of Systems
GES	Good Environmental Status
GIS	Geographic Information System
GPS	Global Positioning System
GSD	Ground Sampling Distance

HAB	Harmful Algal Blooms
HMI	Human-Machine Interface
ICES	International Council for the Exploration of the Seas
IMP	Integrated Maritime Policy
INMP	Integrated National Maritime Policy
INNS	Invasive Non-Native Species
ISO	International Organisation for Standardization
IT	Information Technology
JRC	European Commission's Joint Research Centre
MaxEXT	Maximum Entropy Method
MCS	Marine Conservation Society
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
NERC	Natural Environment Research Council
NGO	Non-Governmental Organisation
NMEA	National Marine Educators Association
NOAA	National Oceanic and Atmospheric Administration, US
NVS	NERC Vocabulary Server
OAO	Oceanographic Autonomous Observations
OECD	Organisation for Economic Co-Operation and Development
OSD	Ocean Sampling Day
OSPAR	Oslo-Paris Convention
PPR	Public Perceptions Research
SEPA	Scottish Environment Protection Agency
SWOT	Strength, Weakness, Opportunity, Threat

UAS	Unmanned Aerial Systems
UCL	University College London
UK	United Kingdom
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
US	United States
WFD	Water Framework Directive
WWF	World Wildlife Fund

Annex I

Members of the European Marine Board Working Group on advancing Citizen Science for coastal and ocean research (WG Citizen Science)

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Annex III

Marine Citizen Science initiatives in Europe

Information in this table has been taken from a number of sources including:
- The Seachange project Ocean Edge Database (http://seachangeproject.eu/campaign/sea-change-database)
- The European Environment Agency (EEA) list of biodiversity monitoring through Citizen Science (www.eea.europa.eu/themes/biodiversity/biodiversity-monitoring-through-citizen-science)
- The Marine Sightings Network list (http://marinesightingsnetwork.org/#2)
- (Science Communication Unit - University of the West of England 2013)
- The Wikipedia list of Citizen Science projects (https://en.wikipedia.org/wiki/List_of_citizen_science_projects)
- The SciStarter website (https://scistarter.com)
- Bürger schaffen Wissen database of Citizen Science projects (www.buergerschaffenwissen.de/en)

NAME	PARTICIPATING COUNTRIES/ REGIONS	WEBSITE	SUMMARY
ANEMOON	The Netherlands	www.anemoon.org/	Biodiversity projects from both the coast and for recreational divers including a national inventory of sea molluscs
Angler Recording Project	UK	www.sharktrust.org/en/anglers_recording_project	Anglers record all catches of shark, skate and ray species to increase understanding of national populations
Basking Shark Watch	UK	www.sharktrust.org/en/basking_shark_project	Incidental reporting of basking shark sightings and photographs
Beachwatch	UK	www.mcsuk.org/beachwatch	A beach cleaning and litter surveying programme
Big Sea Survey	UK	www.marinecitizenscience.com/projects/bigseasurvey.html	Gathering ecological data on the range and distribution of coastal marine species
Bioblitz	UK	www.mba.ac.uk/bioblitz	Timed race to discover as many species of plant, animal and fungi as possible
Biolit	France	www.biolit.fr	Coastal flora and fauna biodiversity observations supplemented with photographs
Biowatch	Greece, Worldwide	www.bio-watch.com	Using identification cards, citizens can identify fish species and submit observation logs
Black Sea Watch	Bulgaria, Turkey	http://blackseawatch.org	Marine biodiversity observations are uploaded via an app, which also provides educational information
CIESM Jelly Watch Program	Mediterranean	www.ciesm.org/marine/programs/jellywatch.htm	Visual observations on jellyfish outbreaks
Citclops	Worldwide	www.citclops.eu/home	Assessing water environmental properties, using an app to photograph and classify the colour

NAME	PARTICIPATING COUNTRIES/ REGIONS	WEBSITE	SUMMARY
Coastwatch Europe	Ireland, Europe	http://coastwatch.org/europe	Coastal area surveys addressing wide variety of topics
CoCoast	UK	www.capturingourcoast.co.uk	Coastal surveys to assess the abundance and distribution of marine life
COMBER	Europe	www.comber.hcmr.gr	Divers and snorkelers identify fish species and enter observations into the database
Explore the Seafloor	Worldwide	http://exploretheseafloor.net.au	Online tagging of marine flora and fauna species in photographs
FAMAR	Portugal	https://famar.wordpress.com	Volunteers join scientists in surveillance to study the quality of seagrass beds
Ghost Fishing	Norway	www.ndf.no/index.php?menuid=252&expand=252	Collaboration between the Norwegian Diving Association and the Institute of Marine Research to provide standardised reports for every set of ghost fishing gear found
Great Eggcase Hunt	UK	www.sharktrust.org/en/great_eggcase_hunt	Eggcase finds on the shore and in coastal waters are recorded to locate potential shark, skate and ray nursery grounds
Hebridean Whale and Dolphin Trust	Scotland	www.whaledolphintrust.co.uk	Collect marine mammal sightings by members of the public
Irish Basking Shark Project	Ireland	www.baskingshark.ie	Amalgamation of basking shark research and education programmes including a shark tracker and records of sightings
Irish Whale and Dolphin Group	Ireland	www.iwdg.ie	Volunteers assist with recording sightings, stranding events and research
iSeahorse	Worldwide	www.iseahorse.org	Citizens can interact with the seahorse conservation research through adding observations, diving and long-term monitoring of populations
Lamprey Watch	UK	https://envscot-csportal.org.uk/lampreywatch	Submission of observation records of brook, river and sea lamprey species during spawning season
Les Mammifères Marins en Bretagne	France	www.mammiferes-marins-bretagne.fr	Collection of marine mammal sightings in Brittany and provision of educational material aimed at children
Lobster Stock Monitoring	Norway	www.scanatura.no/default.aspx	Online catch diary for recreational lobster fishing where data are used directly to monitor stock development

NAME	PARTICIPATING COUNTRIES/ REGIONS	WEBSITE	SUMMARY
MantaMatcher	Worldwide	http://mantamatcher.org	Users report manta ray encounters and upload photographs which are then matched to a database of records
Marine Conservation Society	UK, Ireland	www.mcsuk.org/what_we_do/ Wildlife+protection /Report+wildlife+sightings	The general public can report sightings of basking sharks, jellyfish, marine turtles and alien species
MARLIN – Baltic Marine Litter	Sweden, Finland, Latvia, Estonia	http://projects.centralbaltic.eu/ project/447-marlin	Numerous initiatives run throughout the region to reduce the litter on the shores
MED-JELLYRISK	Mediterranean	http://jellyrisk.eu	Coordination of research and initiatives to reduce impacts of jellyfish proliferation
MOBIDic	Portugal	www.ciimar.up.pt/mobidic/index.php	School children collect data on algae, mussels, barnacles and focus as well as gaining Ocean Literacy knowledge
My Ocean Sampling Day	Germany, Worldwide	www.microb3.eu/myosd	Global campaign to take coastal water samples and contextual environmental data for study of microbial communities on summer solstice, in sequential years
National Algal Bloom Monitoring	Finland	www.jarviwiki.fi/wiki/Algal_situation	Inland and sea monitoring of algal blooms at 300 observation sights with assistance from trained observers
ORCA – Looking out for Whales and Dolphins	UK, Europe	www.orcaweb.org.uk	Monitoring and surveying whale and dolphin habitats from ferries, cruise ships, dedicated watching trips and on land
Penguin Watch	Worldwide	www.penguinwatch.org	Online identification of adults, chicks and eggs in photographs
Perseus Jellyfish Spotting	Mediterranean and Black Sea regions	www.perseus-net.eu/site/content.php?locale=1&sel=515	Report jellyfish sightings using species identification chart, with results presented on an online map
PlanktonID	Germany, Europe	https://planktonid.geomar.de/	Volunteers help to identify plankton organisms in photographs via an online game
Plankton Planet	France	http://planktonplanet.org	Sailors sample seawater and identify plankton species
Plankton Portal	Worldwide	www.planktonportal.org	Online-based programme where users mark and identify plankton species in photographs

NAME	PARTICIPATING COUNTRIES/ REGIONS	WEBSITE	SUMMARY
Plastic Pirates	Germany	www.wissenschaftsjahr.de/2016-17/weiterfuehrende-informationen/englisch/plastic-pirates/collect-upload.html	Collection of macro and micro-plastic litter data by teams of 10-16 year olds
Porcupine Marine Natural History Society	North-East Atlantic, Mediterranean Sea	http://pmnhs.co.uk/found-something-unusual	Collection of informal / chance records of sightings by members of the public
RecFishFuture	Norway	www.facebook.com/fritidsfiskeforskning	The goal is to estimate the recreational harvest of important coastal stocks, and to study the ecosystem impacts and socio-economic values of the fishery
Recreatieve Zeevisserij	Belgium	www.recreatievezeevisserij.be	The marine recreation fishing community provide logs of individual catches to contribute to stock assessment research
Red Posidonia Murcia	Spain	www.facebook.com/redposidoniamurcia	Volunteer divers assist scientists in monitoring seagrass meadows
Reef Life Survey Programme	Worldwide	http://reeflifesurvey.com	Trained volunteer divers work with scientists to survey reef life
REEF Volunteer Fish Survey Project	UN	www.reef.org/programs/volunteersurvey	Snorkelers and scuba divers collect and report information on marine fish populations, and selected invertebrate and algae species in temperate reef areas
Return the Tag	Finland	www.rktl.fi/kala/kalavarat/kalamerkinta/palauta_kalamerkit	Fishers are asked to return fish tags from landed fish and are provided information about the fish in return
Sandwatch	UN	www.sandwatch.ca	Children, youth and adults work together collect marine scientific data and then co-design measures to address particular issues
Seasearch	UK	www.seasearch.co.uk/index.htm	Sport divers can learn about what they see and record species observed
Sea Watch Foundation	UK	www.seawatchfoundation.org.uk	Education programme where cetacean sightings can also be reported
Seawatchers	Spain	www.observadoresdelmar.es	Wide-ranging observations on coastal flora and fauna presence, abundance and health
Secchi Disk Study	UK	www.secchidisk.org	A Secchi Disk is used to measure water clarity as an indicator of phytoplankton abundance

NAME	PARTICIPATING COUNTRIES/ REGIONS	WEBSITE	SUMMARY
Shark By-Watch UK	UK	www.sharkbywatch.org	A collaboration between fishers and scientists for tagging, surveying and improving fisheries practices for sharks, skate and rays
Species Observations Service	Norway	https://artsobservasjoner.no	A reporting system that is open to both professionals and amateurs to record species sightings from all species groups, including marine species
Spot the Jellyfish	Malta	http://oceania.research.um.edu.mt/jellyfish	Recording jellyfish species and locations, aimed at younger children
Studland Tagging Project	England	www.theseahorsetrust.org/studland-tagging-project.aspx	Seahorse tagging and observation project in seagrass beds with significant contributions of volunteer divers to the project
The Conchological Society of Great Britain and Ireland	UK, Ireland	www.conchsoc.org/recording/marine-rec.php	The general public can supply records on molluscs found at the shore
The Shore Thing	UK	www.mba.ac.uk/shore_thing	Volunteers, schools and community groups collect information on rocky shore line life to monitor the impact of warming seas
Virtue	Sweden	http://science.gu.se/english/cooperation/virtue	A school education project on underwater marine organisms that can also contribute to real estate management

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Cover Photo: Children engaging in coastal surveys and monitoring
Credit: Institute of Marine Research, Norway

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