wadden sea
LONG-TERM ECOSYSTEM RESEARCH

Sound, innovative and connective monitoring
for the Wadden Sea area

CITIZEN SCIENCE

CITIZEN SCIENCE

AN OVERVIEW OF THE CURRENT STATE, THE POSSIBILITIES AND CHALLENGES AND THE OPPORTUNITIES FOR THE FUTURE

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1 CITIZEN SCIENCE

Having received a World Heritage status in 2009 the Wadden Sea is recognized as one of the most important intertidal areas in the World (Baptist et al, 2007; Koffijberg & Smit, 2013). The Wadden Sea is not a pristine nature area, but also used by man. This human use may harm the natural values of the Wadden Sea, protected under de Natura2000 regime. Both human use and natural values are monitored, and some of this monitoring is required by law. This monitoring is of great value for science, policy and proper management of this unique area. Yet, the various monitoring programs come in all shapes and sizes and are sometimes poorly integrated. Furthermore, the accessibility of the data is quite variable. This hampers putting the monitoring data to good use in signalling unwanted developments, gaining understanding, evaluation of management and designing new management policies.

The project "Wadden Sea Long-Term Ecosystem Research", also known as WaLTER, aims to provide advice on how to improve the efficiency of these monitoring programs, to fill the gaps and to provide users with an organized data portal in which they can find specific data www.walterwaddenmonitor.org. As part of this enterprise, we investigated the potential of so-called "Citizen Science", i.e. monitoring by volunteers, to increase the efficiency of current monitoring in the Dutch Wadden Sea. As a first step, we examine in this report the strengths and weaknesses and future possibilities of Citizen Science in general. In this way, this report lays the foundation for a second report, which focuses on the state of the art and future opportunities for Citizen Science in the Dutch Wadden Sea (Engels et al., 2015). The third and last report will examine the possibilities for initiating a new Citizen Science project in the Dutch Wadden Sea on estimating juvenile percentages of various shorebird species to strengthen demographic monitoring of these birds (Engels in press).

1.1 The basics of CS

When volunteers participate in collecting data for scientific purposes and therefore contribute to the expansion of scientific knowledge, it is nowadays often called Citizen Science (which will be abbreviated as CS) (Dickinson et al, 2010; Roy et al, 2012; Wiggins & Crowston, 2011). There are several terms and definitions of CS; terms that are frequently used are "public participation in scientific research", "volunteer-based monitoring" and "participatory science", but currently, CS is used most often (Miller-Rushing et al, 2012). Definitions can be questionable and often depend on the point of view of the user. Tulloch et al (2013) describes the method as 'the involvement of citizens from the non-scientific community in academic research', while Wiggins & Crowston (2011) defines CS as 'a form of research collaboration involving members of the public in scientific research projects to address real-world problems'. This shows that CS can be seen as just a method to help out scientists, but also as a solution to real-world problems, such as climate change and ocean acidification. In this report, CS is defined as "scientific research undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions" (Oxford English Dictionary, 2014). Appendix A provides some examples.

Figure 1 shows a Venn diagram containing the basic elements of modern CS. The first layer shows the three basic elements; public participation, online communities and scientific collaboration. They can also be replaced by ‘volunteers’, ‘scientists’ and ‘communication tools’; all three elements rely on each other and will interact during a CS project. These elements form the basics of the second layer, which consists of cyber-infrastructure, crowdsourcing (=obtaining needed data from a large (online) group of people (Howe, 2006)) and volunteer monitoring. This layer shows how participants and scientists should work together by using communication tools as a link between them to come up with results. All combined, this provides us with the general definition of CS.

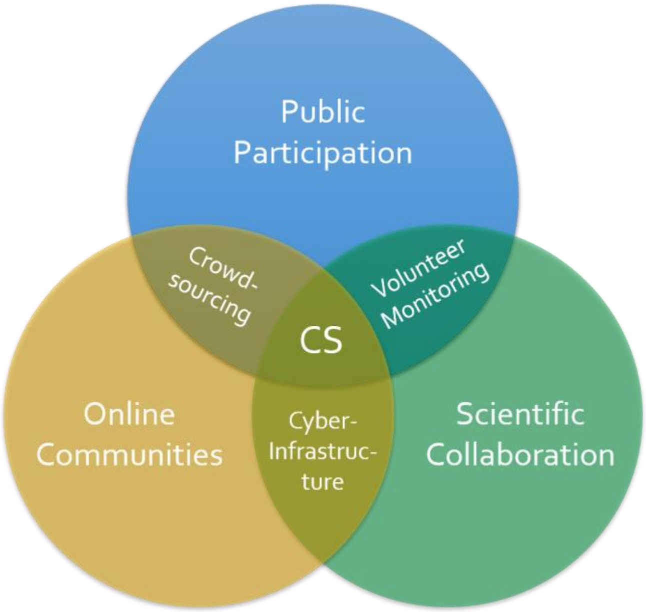

Figure 1. Venn diagram showing the three basic elements of modern CS and the importance of these elements combined to come up with results.

CS is widely used and advances in many different fields; medicine, computer science, genetics, engineering and many more. Within these fields, the need for public data is high and scientists encourages the general public to collect data. For many environmental and ecological studies, CS is getting very popular and attractive to use. A growing interest for ecological-related subjects by the general public due to many different campaigns and documentaries is one of the reasons for this increased popularity (Roy et al, 2012).
Using volunteers in monitoring projects is relatively inexpensive; these can mostly replace expensive professionals, although more focused studies are needed after or in conjunction with CS based monitoring (Bonney et al, 2009b). In the UK, an estimation of the input of volunteer data in bird monitoring projects implies that well over 90% of the data is collected by volunteers (Battersby & Greenwood, 2004). In the Netherlands, over 9.000 volunteers participate in many different bird monitoring schemes (www.sovon.nl). This shows that in some fields of science, CS plays a crucial role. Examples of research topics and projects are climate change, invasive species, population ecology and many different types of monitoring, such as targeted-, surveillance- and long-term monitoring (Silvertown, 2009). It can also be

used on multiple geographical scales; from local, to regional and even across large geographical locations globally (Bosch et al, 2014; Devictor et al, 2010).

Volunteers of CS projects, also called ‘Citizen Scientists’ (Hochachka et al., 2012), already exist for more than two centuries. One of the first known CS projects was implemented in 1749 in Finland. Here, Professor Johannes Leche began to collect data about the spring arrival dates of bird migrants. He succeeded in recruiting participants to help him collect data all over Finland (Bonney et al, 2014; Greenwood, 2007; Dickinson et al, 2010). For a long time, CS projects were implemented on an extensive level. However, they proliferated in the past decade due to the recent ability to track ecological and social impacts on the environment online (Dickinson et al, 2012; Lepczyk et al, 2009; Roy et al, 2012).

Figure 2 shows the increase of CS articles on the ISI Web of Science, an online search engine focusing on literature resources, both in titles as in citations. This shows that around 2005 and 2006 the number of articles mentioning CS increased and since 2009, the method flourished and went through a huge development. This happened due to the simultaneous development of a broad range of online applications; these became more sophisticated and made it possible for the public to effectively utilize data collections over large geographical locations (Dickinson et al, 2012; Howe, 2006). Also, the internet and geographical information system (GIS) based web-applications provided volunteers with the possibility to submit large quantities of data to centralized databases (Dickinson et al, 2012). Another reason for this huge development is that scientists started to realize that volunteering participants could provide a free source of labour, skills, computational power and in some cases even finances (Silvertown, 2009). Hence, an increase in motivation of the public to provide projects with their data and scientists to integrate CS in their project designs (Dickinson et al, 2010).

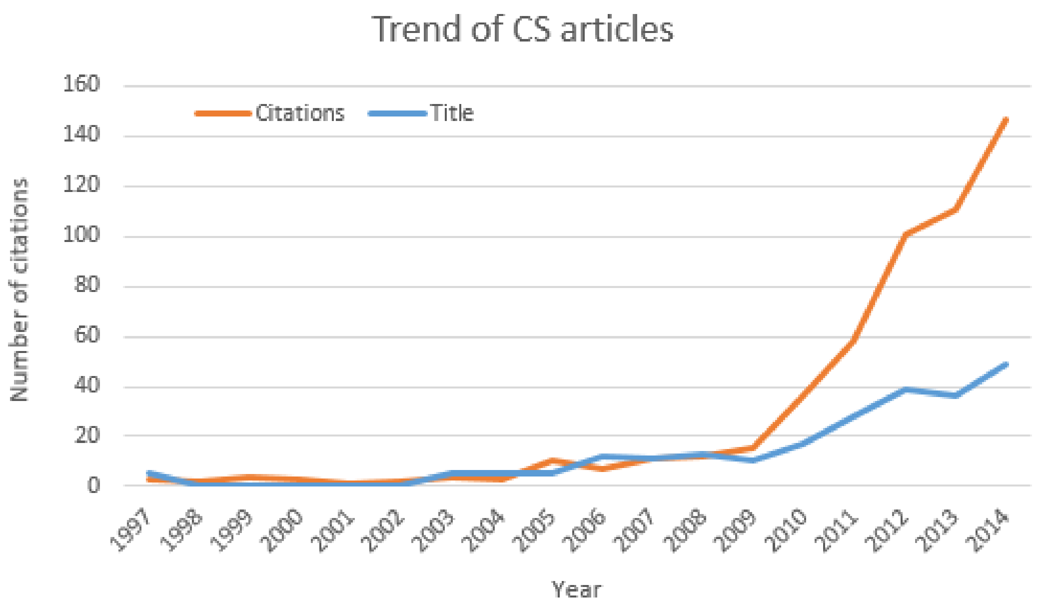

Figure 2. This diagram shows the trend of development of Citizen Science between 1997 and 2014. By using the term ‘citizen science’ in the ISI Web of Science literature search engine, a total amount of titled articles (n = 226) and cited articles (n = 530) is graphically shown by the trend lines.

1.2 Types of CS projects and designs

As mentioned in chapter 1.1, the definition of CS can be confusing and is often defined differently among authors. Therefore, the Centre for Advancement of Informal Science Education (CAISE) published a report about the division of three different types of CS projects to avoid further confusion. These categories reflect the different levels of public participation and the involvement of participants in monitoring and research projects, as shown in table 1.
The categories are:

- Contributory projects
- Collaborative projects
- Co-created projects

Out of the three categories, contributory projects require the least involvement of volunteers. Roy et al (2012) reviewed many different research projects which integrated CS and found that 96% of the reviewed articles used contributory setups. These projects are primarily researcher-driven data collection setups in which scientists require large amounts of data on a large geographical scale and/or a longer time span. This data is collected by participants which follow a predetermined protocol to collect high quality and quantity data. Some projects also give some responsibility to participants by letting them analyse their own data. This is typically done by online visualisation tools and required for the end conclusion of the project. After data collection, and in some cases data analysis, researchers take over the data and perform a final analysis of their own (Bonney et al, 2009a).

Collaborative projects strongly resemble contributory projects; scientists still decide the general setup and establish the main research questions of the project. However, volunteers are also involved in several other research activities during the process (Bonney et al, 2009a). The most important aspect of collaborative projects, in which it most clearly differs from contributory projects, is the inclusion of volunteers in the (full) analysis of the data. In some projects, participants even help out with interpreting data and draw draft conclusions from databases (Bonney et al, 2009a).

Co-created projects are basically projects which have been established in (equal) collaboration between scientists and public participants. Often, the main research questions are mostly established by participants, but both scientist and participant are involved in every step of the process (Bonney et al, 2009a). Not all the associated steps of each project design, shown in table 1, are necessarily included by CS projects; rather, the table shows the steps that are often taken in general (Bonney et al, 2009a).

Table 1. Table showing the three CS project designs (contributory-, collaborative- and co-created projects) with each showing the steps that have to be taken by participants involved in the project. According to this table, it is very clear that co-created projects require high involvement of participants, while contributory projects are still mainly being designed by scientists (Bonney et al, 2009a).

Step in Scientific Process	Steps included in Contributory Projects	Steps included in Collaborative Projects	Steps included in Co-created Projects
Choose or define question(s) for study			X
Gather information and resources			X
Develop explanations (hypotheses)			X
Design data collection methodologies		(X)	X
Collect samples and/or record data	X	X	X
Analyze samples		X	X
Analyze data	(X)	X	X
Interpret data and draw conclusions		(X)	X
Disseminate conclusions/ translate results into action	(X)	(X)	X
Discuss results and ask new questions			X

X = public included in step; (X) = public sometimes included in step

Haklay (2013) came up with a similar model, but added another level; crowdsourcing. As seen in figure 3, this level of public participation is even less involvement compared with contributory projects. This level focuses on the most basic and easiest tasks of participants and makes use of sensors which are carried around by these volunteers. Examples of these sensors are (fixed) GPS locations or mobile connectivity.

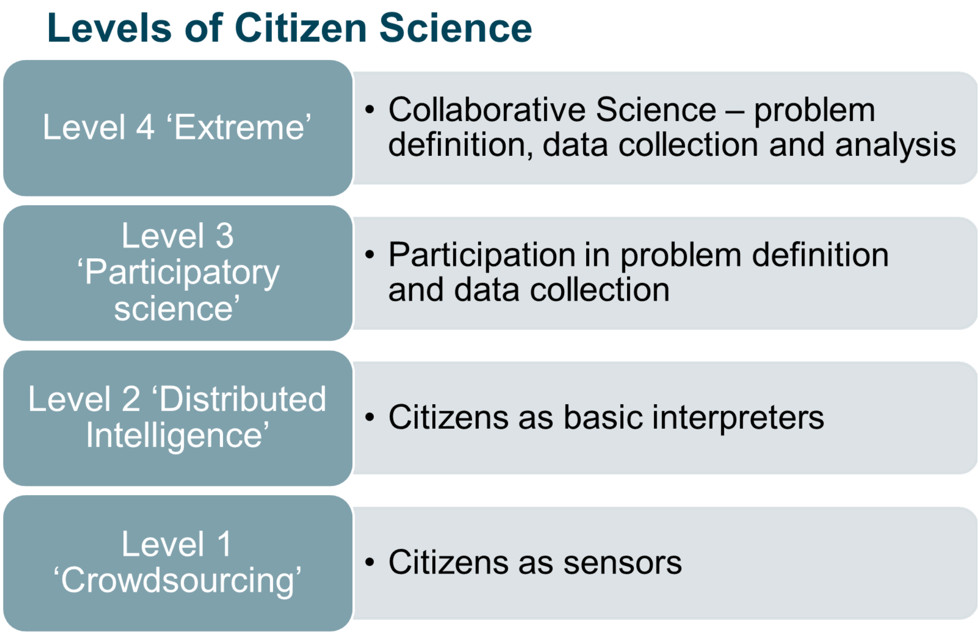

Figure 3. The different levels of public participation in CS projects, established by Haklay (2013), having the extra first level of 'Crowdsourcing' which uses citizens purely as sensors.

Besides the classification of CS projects based on their design, some authors use the intended goals as the factor of division. Many articles describe the importance of (long-term) monitoring and research programs in general and describe their own objectives towards CS. Tulloch et al (2013) summarized these objectives and identified eight composed objectives about gathering and utilizing CS data:

- The first objective is based on the management of a certain system. For example, it describes the response of an ecosystem to particular management decisions and the importance to know how such a system works before implementing new decisions (Tulloch et al, 2013).

- The second objective describes how raising awareness and sharing scientific knowledge with the public can ultimately help influencing policy makers with management decisions in important dilemmas. This shows that it can be useful to combine scientific studies with public data to jointly reach final goals (Tulloch et al, 2013); local habitat loss and fragmentation is a perfect example of which the public is more aware of compared to higher management levels (Dickinson et al, 2010).

- The third objective focuses on the educational side of CS. By integrating the public in (long-term) monitoring and research projects, public knowledge will increase and this ensures that they will be more engaged in ecological issues in the future. Eventually, this leads to more support and effort which can be linked with the second objective (Tulloch et al, 2013).

- The fourth objective is established around the possible side effects of using CS in (long-term) monitoring and research projects. Combining public knowledge with scientific knowledge sometimes leads to serendipity, or so called ‘pleasant surprises’. These ‘extra’ results can initiate new research topics or can be an addition to existing projects (Tulloch et al, 2013; Wintle et al, 2010).

- The fifth objective also focuses on the effects of integrating the public with (long-term) monitoring and research projects by creating broader recreational options or establishing new community groups. By involving the public in these projects, a connection between participants can be created or strengthened by sharing the same interests and activities with each other which will result in new social communities (Tulloch et al, 2013).

- The sixth objective is, again, based on the effect of integrating the public with (long-term) monitoring and research projects, but this objective focuses on what the participants are willing to do to be part of such a project. For example, it shows the distance participants are willing to drive, the costs they are willing to spend, or how participants value the particular system they visit by examining the time they spend on collecting data. Also, this results in a better understanding of the motivations participants have to spend a certain amount of time on a project (Tulloch et al, 2013).

- The second to last objective is based on what CS projects can result in. Participants can help to better understand systems and species and can even test theories in the field (Tulloch et al, 2013).

- The last objective is based on what (long-term) monitoring and research projects can do with participants in general. In this case, participants can help out testing new methods and theories out of which scientists can make a suitable selection to adjust the research designs or sampling protocols (Tulloch et al, 2013).

Wiggins & Crowston (2011) have divided CS in several project types based on the goals of these projects. Five different types are discussed:

- Action projects
- Conservation projects
- Investigation projects
- Virtual projects
- Education projects

Action projects can be defined as project designs which employ volunteers to participate in local concerns by integrating them in the research process. Hence, locals feel part of the final solution of the problem. Conservation projects focus on attracting participants helping out nature conservation organizations (NGOs) and so create more support for these organizations. Still, these types of CS projects mainly focus on collecting data by using participants instead of involving them in other steps of the project. Investigation- and virtual projects use the same level of public involvement, but differ in the way they offer necessary material; investigation projects make use of physical learning materials, like books and sheets explaining what participants have to know or how to collect data, while virtual projects have their material ICT-mediated. Education projects primarily focus on the educational side of the project; their main goal is to educate volunteers while performing data collection (Wiggins & Crowston, 2011).

Every type of CS project comes with its own design. Depending on the field of study these projects are part of, project designs can differ in setup and organization. Conservation and ecosystem understanding require studies of habitats and abundance, distribution, and movements of organisms (Hochachka et al, 2012). At the moment, the strongest influence of CS in scientific studies is performed in the field of ecology and especially in monitoring biodiversity over broad geographical scales worldwide. The main reason for this increased interest is probably due to the increased awareness of the general public in ecological-related topics by to campaigns and nature documentaries (Roy et al, 2012). The most important impact of CS within this field is that ecologists are able to draw conclusions on a broader instead of just on a local scale. This upscaling allowed ecologists to detect changes in ecosystems which could only be detected on larger geographical scales (e.g. change in phenology due to climate change). Also, it turned out that Citizen Scientists are particularly effective in research and monitoring projects focusing on rare and invasive species and registering the absence or decrease of native species (Dickinson et al, 2010).

Dickinson et al (2010) describes the process of using CS in ecological studies in four major steps, as graphically shown in figure 4. Step 1 focuses on collecting already existing CS data. This should be pre-analysed to detect patterns and trends which could contain a new research topic. This can be done by data mining; the extraction of knowledge from large amounts of data by running statistical tests and models, by interpolating map surfaces and presenting graphs and charts (Han & Kamber, 2006). Step 2 is the establishment of a priori hypotheses and predictions. By setting up these hypotheses, strong inference is possible during the process. After predictions have been made, ecologists start setting up additional CS activities for potential participants in step 3. Depending on the design of the research, participants are asked to conduct targeted data collection and experiments, receive samples to be analysed and asked to place sensors or upload their data. Together with already existing data, the new CS data can be analysed by statistical tests and the final results will be presented in a report in step 4 (Dickinson et al, 2010).

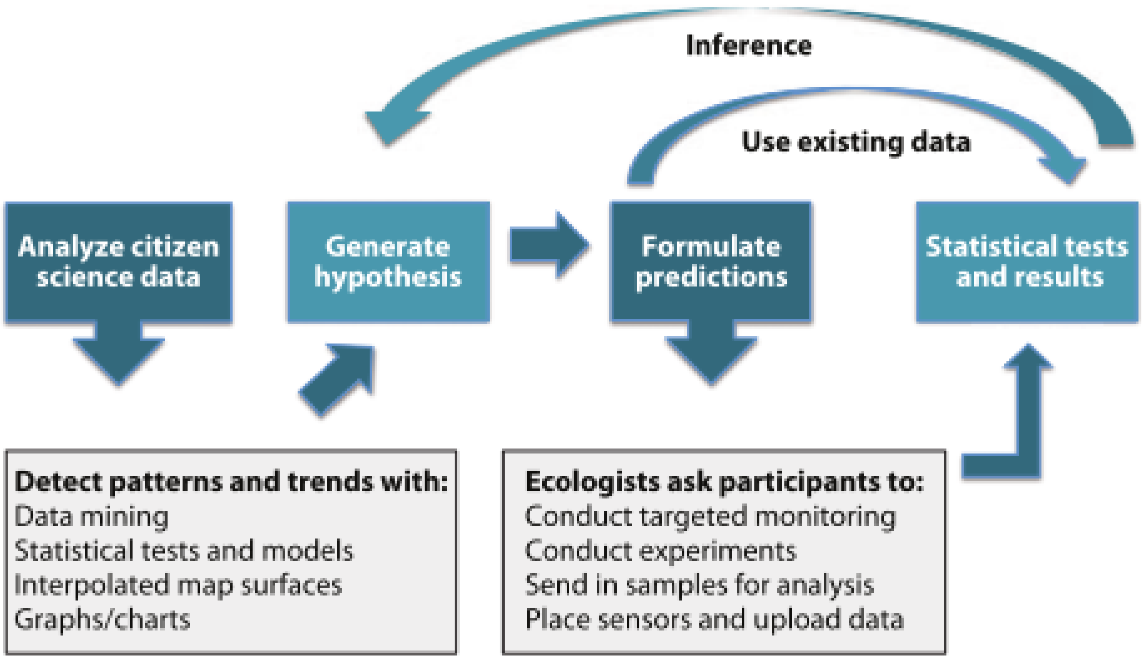

Figure 4. A simplified model showing the general integration of CS within an ecological research design. Four important steps are described of which the first one is the most important; analyse existing CS data and detect patterns and trends within large datasets. Gathered CS data can later be compared with already existing data during the final step of the process. The amount of inference during the process is important for the quality of the results (Dickinson et al, 2010).

As graphically shown in figure 5, Tweddle et al (2012) came up with a more extensive process description which resembles the one from Dickinson et al (2010). The difference between the two of them is that Dickinson focuses on the scientific side of CS, while Tweddle has a more general view of the process which can be implemented on every kind of CS project. He divided the process in five major phases:

- Phase 1: Before you start
- Phase 2: First steps
- Phase 3: Development phase
- Phase 4: Live phase
- Phase 5: Analysis and reporting phase

This process will be extensively described in chapter 2 “The organizational structure of CS” of this report.

In general, although CS can be applied in question-driven and experimental research projects, most participants are recruited for large-scale monitoring programs focusing on long-term monitoring and research (Dickinson et al, 2010). Nichols & Williams (2006) describe two types of monitoring in research projects:

- Targeted monitoring
- Surveillance monitoring.

Targeted monitoring is based on a project design with a priori hypotheses. Associated models and research methods are more likely to result in expected conclusions and if not, new hypotheses are formulated. Surveillance monitoring is the opposite of targeted monitoring and is based on a project design in which no priori hypotheses have been formulated and is not restricted to use certain models to find results (Nichols & Williams, 2006). In environmental studies, and especially in long-term monitoring projects, surveillance monitoring usually consists of broad-scale monitoring of numerous species on a large geographical scale. As a result, most of these monitoring projects expect large datasets over a longer timespan which will be useful to answer many related questions. It is easier to evaluate project designs and results when specially designed and focused on targets, like in targeted monitoring. However, surveillance monitoring can reveal unanticipated effects in the researched topic.

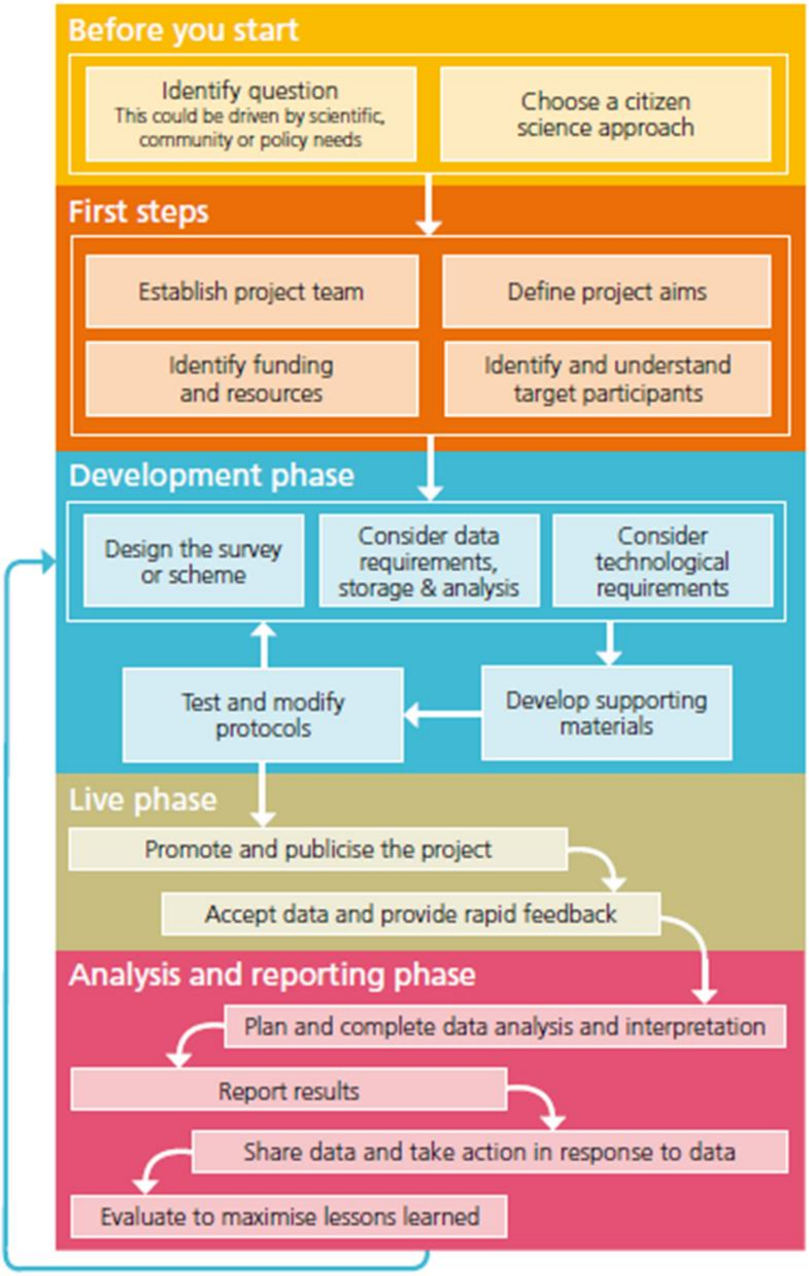

Figure 5. A method, proposed by Tweddle et al (2012), containing the most important steps that need to be implemented during a CS project process: developing, implementing and evaluating.

2 THE ORGANIZATIONAL STRUCTURE OF CS

The most important step that monitoring and research projects have to take to integrate CS in their project design, is to setup a proper organizational structure that will guide volunteers during their data collection and that facilitates storing and handling of large amounts of data that need analysis. Especially large-scale monitoring projects have to be able to deal with thousands of participants (Devictor et al, 2010).

As described in chapter 1.2, Tweddle et al (2012) came up with a method for developing a CS project of any kind (figure 5). In this chapter, the method will be used as the basics for describing the process of CS in monitoring and research projects. Besides the development of a CS project, implementation and evaluation of the project needs to be taken into account as well.

2.1 Phase 1: Before you start

During this phase, the project manager needs to think about what should be the result of the project and who will be addressed with these results. It is important to find out if CS is the best approach by looking at, if possible, similar projects which successfully implemented CS (Tweddle et al, 2012).

2.1.1 CS project types

To make it easier for project managers to decide which project type matches best with the research topic, several articles proposed different project types which are able to integrate CS. The project's design depends on the amount of volunteer influence on which researchers decide to. As already described in chapter 1, Bonney et al (2009a) describes three levels of volunteer influence in a project design; contributory projects, collaborative projects and co-created projects (table 1). After deciding the amount of public influence is needed for the project, a certain project type needs to be selected. Bell et al (2008) describes four 'ideal' types of projects according to their goal and formation:

1. In Participatory Environmental Tourism, volunteers travel short distances to reach a fixed location to collect data and contribute financially to the project by using primarily their own belongings. In this case, scientists or experts are in charge during the data collection (Bell et al, 2008).

2. Virtual Network Organizations rely completely on electronic communication. This type contains multiple groups of participants spread over a larger geographical area having the same objective of collecting data on specific locations (Bell et al, 2008).

3. National Non-Governmental Organizations, or so called National NGO's, are mostly independent and spread out over a large geographical area. These NGOs continually work together to collect data about the same research topic, but are able to perform their own side topics during the research. In some cases, these NGOs receive governmental grants but this doesn't occurs frequently and they often stay independent (Bell et al, 2008).

4. Local Associations are basically small organizations or groups of people with the same interests. These groups are led by volunteers only and can perform small scale data collections in the area of interest (Bell et al, 2008).

2.1.2 Key considerations

Tweddle et al (2012) defined a number of key considerations which should be taken into account before choosing a certain type of project design; what geographical or temporal scale will the project attempt to use? How much data is needed to come up with an answer on the research questions? Are there enough financial and material resources to recruit and stimulate participants? If the answer is yes, the project should choose a certain project type. As described in chapter 2.1.1, these differ mostly in the extent of participation required from the volunteers involved in the process (Tweddle et al, 2012).

2.1.3 Scientific question(s)

Project managers have to bear in mind that many CS projects are long-term monitoring projects. These projects have to focus on doing analyses of large amounts of data collected on a large geographical scale and over a longer period of time (Bonney et al, 2009a). Effectively formulated questions should make the analysis phase easier and more standardized for further use (Hochachka et al, 2012). Scientific questions should be established and should contain the most important aspects of the research. The project manager has to bear in mind that most volunteers are amateurs and do not have the expert skills of observing and analysing data. Therefore, research questions should be simplified. It is possible to formulate more advanced research questions, but this requires more training and supporting materials for participants to obtain high(er) quality data (Bonney et al, 2009b).

In co-created projects, volunteers (are asked to) come up with the research questions. This should be taken into account when projects make use of this level of participant involvement. Communication between scientists and volunteers is very important in this type of project and probably crucial for the progress of the whole project; volunteers are mostly not able to come up with proper scientific research questions (Bonney et al, 2009a).

2.2 Phase 2: The first steps

During the second phase, a newly established project team needs to design the basics for a monitoring or research project: define project aims, identify funding and resources and describe and understand targeted volunteers (Tweddle et al, 2012).

2.2.1 Project team

First, a project team needs to be established, which is able to engage relevant stakeholders (Tweddle et al, 2012). A research project team should consist of multiple disciplines:

- Researchers or scientists
- Educators
- Technologists
- (Evaluators)

Researchers and scientists are important to ensure the scientific integrity of the project, to develop methods which eventually lead to data collection and to analyse and publish final results (Bonney et al, 2009b). These people are the most important part of the team; most reviewed CS projects (42%) were led by academics and NGO's (Roy et al, 2012). Educators are important for communication with volunteers and should be able to explain the project's importance, clarify data collection methods, develop clear supporting materials and deliver feedback after obtaining data. Technologists are needed to develop mechanisms to store, analyse and visualize data and preliminary results, required for both data collection and giving feedback and rewards. An evaluator might be needed to ensure that the project uses measurable objectives and needs to evaluate the quality of the data during the process (Bonney et al, 2009b), however, this can also be done by the researchers/scientists of the team.

2.2.2 Define project aims

Project aims are needed to make sure that the project team knows what to do and what to aim for. Further, it will allow the team to keep track of the process and make sure the project will be successful. Multiple aims can be helpful to make the tracking of the process easier. It has to be taken into account that each member of the team will have its own aims. To make sure these personal aims are clear to every member, it is effective to meet on a regular basis and communicate about their assigned research parts (Tweddle et al, 2012).

2.2.3 Funding and resources

As the definition implies, the method of CS is not free of costs. Still, CS is a relatively inexpensive method of data gathering, but funding and resources are indispensable (Devictor et al, 2010). Funding and resources are especially needed during the development of the project; defining aims, develop supporting materials, support of volunteers, etc. Funding can be provided from within the project team or from external stakeholders (Tweddle et al, 2012).

2.2.4 Recruit and retain volunteers

Volunteers are crucial for CS projects. The Oxford English Dictionary describes two definitions of the word ‘volunteer’:

1. *A person who freely offers to do something*
2. *A person who works for an organization without being paid*

Volunteers donate their personal spare time and use their own resources (transport, mobile devices, etc.). Experts and scientists are regularly considered as the counterpart of volunteers, but often truly dedicated volunteers can achieve higher expertise in their field of interest (Bell et al, 2008). Therefore, it is important that potential participants are well-defined during the early stages of the project. Potential volunteers need to be engaged in the project process as soon as possible. This will affect the project’s protocols, data gathering methods and training methods and approaches (Tweddle et al, 2012).

CS projects rely completely on the amount and expertise and dedication of volunteers that will be recruited during this phase. First, the project needs to be advertised so potential participants notice the project, get interested and understand the intentions of the project. Second, participants need to know what the project expects them to do and how they can participate. Finally, participants need to know how much time they are expected to invest during the process (Bell et al, 2008; Bonney et al, 2009b; Chu et al, 2012).

The project designer has to bear in mind whether they want to attract amateur or more experienced volunteers; the more complicated the protocols get, the less participants will be attracted (Bonney et al, 2009b). Chu et al (2012) came up with three strategies of participant recruitment:

- Creating projects for people
- Spreading the word
- Building communities

The first strategy focuses on the motivations of participants to join a CS project. Low et al (2007) conducted a survey among volunteers in several CS projects and found three main motivations; 53% wanted to help out others and improve scientific studies, 27% mentioned they wanted to use their already existing skills while 19% wanted to learn or improve these skills. In many CS projects the sentence “easy, fun and social” describes the motivation of participants best (Dickinson et al, 2012), but this can vary and is definitely personal. Other possible motivations are gaining practical skills and interacting with other participants. The project team should find out what the motivations from targeted participants are and address these separately by launching multiple campaign plans each focusing on different motivations of the segmented audience (Chu et al, 2012) and by sending different kinds of messages on various media (Greenwood, 2007; Tweddle et al, 2012).

Additionally, besides focusing on results only, it is important that the project makes the process enjoyable for volunteers; people do not like to spend their precious time in an area with nothing happening (Greenwood, 2007). Keeping participants motivated not only positively reflects on the project, it also leads to retention of participants, which is most often even more important. Retention of participants can be realised by a combination of three types of motivations:

- Cognitive drivers
- Social drivers
- Emotional drivers

Cognitive drivers are important to take into account when volunteers come up with their own thoughts and ideas about the project's process; especially in co-created projects in which volunteers have the main lead. They want to feel part of the project by sharing their knowledge with both the experts and the other volunteers (Bell et al, 2008).

Social drivers can be stimulated by giving volunteers the opportunity to communicate with each other. This can be done by establishing a communication mechanism, such as a forum or board. Furthermore, giving these volunteers the opportunity to communicate with experts personally could significantly increase retention of participants (Bell et al, 2008).

Emotional drivers are primarily influenced by the research topic or the result of the project; participants strive for a good outcome of the project and share their emotions with each other. All three of these drivers create trust and recognition between volunteers and the project and can ensure that they will be retained for further data collection or other related projects (Bell et al, 2008).

The second strategy, spreading the word, is based on advertising the project to attract potential volunteers. Especially during the past decade, several new technologies and (social) media facilitated easier contact with the public. Examples of these technologies or media are web blogs, Facebook and Twitter. These virtual communities enhance the enjoyment and satisfaction of volunteers and let them feel they are part of the project; especially for projects in which participants are geographically dispersed, these virtual communities serve as a community basis. Here they can communicate with the scientists, but also, and maybe even more important, with other participants (Roy et al, 2012). Giving participants an easy opportunity to communicate with each other will lead to a higher retention of participants (Chu et al, 2012) and can lead them to promoting the project to new participants.

Project teams should make use of already existing communities to spread the word about the project's existence. For example, this can be done by using the communities of the project's partnerships (Chu et al, 2012). Digital flyers can be sent to organizations to spread them through their community within a very short amount of time. An important part of these messages is a call for action to go out and explore the field of science. These messages can help make volunteers feel invited by science instead of feeling intimidated and treated as amateurs (Dickinson et al, 2012; Chu et al, 2012).

Collaboration between participants and scientists may be the most important aspect of CS; especially for long-term monitoring projects which require participants continuously to collect necessary data (Chu et al, 2012; Dickinson et al, 2012). Besides a collaboration between scientists and participants, CS projects can be the start of a community containing people with the same interests and hobbies (strategy three) (Chu et al, 2012).

Promotion and publication is necessary to make potential volunteers aware of the project’s existence and stimulate them to join the data gathering or even the analyses (Dickinson et al, 2012; Tweddle et al, 2012). The amount of promotion and publication depends on the project design and the number and types of participants the project wants to attract; if the project only needs about twenty people, personal communication would be a better method than launching an event. A very efficient method of promoting the project is by launching an event or providing a stand on an already existing event to be more cost-efficient (Tweddle et al, 2012). Furthermore, well-timed press releases are vital to the project to get picked up early enough by media such as local newspapers and television/radio, but also blogs and social media need to be aware of the project’s existence (Dickinson et al, 2012; Chu et al, 2012).

2.3 Phase 3: Development phase

During the development phase, the project team will establish a practical design for the project. Data requirements will be defined and the method of storing and analysing data will be chosen. These methods need technological support of mechanisms or webpages, so these need to be established too. Supporting materials need to be developed to train participants in data gathering and keep them motivated until the actual research starts. In the end, inspection of the established mechanisms is necessary to ensure they work which will prevent data loss (Tweddle et al, 2012).

2.3.1 Survey design and data collection

Survey protocols need to be established to specify where, when and how data should be gathered by volunteers. These protocols need to be easy to understand, easy to perform and engaging, to motivate and stimulate participants (Bonney et al, 2009b). During the development of survey protocols, it is important that the project team bears in mind the motivations of participants, data requirements and technologies which will be used during data collection. The team has to decide what type of data they require and on what geographical and temporal scale they need to gather it (Tweddle et al, 2012). Also, data collection should be as consistent as possible to make it easier to perform analyses (Devictor et al, 2010).

The protocols need to be as simple and intelligible as possible for participants to keep on track during the process and the workload needs to be defined and allocated equally (Bonney et al, 2009b; Tweddle et al, 2012). Consequences of overcomplicating the protocols and putting too much workload on participants are that participants get demotivated and data gathering can result in errors. By introducing a progressive structure during the process, participants can get more accustomed with the data gathering method; starting with something easy and ending with collecting the most important and difficult data (Tweddle et al, 2012).

2.3.2 Data requirements

Data requirements should ensure that the gathered data is scientifically sound, both qualitatively and quantitatively, and that the data is ready to be processed in the analysis phase. The following data requirements are important to take into account:

- Standardized research formats
- Data quantity
- Data quality

It's highly recommended to increase the value of the data by making it more accessible for other projects and organizations. This can be done by using accepted and standardized data and metadata formats. These formats should also improve the data quantity and quality (Tweddle et al, 2012).

Data quantity is one of the major strengths of CS in environmental studies (Devictor et al, 2010). A sufficiently large amount of data, containing low quality information, can still reveal more results compared to small datasets containing high quality data (Hochachka et al, 2010). Many volunteers are able to collect large amounts of data in a very short amount of time. This can ensure a strong statistical power during the analysis phase; the probability that trends will be detected is high (Devictor et al, 2010). This means that the required quantity of the project strongly depends on how many participants they attract during the earlier stages and how much workload each participant gets during the data collection (Tweddle et al, 2012). The protocols and rewards the participants receive during the data collection can also provide higher quantities of data (Hochachka et al, 2012). After a rough estimation of the number of volunteers, the desired data quantity per person can be defined. When the project expects many participants, the team has to be sure the developed tools for data storage are up and running before the project starts, to avoid a congestion of data and even data loss (Tweddle et al, 2012).

Data quality has always been an issue in CS projects. Maintaining data quality during the process requires appropriate project protocols, designs and communication between project management and volunteers (Hochachka et al, 2012). This is also strongly influenced by the amount of training, supporting materials and the support of scientists and experts during the data collection (Bonney et al, 2009b; Bonney et al, 2014; Tweddle et al, 2012). Therefore, it is important that opportunities for errors will be minimized and random data inspections are performed to test the quality. There are two methods to reduce the amount of errors in a database:

- Validation
- Verification

Validation is a method which can be applied automatically on large databases. This method uses criteria to check whether imported data is valid by using certain ranges or orders. This can ensure that anomalous data or invalid data entries are noticed and can be erased or questioned (Bonney et al, 2009b; Tweddle et al, 2012). Furthermore, (automatic) error messages can be sent to volunteers to make clear that the data they just submitted is unusual and should be checked (Bonney et al, 2009b).

Verification is the equivalent method of validation and can be applied manually during the process of data gathering; i.e. illustrations or photographs can be used to check whether the collected data is correct (Tweddle et al, 2012). The project team can also train volunteers to compare incoming data and documentation to reference material, e.g. photographs and recordings. This will motivate participants because of the opportunity to increase their skills in observation and get more involved in the project (Cohn, 2008).

Another method to check the quality of the data is to investigate the process of data gathering. This can be done by selecting a random group of participants to check if data collection and entry is done correctly. By observing participants during their data collection and understanding what types of mistakes they make, protocols can be adjusted to prevent these common mistakes in the future. Another option is to ask participants to check each other's work for possible mistakes. This will ensure that mistakes are noticed and that participants get more confident with their own skills (Tweddle et al, 2012).

2.3.3 Data management

To maintain the quality of the data, data management is an important component of the development phase of a CS project. CS data needs special requirements of data management because some projects involve anonymous volunteers with different backgrounds and levels of data management knowledge. Therefore, CS projects should address the data life cycle in their project (figure 6). This cycle describes eight steps in CS projects in general, but some projects combine certain steps or perform them multiple times during the process (Wiggins et al, 2013).

These steps will be explained individually:

- *Plan*: Planning is needed to map the processes and the resources which are required for the project. This step should give an overview about how the data will go through the cycle and eventually indicates what should happen with the data afterwards.

- *Collect*: How to collect required data and determine the best way to get data from volunteers in specific data files is the second step in this cycle. A model should eventually demonstrate how the data will be acquired and eventually stored.

- *Assure*: When receiving data, the quality should be enhanced by performing quality control procedures; examples are validation and verification, explained in the previous chapter. This step should identify potential techniques which can address certain errors.

- *Describe*: For a sustainable database, describing the acquired data is important to make the data sharable in the end. The data should be described in a metadata table which can be presented to potential end users. Besides data, the used mechanisms and tools should be described in this table to provide end users with correct data processes.

- *Preserve*: Deciding what parts of the data to preserve is important during this step. There is a difference between short-term and long-term preservation; short-term preservation should protect the data against accidental data loss or mechanism failures, while long-term preservation is needed to make the data accessible for end users.

- *Discover*: For potential end users, it is important to be aware of the existence of the project's database. Therefore, research needs to be done where to register the database so these potential end users can find and use it. The metadata tables are important to be registered on these media to give a proper overview of the database.

- *Integrate*: This step can easily be combined with the previous step; finding other databases to combine with could make it more interesting for end users to utilize the database in new research projects. Proper data collection methods and metadata tables should make this process easier.

- *Analyse*: Other databases which meet the project's goals could be analysed in combination with the own database to find potential new research topics for further research.

Data storage for long-term monitoring projects is slightly different compared to short-term projects. Because data is acquired continuously or after certain periods, data storage needs to be planned to prevent data loss or failure. Archiving data every month or annually could help to maintain a long-term database. This requires very little effort due to mostly automatic processes. The storage location is important and depends on the enduring technology and infrastructure. Doing research about data centres and repositories is therefore important during the first step of the data life cycle (Wiggins et al, 2013).

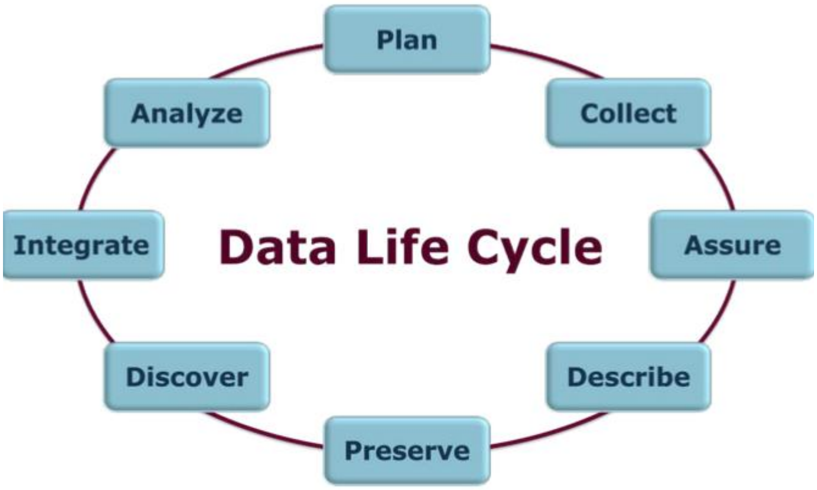

Figure 6. The data life cycle shows the various processes which are involved in data management. In general, this cycle represents all data management of all projects, but some projects combine processes or perform them multiple times (Wiggins et al, 2013).

2.3.4 Data ownership

Besides the importance of data management, the laws and responsibility policies which can be enforced on the database need to be examined; if stakeholders and end users are going to utilize the published database, it is necessary to protect the database under certain rights and responsibilities so the ownership of the database is clear. These terms also apply to the volunteers involved in the project. They have to agree to these terms before actually participating in the process (Bowser et al, 2013). Different policies can be implemented, depending mostly on the following variables:

- Level of public participation
- Organization
- Method of data collection
- Type of data

Because there are several variables which require different policies, no single policy can be addressed to a database alone. To find out what variables require which policy, four components are used to define the correct one:

- User agreements
- Terms of use
- Legal policies
- Privacy policies

User agreements are enforceable contracts between a project and stakeholder or between a project and its volunteers. These contracts make sure that the stakeholders and participants are legally bound to the other three components (terms of use, legal policies and privacy policies) and should abide the project's policy. These agreements are necessary to make sure that users or contributors of the project are provided with enough information of the enforced policies (Bowser et al, 2013).

The terms of use explain how the project decided how the database can be used by potential stakeholders and end users. These terms provide the dataset with certain ownership of the data, mechanisms and policies used during the establishment of the database. It is important that the ownership of the database is established in the terms of use, which can be implemented by i.e. adding trademarks, patents or copyright to the database. The database can be treated as a whole or can also be separated in individual parts with different terms of use (Bowser et al, 2013).

In the legal policies, the local, national and even international laws and other guidelines are explained and provided to stakeholders, end users and volunteers. This component should explain what rights and responsibilities the owner of the project has towards both the project and the other party (stakeholder or volunteers) and should protect them if discussions may occur (Bowser et al, 2013).

The last component explains how the project gathers, discloses and manages the data which will be or has been acquired during the project's process. This should provide the stakeholders, end users and volunteers with information about i.e. data contributions by volunteers and gathered personal information, cookies and web logs during the process. This component should also explain how the owner of the project protects this information (Bowser et al, 2013).

2.3.5 Technological tools

Technological tools mostly consist of online data capture, data analysis, presentation tools and smartphone apps. Many of these tools have only recently appeared on the market and still many more are in development (Crain et al, 2014; Tweddle et al, 2012). These tools can be divided in two sections:

- Front-end tools
- Back-end tools

Front-end tools are technologies which directly interact with volunteers, like smartphone apps and websites. These tools are primarily used during data collection and, very important, during the communication with scientists and other participants. Most back-end tools do not require any interaction with volunteers and are primarily used by scientists. These mechanisms are mainly used for proper handling and storage of data and during quality control. This can be, for example, a tool for checking the quality of submitted data using certain thresholds (Crain et al, 2014).

A main webpage can be very important for a project. This online location can include data entry mechanisms, data validation- and verification tools and can show volunteers the first results of the project they are working with. The webpage can also provide supporting materials, background information and a forum where participants can communicate with each other and with scientists and experts. Furthermore, promotion of the project can be done on this page as well (Tweddle et al, 2012).

2.3.6 Supporting materials and participant training

Many CS projects received funding due to the provision of supporting materials to the general public or just the volunteers involved; creating a connection between science and education is decisive (Dickinson et al, 2012). Supporting materials can be crucial in more difficult project designs, but are also necessary in simple ones. Sometimes, these materials are needed to teach participants the skills needed to collect and/or analyse data (Bonney et al, 2009b).

Scientific or critical thinking is another aspect which volunteers can learn from their efforts, which can help the project in generating new research questions or research designs (Dickinson et al, 2012). This can be accomplished by providing participants with information they need online or by sending them a package containing supporting materials (Bonney et al, 2009b; Tweddle et al, 2012). These supporting materials can consist of identification guides, posters, manuals, videos, newsletters and an (online) FAQ (Bonney et al, 2009b).

Personal training of volunteers is another possibility to support participants in their data collection methods and skills. Volunteers improved when trained personally or in small groups by scientists or professionals. It is clear that more research needs to be done about how effective a certain level of training is in different groups of volunteers (Dickinson et al, 2010). Especially when data collection is done in groups, designated scientists or experts can help out by joining these groups and jointly collecting data or even by providing training in which participants learn required techniques (Bonney et al, 2009b).

2.3.7 Test and modify protocols

Especially for newly established projects, pilot-testing with volunteers can be very valuable to the project. This can indicate whether the used methods work and if desired data is collected. Using different groups of potential participants (age, gender, education, etc.) can also be useful to test; each group has diverse ways of interpreting protocols. When protocols seem to be overcomplicated or confusing, modification is needed. This can be done by simplifying the descriptions or adjusting the protocols until the testing participants understand what is expected from them (Bonney et al, 2009b). Furthermore, data entry mechanisms and supporting materials need to be tested to ensure that they are ready for use (Tweddle et al, 2012).

2.4 Phase 4: Live phase

During the live phase, the project will be promoted and advertised to recruit more volunteers which can directly start gathering data. The data will be provided through the established protocols which means that the project has to be ready to accept data, provide rapid feedback and reward participants (Tweddle et al, 2012).

2.4.1 Acceptance of data

Acceptance of data will be done by the established data entry methods and protocols, both electronically and manually. It is important to check these tools regularly for any faults to prevent errors. Errors in these tools can lead to demotivation of participants and finally loss of data. Communication with the participants is important when something is going wrong, especially when data entry mechanisms are not working properly anymore. Providing explanation of the problem and solutions can prevent miscommunication (Tweddle et al, 2012).

2.4.2 Participant recognition, feedback and rewarding

Demonstrating the extent to which participant's data is valued and applied by scientists and policy makers is a key strategy to ensure participant's satisfaction and eventually retention (Bell et al, 2008). Providing volunteers with feedback and rewards causes increased motivation and stimulation to gather more data for the project (Tweddle et al, 2012). Granting participants with rewards during data collection is an option which is often used in CS project designs. Figure 7 shows an example of the project called "Notes from Nature" in which participants are asked to electronically transcribe tags of collected organisms. The number of completed tags done is rewarded by granting a certain rank to the participant; mutual competition can be very stimulating for some participants (Notes from nature, 2013).

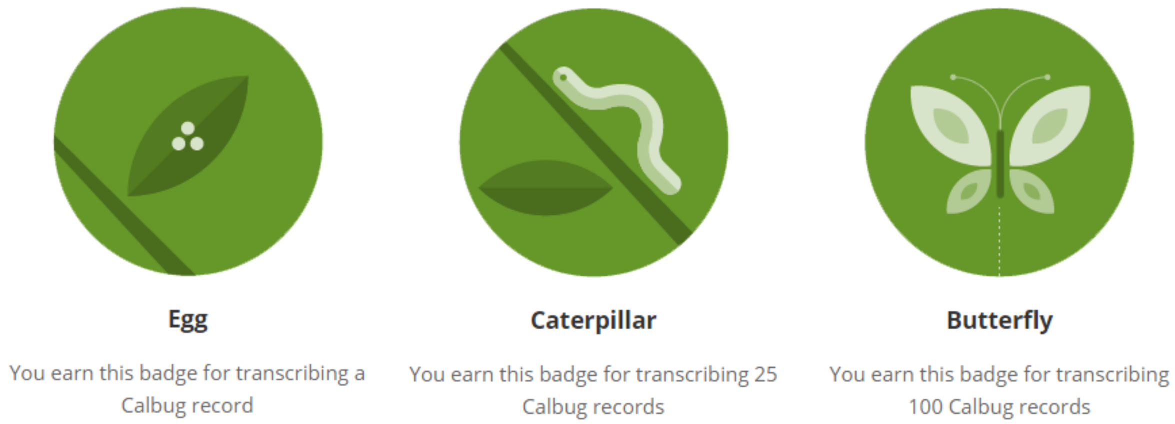

Figure 7. In a web-based CS project, called Notes from Nature, participants are rewarded during their process by granting them with a certain rank. In this case, 'Egg' when transcribed one record, 'Caterpillar' when transcribed 25 records and 'Butterfly' when transcribed 100 records (www.notesfromnature.org).

Another, more sophisticated example is shown in figure 8. In this project, called WaderTrack.nl, volunteers are asked to observe individually colour-marked Eurasian Oystercatchers (*Haematopus ostralegus*) and describe the colour-coded rings around their feet. After submitting the observed ring codes a match is automatically found in the online database and participants are rewarded by showing them all previous observations of this specific individual and their own observation in a map. This reward is received directly after the participant submitted his or her data (WaderTrack.nl, 2015). Rapid feedback on submitted data makes participants feel valued. This feedback can consist of short texts thanking volunteers for participating and an overview of some preliminary results; i.e. highlighting their contribution on a map or in a table (Tweddle et al, 2012). E-mail, phone and/or web-based mechanisms, such as blogs or webpages, are ideal techniques for providing feedback (Bell et al, 2008; Tweddle et al, 2012). Providing participants with a short summary containing the current state of affairs on a regular basis can be motivating and makes sure they will not forget about the project's existence (Tweddle et al, 2012). Personal interactions between scientists and participants are the best way to provide feedback and rewards (Bell et al, 2008).

kleurring

ID vogel: **5192352**
korte notatie: **LR-RYQB**, lange notatie: **LAR;RBYN(Q),N**

eerste vangst/waarneming

datum: **29/05/1985**, NB/OL: **53.013/4.762**, leeftijd: **pullus**

details waarnemingen

pagina: 1 2 3 4 5 6 7

#	waarnemer	datum waarneming d/m/j	locatie	gedrag	acties
1	Kees Oosterbeek	28/03/2015	Texel, Mokbaai	hoogwatervluchtplaats	
2	Kees Oosterbeek	21/03/2015	Mokbaai Texel	hoogwatervluchtplaats	
3	Kees Oosterbeek	08/03/2015	Mokbaai Texel	hoogwatervluchtplaats	
4	Kees Oosterbeek	27/02/2015	Mokbaai Texel	hoogwatervluchtplaats	
5	Kees Oosterbeek	07/02/2015	Balgzand, 't Kuitje	hoogwatervluchtplaats	
6	Jenny Cremer	07/08/2014	Mokbaai, Texel	foeragerend	
7	Jenny Cremer	27/07/2014	't Stoar,Texel	broedterritorium	
8	Wiebe Kaspersma	23/04/2014	Mokbaai Texel	foeragerend	
9	Wiebe Kaspersma	15/04/2014	Mokbaai Texel	hoogwatervluchtplaats	

Figure 8. Example of the “reward” obtained by an observer after entering his observation of an individually colour-marked Eurasian Oystercatcher (*Haematopus ostralegus*) in WaderTrack.nl. In case the observed rings match with the data on marked individuals in the online database, observers are shown all previously submitted observations of this specific individual and their own observation in a list and on a map (WaderTrack.nl, 2015). In this case, a bird that was ringed as chick on Texel in 1985 and was observed no less than 306 times since marking. Only the 9 most recent observations are listed in the screenshot, but all 306 observations are available.

To explain the importance of feedback and recognition towards participants, figure 9 shows a model containing the process of participant motivation and the need for recognition and feedback from scientists; recognition and feedback during the process is essential to keep participants motivated and to let them feel part of the project (Rotman et al, 2012). To keep the wheel of volunteer involvement turning, scientists need to give their input and recognition along the way. Volunteers will have a personal interest to get involved with a certain project. Scientists need to communicate their interest with potential participants by explaining their need for data. Volunteers will collaborate actively when scientists give them recognition for joining the project. Volunteers can be motivated to continue in the project by offering education and giving them, again, recognition and feedback. If scientists refuse to give recognition or if the project is not satisfying enough for the volunteers, loss in motivation could occur which leads to abandoning the project (Rotman et al, 2012).

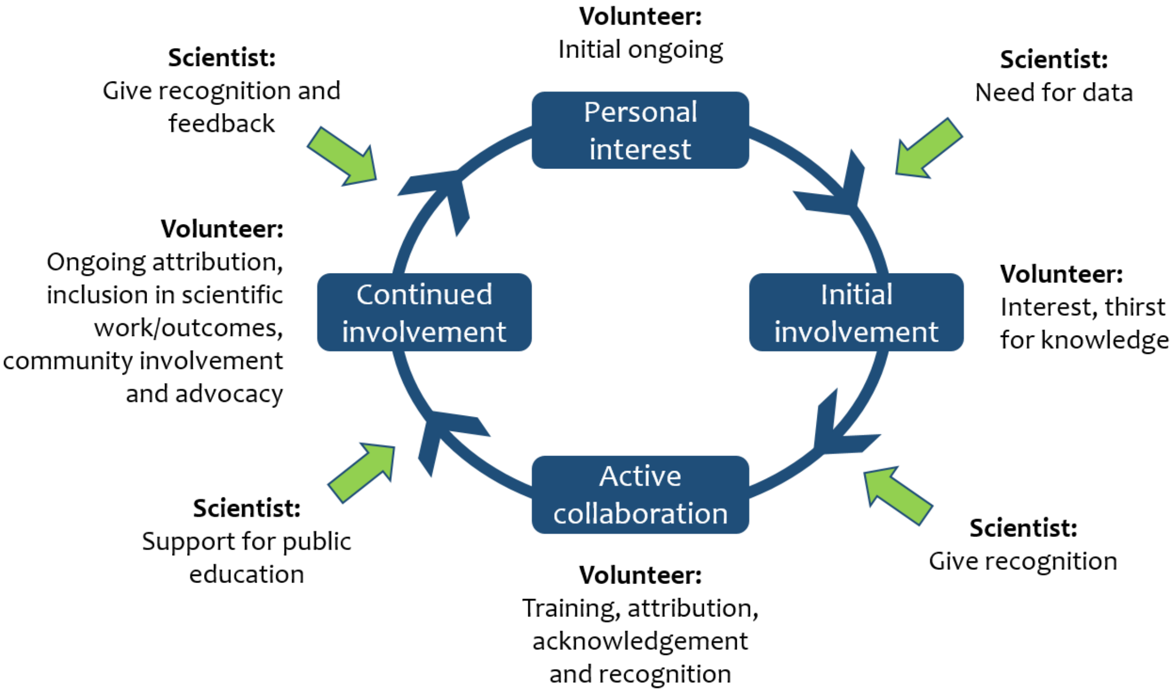

Figure 9. This model, based on a model of Rotman et al 2012, shows the importance of participant recognition and feedback. If scientists keep motivating the participants, the blue circle will continue, starting off with a personal interest, the initial involvement, active collaboration and continued involvement. Scientists need to stimulate this circle by communicating the need for data, give recognition, support public education and, again, give recognition.

2.5 Phase 5: Analysis and reporting phase

During this last phase, the gathered data will be analysed and presented in a report. Results need to be visualized by producing maps, tables and/or figures. After the report is approved, it will be sent to important stakeholders, end users and other interested parties. Therefore, the data should be made easily accessible. In the end, the team needs to evaluate and if necessary adjust the whole process before continuing with the project (Tweddle et al, 2012).

2.5.1 Data analyses

CS projects are known to produce large, coarse data sets which may cause significant challenges during the analysis phase. Luckily, due to large data sets, strong patterns can often be easily noticed and interpreted (Bonney et al, 2009b). Already during the development of the project design, data requirements should be identified to facilitate data analyses (as addressed in paragraph 2.3.2 on data requirements). In some projects, data analyses can already start during data collection by continually analysing the incoming data. Other projects wait until they receive all vital data and start analysing after. In case of long-term projects, analyses can be done during several moments in time, for instance monthly or annually (Tweddle et al, 2012).

Data cleaning is the first step that needs to be done before going through with any analyses. As mentioned in chapter 2.3.2, data validation and verification can be used to remove incorrect or anomalous data. This step also means that the required data has to be formatted to the format that will be used during analyses (Bonney et al, 2009b; Tweddle et al, 2012). Data cleaning can also be done by participants themselves and is believed to be one of the most educational features of a CS project (Bonney et al, 2009b). Besides data cleaning, the quality of the data should be mentioned alongside the database in, for example, a metadata table. If the project wants to export its data to interested end users, it is important to give them enough information about the quality of the data and the methods of data collection (Tweddle et al, 2012).

2.5.2 Visualization and reporting of results

CS projects need to think about how to present their findings to different types of people; participants, data users, funders, etc. The most important part of the reporting step is to give volunteers a well-developed overview about what they collected and what they contributed to, to keep them motivated to continue in the project. This can be done by showing them a summary of results with several graphical elements which are intelligible for all types of volunteers (Tweddle et al, 2012).

Volunteers can be enthused and motivated by seeing their own results and contribution to the project by visualizing some (preliminary) results. Furthermore, it helps to engage people when they are able to interpret the results themselves. The team needs to bear in mind how to present the data: the more sophisticated and complex maps or tables are, the less motivated volunteers will become. Therefore, short visual summaries, simplified maps and tables and snapshots of data are strongly recommended (Roy et al, 2012).

The best method to show final results is to address participants by using the main webpage, blog or a mailing group (Tweddle et al, 2012). Another frequently used method is to publish results in newspapers, magazines and newsletters. The effect of this is that fellow citizens read that other citizens contributed to science and may become motivated to join during follow-up events (Bonney et al, 2009b). Presenting the data to participants and giving them the opportunity to ask questions is even better; close contact can help to stimulate participants (Tweddle et al, 2012).

Other scientists and policy makers may be interested in the final results too, but they need a different way of reporting. Broad results and methods are interesting for other scientists if they want to learn from the project. Furthermore, it can be important to communicate the value of CS within these types of projects to other scientists and policy makers. This can stimulate to increase the integration of Citizen Scientists in scientific research projects (Tweddle et al, 2012).

2.5.3 Evaluation

The final step of CS projects is to evaluate the process. What worked well? What did not work at all? Which protocols came up with the best data? What approaches need adaptation? Not only in the end of the project, but also during the process, is evaluation an important step to check whether the design is working or not. Especially long-term monitoring projects with continuous data collection should be able to quickly adapt. Evaluation can be helpful to check if data collection is working with the established protocols and how volunteers go through the process. Tweddle et al (2012) describes three methods of evaluation:

- Baseline evaluation
- Formative evaluation
- Summative evaluation

Baseline evaluation can be implemented prior to the development of the project design. This type of evaluation establishes a baseline of participant's knowledge and attitudes. In the end, the final evaluation can be compared with the baseline evaluation to observe changes or processes which need adjustment (Tweddle et al, 2012).

Formative evaluation has to be implemented during the development phase and during data collection. This evaluation checks whether established protocols work and shows the effectiveness of the process (Tweddle et al, 2012).

A summative evaluation has to be implemented in the end of the project and focuses on the results and final conclusions. This evaluation compares the results with prior established aims and checks whether they have been achieved or not (Tweddle et al, 2012).

Often, volunteers provided comments or suggestions during the process which need to be looked through thoroughly. These can give some insights on how volunteers experienced the research process and can provide the project team with another point of view on the different processes (Tweddle et al, 2012). A possibility for volunteers to make it easier to provide feedback, is to give them the opportunity to submit direct feedback during data entry.

3 OPPORTUNITIES & CHALLENGES OF CS

Every change comes with its own opportunities and challenges; so does CS in environmental studies. The use of CS in ecological studies is known for its issues; especially volunteer recruitment and data quality have often been questioned by scientists (Conrad & Daoust, 2008). In the next chapter, both opportunities and challenges will be discussed and how they influence both scientists and volunteers.

3.1 Opportunities for CS

New technologies (smartphone apps, online data entry tools, etc.), developed during the past decade, made it possible to use volunteers in scientific research by adjusting data collection protocols and several parts of research processes to integrate CS data. Devictor et al (2010) described five key factors of success for a CS based project:

- Simplicity of the protocols
- Structured schemes
- Well-substantiated feedback
- Communication between scientists and participants
- Secured sustainability of the program

3.1.1. Websites

Websites, smartphone apps, different sensors and digital image and sound analyses can all be used during data collection, and more importantly, used by both scientists and participants. Websites are the most prominent technology used by any existing CS project. Involved scientists and volunteers can find explanations of the project on the website and the website is also used as an important tool for promotion. Examples are the main webpages of several bird research organizations like eBird, the British Trust for Ornithology and Sovon (figures 10 and 11). These webpages provide both scientist and volunteers with information about current projects, data gathering methods and data entry mechanisms.
Websites are also used as an online database in which volunteers are able to add their observations; a large range of services is available (Roy et al, 2012). Due to the fact that websites are a mature technology, associated risks are relatively low (Sullivan et al, 2009).

Having a website also means that regular maintenance is needed to make sure that data entry tools and information is still available. Updates of the project and feedback after data entry keeps volunteers up to date, motivated and helps to retain them in the project. All of these services are relatively low in costs; a website is therefore an ideal technology to start a project with, especially for small-scale projects (Roy et al, 2012).

Figure 10. The main webpages of eBird (eBird, 2014) and the British Trust for Ornithology (BTO) (BTO.org, 2015).

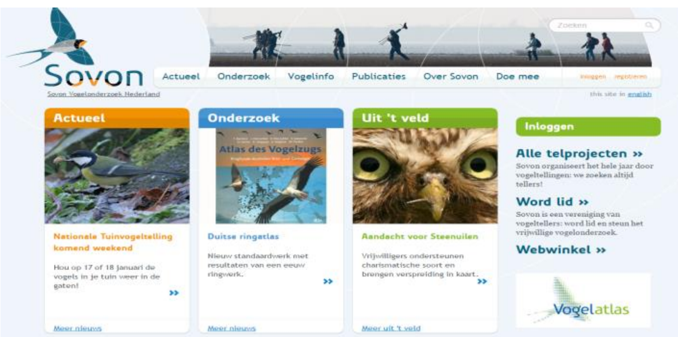

Figure 11. The main webpage of Sovon (Sovon.nl, 2015).

3.1.2 Smartphone apps

Smartphone apps are a newly developed technology of the past decade. Increasing availabilities of different types of smartphones, enabled the use of these mobile devices as research equipment; especially the GPS function on most of these devices is crucial. I.e. submitting photos and sound recordings combined with a geolocation made it possible to validate and verify this data easily. Most of the extant apps use the same method: submitting observations, photos, videos and/or sound recordings combined with the exact geolocation. An example is shown in figure 12. This smartphone app is intended for submitting observations of juvenile Common Starling (*Sturnus vulgaris*) in groups to determine why the population of this species is declining at the moment. Furthermore, smartphone apps provide opportunities to socialize with other volunteers and scientists of the project. Another strength is that data can be submitted directly at the time and location where it is collected (Roy et al, 2012).

Figure 12. An example of a smartphone app for submitting data on counts of numbers of juveniles in groups of Common Starling (*Sturnus vulgaris*) (Sovon.nl, 2015).

3.1.3 Sensors

Sensors are devices that automatically record signals that are used by smartphones and many other mobile devices, like mobile connectivity and GPS location. Similar to smartphone apps, sensors develop quickly and need regular maintenance. Almost all of these sensors are standard features of smartphones, so no extra effort is needed to develop these features. Another strength of sensors is the connection between smartphones or any other sensor-containing mobile device with other devices at home. This means that volunteers can upload their data in the field or at home by using these sensors (Roy et al, 2012).

3.2 Challenges of CS

3.2.1 Organizational issues

Finding suitable funding for CS projects is a challenge for many individual and starting projects. In the early stages of CS development, many existing long-term CS projects failed to contribute valuable data to scientists or at least valuable data answering important questions. This hindered finding potential funding. Newly developed projects often rely on private and public funding from diverse sources which may influence the project's goals and results. These individual funders all have their own reasons to fund the project and expect something in return. Therefore, many projects need to adjust their goals to fit properly with their funder's diverse expectations. Having a single funding source means that the project can probably keep its own goals without doing a lot of adjustments (Crain et al, 2014).

3.2.2 Data collection

Data quality is the most important challenge of any CS project and already starts in the early processes. Protocols for data collection need to be established and double-checked carefully, because these need to be executed by volunteers for collecting data. Standardization and consistency is therefore important to prevent data quality loss. These standards are particularly required when participating volunteers have different backgrounds and each have their own point of view on the subject (Conrad & Daoust, 2008).

Conrad and Daoust (2008) describe three standardized aspects of CS based monitoring programs:

- Standardized methodology
- Standardized results
- Standardized conclusions

These aspects should be standardized for many related CS projects to have to opportunity to combine final databases with each other and perform analyses to reveal new studies. In the methodology, basic training for both scientists and participants is needed to communicate the project's protocols. If equipment is used during the data collection, explanation is necessary. This ensures that the protocols are clear and used properly during data collection (Conrad & Daoust, 2008).

Observer variability and detection probability are two challenges during data collection processes in environmental studies (Cooper et al, 2012). Citizen Scientists can vary in age, gender, experience, skills, willingness towards training and several other aspects which all influence data accuracy (Dickinson et al, 2010). Therefore, protocols should ensure that submitted data is consistent across all volunteers. The Cornell Lab of Ornithology used a method of estimating the detectability rate of observers when submitting their data; by doing this, this parameter could be taken into account during the analysis of the data (Cooper et al, 2012).

Detection probability or observer quality focuses on comparing skills of untrained participants, trained participants and scientists. This means that a certain detection skill is required to perform a data collection method and gather high quality data. The type of training or level of experience has much influence on the quality of the data. Therefore, current studies are examining the effectiveness of self-study, internet training or personal training (Dickinson et al, 2010).

The variation in spatial sampling methods is questioned by analysts. Although many CS projects make use of standardized sampling methods and use divided geographical grid maps, most Citizen Scientists are still free to choose where to collect the data within allocated areas. This means for instance that many areas are sampled from accessible roads and road-less areas are underrepresented. These maps also show the most interesting areas to find certain organisms. Residential areas are often oversampled due to the high abundance of participants (Dickinson et al, 2010). Figure 13 shows a map of North-America with the GPS locations of all participants of a CS project, called FeederWatch. This map gives a good example of how data is collected unequally over the total research area of the project. Here, the states on the east coast are overrepresented, while there is a gap in the mid-west.

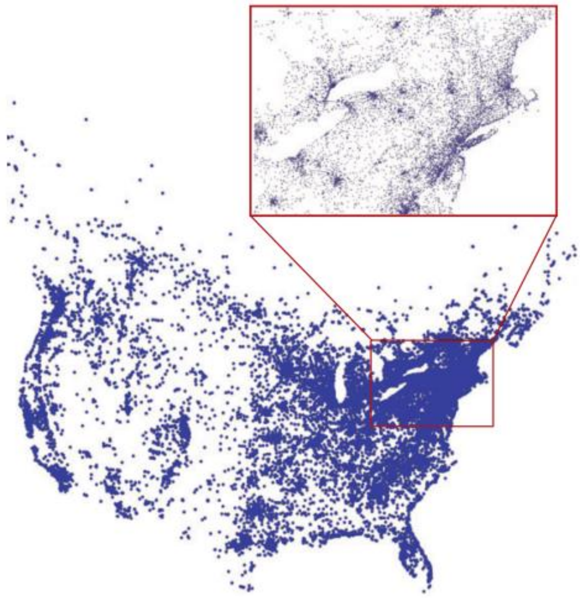

Figure 13. The participant's locations on a map of North-America for a CS project, called FeederWatch. This map shows that in high density areas, especially on the east coast, more data is submitted compared to the provinces in the centre of the USA (Dickinson et al, 2010).

Besides spatial sampling methods, temporal sampling methods are a challenge for CS projects as well. Cooper (2014) showed that there is a weekend bias in data focusing on the phenology of migrating songbirds. During the week, volunteers often visited birding areas on Saturdays which caused biases in the database on phenology, breeding periods and feeding peaks of young. This means that, besides spatial also temporal standardization of project protocols is needed (Cooper, 2014).

Many environmental CS projects make use of well-known taxonomic classes, such as birds and mammals, as their main research topic. During data collection, it is required that participants already possess some knowledge about taxonomic groups and identification methods. This excludes a group of willing participants which are identified as beginners. On the other hand, if this group is still able to submit data, data quality is lost because of misidentified targets or wrong assumptions (Lukyanenko et al, 2011).

Often participants do not value their collected data if in their opinion they did not find anything ‘special’. This means that participants may fail to submit uninteresting data, such as very common observations. Scientists, on the other hand, may interpret the lack of ‘normal’ observations as true null observations, which leads to wrong conclusions. To prevent this, protocols need to take into account ‘zero’ observations as in ‘not present’ in that area. This will make analyses of data easier and far more representative. These effects should be communicated with participants by explaining the value of these ‘zero’ observations (Cooper et al, 2012).

3.2.3 Technology

During data collection, technologies are expected to store data, but often these technologies are not able to handle large quantities of data properly. Due to the fast development of CS, the development of new technologies falls behind and sometimes struggles in the process. Besides data handling, issues such as interoperability of the data with other CS projects are common challenges as well. This means that two individual databases cannot inter-operate with each other due to differences in design, goals or data collection standards (Crain et al, 2014). Also websites, smartphone apps and sensors are known to have challenges during data collection.

There are several known challenges of websites in general:

- Separation between data collection and data entry
- Internet accessibility
- Out-of-date websites

Websites separate data collection and data entry methods and cause an extra step which has to be taken during the project. This means that there is a possibility that data will not get submitted and will get lost. Furthermore, the project has to bear in mind that not all people are connected to the internet everywhere. This means that some people cannot access the website every moment of the day. The last challenge is that websites quickly get out-of-date and need to be changed regularly to keep volunteers up to date. For example, it is often not clear whether projects are still running or have already stopped (Roy et al, 2012).

Although smartphone apps are promising to CS based research projects, this new technology still struggles with many challenges. The development costs of smartphone apps are relatively high, need to be adjusted for different operating systems and, combined with the fact that the development of smartphone apps is fast, extant apps can quick become redundant. Almost continual maintenance and updates are needed to keep these technologies running and interesting. Also, participants without a smartphone are automatically excluded in the project or at least in that process (Roy et al, 2010).

A challenge for sensors is the variety in sensitivity they use. Different settings on each device can cause variations in data retrieved from sources. Furthermore, volunteers do not need to actively do anything when only mobile connectivity or GPS location is needed, besides turning on these sensors. This means that retaining these participants is hard because they may not feel satisfied while participating (Roy et al, 2010).

3.2.4 Utilisation of data

CS databases are often large and mostly cannot be used by smaller spreadsheet programs. Therefore, scientists need to have the knowledge on how to cope with large databases and how to use programs which are capable of working with these datasets. This can be done by collaboration of scientists and specialists to build up such knowledge. Furthermore, scientists should familiarize themselves with analysis methods which are capable of analysing broad and messy CS datasets (Cooper et al, 2012).

Another issue of implementing CS data is achieving influence in decision-making processes. Often, Citizen Scientists and CS based project managers complain about the disinterest of policy and decision makers. Participants put their time, energy and sometimes money in these projects and are disappointed if the results are not being implemented. Therefore, it is necessary to understand why CS data is not being implied. Possible answers are lack of communication between policy makers and scientists, difficulty to access data, lack of trust in the quality of the data and the lack of willingness to use CS data in decision making processes (Milne et al, 2011). These issues should then be addressed.

4 THE FUTURE OF CS

Due to the increased popularity of using CS in scientific studies, the current state of CS is expected to change fast. In the future, Citizen Scientists will not only participate and help out scientists in projects, but also help in setting conservation targets and in the development of new data collection techniques like smartphone apps and online analyses methods. Besides future possibilities and opportunities, potential future risks will be discussed in this chapter as well.

4.1 Future possibilities of CS

4.1.1 Smartphone apps

Potential rapid developments of smartphone apps will occur in all ranges of possible apps. Plug-in or inbuilt sensors will make it easier to connect with designated receivers. Communicating by using these apps is another possible opportunity; scientists and volunteers will be able to provide prompts and requests through these mechanisms based on their current time and location. Creating multi-access databases will make it easier for analysts to gather data and analyse it (Roy et al, 2012).

4.1.2 Sensors

In the near future, rapid development of inbuilt or plug-in sensors will make it possible to provide high quality spatio-temporal resolution data. This type of data can be relevant for physical characteristics such as weather and air quality in the current research area of a project. Furthermore, receiving data from remote areas could become better and more detailed (Roy et al, 2012).

4.1.3 Image and sound analysis

Automatic recognition of images or sounds can only improve in the near future. The development of more sophisticated handware, such as smartphones and their designated smartphone apps, can increase the usage of these analyses already in the field. The image and sound recognition software will become more sophisticated which makes it possible to detect smaller details as well (Roy et al, 2012).

4.2 Cyber-infrastructure and data sharing

Many CS projects create databases containing highly specific information for a designated project area only. This creates isolated projects executed in the same area of research. As graphically shown in figure 14, the current scenario shows a cyber-infrastructure linking several CS projects to each other which permit data sharing. Aside from those projects, several other projects are completely isolated while performing research in the same area. In the future, these cyber-infrastructures should connect all CS projects which allows them to share data and make use of standardized data collection protocols. Furthermore, connections between several cyber-infrastructures in different research areas should interact with each other to expand their data sharing possibilities (Roy et al, 2012).

Individual CS projects should be encouraged to make their datasets downloadable in standardized files to facilitate data sharing. This will enhance the connection of the project to the rest of the cyber-infrastructure. Another option that needs to be stimulated is a centralized data portal in which individual projects can upload their datasets, which soon after can be shared more easily to permissioned users. To achieve such a data portal, CS projects should introduce standardized protocols within their current cyber-infrastructures to enhance data sharing; sharing data requires a good metadata and proper data management (Roy et al, 2012).

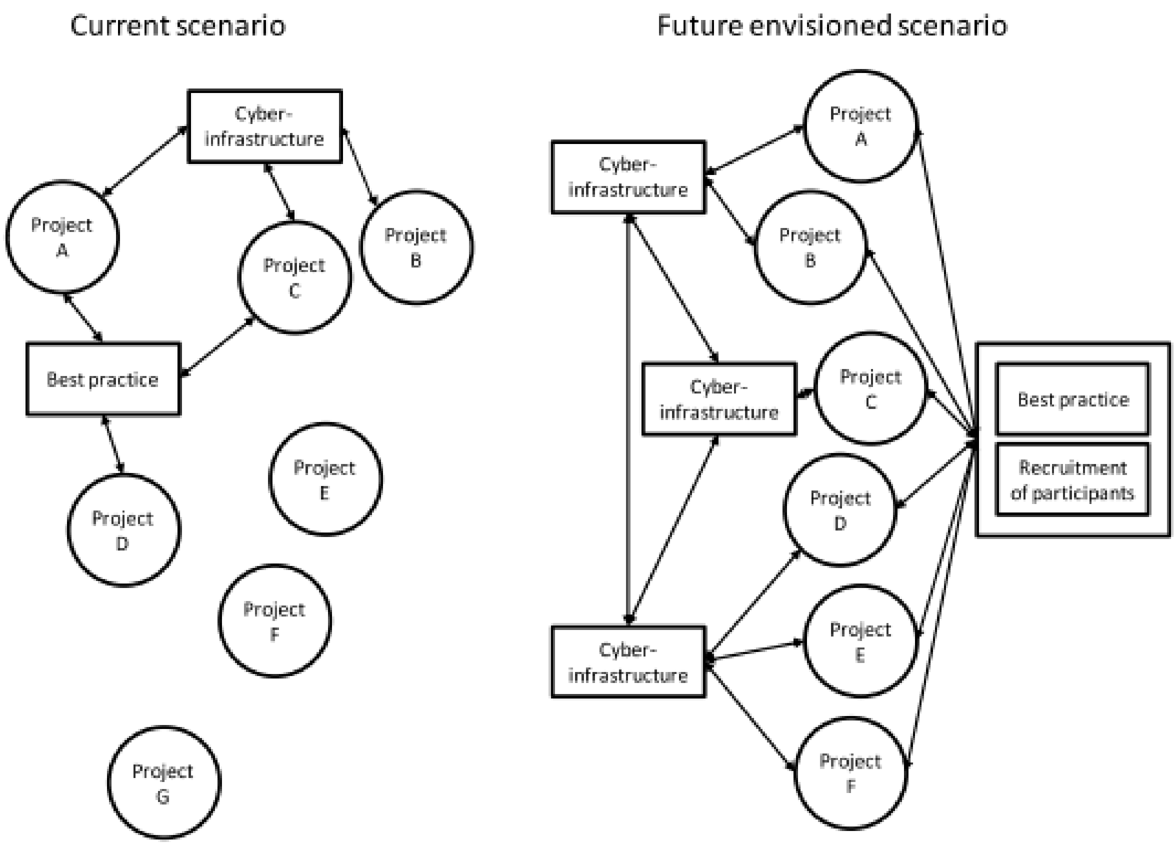

Figure 14. The current and potential future scenarios of CS projects and their connection to other related projects. This diagram shows the importance of a cyber-infrastructure linked by web-services which permit data sharing between different projects (Roy et al, 2012).

Data portals can have another function besides sharing data. To understand where data is coming from, individual projects create metadata tables; these tables contain all possible, potential and used data sources. These data mashups could be combined among participating CS projects within the cyber-infrastructure to create a main database of all used data sources. Currently, most of these data mashups are only used in academic research projects, but could be very effective in CS based cyber-infrastructures (Roy et al, 2012).

Strengths of sharing data by using cyber-infrastructures are increased data quality and accessibility. Making data open access to certain projects and setting up several ways to collect these datasets, increases the quality of the data. On the other hand, weaknesses of sharing data revolve around funding and vulnerability of the data. Setting up a cyber-infrastructure needs funding as well, for setting up centralized data portals and web-based communication tools. If participating organizations start collaborating, this could lead to more professional projects, which in turn affects the status of CS as science for 'citizens'. Finally, making data open access could increase the risk that data is misused by not-permissioned users (Roy et al, 2012).

4.3 Future CS datasets

Storing CS data is probably the most important part of the process. It is therefore important to devise a method to store large amounts of data and still make it easy to use for analysts to find results. This method should both be cost-effective and ready to serve multiple purposes. Currently, most CS project designs show some challenges in addressing multiple questions; the spatial extent of projects, the resolution of data and the design of certain parts of the project design, i.e. volunteer coordination and using standardized data collection methods. Tulloch et al (2013) made four recommendations to ensure that CS datasets are used to their full potential;

- Incorporate well-structured monitoring
- Regional coordinators
- Encouragement of under-explored applications
- Better communication

A well-structured monitoring is needed to create higher quality datasets. To create a more stratified monitoring, fine-scale data collection, temporal replication covering all possible habitat types or land uses and communication with volunteers about data needs should be emphasised during this process (Tulloch et al, 2013).

When CS projects focus on large spatial research areas, introducing regional coordinators could be a valuable addition to maintain data quality in that specific region or research area. Besides keeping track of gathered data quality, these coordinators should assess the value of additional information available for volunteers (Tulloch et al, 2013).

Rather than struggling with current CS data issues and waiting for a 'completed' dataset, scientists should focus on using more under-explored applications with higher impacts, like automatic sensors for example. Although these applications have lower data quality requirements, they are ideal to answer questions which do not require a targeted nature of sampling. Scientists would have more time to perform social studies on participants during this period. Examples of these social studies are studying participant behaviour, investigating participant motivations and interests and public involvement in conservation (Tulloch et al, 2013).

"In the end, scientists should focus more on the strengths of integrating CS in scientific studies in the future instead of keeping the main focus on its challenges" (Tulloch et al, 2013)

The last recommendation focuses on enhancing communication between scientists and participants. Scientists should make participants more aware of the project's objectives, benefits and the costs of the program. This could ensure that, while collecting data, participants feel more integrated in the project and probably collect higher quality data. But scientists need to communicate with each other as well. CS projects should make their data more and more easily available for other scientists to promote the use of CS. In the end, scientists should focus more on the strengths of integrating CS in scientific studies in the future instead of keeping the main focus on its challenges (Tulloch et al, 2013).

4.4 Professionalization of CS

CS is already acknowledged by many different fields of science and sometimes even seen as important for science in general, but it is still a developing method which needs more professionalization in the future. To achieve this goal, the field of CS needs more training opportunities for participants and scientists, more professional experiences and successful results and clear pathways to support in funding. Broadening the scope and professionalization of CS can lead to growing recognition of its importance and capacity (Crain et al, 2014).

4.5 (Possible) future risks of CS

Roy et al (2012) describes five possible risks for CS in the future by developing and using more sophisticated techniques:

- Excluding people
- Financial costs
- Mobile connectivity
- Volunteer confusion and fatigue
- Increased centralization

Due to the rapid development of new technologies, one of the bigger risks which will probably occur is that some participants are not as technology savvy as others. The difference lies in the degree in which participants are open to and in which they have access to new technologies. Making use of relatively mature technology, like websites, could ensure that participants keep track with new developments. If CS projects rely on highly technological mechanisms, they risk to increase the proportion of participants becoming excluded, but also attract a younger group of participants which enjoy trying new technologies (Roy et al, 2012).

Another problem is the ease of establishing a new CS project. This means that a potential risk in the future could be a plethora of all sorts of CS projects which cause volunteer confusion and fatigue; potential participants will have no idea how and for whom they are contributing. This problem could be solved by attempting to control the growth of new CS projects or by combining certain projects (Roy et al, 2012).

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5.3 Figures and tables

Figure 1.	Bas Engels ©; based on figure in presentation Andrea Wiggins on 17 September, 2012; http://www.slideshare.net/AniKarenina/citizen-science-what-every-researcher-should-know-about-crowdsourcing-science?qid=be02d95f-5a72-4853-bc49-b6f4371b1fd1&v=qf1&b=&from_search=6
Figure 2.	Bas Engels ©
Figure 3.	Haklay (2013); page 116
Figure 4.	Dickinson et al (2010); page 156
Figure 5.	Tweddle et al (2012); page 6
Figure 6.	Wiggins et al (2013); page 2
Figure 7.	http://www.notesfromnature.org/images/badges/calbug/caterpillar.png
Figure 8.	http://www.wadertrack.nl/default.asp
Figure 9.	Bas Engels ©; based on model of Rotman et al (2012); page 224
Figure 10.	http://ebird.org/content/ebird/ en http://www.bto.org/
Figure 11.	https://www.sovon.nl/
Figure 12.	http://spreeuw.sovon.nl/#telling
Figure 13.	Dickinson et al (2010); page 154
Figure 14.	Roy et al (2012); page 55
Table 1.	Bonney, et al (2009a); page 17

6 APPENDIX: CS PROJECT EXAMPLES

This appendix provides short descriptions of a selection of interesting and successful CS projects where participants are asked to score photographic and/or sound material.

Snapshot Serengeti

Primary aim: Understanding how competing species coexist is a fundamental theme in ecology with important implications for food webs, biodiversity and the sustainability of life on Earth. Much of our current research focuses on how carnivores coexist with other carnivores, herbivores coexist with other herbivores and the joint dynamics of predators and their prey. These insights will guide strategies for species reintroduction, conservation and ecosystem management around the world.

Photographic material: 255 camera traps spread across Tanzania collecting photographic material of passing animals which trigger motion sensors.

Project definition: Participants are asked to answer a couple of questions about camera trap photos taken in Tanzania. Which species or multiple species is/are present on the photo, how many individuals can be counted of each species on the photo and what's their activity? A database of potential species is shown besides the data entry screen in which participants can easily scroll through to find out what's on the picture.

Successes: In total three papers have been published containing data retrieved from their website. The last publication (Swanson, A. (2014) Living with lions: spatiotemporal aspects of coexistence in savannah carnivores) used data about large carnivores to conduct research on how they manage to coexist with each other.

Link: http://www.snapshotserengeti.org/

Seafloor Explorer

Primary aim: Using data from Seafloor Explorer we can now begin to build training sets of images and data that will provide the foundation for automated machine vision approaches to target classification from HabCam (Habitat Mapping Camera System) images. These tools must be developed if the untapped wealth of information available in optical imagery is to be fully realized in Ecosystem Approaches to Management and understanding Essential Fish Habitat.

Photographic material: By using the HabCam, a cabled optical and acoustic imaging system, hundreds of high resolution photos have been taken from the ocean floor in the eastern USA.

Project definition: Participants of this project are asked to examine pictures of the ocean floor and pinpoint organisms and sediment structure on each photo. Besides counting and defining, the length of each organism needs to be measured using simple tools. Explanation of the organisms is shown in a guide and a tutorial tells the participants what and how to do their job.

Successes: Until now, 93% of the total amount of images have been examined by participants. Some preliminary results are shown on the project's blog.

Link: http://www.seafloorexplorer.org/

Plankton Portal

Primary aim: Plankton are a critically important food source. No plankton means no life in the ocean. Plankton also play an important role in the global carbon cycle. This cycle captures Sun's energy and the atmosphere's CO_2 at the surface of the ocean and releases it to other organisms and other areas of the ocean. Understanding where and when plankton occur at different depths in the ocean allows scientists to get a global understanding of the function and health of the ocean from small to global scales.

Photographic material: Photos are made by ISIIS (In Situ Ichthyoplankton Imaging System) which moves through the water and takes samples of sea water. This is photographed and stored in a database.

Project definition: Participants are asked to measure all the different species of plankton visible on the photograph by measuring the height and width of the organism. After measuring, participants are asked to identify the species of plankton by showing a couple of figure groups. This guide is extensive and helps identifying the different species of plankton.

Successes: The project is still up and running and already reached over half a million of classifications in April 2014.

Link: http://www.planktonportal.org/

Floating Forests

Primary aim: By providing classifications of changes in kelp canopy cover over the past 30 years on global scales, this project will identify regions where kelp forests have experienced significant long-term changes. We will then identify the likely environmental and human drivers of these observed changes.

Photographic material: The photos have been and are taken by the Landsat satellite every 16 days from 1984 on. These photos show the coastline with visible kelp forests in Southern Australia and California.

Project definition: The project focuses on showing satellite images of coastlines with potential kelp forest densities. Participants are asked to, when visible, encircle the kelp forests with a polygon. Furthermore, participants are asked to pinpoint cloudy and faulty images so they can be deleted from the database.

Successes: The project is still up and running. Until now, almost 980.000 classifications have been done by about 2.700 participants.

Link: http://www.floatingforests.org/

Notes from Nature

Primary aim: For the information held in these collections to be used to its full potential there must be better digital access to these data. Most natural history collections are housed in museum cabinets, where they are not easily available to citizens and researchers. Only a small fraction of all natural history specimens is available digitally on the Internet, while the vast majority remains locked away from view in an inflexible, limited format.

Photographic material: The photos are taken from huge collections of birds, plants, insects and fungi. On each photograph, the specimen and several information tags are visible.

Project definition: Participants are asked to join one of the four collections in the project: insects, plants, birds or macrofungi. In each collection, photographs will be shown to the participants who needs to transcribe the information tags, like location, date and ID.

Successes: The projects are still running with over 200.000 transcriptions completed for plants, over 400.000 for insects, over 12.000 for birds and over 55.000 for fungi.

Link: http://www.notesfromnature.org/

Ancient Lives

Primary aim: The data gathered by Ancient Lives will allow us to increase the momentum by which scholars have traditionally studied the collection. After transcriptions have been collected digitally, we can combine human and computer intelligence to identify known texts and documents faster than ever before. For unknown documents, we can isolate them and begin the long process of identification.

Photographic material: From each piece of papyrus, a photograph has been made which will be presented to the participants. On these photographs, old notes are written in old languages.

Project definition: Participants are asked to take a look at pieces of papyrus and try to identify individual characters. Besides identifying what's written on the paper, the measurements of the piece needs to be defined as well. A clear guide is available on how participants need to identify each character.

Successes: Nothing mentioned on the website, but the project is still running.

Link: http://www.ancientlives.org/

Old Weather

Primary aim: The climate data will be processed by our team at the Met Office and NOAA and eventually contributed to international databases of historical weather records. These are used to test our computer models of the climate - leading us from the weather's past to understanding the future of the climate.

Photographic material: The photographs are made of logbook entries, written down by captains on their voyages. These logs consist of ship bearing, weather aspects, sightings, etc.

Project definition: Each participant is asked to transcribe a certain data log entry. Information such as location, date, refuelling timing, sightings, weather and many more are asked to be transcribed. Eventually, these transcriptions should help out in receiving knowledge about historical weather types.

Successes: Until now, 44% of all the logs have been transcribed, which is about 70.000 pages of data log entries.

Link: http://www.oldweather.org/

Whale FM

Primary aim: The communication of killer whales and pilot whales is still poorly understood. While we know for some species the general context in which sounds are made (reproduction, contact calls for finding each other) many of the calls remain a mystery to us. To properly understand the implications of these responses, we need to know more about why and when animals make specific calls.

Sound material: The sounds made by Pilot Whales and Killer Whales are collected by the Delphinus hydrophone, dragged behind a boat to record underwater sounds.

Project description: Participants are asked to match a particular whale sound to another whale sound in the database. A guide with different sounds will help to find the perfect match. A tutorial is available for starting participants in which the project is explained.

Successes: Nothing mentioned on the project's webpage, but the project is still running.

Link: http://whale.fm/

Bat Detective

Primary aim: Humans are absolutely fantastic at hearing and seeing the difference between a bat and a non-bat call, the different types of calls and what sequence a call belongs in. We need your help going through our recordings to pick out the different calls. The ultimate goal is to use your classifications to make a new automatic programme that researchers all over the world can use to extract information out of their recordings, making it really easy to track populations of bats. This will make understanding how bat populations are being affected by global change much easier.

Sound material: The bat sounds are recorded by using a bat detector. These devices can pick up the highest pitches of sounds and are able to produce sonograms.

Project description: Participants are asked to examine a sound recording and identify each sound separately. When a certain sound is separated, participants are asked to define whether it's a bat, insect or machine sound. In case of a bat, the type of sound needs to be defined as well (searching, social or feeding).

Successes: In May 2014, over 310.000 classifications have been done after 1.5 years by about 2.400 participants online. The project is still up and running.

Link: http://www.batdetective.org/