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Marine Citizen Science in the North Sea area

and what policy makers can learn from it

Policy Informing Brief
December 2020

Flanders Marine Institute (VLIZ)

Policy Informing Brief

Introductory note

Flanders Marine Institute (VLIZ) can provide policy-relevant information free of charge at the request of its target groups, as well as on its own initiative. This information is made available in the form of policy information briefs (*in Dutch: Beleidsinformerende nota's - BIN*).

The content of the policy information notes is based on current scientific insights and objective information and data. VLIZ relies as much as possible on the expertise of coastal and marine scientists in the network of marine research groups in Flanders/Belgium and the international network.

The policy information notes reflect the neutral and unbound character of the VLIZ and strive for a maximum translation of the basic principles of sustainability and an ecosystem-based approach as endorsed in the European Integrated Maritime Policy and Coastal Zone Management.

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Content of the report

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Summary

In addition to terrestrial citizen science and considering the vastness and attraction of the ocean and the world's coastlines, marine and coastal citizen science is a highly recommendable tool for the purpose of science and awareness. In the meantime, marine and coastal citizen science can contribute significantly towards a more ocean literate population by creating awareness on the enormous importance of and dependency on the ocean for our wellbeing.

The current policy informing brief thoroughly reviews and analyses 127 marine citizen science projects in the North Sea area, and formulates recommendations for policy makers. Of those projects, 25 are no longer active. Two out of three of the North Sea projects (85) are country specific, meaning they take place on the beach or in the coastal waters of one of the riparian countries. Of those 85 projects, 66% take/took place in the UK. Another nine projects investigate the entire North Sea, four projects study European waters including the North Sea, and 28 projects have a global character.

There is a clear focus on monitoring marine and coastal animals and plants. Almost half of the North Sea CS-projects (61 projects) deal with the study of 'species'. They follow the distribution or abundance of one or more species, or gather information about population changes (migration patterns, behaviour). Most wanted are marine mammals (28%), fish (20%) and birds (20%). Another 17% of the projects deal with 'pollution', such as marine litter or oiling in seabirds. Some 16% have a more general 'biodiversity' focus. The other categories ('Ecology', 'Fisheries', 'Environmental' and 'Archaeology') are less common. Undoubtedly there is still a big untapped potential for marine and coastal citizen science initiatives in the non-biological sciences (geology, archaeology, history, coastal engineering, maritime technology, etc.).

Citizen Science projects in the North Sea area are the playing field of a variety of organisations (charities and foundations, governmental organisations, research institutes, non-governmental organisations, partnerships or individuals). NGOs are the major contributors to North Sea CS-initiatives, research institutes are second. Overall, our analysis displays a mixed pattern in what organisations aim for. Government organisations prefer 'composite' projects, i.e. projects that draw attention to important policy issues by providing a 'shared conceptual framework as basis for interpretation, analysis and practice'. Research institutes invest most in 'descriptive' initiatives, whereas NGOs have a slight preference for 'performance' initiatives, in which monitoring and evaluation is crucial. Most North Sea CS-projects deal with sightings as 'data type' (43%), followed by 'systematic observations' (28%).

There is certainly scope for growth in the level of participation, compared to what is at stake today. It is not surprising that, the higher the level of participation, the more effort needed from the citizen scientists (and from the organisers) and the less projects you will find. From the categories in citizen science defined by Hacklay (2013), crowdsourcing is evidently the most frequently used method (69%), followed by distributed intelligence (25%). Two projects explored participatory science, and only five projects reached the most interactive level of extreme citizen science. Currently, 72% of all projects collect data in a continuous way (with no obligations). Another 19% collects data at a fixed number of occasions, the remaining 9% collects data only once a year. Beach-based projects are more accessible for citizen scientists than projects that require data collected at sea. Currently, almost 60% of the projects in

the North Sea region collect data from the beach. A large part of those projects deal with species-specific research (40%), followed by pollution (25%) and biodiversity (17%). Birds are major targets for projects at the beach. Also at sea, a majority (60%) of the projects is species oriented. Algae/plankton/micro-organisms and fish are for obvious reasons more frequent in CS-projects at sea.

Citizen science, and more specifically marine citizen science, is not new. The oldest project in this inventory of 127 North Sea CS-projects, was launched in 1876 (a crowdsourcing initiative by the Conchological Society of Great Britain and Ireland). Another five projects started before 1960. From 1960 onwards, first we see a slow increase in new projects turning into an exponential growth after 1990. Particularly from 2010 onwards, there is a marked increase in the number of new North Sea CS-initiatives, illustrating the increasing recognition of the potential of the ocean and coasts for these purposes. In terms of the topics that are studied, there is not much change, although 'pollution' projects show a visible increase since 2010 coinciding with the media attention for the marine litter issue. Of the 127 projects in our database, 25 have ceased. The mean duration of these ended projects is 18 years, while ongoing projects on average have been active for 20 years. Some of the topics have longer lifespans. Birds and mollusc projects for instance have a mean duration above 37 years, followed by marine mammals (28 years) and other topics (9-17 years). With regard to the level of involvement, extreme citizen science projects have a shorter duration, as they require more effort and engagement from both the participants and the organisers. Differences in data type show that projects relying on 'measurements' have the longest lifespan (27 years), while 'imagery' projects are on average the shortest (10 years).

In summary, although this study shows an interesting and growing number and variety of marine citizen science projects in the North Sea area, there is undoubtedly still a high and partly untapped potential. In a data-driven society, scientists need more observations from that vast ocean realm, increasingly targeted as a place for recreation and blue economy purposes. Citizens can help to make this happen from their fascination with the sea, in an area that is high on their list of favourite destinations. Whereas today a majority of the projects focusses on life sciences and study of species, new opportunities are present in the field of coastal morphology and protection, history, weather and climate, human health at the coast, etc.

Also in terms of policy, marine and coastal citizen science is a very promising and still undervalued and underutilised format, not at least on the vast and open sandy beaches and in the easily accessible coastal waters of for instance the low-lying countries. It is highly recommended that marine policy and science further stimulate and mediate the growth in North Sea citizen science initiatives. More observations lead to a higher scientific input into policy and management of coastal waters. It will help bridging the gap between researchers and the wider public, stimulate a STEM-approach in children, provide bottom-up tools for citizens towards marine and coastal policy (e.g. with regard to marine litter, coastal defence, etc.), and create a higher ocean awareness.

Today, citizen science in the marine field is still lagging behind what is happening in the terrestrial and freshwater era. This is partly because there is no specific strategy, no existing platforms with a focus on the marine realm, and virtually no incentives for more ocean-based citizen science. The present initiatives and best practices should be easily and widely

accessible and shared in an open and transparent way. We plea for additional incentives, including seed money, in order to create a wide range of marine citizen science projects and initiatives, from easy, well-attended beach-based reporting of sightings to more complex 'extreme' forms of citizen science. It is clear that a well-designed strategy – in line with the expectations with regard to research and management – could lead towards a more diverse, more accessible and highly desirable spectrum of marine citizen science initiatives in Europe.

Preface: VLIZ and marine citizen science

The Flanders Marine Institute (VLIZ) has been at the cutting edge on advocating more ocean literacy in Europe and beyond. As one of the pioneers of ocean literacy in Europe, it coordinated the 'Engaging with the public' work-package of the European H2020 'Sea Change' Ocean Literacy project. Within 'Sea Change', VLIZ produced the Ocean Edge Directory, an inventory of European marine science outreach and education initiatives, including 85 citizen science projects. On this mission to bridge the gap between ocean scientific knowledge/awareness and the public, citizen science is undoubtedly a promising field of action. VLIZ launched several marine citizen science projects as well. Since 2014, '**SeaWatch-B**', a trained network of citizens, is monitoring the state of the Belgian part of the North Sea by seasonally measuring and reporting ten variables in a standardised way, including marine litter, biodiversity, seawater temperature, archaeology, etc. (www.seawatch-b.be). In 2018, one of those variables, the species composition of empty shells found on the beach, became the topic for another Belgian citizen science initiative, a national '**Big Seashell Survey**' (*Grote Schelpenteldag* - GSTD). Within this GSTD-project, 1,500 citizens collected and identified more than 100,000 shells from Belgian beaches during three editions (2018, 2019, 2020). Internationally, VLIZ was also a co-author of the position paper of the European Marine Board on citizen science, 'Advancing citizen science for coastal and ocean research' (Garcia-Soto et al. 2017).

It is within this framework that VLIZ has made an inventory and analysis of all marine citizen science initiatives in the North Sea area in order to develop and implement an underpinned strategy in this field for the future. Another stimulus was the ongoing 'Baltic and North Sea Coordination and Support Action' (BANOS CSA), a joint Baltic and North Sea research and innovation programme. This programme, prepared by major research and innovation funders of twelve countries (BE, DK, EE, FR, DE, LV, LT, NL, NO, PL, SE, UK) including VLIZ, aims to "fund high quality science and innovation, based on its joint marine and maritime strategic agenda in support of sustainable use of ecosystem goods and services" (Baltic Marine Environment Protection Commission 2018). Four key action areas are included in BANOS CSA: strategic research and innovation agenda, implementation, communication, and impact. Citizen science fits into this last area about knowledge transfer, open science, new skills and open data.

1. Introduction

This report gives a first overview of marine and coastal citizen science projects in the North Sea area until spring 2018. Although it does not pretend to provide a comprehensive and full state of the art, the multitude and variety of initiatives clearly demonstrate how society has embraced this 'new' form of science awareness and interaction.

1.1 What? Why?

The term 'citizen science' was first defined by Alan Irwin, and has only been in dictionaries since 2014 (Irwin 1995; The Zooniverse 2014). Citizen science projects can have many different aims, from collecting and analysing data for the sake of scientific research, over creating awareness, to tackling important policy issues (Dickinson et al., 2012). In many citizen science projects, citizens and scientists collaborate with a clear scientific purpose. As citizens outnumber professional scientists by orders of magnitude, involving non-professionals in science definitely creates new opportunities with regard to the temporal and spatial scale of what can be achieved (Cigliano et al. 2015). Considering the vastness of the ocean and the world's coastlines, involving citizens is a highly recommendable tool for the purpose of science and awareness (Garcia et al 2017; VLIZ 2017). In the meantime, this format can contribute significantly towards a more ocean literate population, by creating awareness on how science operates and by demonstrating evolutions at first hand. For instance, citizen science projects can help in raising awareness under participants about sustainability issues, encourage acknowledgement of those issues and stimulate people to change their unsustainable behaviour (West & Pateman 2017). Also in terms of policy-making and ocean governance, it can play a role with regard to marine conservation. More ocean literate citizens will influence management and policy of the ocean realm, and improve community capacities to address environmental issues (Cigliano et al. 2015). Projects aiming at monitoring the state of a specific ecosystem may provide the information to governmental departments that subsequently implement new or change existing management concepts and approaches. Adaptive management requires systematic monitoring in order to improve environmental management (Murray & Marmorek 2003).

1.2 Types of participation

In terms of general aim, one can distinguish three major types of initiatives: descriptive, performance and composite projects (Lehtonen et al. 2016). In '**descriptive projects**', data are being collected without specified intended use. In '**performance initiatives**', monitoring and evaluation is crucial, as these projects often collect data on the long term in order to monitor and evaluate their research topic towards a norm. Finally, '**composite projects**' draw attention to important policy issues by providing a 'shared conceptual framework as basis for interpretation, analysis and practise'. This enables comparison between theories and encourages a collective understanding. Projects with this aim differ from projects with a performance aim, in specifically aiming at management and policy.

Citizen science has four frequently described levels of participation (Figure 1) (Shum et al. 2012; Haklay 2013). '**Crowdsourcing**' requires the lowest level of participation. Every citizen

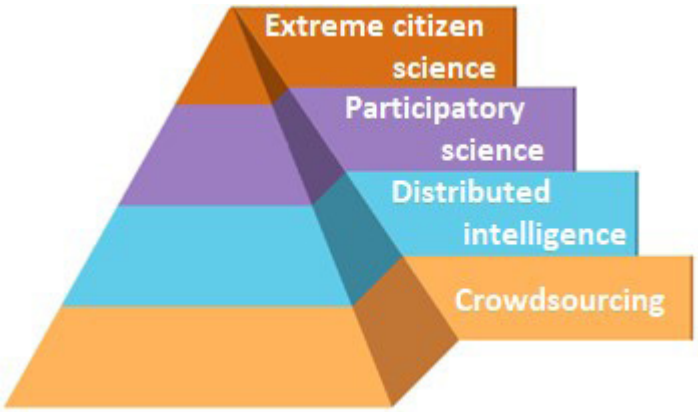

Figure 1: Levels of participation in citizen science.

can participate, because no knowledge on the subject is required. Citizens act as sensors or for volunteered computing, frequently in the form of reporting observations. The second level, '**distributed intelligence**', requires more effort from the citizen scientist. At this point, a certain level of knowledge is required in order to collect data or for the sake of interpretation. These citizens often have to take a training course to get the necessary skills and knowledge, or they already need to have specific skills or knowledge before participating. This level is especially beneficial in areas where certain skills are uncommon in the culture of people (Cigliano et al. 2015). The next level, '**participatory science**', involves citizens in defining the problem, composing a method and in data collection. Scientists still play a leading role in analysing the data and interpreting the results. Lastly, '**extreme citizen science**' also referred to as '**collaborative science**' motivates non-professionals to participate in all steps of research: problem definition, data collection, analysis and results. Citizens can however choose their level of engagement, and do not need to participate in all steps. Additionally, amateur-scientists are nowadays able to create their own research project due to the creation of online citizen science platforms such as 'iNaturalist'.

2. Methodology

2.1 Study area & methods

We defined our study area as the North Sea s.s., i.e. excluding the English Channel (Figure 2) (WorldAtlas 2017; Alexander 2015)

The inventory built on earlier VLIZ-work, carried out within the framework of the EU H2020 'Sea Change' project, and fine-tuned by Arya Seldenrath. In a first step, we critically revised this baseline of 118 projects, selected the North Sea projects and complemented the available information. Next, several additional steps were taken:

- Websites of projects included in the baseline inventory often refer to other citizen science projects, which could then be included.

Figure 2: The North Sea study area, including boundaries (WorldAtlas 2017).

- An intensive Google Search for the whole North Sea area, using specific search terms (see **appendix II**). Sometimes, the search terms led to websites maintaining lists of many citizen science projects (adding information).
- A search on social media, such as Facebook, Twitter, Instagram and LinkedIN (search terms: Citizen science, marine citizen science, North Sea, sea-/shore-/life-/bird-/marine mammal-/seaweed-/marine litter-watch/project/survey/programme).
- A Google Search to find organisations that might be involved in marine citizen science, even though their sites do not mention it. This includes marine research institutes, NGOs, universities, museums, governmental institutions, nature organisations/associations and conservation organisations (search terms: marine research institutes, NGO, mariene onderzoeksinstituten, marine forskninginstitutt).
- Directly contacting organisations, found during previous steps, by phone or email. In the case of direct contact, we asked the organisations whether they are involved in marine citizen science, and if they were aware of other projects.

As far as possible, we tried to obtain a broad overview of what the project is all about (Table 1). A more comprehensive overview of the variables and their given values/categories that were used in the process of analysis, can be found in **appendix I**.

Table 1: Variables of citizen science data.

Variables					
1	Name of project	7	Start-up year	13	Aim
2	Organisation(s)	8	Last year of the project	14	Number of participants
3	Type of organisation	9	Period of data collection	15	Level of participation
4	Country	10	Discipline	16	General aim
5	Monitored area	11	Category (topic)	17	Source and contact information
6	Language	12	Data type		

2.2 What to consider as CS-projects in the North Sea area?

For the selection of appropriate projects, we used the '10 principles of citizen science' listed by ECSA (European Citizen Science Association 2015) and following criteria:

- Monitoring and data collection has to occur in the **North Sea s.s.**. Projects without a focus on the North Sea, or with only a small, unintentional chance of data collection in the North Sea, are not included.
- The project should involve **non-professionals** (citizen scientists) in one or multiple stages of the research process (data collection, data analysis, communicating the results, etc.).
- The project should have a genuine **scientific** outcome. If citizens are involved with the sole purpose of education, we do not consider the initiative a citizen science project.

Furthermore, projects that only investigate the validity of data collected by citizens are not included.

3. Results

We gathered **127 marine citizen science projects in the North Sea area**. For 77 projects, we managed to get all the data listed above. For the remaining 50 projects, the number of participants seemed to be hard to get. Of all projects, 25 have ended and are no longer active at this moment (see further).

3.1 Where do North Sea CS-projects take place?

Of the 127 North Sea projects, 85 (or two out of three) are country specific, meaning they occur(red) in the exclusive economic zones (EEZs) of one of the riparian countries. Of those projects, 66% take place in the UK part of the North Sea (Figure 3). Nine projects investigated the whole North Sea, four projects studied European waters including the North Sea, and 28 projects occurred worldwide. Only one project specified their research area as the international Wadden Sea area, shared by the Netherlands, Germany and Denmark.

The projects that collect data in one specific country, are all coordinated by organisations in that state. However, France, Germany, Norway, the Netherlands and the United Kingdom also coordinate projects outside their borders. A minority (20 projects) is not organised by

one of the North Sea riparian states. Of these, 11 projects are coordinated by international organisations, four projects take place at a European level and five projects are led by countries not bordering the North Sea (Ireland, Sweden, USA, Australia) (Figure 4).

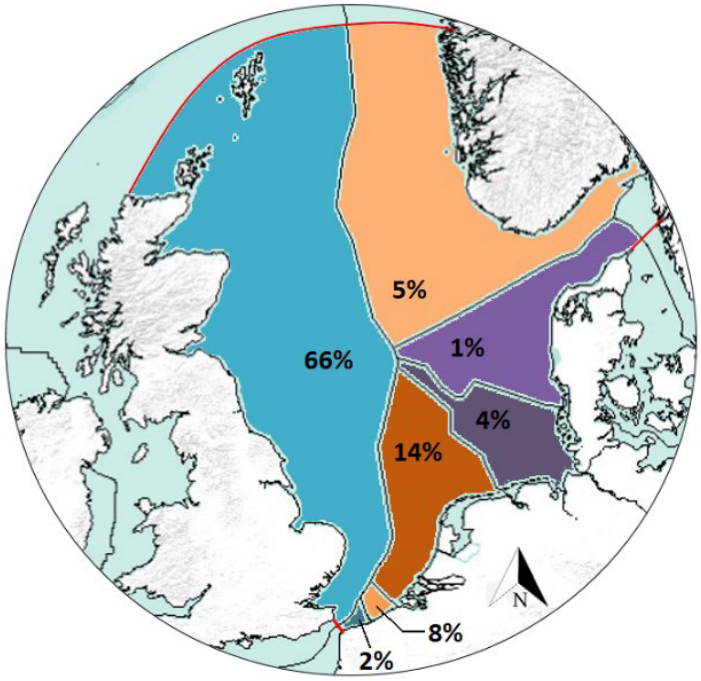

Figure 3: Distribution of marine CS-projects in the North Sea area by EEZ (n=85).

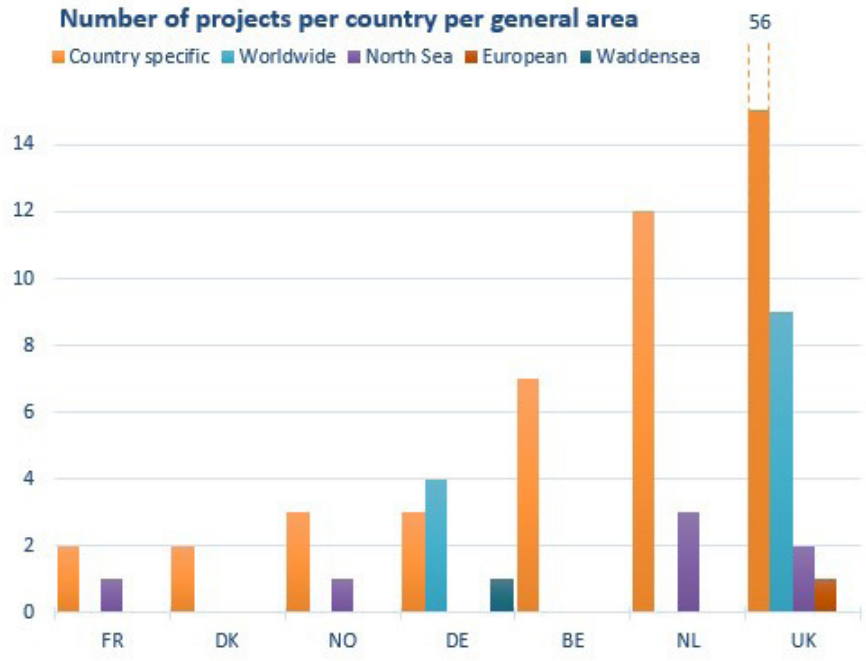

Figure 4: Number of North Sea CS-projects per country per area (n=107).

EyeOnWater is an app developed under the Citclops project and funded by the EU FP7 programme. The project, launched in 2013, aims to develop systems to retrieve and use data on optical water properties, using low-cost sensors combined with people acting as data carriers. Using a crowdsourcing level of participation, the project provided an app for citizens to take photographs of the sea surface on for example ferries on the open ocean or from the beach. **(eyeonwater.org)**

3.2 What do North Sea CS-projects study?

For the analysis we used seven main categories: 'Species', 'Biodiversity', 'Ecology', 'Fisheries', 'Environmental', 'Pollution' and 'Archeology'. Almost half of all projects study 'species', meaning they perform research on a specific species or group of species, such as birds or fish (Figure 5). Some 17% of the projects work on pollution, such as marine litter or the effect of oil spills on birds. Another 16% have a more general 'biodiversity' focus. They collect information on many different species, mostly to map the biodiversity of a region. The category 'ecology' (8%) includes projects on for example coastal ecology, the state of certain habitats, species interaction with the habitat, or the impact of climate change on the ecosystem. The remaining 11% performs research on 'fisheries' (fishery catches or fish stocks), 'environmental variables' (such as water quality, temperature or sea level rise), and 'archaeology' or maritime history.

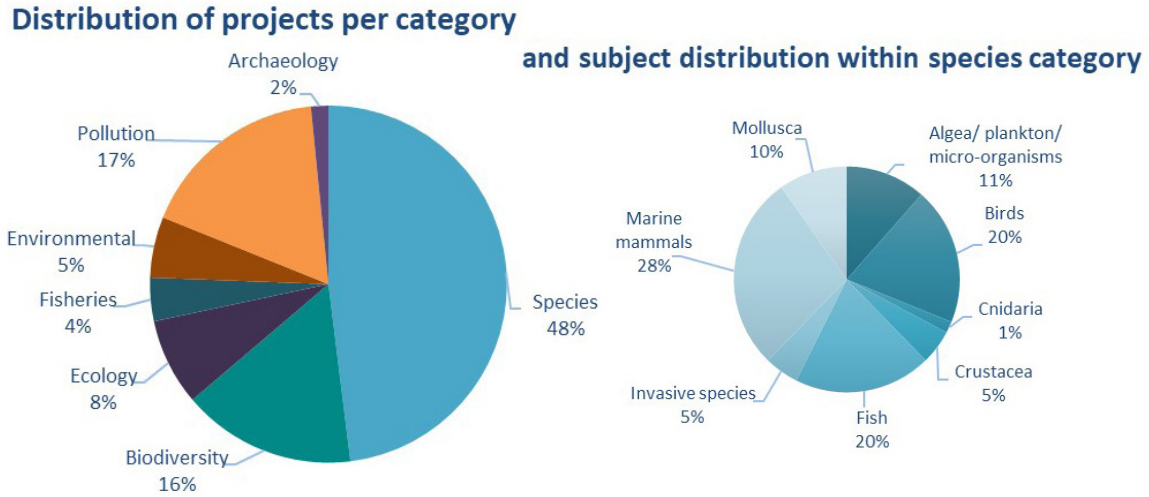

Figure 5: North Sea CS-projects focus on 'species', 'biodiversity' and 'pollution' (left; n=127). Within the 'species' category (n=61) birds, fish and marine mammals got most attention.

Almost half of the North Sea CS-projects (61 projects) deal with the study of 'species'. Often they monitor the distribution or abundance of one or more species, or gather information about population changes (migration patterns, behaviour). Most wanted are marine mammals (28%), fish (20%) and birds (20%), followed by projects on algae/plankton/micro-organisms (11%) and molluscs (10%). Crustaceans, invasive species and cnidarians (e.g. jellyfish) are being studied by only seven projects all together.

Earthdive Global Dive Log is a unique research project created and developed by Earthdive in partnership with the United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) and with marine biologists from all over the world. The project, launched in 2003, encourages divers to act as citizen scientists and record observational data that are useful for marine conservation (distributed intelligence). Ultimately, the organisers strive to stimulate divers to take part in a massive global effort to monitor and help conserve life on this planet. **(earthdive.com)**

Not surprisingly, the country where we could identify the largest number of North Sea CS-projects (UK) demonstrates the largest diversity in topics dealt with (Figure 6). All environmental and archaeology projects occur in the UK. Two out of three (67%) of the ecology and the fisheries projects take place in the UK and 33% in Belgium. Projects on biodiversity also mainly occur in the UK (63%), with another 25% in the Netherlands and 6% in both France and Norway. 'Pollution' CS-research occurs for 58% in the UK, 25% in the Netherlands and 17% in Germany. The topic 'species' is studied in all countries bordering the North Sea (UK: 70%, the Netherlands: 11%, Belgium: 9%, and France, Germany and Norway each 2% of the projects).

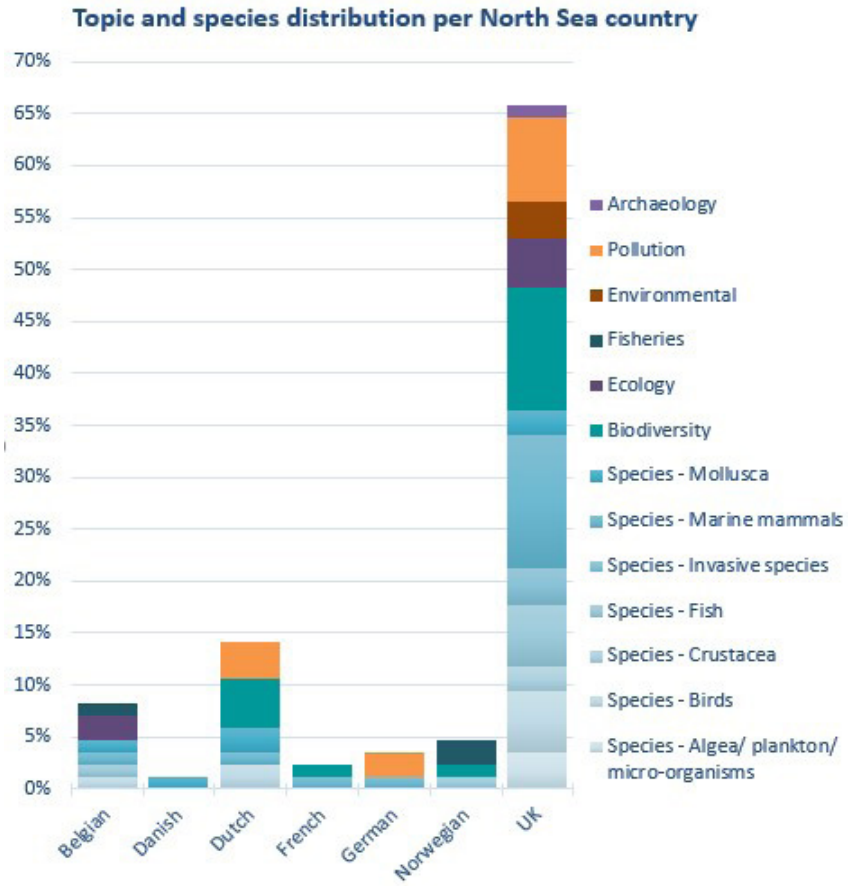

Figure 6: The distribution of topics and species as focus of country specific North Sea CS-projects (per country as % of total)(n=85).

OpenLitterMap is a citizen science project developed by one single person, Seán Lynch. He aims to develop an open accessible database with information about the distribution of litter, to communicate the problems and solutions, and to stop litter reaching the ocean. Citizens from all over the world can add photographs to the global map, which automatically includes GPS location. Lynch launched his crowdsourcing project in 2016. **(openlittermap.com)**

Zooming in on the 'species' category, the UK is currently the only country researching marine algae/plankton/micro-organisms, crustaceans and invasive species with the help of citizens (Table 2). The UK also has the largest share in research in marine mammals (73%). The remaining projects are evenly divided over the Netherlands, Belgium, France and Germany. The same applies for 'fish' (71% in the UK), and 14% in both Belgium and Norway. 'Birds' are dealt with mainly in the UK (63%), besides another 25% in the Netherlands and 13% in Belgium. Research on Mollusca is done mainly in the UK and the Netherlands (both 33%), followed by Belgium and Denmark (17%).

Table 2: The distribution of topics and species as focus of country specific North Sea CS-projects.

Topic	Area (country specific)
Archaeology	United Kingdom
Pollution	United Kingdom, The Netherlands, Denmark
Environmental	United Kingdom
Fisheries	Belgium, Norway
Ecology	United Kingdom, Belgium
Biodiversity	United Kingdom, The Netherlands, France, Norway
Mollusca	United Kingdom, The Netherlands, Belgium, Denmark
Marine mammals	United Kingdom, The Netherlands, Belgium, France, Denmark
Invasive species	United Kingdom
Fish	United Kingdom, Belgium, Norway
Crustaceans	United Kingdom
Birds	United Kingdom, The Netherlands, Belgium
Algae/plankton	United Kingdom

3.3 Who is organising North Sea CS-projects?

Citizen Science projects in the North Sea area are hosted by a variety of organisations (charities, foundations, governmental organisations, research institutes, non-governmental organisations, partnerships or individual people). Using five categories (see **appendix I**), it is clear that NGOs were the major contributors to North Sea CS-initiatives (Figure 7). Research institutes are second, the remaining 15% is coordinated by collaborative effort, government organisations or individual persons.

The Shore Thing has been developed by MarLIN and the Marine Biological Association in Plymouth, in collaboration with Dove Marine Laboratory, University of Newcastle. The project, launched in 2005, is being funded by Scottish Natural Heritage. It aims to generate records of marine wildlife by facilitating intertidal biological surveys at sites around the British Isles. Citizens can participate in the surveys with the use of a survey guide, and collect data on intertidal biodiversity. In addition, the project aims to raise awareness of marine science and the marine environment. **(mba.ac.uk/shore_thing)**

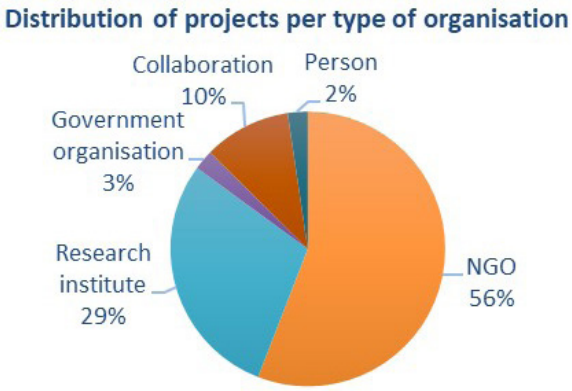

Figure 7: North Sea CS-projects per type of organisation (n=127).

In terms of the topics being studied, NGOs have a focus on species-specific research (55%), and show less interest in the other topics (Figure 8). Research institutes show a smaller difference in topic distribution, although 'species' still stands out. Finally, governmental organisations focus on pollution related topics and species research.

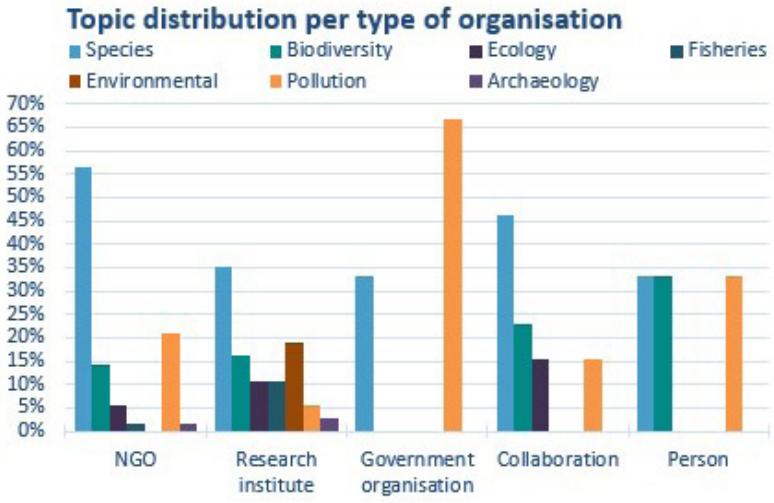

Figure 8: What topics do organisations focus on, with regard to North Sea CS-projects (in % per type of organisation: NGO (n=71), research institute (n=37), government organisation (n=3), collaboration (n=13), Person (n=3)).

All types of organisations support citizen science initiatives that focus on certain species or species groups. Excluding the categories 'person' and 'government organisation' (dealing with only one project each), for NGOs we see a bias towards 'marine mammals' (30%) and fish (25%) as study objects (Figure 9). Research institutes include an equal number of projects on invasive species (23%), as on marine mammals and on birds.

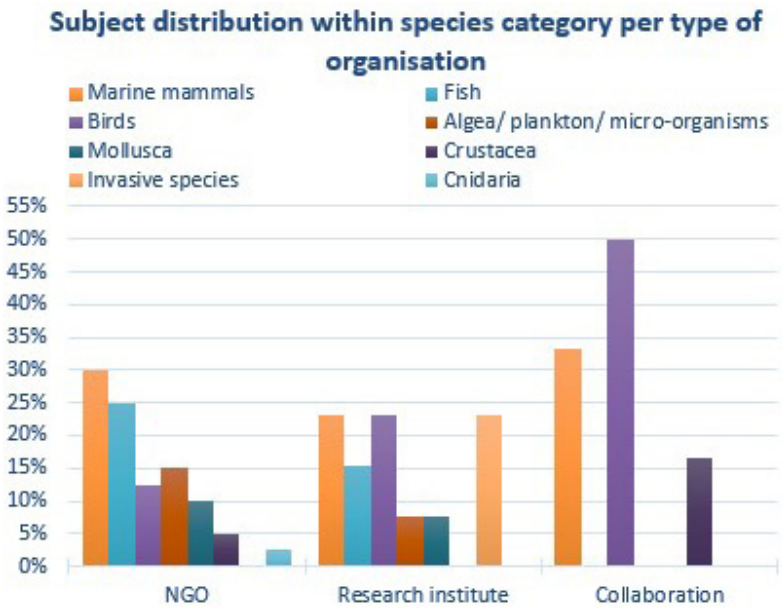

Figure 9: Subject distribution within species category in percentage per type of organisation: NGO (n=40), research institute (n=13), collaboration (n=6).

3.4 What do organisations aim for?

The general aim of citizen sciences projects, as explained in the introduction, can be 'descriptive' (i.e. purely collecting data), 'performance oriented' (i.e. monitoring and evaluation) or 'composite' (i.e. tackling important policy issues).

Overall, our analysis displays a mixed pattern in what organisations aim for (Figure 10). They all cover each of the aims, although government organisations prefer composite projects, research institutes the more descriptive ones and NGOs have a slight preference for performance initiatives. On average, the mean number of participants in descriptive projects (2,330) is smaller than in performance (5,263) and composite initiatives (19,103).

Most 'performance' and 'descriptive' projects deal with species-specific research (72% and 48%, respectively), followed at some distance by biodiversity research (16% and 24%, respectively) (Figure 11). Projects with a composite aim are different and show a high number in the category pollution (54%), followed by species-specific research (21%).

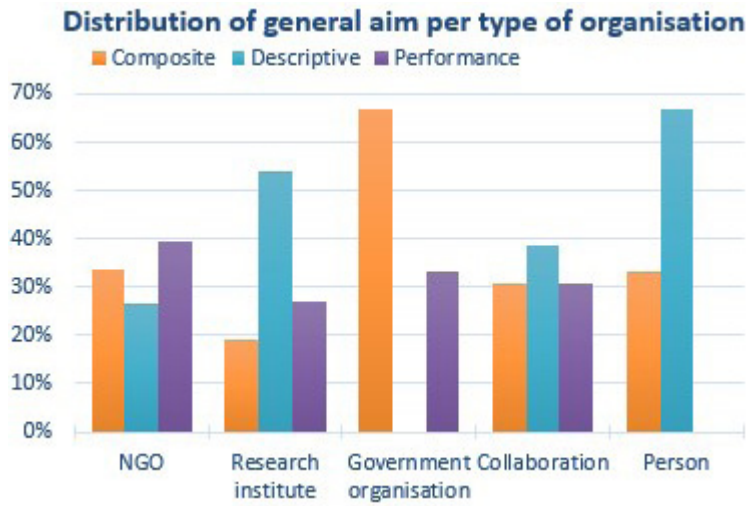

Figure 10: General aim for organisations in North Sea CS-projects (in % per type of organisation: NGO (n=71), research institute (n=37), government organisation (n=3), collaboration (n=13), person (n=3)).

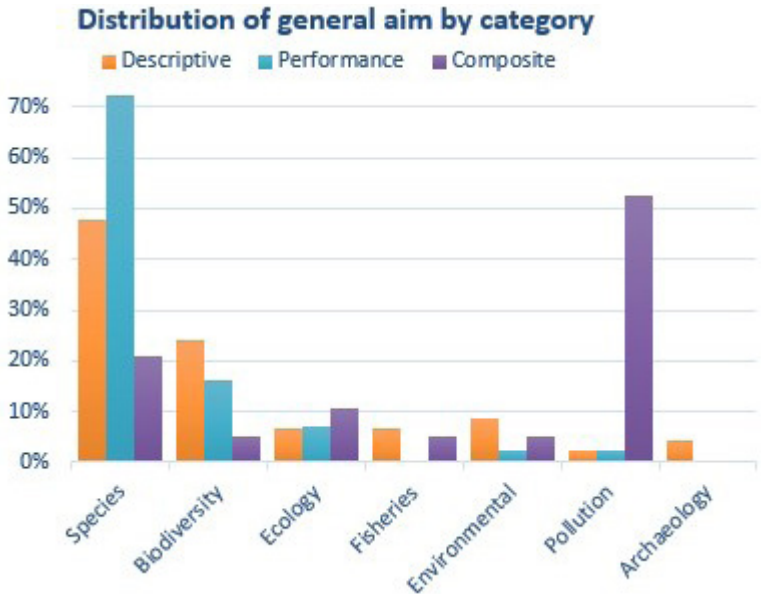

Figure 11: Main topics of North Sea CS-projects per aim category (in %): Species (n=61), Biodiversity (n=20), Ecology (n=10), Fisheries (n=5), Environmental (n=7), Pollution (n=22), Archaeology (n=2).

3.5 Level of involvement

We scored how deeply the citizen scientists are involved in the projects by exploring the level of participation, the kind of data they collect, the period of data collection, and by determining whether the data can be collected from the beach or not.

First, and to be expected, the level of participation that is required determines the number of projects. Crowdsourcing is evidently the most frequently used method (69%), followed by distributed intelligence (25%) (Figure 12). Two projects explored participatory science, and only

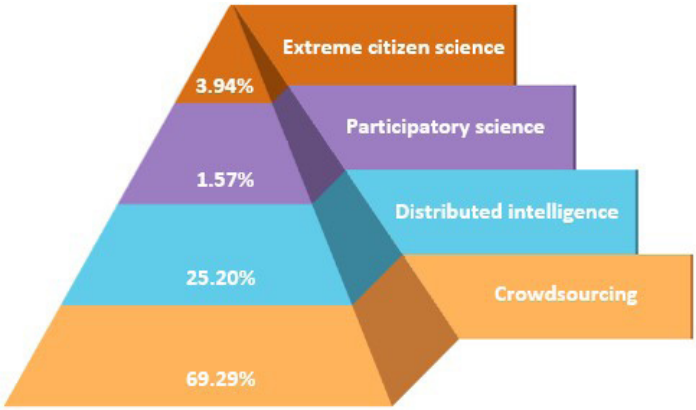

Figure 12: Pyramid of the levels of participation, showing the percentage of projects per level for this North Sea area CS-study (n=127).

five projects reached the most interactive level of extreme citizen science. This distribution meets the expectations, as demonstrated with the citizen science pyramid: the higher the level of participation, the more effort needed from the citizen scientists (and from the organisers) and the less projects you will find. The lowest level of involvement, crowdsourcing, requires least effort or knowledge in order to participate and are most successful in terms of number of projects and participants.

Secondly, the analysis shows that most North Sea CS-projects deal with sightings as 'data type' (43%), followed by systematic observations (28%) (Figure 13). Over 80% of all projects with sightings as data type are at a crowdsourcing level, while this is only 50% for systematic observations (Figure 14). For the latter group, 42% is at the level of distributed intelligence, which is to be expected as distributed intelligence demands more effort from its participants. Interestingly, 'measurements' is also mainly at crowdsourcing level (71%), while for this data type you would expect a higher level of involvement from citizen scientists.

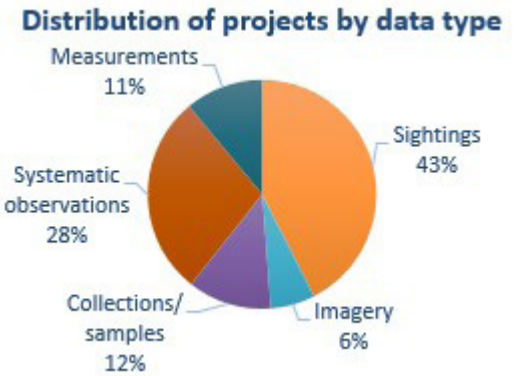

Figure 13: Pyramid of the levels of participation, showing the percentage of projects per level for this North Sea area CS-study (n=127).

Thirdly, the required time investment also influences the level of involvement. Currently, 72% of all projects collect data in a continuous way (with no obligations), with a mean number of participants of 13,466. Another 19% collects data at a fixed number of occasions, with a mean

SeaWatch-B is a VLIZ marine citizen science initiative launched in 2014. This beach observation network monitors long-term changes of more than ten variables (e.g. litter, fish & crustaceans, limpets, seashells, archaeology, seawater temperature, lugworms, etc.) in the Belgian part of the North Sea. These '**SeaWatchers**' – volunteers, trained and provided with supportive material by VLIZ – survey fixed beaches at least seasonally in a systematic way (distributed intelligence). **(seawatch-b.be)**

Big Seaweed Search, a partnership of The Natural History Museum and the Marine Conservation Society since 2009, aims at gaining knowledge of the seaweed species in UK waters, identifying their exact locations and monitoring changes over time. Citizens receive a guide on how to do their seaweed surveys, but no extra training is provided (crowdsourcing). Similar to SeaWatch-B, the project uses systematic observations, but in contrast, the seaweed surveys require no specific location. **(bigseaweedsearch.org)**

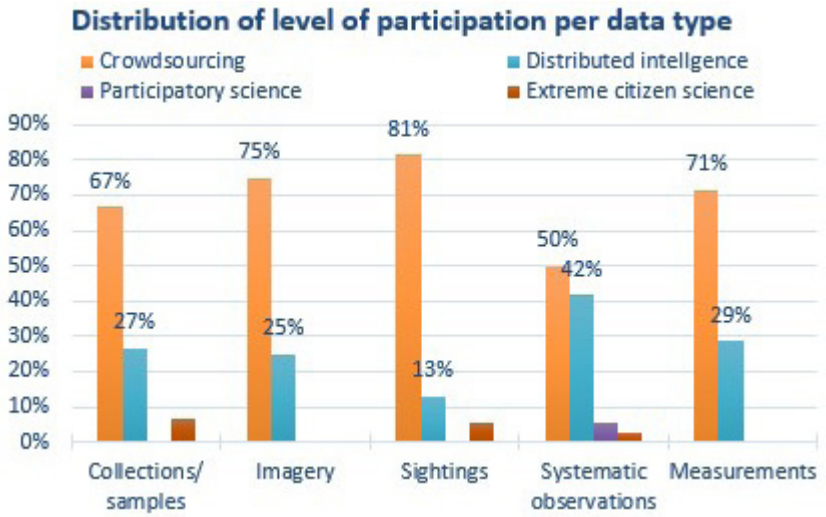

Figure 14: North Sea CS-projects by level of involvement (in %; collections/samples (n=15), imagery (n=8), sightings (n=54), systematic observations (n=36), measurements (n=14)).

number of participants of 3,344. The remaining 9% collects data once a year with a mean number of participants of 2,884. Projects that are collecting data in a continuous way, are often at a crowdsourcing level (73%), and provide 'sightings' as data type (53%) (Figure 15). Projects that collect data once a year are mostly (75%) at crowdsourcing level, and as data type they require 'systematic observations' (33%) and 'collections/samples' (33%). Projects collecting data multiple times a year have a distinct higher number of projects in the category 'systematic observations' (63%), as they often occur as surveys.

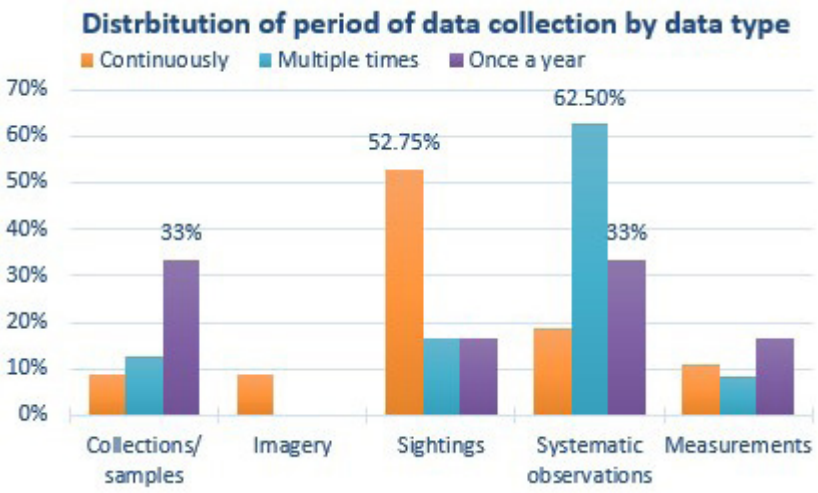

Figure 15: Relationship between the required time investment for citizen scientists and the kind of data they collect (in %: collections/samples (n=15), imagery (n=8), sightings (n=54), systematic observations (n=36), measurements (n=14)).

Lastly, the location of data collection influences the level of involvement as well. Beach-based projects are more accessible for citizen scientists than projects that require data collected at sea. Currently, almost 60% of the projects in the North Sea area collect data from the beach. The corresponding mean number of participants is 13,023. A large part of those projects deal with species-specific research (40%), followed by pollution (25%) and biodiversity (17%) (Figure 16). A majority (60%) of the projects at sea are species-oriented. Birds are targets for projects at the beach. Algae/plankton/micro-organisms and fish are evidently more frequent in CS-projects at sea (Figure 17).

Whether data are collected on the beach or at sea, can influence the data type. For example, projects collecting data at sea are less likely to use systematic observations, as it is harder for citizens to get there (though some projects provide the necessary recourses to monitor at sea). Analysis shows that projects at sea mainly use sightings as data type (52%), followed by measurements (17%) (Figure 18). Projects collecting data at the beach also have a relatively high percentage of projects using sightings (36%), but systematic observations are more frequently used (39%), especially in comparison with projects at sea (systematic observations: 13%).

Furthermore, both beach- and sea-projects are predominantly continuous in the way they allow data collection, with less projects in the categories 'multiple times a year' and 'once a year'. The majority of both beach- and sea-projects depend on crowdsourcing (60% and 76%, respectively), and less 'distributed intelligence' (35 and 19%, respectively).

3.6 Have CS-projects in the North Sea area increased?

Citizen science, and more specifically marine citizen science, is not new. The oldest project included in this inventory of 127 North Sea CS-projects, started in 1876. This crowdsourcing initiative by the Conchological Society of Great Britain and Ireland, asked citizens to send in records of molluscs, as 'excellent environmental indicators' (Light 2016). The project is still

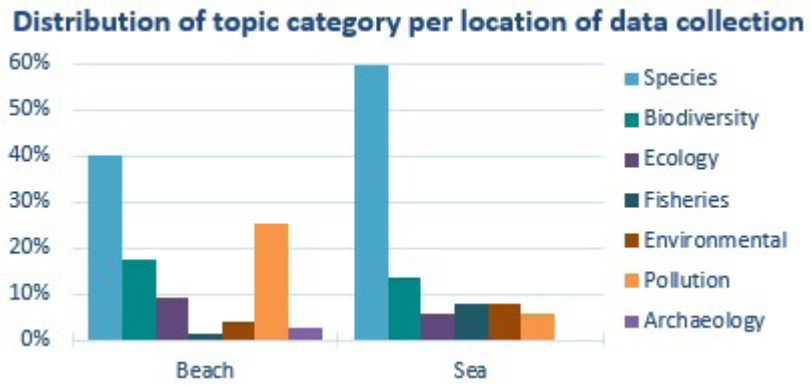

Figure 16: Relationship between the location of data collection and the topic of research (in %: beach (n=30), sea (n=31)).

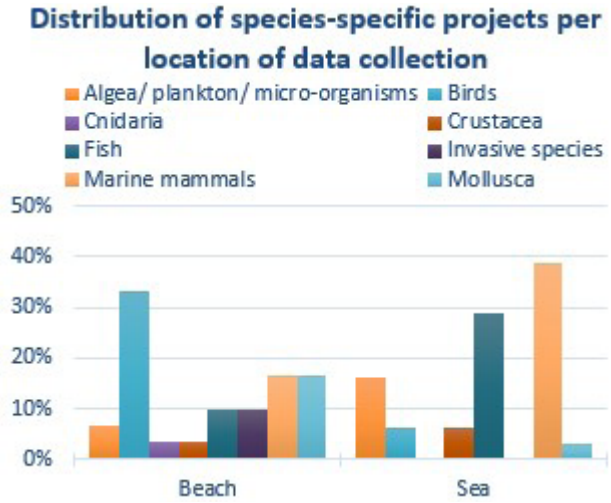

Figure 17: Relationship between the location of data collection and the species group that is being studied (in %: beach (n=30), sea (n=31)).

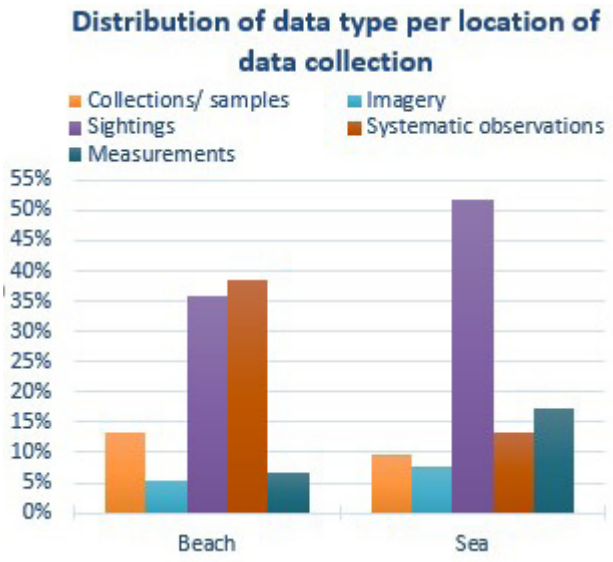

Figure 18: Relationship between the location of data collection and the type of data gathered (in %: beach (n=75), sea (n=52)).

ORCA is a charity helping to protect whales and dolphins. They encourage citizens to become a **Marine Mammal Surveyor** and actively participate in whale and dolphin conservation. Their marine mammal surveyors are the backbone of all of ORCA's research since 2006. Teams aboard ferries and cruise ships to conduct surveys and record species, their location and activity. Citizens have to take a course in how to identify and record whales, dolphins and porpoises during offshore surveys, before they can participate (distributed intelligence).

active (though we could not find how many people participate), meaning it has been going on for 143 years! Another five projects started before 1960. From those 6 'early adopter' initiatives, 5 did research on species, one dealt with pollution.

From 1960 onwards, first we see a slow increase in new projects turning into an exponential growth after 1990 (Figure 19). Particularly from 2010 onwards, there is a marked increase in the number of new North Sea CS-initiatives. In terms of the topics that are studied, there is not much change, although 'pollution' projects show a visible increase since 2010 coinciding with the media attention for the marine litter issue (Figure 20).

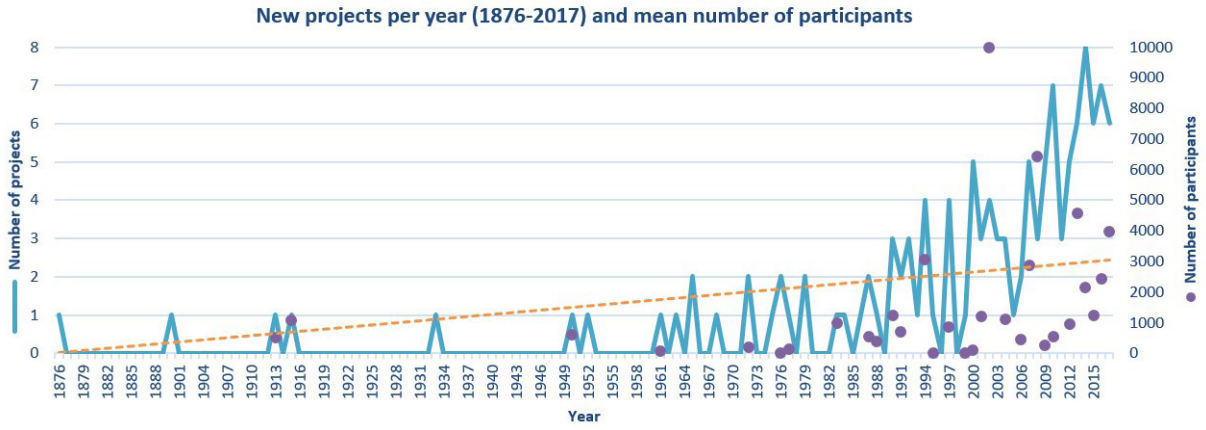

Figure 19: The annual number of new CS-projects in the North Sea area from 1876 to 2019 (blue line + trend), and the number of participants (purple dots) averaged for all projects per start year. Three outliers are not included in the graph (1979=120,000; 1992=97,459; 2003=122,906).

3.7 Continuity of the projects

Of the 127 projects in our database, 25 do not exist anymore. The mean duration of these ended projects is 18 years. Of those initiatives, 60% collected data continuously, with an average duration of 11 years. The data type most used was 'sightings' (40%; mean duration: 16 years), followed by systematic observations (32%; mean duration: 8 years). Furthermore, 16 projects were at crowdsourcing level, eight projects made use of distributed intelligence and one

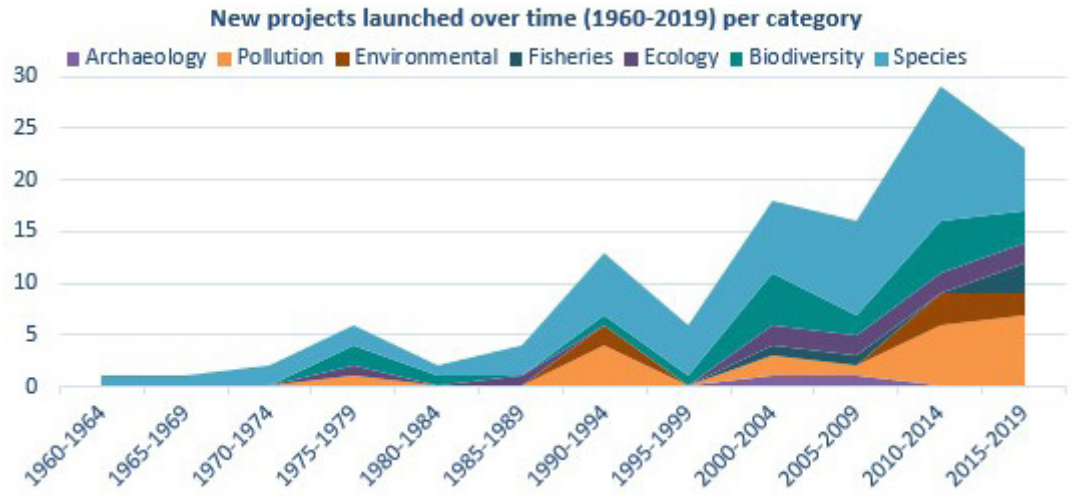

Figure 20: New North Sea CS-projects launched over time (1960 - 2019), per category.

project fitted in the category of extreme citizen science (duration: 3 years). The mean number of participants – for the 14 out of 25 projects with a known number of participants – is 2,144 (ranging between 77 and 11,709) (Figure 21). Projects with the highest number of participants were mostly continuous, crowdsourcing and using sightings as data type. Projects with lower numbers of participants include more projects at distributed intelligence level.

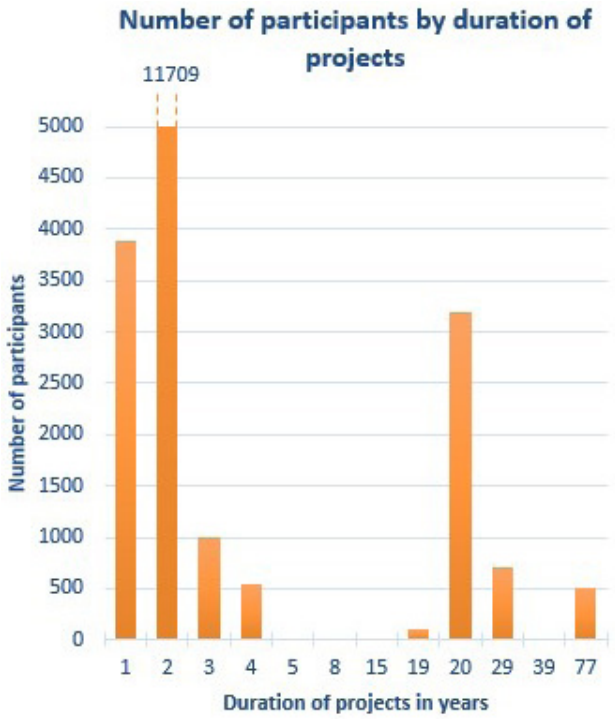

Figure 21: The number of participants in North Sea CS-projects by duration (in years) of ended projects (n=25).

Seven of the projects launched in 2010-2014 have currently ended, of which three were at composite aim level. An example is 'The Big Sea Survey' by New Castle University and Dove Marine Laboratory. This three-year project aimed at creating a baseline of marine intertidal

CoCoast (Capturing Our Coast: 2015-2018), funded by the Heritage Lottery Fund, trained citizen scientists – distributed intelligence – to carry out transect surveys of marine species on UK rocky shores, contributing to gaps in knowledge of marine biodiversity and providing a baseline to explore responses to environmental change. This project ended in 2018, but there are still surveys in which citizens can contribute data. Meanwhile the coordinator is looking for funds in order to launch a 'CoCoast 2'.

organisms in the UK, as this is essential in times of ecological change (Sugden & Delany 2013). 357 trained citizen scientists sent in records of species abundance, communities in kelp forests, seasonal events. After three years, the project developed into CoCoast 1, that has ended by now.

The mean duration of ongoing projects is 20 years. Some topics have longer lifespans. Birds and mollusc projects for instance have a mean duration above 37 years, followed by marine mammals (28 years) and other topics (9-17 years). With regard to the level of involvement, extreme citizen science projects – with a mean duration of 10 years – clearly fall below the mean of 20 years. Differences in data type show that projects relying on 'measurements' have the longest lifespan (27 years), while 'imagery' projects are on average the shortest (10 years).

4. Discussion & recommendations

4.1 Marine citizen science, a growing & invaluable 'market'

We found 127 marine citizen science projects investigating the North Sea area. It demonstrates the success and variety in sea-related and other citizen science. Moreover, the future looks bright as a trend towards more cooperation between marine scientists and citizens appears from 1990 onwards. An increase that coincides with the launching of mass media such as the internet, smart phones, etc. (Andrews 2019; Silvertown 2009) and with a move towards a more ocean literate society. In an era where online communication creates huge new opportunities, ocean challenges easily translate into citizen actions. In 2010, in the aftermath of the massive oil spill at the Deepwater Horizon oil well in the Gulf of Mexico, scientists worked together with local people reporting relevant observations. In the summer of 2010 alone, locals submitted over 100.000 observations, providing information on the degree of oil contamination. This immediate and large-scale monitoring became a milestone achievement in citizen science (Dickinson & Bonney 2012). Independently but also from then onwards, public indignation over the widespread marine litter issue led to a substantial growth in the number of citizen science initiatives on plastic garbage.

In the North Sea area, a densely populated and heavily impacted marine region, a further growth in this way of cooperation is very much welcome. First, the number of citizens visiting its coasts is orders of magnitude bigger than the number of professionals studying North Sea waters. Therefore, the help of the public offers huge opportunities in monitoring this

central European marine basin. Second, the beach is the interface of land and sea, where the public meets – sometimes in large numbers – with the marine realm and where they cherish childhood memories and feel good. It is the ideal place to create awareness and to deepen the feeling of responsibility towards the blue part of our planet. Particularly in the shallow and easily accessible coastal waters and on the vast sandy beaches of the low-lying countries in the southern part of the North Sea, there is room and demand for more marine and coastal citizen science initiatives. Belgium, the Netherlands and Germany share 22 projects, for a North Sea coastline stretching over 1,500-2,000 kilometers (World Factbook), and hosting millions of tourists and visitors each year. Moreover, most countries have national policy guidelines that emphasises the importance of citizens being involved in research in a more engaging way, including citizen science (e.g. Flemish Policy Note 'Beleidsnota 2019-2024. Economie, wetenschapsbeleid & innovatie': www.vlaanderen.be/publicaties/beleidsnota-2019-2024-economie-wetenschapsbeleid-en-innovatie). However, there is no specific policy targeting marine or coastal citizen science in those countries or for Europe as a whole.

This study also demonstrates the lack in open databases and directories that provide easy access to the multitude of existing marine citizen science initiatives. As a matter of fact, it took several months to compile the 127 projects in this study on North Sea citizen science. Having an open database with best practices would definitely help inspiring scientists, policy makers and members of the public.

In conclusion, **marine policy and science should stimulate and mediate the further growth in North Sea citizen science initiatives, and make sure the present initiatives and best practices are easily accessible and shared in an open and transparent way.**

4.2 Bias in study objects, a call for more diversity

Almost half of all the projects in our analysis deal with biological species research. Another 17% of the projects deal with pollution (e.g. marine litter and oil spills), 16% have a more general biodiversity focus, while 8% includes projects on for example coastal ecology, the state of certain habitats, species interaction with the habitat, or the impact of climate change on the ecosystem. Within the group of 'species' citizen science projects, there is another bias towards large, visible and charismatic species such as marine mammals, seabirds and fish. This can partly be ascribed to the fact that these flagship species 'serve as symbols and rallying points to stimulate conservation awareness and action' (Heywood et al. 1995) and/or attract donations and other financial support (Ducarme et al. 2013). Least studied species involve crustaceans, invasive species and cnidarians, molluscs and algae/plankton/micro-organisms.

Although the traceability of the projects may have played a role, it is striking how little marine citizen science projects we have found in the North Sea area beyond the biological and environmental sciences. Only 11% of all projects deal with 'fisheries' (fish catches or fish stocks), 'environmental variables' (such as water quality, temperature or sea level rise), 'archaeology' or maritime history. And we could find no examples of citizen science in the North Sea area dealing with beach morphology, weather patterns, human health at the coast, etc. **We believe that a well-designed strategy – in line with the expectations with regard to research and management – should aim at a more diverse spectrum of marine citizen science initiatives in Europe, in terms of the study objects dealt with.**

4.3 From citizen science to co-science

Our study shows that, on average, citizen science projects in the North Sea area last 19 years. Crowdsourcing activities on the beach, with not much obligations for the participants, is the most frequent format in terms of level of participation, while participatory science and extreme citizen science are rather rare (and short in duration). In our analysis, we see a bias towards 'easy' projects, with rather low levels of involvement (such as reporting of sightings). Under these circumstances, projects are able to survive for quite a long period. This is in line with Ponciano & Brasileiro (2014), who state that projects with a higher level of involvement (e.g. extreme citizen science), have a relatively shorter duration.

This is confirmed by a study on citizen science in Australia, reporting that 'opportunistic citizen science' (a.k.a. crowdsourcing) projects are most common. They provide the opportunity to involve large numbers of participants in science, partly because these projects are attractive due to the limited involvement that is required (Martin et al. 2016). In most cases, the level of participation is limited to data collection, thus crowdsourcing and distributed intelligence (Rotman et al. 2012; Freiwald et al. 2018). Our North Sea study reveals sightings as the most common data type, followed by systematic observations (taking place multiple times a year). On average, sightings have almost five times more participants than systematic observations. On top of that, most projects collect data from the beach, having almost twice the amount of participants compared to projects at sea. In other words, there is a clear bias towards 'easy' projects, i.e. initiatives one can join with minor effort and leave whenever a participant wants to.

On behalf of the organisers there is a bias as well. Citizen sciences projects can be 'descriptive' (i.e. purely collecting data), 'performance oriented' (i.e. monitoring and evaluation) or 'composite' (i.e. tackling important policy issues). Government organisations prefer composite projects, research institutes stick to the more descriptive ones and NGOs have a slight preference for performance initiatives. Very often, they project their goals on the participants in a top-down approach, without the citizens having a say. The most successful projects seem to be those that have found the perfect match between what the provider aims at (and can accommodate) and what the participant wants in terms of output and engagement. In other words, it is all about diversity, balance and real interaction. Providing the framework and the tools to enable citizens and governments, research institutes and NGOs to launch new projects – top-down and bottom-up – is a prerequisite for a successful and growing interaction between citizens and scientists. Very often, citizens still have reservations on working together with so-thought 'erudite' scientists and feel uncomfortable in contacting them. They don't want to fail and are hesitant in whether they can do the job as it is required. Incentives to stimulate citizens to start new citizen science projects themselves, in a bottom-up approach ('extreme citizen science'), will be needed to overcome the existing barriers. A next step from citizen science to co-science.

We plea for additional incentives in order to create a wide range of marine citizen science projects and initiatives, from easy, well-attended beach-based reporting of sightings to more complex 'extreme' forms of citizen science. This should come with a strategy opening up dozens of citizen science opportunities, and hence stimulating a growing group of citizens.

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Appendices

A.I: Detailed overview of variables including given values.

Variable	Values	Extra information
Name of project		
Organisation		
Type of organisation	1. Person 2. Research institute (founded for doing research) 3. NGO (operate independently from government and rely on external funding) 4. Collaboration (communities, networks, partnerships) 5. Government organisation	Universities are treated as research institutes. 'NGO' includes NGO's, charities, foundations and NPO's, considering they all rely on external funding. The term government organisation includes organisations, agencies and public bodies established by the government, other than research institutes.
Country	1. Belgium (BE) 2. Germany (DE) 3. Denmark (DK) 4. France (FR) 5. Ireland (IE) 6. Netherlands (NL) 7. Norway (NO) 8. Sweden (SE) 9. United Kingdom (UK) 10. Europe 11. International 12. Other (US/AU)	
Area	1. Belgian sea 2. German sea 3. Danish sea 4. French sea 5. Dutch sea 6. Norwegian sea 7. UK sea 8. European seas 9. Worldwide 10. North Sea 11. Wadden Sea	All of the country specific "seas" named here, are parts of the North Sea. For example 'Danish sea' is the Danish part of the North Sea. The EEZ determines the boundaries. Some projects occurring in the UK and IE, are treated as UK areas (as IE is not North Sea).
Beach/sea	1. Beach 2. Sea	Projects are termed 'beach' when data collection can be done from the beach, otherwise they are termed 'sea'.
Language	1. Danish 2. Dutch 3. English 4. French 5. German 6. Norwegian 7. Multiple	
Start year		
End year		
Period of data collection	1. Continuously 2. Once a year 3. Multiple times a year	Projects that collect data seasonally, monthly or weekly are termed 'multiple times a year'. Projects collecting data, for example for one month a year, are termed 'once a year'.

Discipline		Detailed subject description.
Category	1. Archaeology 2. Fisheries 3. Pollution 4. Environmental 5. Biodiversity 6. Ecology/ habitat 7. Species	'Species' applies to projects that monitor a specific species or group of species. In case of monitoring of general wildlife, we used the category 'biodiversity'. The term 'environmental' includes subjects such as water quality, temperature, sea-levels rise and coastal erosion.
Taxonomy	1. Birds 2. Marine mammals 3. Fish (incl. Elasmobranchii) 4. Mollusca 5. Crustacea 6. Cnidaria 7. Algae/plankton/micro-organisms 8. Invasive species	Species-specific information about the projects in the category 'species'. This variable was extracted from 'disciplin' in the process of analysing.
Data type	1. Sightings 2. Imagery 3. Collections/ Samples 4. Systematic observations (counts/surveys) 5. Measurements/ specified data	Stranding reports are considered sightings. These categories are ranked in terms of the effort needed.
Aim		Objectives stated by the project.
Level of participation	1. Crowdsourcing 2. Distributed intelligence 3. Participatory science 4. Extreme citizen science	
General aim	1. Descriptive 2. Performance 3. Composite	General aim is based on the sustainable development indicators. 'Descriptive' means purely collecting data, 'performance' means monitoring and evaluation, and 'composite means tackling important policy issues.

A.II: Search terms and existing gatherings.

Google search terms	Existing gatherings of projects/organisations
Marine citizen science	Ocean edge directory
Marine citizen science in North Sea	EurOcean
Citizen science North Sea	World ocean network
Marine citizen science Europe	European association of Zoos and Aquaria
Volunteer projects North Sea	Marinetraining.eu
marine borger videnskab (Danish)	natural-apptitude.co.uk
borgervitenskap (Norsh)	iNaturalist.org
Maritim statsvitenskap (Norsh)	iedereenwetenschapper.be
Meeresbürgerwissenschaft (German)	Zooniverse.org
Mariene burgerwetenschap (Dutch)	buergerschaffenwissen.de
Science civile (French)	meeresbuerger.de
Nature associations	European Alien Species Information Network
Onderzoeksinstituten	National Biodiversity Network
Marine citizen science projects	Scistarter.org
Save the North Sea	Bionyt. (n.d.). Borgervidenskab. Retrieved March 17, 2019, from: http://bionyt.s807.sureserver.com/borgervidenskab/
Marine citizen science Netherlands/ Belgium/ UK/ Germany/ Denmark/ Norway/ France	Thiel, M., Penna-Diaz, M. A., Luna-Jorquera, G., Salas, S., Sellanes, J., Stotz, W. B. (2014) Citizen Scientists and Marine Research: Volunteer Participants, Their Contributions, and Projection for the Future. Oceanography and Marine Biology, 52, 257-314. doi: 10.1201/b17143-6.
Sea-/ shore-/ life-/ bird-/ marine mammal-/ seaweed-/ marine litter- watch/project/ survey/programme	Scotland's environment citizen science portal
Universities citizen science	Citizen-science.at
North Sea research	Researchgate.net
Mariene onderzoeksfaciliteiten (Dutch)	Marenet.de
Beach cleans	
Citizen science in ocean research	
Citizen science in marine research	
Natural history museum	
Marine volunteer projects Europe	
Maritime citizen science	

A.III: Inquired organisations.

Organisation	Project?	Comment
British Geological Survey	V	
Buglife	V	Contacted for extra information on project(s)
Citclops	V	Contacted for extra information on project(s)
Coastal Risks and Sea-level Rise Research Group	V	Contacted for extra information on project(s)
Coastwatch Europe	V	Contacted for extra information on project(s)
De Rijke Noordzee	X	No citizen science projects
Dorset Wildlife trust	V	Contacted for extra information on project(s)
Duik de Noordzee schoon	V	Contacted for extra information on project(s)
Earlham institute	X	
Earthwatch institute	V	Contacted for extra information on project(s)
Eastern Solent Coastal Partnership	V	Contacted for extra information on project(s)
EMEC	X	
Environmental Research institute	X	
eOceans	X	No projects in North Sea
European Citizen Science Association	R	Redirected to lists with projects
European Environment Agency	V	
European Marine Board	R	List with CS projects
EWI Vlaanderen	R	Redirected to 'iedereenwetenschapper.be'
FloWave Ocean Energy Research Facility	X	
GEOMAR	X	No projects in North Sea
Ghost fishing foundation	X	No science involved
Havforskningsintituttet	V	Contacted for extra information on project(s)
IMarEST	X	
Institute of Marine Research (Norway)	V	Contacted for extra information on project(s)
Institute of marine science, University of Portsmouth	X	
International institute for Environment and Development	X	
International Wader study group	V	Redirected to Jeroen Reneerkens and Gwenaël Quaintenne.
JNCC	V	
Lee Knight - Hypogean Crustacea Recording Scheme	V	Contacted for extra information on project(s)
MARIN	X	
Marine biological association	V	Contacted for extra information on project(s)
Marine conservation society	V	Contacted for extra information on project(s)
National oceanography centre	X	
Natural environment research council	V	
Natural history museum of Denmark	V	
Naturalis	V	Contacted for extra information on project(s)
Natuurpunt	X	No citizen science projects in North Sea
Nederlandse Zeevogelgroep	V	Redirected to Kees Camphuysen
NIOZ	V	Contacted for extra information on project(s)

North Atlantic Fisheries College	X	
Oceanlab	X	
Offshore Renewable Energy Catapult	X	
ORCA	V	
Pelagis observatory	V	
Plymouth Marine Laboratory	V	
Pogo Secretariat	X	No non-professionals in projects
Research Institute Nature and Forest (INBO)	V	Redirected to project 'Glasaalintrek kanaal Veurne-Ambacht'
Rijksoverheid Nederland	R	Redirected to multiple departments
Royal Belgian Institute of Natural Sciences (RBINS)	X	No citizen science projects in North Sea
School of Agriculture & Technology	X	
Seagrass-Watch	V	Contacted for extra information on project(s)
Seán Lynch – OpenLitterMap	V	Contacted for extra information on project(s)
Shark Trust	V	Contacted for extra information on project(s)
Stichting ANEMOON	V	Contacted for extra information on project(s)
Stichting de Noordzee	V	Contacted for extra information on project(s)
Stockholm Environment institute	X	
Strandwerkgroep Belgium	X	No citizen science
The James Hutton Institute	X	Not marine research
The Scape Trust	V	Contacted for extra information on project(s)
The William Harvey Research institute	X	
Tyndall centre for climate change research	V	
UK Energy Research Centre	X	
University of Aberdeen	V	
University of Gent	X	
University of Hull	V	
University of Kiel	R	Redirected to 'coastwards'
University of Utrecht	X	
VIRTUE	V	
VLIZ	V	
Waddenvereniging	X	No citizen projects
Wageningen Marine Research	V	
Wildland Research institute	X	