



QUALITY ASSURANCE INDICATORS FOR ENVIRONMENTAL CITIZEN SCIENCE

DEVELOPMENT OF INDICATORS FOR VOLUNTEER-BASED BIODIVERSITY MONITORING



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ABSTRACT

Volunteer-based biodiversity monitoring schemes are currently developed and tested for feasibility in and for agricultural landscapes in Germany. For the assessment of the effectiveness and efficiency of volunteer-based biodiversity monitoring schemes, indicators are required but so far, such indicators have neither been developed nor tested. Here, sets of indicators are developed and presented based on evidence from scientific literature and from the volunteers' perspectives. As a starting point of the development of indicators, challenges for volunteers need to be identified that may hinder them from taking part in the schemes and from achieving project goals. On the basis of formulated actions to overcome these challenges, three sets of indicators are derived, covering the areas of i) capacity building for volunteer-based engagement, (ii) appreciation and valuing of volunteer commitment, and (iii) education and learning in volunteer-based approaches. Indicators are developed to potentially serve internal and external communication and act as project quality assurance measures. At the same time, the presented indicators may potentially also be applied by decision-makers in policy as well as by funding agencies. In a next step, indicators are co-developed using participatory evaluation approaches to combine conventionally developed indicators with indicators developed with members of the community of practitioners. Implementing indicators in practice as well as regular reflections and revisions will ensure an adaptive quality assurance system for volunteer-based biodiversity monitoring and beyond.

1. INTRODUCTION

1.1 THE SIGNIFICANCE OF VOLUNTEER-BASED BIODIVERSITY MONITORING

The majority of international and national biodiversity monitoring schemes have been established by non-governmental and volunteer-based initiatives and hosted and supported by national and regional NGOs and informed society. Some schemes are supported by academia via infrastructure and personal. Over 80% of biodiversity data on biological diversity (presence, absence, numbers of species of plants and

animals) are gathered by the very heterogenous group of dedicated volunteers (Chandler et al. 2017; Schmeller et al. 2009; Henle et al. 2013). Sets of data collected by volunteers are geographically, as well as taxonomically, fragmented (Pocock et al. 2015a). Some schemes follow strict protocols and generate semi-structured data, others are based on so-called opportunistic data – referring to data that originates from the volunteer's decision about time and location of the observation and the selection of the observed and recorded species (Kelling et al. 2019, Tulloch et al. 2013). Despite the challenges associated with the heterogeneity of biodiversity information (e.g. data and scales) and technical and stakeholder network designs in biodiversity monitoring (Kühl et al. 2019), monitoring of plant and animal species will always rely on the engagement of volunteers with restricted access to areas and regions, time and resources required for monitoring.

Thus, it is one of the greatest challenges to design and perform biodiversity monitoring in such way that the quality and quantity of the biodiversity data and information required by the formalised academic knowledge system are guaranteed. At the same time, the volunteers' personal motivation for participation and engagement in monitoring activity must be acknowledged and considered (Richter et al. 2020, Pocock et al. 2018).

In Germany, approximately 50% of the total area is used for agricultural land use. Therefore, agricultural landscapes play an important role in the conservation of biological diversity. Despite current knowledge that much of the decline of biodiversity is closely linked with the composition and configuration of agricultural landscapes and how these landscapes are managed (Buhk et al. 2017, Burns et al. 2016), most conclusions about the status of biodiversity in agricultural landscapes in Germany are drawn based on a limited set of data and information. For scientifically informed policy decisions (e.g. how to best conserve biological diversity in agricultural landscapes), monitoring schemes of biodiversity are needed to provide reliable information about the status quo of biological diversity and to make informed calls for specific actions for the conservation and rehabilitation of biological diversity. In the framework of developing such a national monitoring scheme of biological diversity for agricultural landscapes (MonViA) in Germany, standardized recording methods and indicators are developed and tested for the performance of trend analyses of the status and development of biological diversity in agricultural landscapes. As monitoring schemes, in general, largely on volunteers, the significance of volunteer-based biodiversity monitoring in the MonViA context is enormous. Current goals of the developed

volunteer-based monitoring schemes are a) to support data-driven trend monitoring schemes by providing complementary sets of data and information on aspects of biodiversity on farms and in rural areas and b) to facilitate learning and participation processes to accompany the transition towards sustainable agriculture.

1.2 AIMS AND OBJECTIVES OF THE INVESTIGATION

Biodiversity monitoring depends on volunteers to willingly initiate and perform tasks involved in monitoring and to openly take part in learning processes in today's and future biodiversity schemes. Therefore, the perspectives of volunteers must be integrated when developing these schemes. This also accounts for the associated development of indicators in volunteer-based biodiversity monitoring, with the purpose of quality assurance in citizen science.

Here, I understand indicators as measures that qualitatively and quantitatively manner progress in projects or programs as well as associated outcomes. Indicators for volunteer-based monitoring of biological diversity in agricultural landscapes will have communication, moderating and regulating functions. First and foremost, they are developed as tools to assess how effective the schemes are coordinated and how successful processes and outcomes are communicated. In the context of assessing the communication, indicators contribute to a factual discussion about the concrete outcomes and outputs of the monitoring scheme. In the sense of a regulating function, indicators allow to objectively assess the achieved volunteer-based monitoring results as well as tools for recording any changes within the monitoring.

The aim of this investigation is to develop sets of indicators for volunteer-based biodiversity monitoring for use by the community of practitioners, serving as infrastructure for future biodiversity monitoring schemes in agricultural landscapes. In this context, the following questions are addressed:

- What are the factors that prevent volunteers from or motivate them to engage in biodiversity monitoring?
- What are the challenges when it comes to achieving goals in biodiversity monitoring?

- What kind of actions are needed to make volunteer engagement easier?
- How can these actions be measured to report and to communicate the success of volunteer-based biodiversity monitoring?

1.3 BACKGROUND: THE MISSING PERSPECTIVE AND LINKS

For Citizen Science - as an approach of voluntary engagement in scientific projects in compliance with scientific standards (Bonn et al. 2017) - quality criteria ensuring and promoting the quality of citizen science projects are in place (Heigl et al. 2018). Criteria are used particularly to determine if a citizen science project is suitable for national online networks (e.g. Österreich forscht, Bürger schaffen Wissen). Criteria are developed from the perspective of the network initiators who apply unified quality criteria to ensure high standards of the network. Criteria such as the ten principles of citizen science are developed from the perspective of the citizen science community. Here, they serve as guiding principles for the design and implementation of citizen science projects (Robinson et al. 2018). For biodiversity networks supported by citizen science, Vohland et al (2016) developed success criteria for networks and identified success as an intersection of program quality, quantity, and accessibility. These criteria were developed from the perspective of project and program initiators and integrate quantitative and qualitative measures. In contrast, the work by Kiesslinger et al. (2018) on the evaluation of citizen science proposes the evaluation of citizen science programs on three main dimensions of participatory scientific processes. These dimensions include i) scientific impact of the project, (ii) learning and achievement of qualification of individual participants as well as (iii) recording the impact on society. The evaluation framework developed by Kiesslinger et al. (2018) integrates science and social science perspectives and is developed from the perspective of citizen science funders and supporters as a tool for informed decisions.

The basis of citizen science builds upon cooperation between volunteers and members from academia. In some cases, the activity is performed without any involvement of science. Any citizen science project depends on the engagement of people and it would be impossible without the interest of people in project topics and their commitment. Volunteers spend their personal time on the project, they devote energy to the tasks associated with it, and share the knowledge derived from the activity. As a consequence, it seems indispensable to re-think the development of indicators to assess the project success from the volunteer's perspective.

Central to this is an understanding about the role of group tasks, such as being part of a group of like-minded people that voluntarily observe and record plant and animal species. Research shows that group tasks rely in large part on individual willingness (Eddy-U 2015). Personal willingness affects the motivation related to the group tasks, whereas the motivation is affected by the task attractiveness as well as by the task feasibility. Both, social factors (e.g. those associated with individual needs and conditions) and task-related factors, impact personal willingness and consecutively the (non) motivation of group tasks (Figure 1).

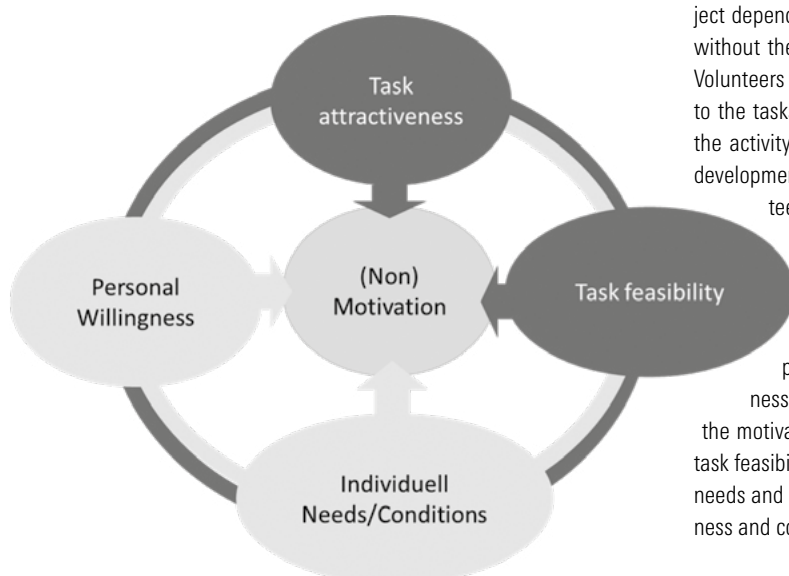


Figure 1: Schematic illustration of the interactions of social factors (yellow) and task-related factors (blue) impacting personal willingness and (non) motivation for group tasks. The interrelatedness of the factors is indicated by the two-colored circles. Figure modified and adapted from Eddy-U (2015).

In the construct of interactions of social factors and task-related factors impacting personal willingness and (non) motivation for group tasks, the factor of volunteer recruitment needs consideration. In the practice of citizen science, citizen science managers and coordinators apply recruitment-, communication- and engagement strategies to ensure that volunteers are satisfied with their volunteer experience and maintain motivated to take part in citizen science (Clary et al., 1998; Ng et al., 2018). This becomes particularly important when international schemes are desired for long-term monitoring to assess global biodiversity (Richter et al. 2021).

2. METHODS: THE STEPS INVOLVED IN THE DEVELOPMENT OF INDICATORS

Indicators are developed for application in volunteer-based monitoring approaches; based on barriers and challenges participants encounter when engaging in ecological and environmental citizen science. The term ecological and environmental citizen science is used as an overarching theme to cover the diversity of approaches in ecological and environmental citizen science projects (Pocock et al. 2017), including systematic and non-systematic monitoring (Pocock et al. 2017). It is acknowledged that much knowledge exists about the opportunities and potentials of ecological and environmental citizen science (Turrini et al. 2018, Brown and Williams 2019, Pocock et al. 2017). However, this work presented here deliberately focuses on the barriers and challenges faced by participants in ecological and environmental citizen science to capture their real-life challenges and experiences.

In the first step, sets of reasons hindering or enabling citizen and stakeholder engagement in agricultural research were identified at the first Thünen-Citizen Science Conference in 2020 (Richter et al. 2020). The lunch to lunch conference entitled "Citizen Science—New Participation Format for Research in the Agricultural, Forestry, Fisheries and Rural Areas" took place in March 2020 in Braunschweig. More than 30 participants from the Thünen Institutes and partner organizations with an interest in learning more about citizen science to add to their experiences in participatory research in rural areas took part in this conference.

Four rounds of roundtable discussions were set up to discuss challenges in contemporary participatory research and citizen science in the context of agricultural sciences. At each table, key questions guided the discussions that were moderated and recorded. The main points of the discussion were transcribed verbatim using posted notes. A person who was not participating in the round table recorded the main statements from the discussion. All information gathered was analyzed thematically. Participants were asked to report on their experiences and research findings related to participants' viewpoints for voluntary participation in research.

In the next step, a scoping literature review was performed in the order of the following steps: identification of relevant studies and selection of literature and collection of information, and reporting of the results. The process was adopted from the five-step approach presented by Arksey and O'Malley (2005). The search strategy included a literature search using combined keywords derived from the roundtable discussion (e.g., citizen science AND challenges, personal barriers AND citizen science).

Also, I applied keyword searches on terms e.g., species skills taxonomy, identification skills volunteers, and understanding concept biodiversity. The search was performed in German and in English using online literature platforms Google Scholar and "Web of Science". The search applied a forward and backward snowballing procedure. The well-established method is suitable for identifying important articles relevant to a topic of interest and implies both, finding citations to a paper and findings citations in a paper (Jalali & Wohlin, 2012). The output of this step is a catalog of factors hindering participation and associated literature supporting these factors from studies about volunteer commitment.

In the third step, actions were formulated to overcome hindering factors for volunteer commitment. For this, all factors were coded using six categories previously identified in step 1. The development of categories was in line with the approaches and levels of participation as outlined in the Green Book for the German Citizen Science Strategy 2020 (Bonn et al. 2016). From here, for each factor actions were identified or, in case the action was already listed, added as a factor to that action. This way, a list of actions and linked factors was developed.

In a final step, qualitative and quantitative indicators were derived for the prioritized actions and presented as sets of indicators. The development of indicators followed the guidelines for a consolidated Citizen Science Impact Assessment framework (When et al. 2021). The six guiding principles were adapted towards a participant perspective and identified barriers to participating in citizen science-based monitoring of biological diversity. The indicator development acknowledged the variety of purposes of indicators and the importance of qualitative as well as quantitative measures. Also, the need to apply indicators across citizen science projects and the purpose of further developing and testing the indicators using mixed approaches were acknowledged. The output of this step is a set of indicators related to pre-identified actions required to overcome the barriers to participation.

3. FINDINGS

At the roundtable discussion, several factors were identified that hinder participation in citizen- and stakeholder engagement in agricultural research. Factors considered as barriers are: "lack of knowledge", "lack of digital know-how", "insufficient digital infrastructure to use applications for recording biological diversity", "lacking spare time" as well as "missing access, e.g., to initiatives originated by academia". Further, the factor "receiving appreciation for the engagement and participation" is still not adequately honored in society and is considered a barrier to participation.

The findings from the roundtable discussion identified social and task-related factors affecting the participation. The literature search identified further social-related factors and complemented the list of factors derived from the roundtable discussion (Table 1). When grouping the factors, it became clear that factors cover aspects of people's challenges (eight factors) and also challenges associated with biological monitoring (five factors). Further, five factors were identified that can be grouped into the category of societal challenges. The analysis made clear that a connection exists between barriers and challenges and the achievement of the aims and objectives of a project or scheme, as well as related outputs (Table 1).

Categories	Factors challenging participation	Literature
People (FP)	Age, ethnic imbalance	Theobald et al. 2015, Burgess et al. 2017, National Academies of Sciences, Engineering, and Medicine. 2018, Statistica 2018
	Insufficient knowledge about the possibilities to participate	Moczek et al., 2018, Ockenden et al., 2007, Unell et al., 2012
	No time capacities	O'Brien et al., 2010, Freiwilliges Engagement in Deutschland (2001)
	No interest or motivation	Walz et al., 2012
	No interest in volunteering	Freiwilliges Engagement in Deutschland (2001)
	Taxonomic species knowledge	Frobel and Schlumprecht 2014
	Voluntariness	Penner, 2002
	Insecurities in dealing with other people	Walz et al., 2013, Moczek et al., 2018
Biological Diversity (FBD)	Plants and animal species are difficult to identify and ways of learning how to identify them are needed	Mitlacher and Schulte (2005)
	Habitat structures are difficult to identify and to assess	Mitlacher and Schulte 2005
	Unfamiliar with the concept of biodiversity	Hunter and Brehm 2003, Lindemann-Matthies and Bose 2008, Fiebelkorn and Menzel 2013
	Recording exclusively via habitat structures/technologies and no direct contact/lack of emotional connection with the actual object	Schemel 2008
	Erosion of taxonomists	Frobel and Schlumprecht 2016
Societal factors (FSF)	Lack of recognition and feedback within the community	Walz et al.; 2013
	Lack of recognition and feedback within the community	Bonney et al., 2009
	Lack of community and communication within the community	Moczek et al., 2018, Ryan et al.; 2001
	Prioritizing other voluntary activities (sports, culture, digital)	Frobel and Schlumprecht 2016
	Discrimination and degradation of social status	Behlau 2002, Trommer 2015
Generation of knowledge (FKG)	Incorrect or no knowledge about biological diversity	Schulemann-Maier et al., 2018
	No appreciation of knowledge as common property to be used by many	Ostrom 2011
Learning & Understanding (FLU)	Different learning types and motivations	Schulte et al., 2019
	Insufficient transfer of knowledge about biological diversity	Moczek et al., 2018
	Specific learning vs. process-oriented learning	Moczek et al., 2018
Active participation (FTT)	Concern about no "real" participation (pseudo-participation)	Kubicek et al., 2009
	Personal restrictions	Freiwilliges Engagement in Deutschland (2001)

Table 1: Overview of categories and associated factors (with codes) related to challenges in participation found in literature.

Goals, as identified by Turrini et al. (2018) as the threefold potentials in environmental citizen science, include the generation of new knowledge, learning, and understanding as well as active participation (Figure 2). Seven additional factors were identified that affect the achievement of goals and outputs in environmental citizen science (Table 1). In total, a catalogue of 25 factors was identified that hinder participation in citi-

zen science-based monitoring and environmental citizen science from a volunteer perspective.

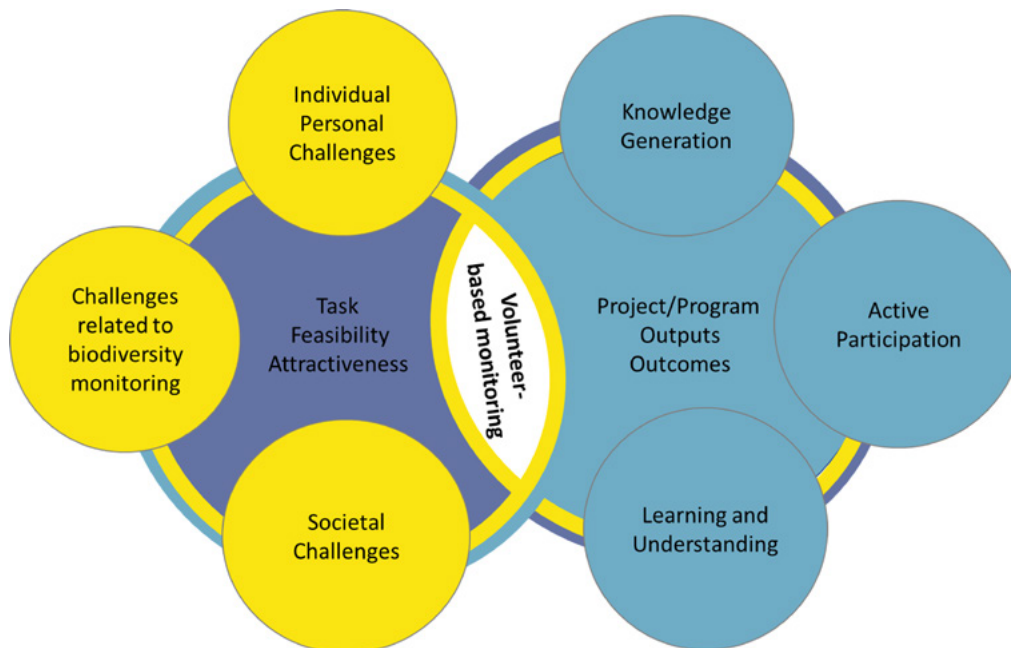


Figure 2: List of social factors (yellow) and task-related factors (dark blue) that impose a challenge to participation as well as to achieving outcomes and outputs in environmental citizen science and in volunteer-based biodiversity monitoring (light blue). The interrelatedness of the factors is indicated by the coloured circles.

3.1 INDIVIDUAL FACTORS THAT CONSTITUTE CHALLENGES AND BARRIERS FOR VOLUNTEERS TO PARTICIPATE IN ECOLOGICAL AND ENVIRONMENTAL CITIZEN SCIENCE

First and foremost, the lack of interest or motivation refrain people from engaging in ecological and environmental citizen science. In fact, Walz et al. (2013) show that lack of interest and no motivation are the greatest challenges when it comes to recruiting people for voluntary nature conservation. In Germany, nearly 40 percent of residents aged 14 and older are engaged in some kind of voluntary work. However, a large proportion of the population is not involved in any voluntary work (Freiwilliges Engagement in Deutschland 2001). 3.5% of all active volunteers engage in nature conservation activities (Moczek 2019).

Key factors affecting voluntarism include personal circumstances and individual attributes such as age, social, educational, and economic status, along with the kind of associated organization and communication within organizations (Penner 2002). For those interested in volunteering work, factors such as having no time capacities to engage in nature conservation activities (O'Brien et al. 2010), and recent shifts in the amount of time available for volunteer engagement, are identified as important barriers for engagement (Freiwilliges Engagement in Deutschland 2001). Today, volunteers in Germany generally spend less time on voluntary activities than they did fifteen years ago. Between 1999 and 2014, the number of volunteers who devote six hours or more per week to voluntary activities decreased. In contrast, the proportion of those spending up to two hours a week increased by 58 percent (Freiwilliges Engagement in Deutschland 2019).

In some cases, people do not participate in voluntary activities due to a lack of knowledge about existing opportunities to do so. Recent re-

search on how people learn about such opportunities in environmental citizen science shows that it is most effective to recruit people in conservation projects via personal communication (Ockenden et al. 2007, Unell et al. 2012). For example, more than half of the participants in the BUND Wildcats Project found out about the project through personal contacts between project coordinators, friends, and/or via family members (Moczek et al. 2018).

Some people distance themselves from community activities because they do not feel confident dealing with other people (Walz et al. 2013). Some people consider mutual exchange of knowledge, skills, and experience between citizens and scientists the greatest added value of citizen science projects (Moczek et al. 2018), others want to gain competencies in leading rounds of discussions and resolving conflicts and, thus, overcome their insecurity to talk and discuss with other community (Walz et al. 2013).

Another individual factor hampering engagement is the imbalance within the group of participants in many environmental citizen science programs. Demographic analysis in the US shows that predominantly male, white (88.6% in biodiversity projects), well-educated people participate in citizen science. In addition, they often tend to have previously participated in other projects (Theobald et al. 2015, Burgess et al. 2017, National Academies of Sciences, Engineering, and Medicine. 2018).

For Germany, less information about demographic variables in volunteers is available. However, census data show that one third of all volunteers in Germany are retirees, with around 23% of German volunteers being older than 70 years (Statistica Report 2018). Analysis of citizen science projects in Germany in the Humanities and Social Science by Göbel et al. (2020) showed that people engaged in these projects are predominantly males over 50 years of age, with an academic background. Moczek et al. (2021) presented similar findings for citizen science in the

Natural Sciences: again, the community is male-dominated and highly educated. In conclusion, participants in many citizen science projects do currently not represent the diversity of citizens. This imbalance may hold back participation of those sharing other characteristics.

3.2 MONITORING OF BIOLOGICAL DIVERSITY-SPECIFIC FACTORS CHALLENGING VOLUNTEERS TO PARTICIPATE IN VOLUNTEER-BASED MONITORING APPROACHES

Volunteer engagement in monitoring schemes is associated with several factors. One of the greatest challenges is to get in contact with monitoring schemes that focus on biodiversity. Numerous empirical studies showed that people are not familiar with the concept of biological diversity (Hunter & Brehm 2003, Lindemann-Matthies & Bose 2008, Fiebelkorn & Menzel 2013). Another barrier, inherent to monitoring of biological diversity, is the fact that plant and animal species, which build the foundation of biological diversity, are highly diverse and difficult to identify. Mitlacher & Schule (2005) showed that NGO members saw great need for educational units to increase methodological competencies for species identification and species observation. This is accompanied by a high demand for courses for qualification in species and biotope protection, nature conservation law, and participation procedures (Mitlacher & Schulte 2005). Thus, limited knowledge and confidence may also hamper engagement in monitoring.

Nowadays, many biological diversity observations and recordings are carried out with the help of digital technology or are performed completely disconnected from nature (e.g. photo ID tasks of camera trap pictures). Schemel (2004) found that missing emotional contact with the original object of interest may lead to negative motivation for participation in nature conservation. Therefore, in order to maintain a high motivation for voluntary commitment in nature conservation, a strong emotional bond with nature is necessary (Schemel 2004).

Finally, our findings show that the erosion of taxonomists over the past 20 years (Frobel & Schlumprecht 2016) also act as a challenge for participation in monitoring schemes. Awareness these schemes is often raised by people who are skilled, highly knowledgeable and enthusiastic about biological diversity. Without experts and mentors of taxonomy that slowly draw particularly young people's attention to species identification, and to methods in monitoring of biological diversity, and who share their expertise and knowledge, access to these schemes is also prevented.

3.3 ADDITIONAL FACTORS CHALLENGING VOLUNTEERS TO PARTICIPATE IN ENVIRONMENTAL CITIZEN SCIENCE

I found several other factors to affect the conditions for volunteer engagement in environmental citizen science. These factors include low societal appreciation for volunteer engagement, the absence of a community of like-minded people as well as the fear of discrimination and social degradation due to volunteering in environmental citizen science.

In their German-based studies, Behlau (2002) and Trommer (2015) describe that specifically young people engaged in environment and nature conservation are referred to as "Ökos (a negative narration derived from the word ecologist, freely translated as "tree huggers"). Young people

with an interest in nature conservation are often perceived as outsiders and considered "uncool". This form of discrimination and the fear of being labeled are presumably putting young people off volunteering in environmental citizen science.

Also, lack of societal recognition for engagement, in the sense of a culture and recognition of volunteering at various levels, together with missing feedback from within the community, is expected to affect people's interest in environmental citizen science. A German-based survey showed that recruiting young people for voluntary nature conservation was mainly challenged by the self-assessed lack of recognition by society (Walz et al. 2013). Nearly half of the respondents feel that their work is not sufficiently appreciated by the public and media. None of the interviewed environmental associations felt sufficiently valued by national, regional and local politics (Walz et al. 2013).

Interestingly, Bonney et al. (2009) showed that participant numbers in eBird tripled after a re-design of the platform. After the make-over, participants were able to access their data and to discuss them with others. In addition to an increase in appreciation from within the community, Moczek et al. (2018) and Ryan et al. (2001) showed that personal contacts among members also promote volunteer engagement. Not only are these contacts important in order to learn about the project, but social factors such as assembling, meeting and sharing information as well as experiences are also decisive for long-term volunteer engagement.

I should also consider the external factor of a shift of interests. Frobel and Schlumprecht (2016) recognized that the behavior of young people and, in particular, the way how they prefer to spend their leisure time have changed. Nowadays, young people spend much of their spare time using digital technologies and social media. The authors consider these trends "a distraction" from spending time outdoors and missed opportunities, e.g. to observe and record species.

In total, I found a comprehensive set of factors challenging the engagement of people in environmental citizen science and volunteer-based monitoring approaches. Factors that cover individual reasons are predominantly and complemented by factors specific to monitoring activities as well as by external factors adding pressure on individual decisions, interests, and positions towards volunteered engagement.

3.4 ENVIRONMENTAL CITIZEN SCIENCE-RELATED FACTORS CHALLENGING THE ACHIEVEMENT OF PROJECT GOALS

Individual factors affecting the engagement of the volunteers are closely related to factors challenging the achievement of project goals and objectives in environmental citizen science. Here, I present and assess challenges for the three main goals in environmental citizen science: (1) the generation of knowledge, (2) learning and understanding, and (3) participation.

Incomplete and/or incorrect data on biological data and a lack of interest to acknowledge local and regional knowledge domains as common goods are considered great barriers for the generation of new knowledge in biodiversity. Schulemann-Maier et al. (2018) found that many active nature enthusiasts lacked knowledge of species (e.g. taxonomic identification). Interestingly, the knowledge deficient in species identification was not fundamentally different between volunteers and experts (Schulemann-Maier et al. 2018). The authors conclude that experiences and the status of being an expert does not necessarily lead to better identification skills in species; both groups can misidentify species.

Further, Ostrom (2011) highlight the importance of recognizing knowledge as a common good. People hold all kinds of formal and informal knowledge, but only if this knowledge is freely available and accessible, can it be used by science, policy and society members.

Also, I found that the achievement of learning and understanding goals in environmental citizen science projects is made difficult due to different types of learners, various motivations for learning, inadequate communication and teaching of biodiversity knowledge as well as various kinds of learning (goal-oriented versus process-oriented learning). Schulte et al. (2019) state that learning about species diversity is made particularly effective by informal settings (e.g. outside a school context) and by mentor-mentee relationships. Moczek et al. (2018) conclude that learning and understanding should focus on subjects of learning in need and on demand. Participants indicated that they specifically needed to improve their theoretical ecological knowledge, research methods, and taxonomic identification (Moczek et al. 2018).

When it comes to achieving the goal of enabling participation, I identified the following challenges identified relevant from a volunteer's perspective: denial of access to participation, concerns about no "real" participation (pseudo-participation), personal restrictions, and mistrust in environmental sciences (Kubicek, Lippa & Westholm 2009, Bundesfreiwilligen Survey 2017). As previously stated, volunteering opportunities are unevenly distributed. Social and personal resources are required to access voluntarism. Most importantly, engagement needs to be compatible with other tasks and obligations such as family or/and work-related responsibilities (Bundesfreiwilligen Survey 2017).

Overall, the most important condition for any kind of cooperation is a trustful relationship. Without trust, no cooperation can take place. Thus, positive and/or negative volunteering experiences affect present and future engagement. Although public mistrust in science is not a novel phe-

nomenon (Braun 1999), this might be still a common barrier for people's interest in science participation.

At this point, I acknowledge that all identified factors lack details related to actors in agricultural landscapes. Both, the approach of ecological and environmental citizen science, and specifically volunteer-based monitoring of biodiversity in agricultural landscapes, have only recently been applied in agricultural landscapes. Most recent research in this domain reveals the promises of citizen science as an innovative approach to participation in research (Gavel et al. 2020, Ryan et al. 2018) but less on why farmers or hunters participate or fail to appear in environmental citizen science. Thus, the basis of the indicator development, namely the factors, must be revised, and adopted accordingly with and by the community of practitioners in the future, hand in hand with the development of environmental citizen science and monitoring of biological diversity in agricultural landscapes.

3.5. IDENTIFICATION AND EVALUATION OF ACTIONS TO OVERCOME THE CHALLENGES

Based on the identified factors, I recommend the implementation of six actions (A1-A6) for short- and medium-term for volunteer-based monitoring of biological diversity (Table 2). From the six actions integrated into A2 as educational and learning aspects are integral parts of BioBlitzes and in program-orientated citizen science. From this matrix, three main actions are prioritized for the derivation of qualitative and quantitative indicators. These final actions are: 1) the development of capacities for volunteer-based monitoring of biological diversity, 2) recognition, and appreciation for those involved in these schemes, and 3) development of educational and learning modules about biological diversity monitoring.

actions to overcome the challenges for volunteer participation

	Description of the action	Linkages to identified factors
A1	Implementation of actions to develop capacities for volunteer-based monitoring of biological diversity to establish opportunities for voluntary engagement and participation in ecological and environmental citizen science projects linked to monitoring activities	FP1, FP2, FP3, FP6, FSF1, FSF2, FSF3, FSF5, FAP1, FAP2, FAP4
A2	Development and implementation of event-based citizen science (Bioblitz), project-oriented citizen science (project) and program-oriented citizen science (monitoring) considering target group-specific requirements and anticipated outcomes	FP1, FP4, FP5, FP6, FP8, FBN1, FBD2, FBD3, FSF2, FSF3, FSF4, FKG1, FLU1, FLU2, FAP2, FAP4
A3	Expansion of existing networks of people and groups of people (clubs, associations) as well as establishment of new partnerships between members from academia and volunteers in the field of biodiversity research	FP2, FP4, FP5, FP6, FP9, FBD3, FSF1, FSF2, FSF3, FSF5, FW2, FLU2, FLU3, FAP1, FAP2, FAP4
A4	Development and implementation of educational and learning modules on biological diversity	FP6, FP9, FBD1, FBD2, FBD3, FBD4, FSF6, FKG1, FKG2, FLU1, FLU2, FLV3, FAP4
A5	Development of tools to improve competencies of monitoring methods and species identification and skills in project communication and management	FP7, FBD1, FBD2, FKG1,
A6	Development of recognition and appreciation mechanisms for voluntary work in monitoring biological diversity	FP1, FP4, FP5, FP8, FBD5, FSF1, FSF2, FSF3, FSF4, FAP2

Table 2: Overview of formulated, actions A4 and A5 may be . The right column shows the links to the factors identified in Table 1 (Suppl. Material) based on a coding system.

3.6. SETS OF INDICATORS FOR VOLUNTEER-BASED BIODIVERSITY MONITORING

Personal responsibility and a feeling of “ownership” by all members involved are central to the development of capacities for volunteer-based monitoring. Thus, capacity development is based on appropriate investments in people, facilities, practices, and partnerships. In the process of indicator development, two main questions are taken into consideration: “capacity for what?” and “capacity for whom?” (Mizrahi 2004). Here, I propose the following set of indicators to determine the success of capacity development for volunteer-based monitoring of biological diversity (Richter et al. 2016).

SET 1:

Indicators for the assessment of achieving capacity development

- Number of identified and voluntarily involved actors in a volunteer-based monitoring activity
- Ratio of active and non-active volunteers
- Compliance with actors involved in the schemes on the resources needed for the implementation of the activity
- Level of visibility of processes regarding development of joint visions and action plans Number of supporting resources developed for the design and implementation of monitoring activities
- Number of internal and external communication measures as well as support resources such as guidelines and handouts
- Quality of communication and organisational measures
- Rates of consultations and advices integrated in the scheme
- Level of participation according to project objectives and participants demand
- Number of developed and implemented Citizen Science-based projects
- Extent of evaluations of these projects in respect to scientific results and influences on social, economic, and environmental levels

Recognition and appreciation in and for volunteer engagement are essential variables for motivation and an integral part of planning and implementation of all volunteer-based monitoring schemes. Projects and their results, as well as those involved in the projects, must be made visible and recognizable, both internally and externally. At the individual level, existing networks and established partnerships build opportunities for exchange and getting to know each other. The following set of indicators is proposed for the establishment of a culture of appreciation of voluntary participation in ecological and environmental citizens science as well as for volunteer-based monitoring schemes.

SET 2:

Indicators for the assessment of recognition and appreciation actions

- Number of network meetings, workshops, and opportunities for encounters and exchanges for those involved in the schemes
- Quality of professional interaction with involved actors, e.g. preparation planning for network meetings, appropriate locations, language and target group-specific contents
- Named volunteers (in relation to total number of volunteers) in presentations of the projects, e.g. in media reports, publications, and social networks
- Number of established networks
- Quality of established partnerships and collaborations
- Quality of instruments of recognition

Education and learning are integral parts of ecological and environmental citizen science and are recommended also for volunteer-based monitoring projects. I propose the following indicators to assess the quality and quantity of educational and learning modules about biological diversity in agricultural landscapes.

SET 3:

Indicators for the assessment of educational and learning actions

- Number of educational units with a focus on the concept(s) of biological diversity
- Number of educational units for the knowledge transfer of biological-ecological systems in the context of socio-economic relations
- Quality of educational units
- Number of target group-specific educational units for species identification and learning tools for gaining competencies in monitoring methods
- Number of participants in educational and communication units
- Level of evaluation of education and learning units about applicability and impact

CONCLUSIONS AND NEXT STEPS

The proposed sets of indicators for volunteer-based monitoring are considered as quality assurance features and for the application as tools to qualitatively and quantitatively measure progress and processes in event-based citizen science (e.g., BioBlitz), project- or program-oriented monitoring of biological diversity. Although initially developed for the purpose of application in the context of biodiversity monitoring in agricultural settings, throughout the investigation, it became evident, that a knowledge gap exists regarding volunteer and stakeholder engagement in ecological and environmental citizen science in agricultural landscapes. The practice of citizen science slowly takes place in agricultural settings and much of the potential of citizen science is yet to be explored

in the context of agricultural research. It seems inevitable that research about reasons why e.g., farmers and agronomists are motivated or less willing to take part in the recording of pollinator species in comparison to researchers and volunteers (Garratt et al. 2019) is needed. Understanding motives and/or the lack of motivation for participation in citizen science-based monitoring by actors of the agricultural landscapes is vital for the success of any future biodiversity monitoring scheme. As a consequence of the current limited information, the presented indicators are not restricted to agricultural landscapes. They are applicable in a more general context in citizen science-based monitoring activities.

Another caveat of the study relates to the fact that findings from the conference and the literature are predominantly reported from experiences and studies from the global North. Consequently, it needs to be acknowledged that the proposed indicators and actions may generally apply well in the contemporary global North. However, the majority of the world's farmers reside in the global South, in some worlds unique and diverse hotspots of biodiversity. The design of biodiversity monitoring schemes, internationally and globally, will depend on volunteers and stakeholder contributions across the globe. Therefore, it is important to acknowledge that indicators assessing quality and quantity of e.g., capacity building for engagement of volunteers, volunteer commitment, and education and learning outcomes are essential to any biodiversity monitoring scheme, but their development will be impacted by regional, national, and global differences. Thus, it seems appropriate to expand the methods for the development as outlined in this study. This expansion beyond the conventional approach toward participatory approaches may guide future indicator development for biodiversity monitoring schemes in different contexts.

One final important point to highlight as a restriction of this study relates to referred effects of demographic barriers to participation. As highlighted by Pandya (2012) the lack of participation goes beyond demographical variables of age and ethnic imbalance. The imbalance reflects a mixture of mechanistic and structural barriers such as access to areas and restricted mobility and barriers that are created by the disconnection of norms and values of the research community and the underrepresented community (Pandya 2012). Designing citizen-science programs that align with community priorities are suggested to overcome the imbalance of engaged communities in citizen science.

The development of the three sets of indicators, as outlined here, can be considered a conventional approach in program or project evaluation. In recent years, conventional program evaluations have been complemented by participatory evaluation. The aim of this was to gain wider ownership, create shared responsibility, and become "ethically sound since it involves those who are most directly affected by its outcomes" (Campilan 2000, p.5).

In general, an effective evaluation consists of a mixed-evaluation approach, including conventional evaluation from outsiders as well as participatory evaluation by insiders. This means, it complements the generic goals of program evaluation and serves the needs of project initiators and funders. The next step towards such an integrated mixed-evaluation approach requires the development of indicators for participatory evaluation to assess to what extent capacity, recognition, and appreciation as well as educational and learning goals were achieved in volunteer-based biodiversity monitoring (Zukoski & Luluquisen 2002). The questions outlined before (see section 1.2) may also guide the processes in participatory evaluation. Once participatory-developed indicators for the assessment of specific volunteer-based biodiversity monitoring are developed

on the basis of participatory evaluation principles, all stakeholders can negotiate the indicators. The sets of indicators should be subject to reflection by both the scientific community, and the practitioner's community regarding their suitability for real-life conditions, reliability, and meaningfulness.

Any integrated citizen science-based monitoring requires a permanent assessment whether the needs of the participants are being met. As highlighted by West & Pateman (2016) evaluation and monitoring are essential part of citizen science to assess e. g. the effectiveness of recruitment and retention strategies. This assessment ideally covers many stages of the participants involvement; starting with the decisions to take part in a project to the question of sustained involvement.

Key to success of the schemes is likely the integration of knowledge about the desire to take part as a combination of individual and organization attributes (Penner 2002) and their interlinkages with volunteers' motivation and retention and communication strategies (See et al. 2016, Dickinson et al. 2012). Hobbs and White (2012) identified three main settings for participants' engagement in environmental citizen science. Most importantly for participants engagements are: being aware that the opportunity for taking part in a project exists, the activity is of relevance to the person, and that the person is motivated. Design of the schemes and recruitment strategies need to take this into consideration to succeed with the project.

Communication, as an essential aspect of any citizen science, secures the processes of recruitment and retention of participants (Hecker et al. 2018). Overall, communication enables participants to be and stay informed about the schemes, be and feel connected to members of the schemes, and be empowered as a speaker of issues of concern. Interestingly, the communication of the project results and regular communication on the contributions made by the participants are more appreciated by the participants than any kind of reward (Alender 2016) and secure engagement (See et al. 2016). This is explicitly the case when participants are intrinsically motivated.

In the end, communication affects and is affected by many factors influencing participants' decisions to take part in citizen science at the same time at addressing the needs of both; the participants and the initiators of a scheme. Thus, competencies in communication are inevitable to meet on equal footing.

REFERENCES

- Alender, B.** (2016). Understanding volunteer motivations to participate in citizen science projects: a deeper look at water quality monitoring. *Journal of Science Communication*, 15(3), A04.
- Arksey H, O'Malley L.** **Scoping** (2005). studies: towards a methodological framework. *Int J Soc Res Methodol*. 8:19–32. doi: 10.1080/1364557032000119616
- Behlau, Arno** (2002). Der Wettbewerb "Spots for Nature" Bericht über eine neue, erfolgreiche Kommunikations-Kampagne im Naturschutz, in: *Natur und Landschaft*, Heft 3, Bonn, Seite 122 ff
- Bonn, A.; Richter, A.; Vohland, K.; Pettibone, L.; Brandt, M.; Feldmann, R.; Goebel, C.; Grefe, C.; Hecker, S.; Hennen, L.; et al.** (2016). *Green Paper. Citizen Science Strategy 2020 for Germany*; Helmholtz

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Bonn, A., Richter, A., Vohland, K., Pettibone, L., Brandt, M., Feldmann, R., ... and Vogel, J. (2017). Grünbuch Citizen Science Strategie 2020 für Deutschland.

Bonney, R., Cooper, C.B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K.V., Shirk, J. (2009). Citizen Science: A developing tool for expanding science knowledge and scientific literacy. *BioScience* 59(11): 977-984.

Braun, R. (1999). The Public's Growing Distrust of Science? *Nat Biotechnol* 17, 14. <https://doi.org/10.1038/70359>

Brown, E. D., and Williams, B. K. (2019). The potential for citizen science to produce reliable and useful information in ecology. *Conservation Biology*, 33(3), 561-569.

Buhk, C., Alt, M., Steinbauer, M. J., Beierkuhnlein, C., Warren, S. D., and Jentsch, A. (2017). Homogenizing and diversifying effects of intensive agricultural land-use on plant species beta diversity in Central Europe—A call to adapt our conservation measures. *Science of the Total Environment*, 576, 225-233.

Burgess, H. K., DeBey, L. B., Froehlich, H. E., Schmidt, N., Theobald, E. J., Ettinger, A. K., ... and Parrish, J. K. (2017). The science of citizen science: Exploring barriers to use as a primary research tool. *Biological Conservation*, 208, 113-120.

Burns, F., Eaton, M. A., Barlow, K. E., Beckmann, B. C., Brereton, T., Brooks, D. R., ... and Gregory, R. D. (2016). Agricultural management and climatic change are the major drivers of biodiversity change in the UK. *PLoS One*, 11(3), e0151595.

Campilan, D. (2000). Participatory Evaluation of Participatory Research. Forum on Evaluation of International Cooperation Projects: Centering on Development of Human Resources in the Field of Agriculture. Nagoya, Japan, International Potato Center. <https://web.archive.org/web/20140703095000/http://ir.nul.nagoya-u.ac.jp/jspui/bitstream/2237/8890/1/39-56.pdf> (archived link)

Chandler, M., See, L., Copas, K., Bonde, A. M., López, B. C., Danielson, F., ... and Turak, E. (2017). Contribution of citizen science towards international biodiversity monitoring. *Biological conservation*, 213, 280-294.

Clary EG, Snyder M, Ridge RD, et al. (1998). Understanding and assessing the motivations of volunteers: a functional approach. *Journal of personality and social psychology* 74 (6): p. 1516.

Dickinson, Janis L., Jennifer Shirk, David Bonter, Rick Bonney, Rhiannon L. Crain, Jason Martin, Tina Phillips, and Karen Purcell. (2012). "The Current State of Citizen Science as a Tool for Ecological Research

and Public Engagement." *Frontiers in Ecology and the Environment* 10 (6): 291–297. doi:10.1890/110236.

Eddy-U, M. (2015). Motivation for participation or non-participation in group tasks: A dynamic systems model of task-situated willingness to communicate. *System*, 50, 43-55.

Fiebelkorn, F., and Menzel, S. (2013). Student teachers' understanding of the terminology, distribution, and loss of biodiversity: perspectives from a biodiversity hotspot and an industrialized country. *Research in Science Education*, 43(4), 1593-1615.

Freiwilliges Engagement in Deutschland (2001). Ergebnisse der Repräsentativerhebung zu Ehrenamt, Freiwilligenarbeit und bürgerschaftlichen Engagement. 2. Korrigierte Auflage. Hrsg. Bernhard von Rosenblatt. Schriftenreihe des Bundesministeriums für Familie, Senioren, Frauen und Jugend. Bd. 194.1 <https://www.bmfsfj.de/resource/blob/95018/26609cab3e0f389cb84b97b15b53a2f6/prm-24454-sr-band-194-1-data.pdf> (download Mai 2022).

Freiwilliges Engagement in Deutschland (2019). Zentrale Ergebnisse des Fünften Deutschen Freiwilligen surveys (FWS 2019). Bundesministerium für Familie, Senioren, Frauen und Jugend. <https://www.bmfsfj.de/resource/blob/176836/7dffa0b4816c6c652fec8b9eff5450b6/freiwilliges-engagement-in-deutschland-fuenfter-freiwilligen-survey-data.pdf> (download Mai 2022)

Frobel, K., and Schlumprecht, H. (2014). Erosion of species experts. Final report commissioned by BUND Naturschutz in Bayern eV, Nürnberg.

Garratt, M. P. D., Potts, S. G., Banks, G., Hawes, C., Breeze, T. D., O'Connor, R. S., and Carvell, C. (2019). Capacity and willingness of farmers and citizen scientists to monitor crop pollinators and pollination services. *Global Ecology and Conservation*, 20, e00781.

Göbel, C., Henke, J., Mauermeister, S., and Plümpe, V. (2020). Citizen Science Beyond STEM: Citizen Research in the Humanities and Social Sciences. Institute for Higher Education Research at the Martin Luther University Halle-Wittenberg (HoF)

Hecker, S., Luckas, M., Brandt, M., Kikillus, H., Marenbach, I., Schiele, B., ... and Wende, W. (2018). Stories can change the world—citizen science communication in practice. UCL Press.

Heigl, F., Dörler, D., Bartar, P., Brodschneider, R., Cieslinski, M., Ernst, M., ...and Ziegler, D. (2018). Quality criteria for citizen science projects on Österreich forscht| Version 1.1.

Henle, K., Bauch, B., Auliya, M., Külvik, M., Pe'er, G., Schmeller, D. S., and Framstad, E. (2013). Priorities for biodiversity monitoring in Europe: A review of supranational policies and a novel scheme for integrative prioritization. *Ecological Indicators*, 33, 5-18.

Hunter, L. M., and Brehm, J. (2003). Qualitative insight into public knowledge of, and concern with, biodiversity. *Human Ecology*, 309-320.

- Jalali, S., and Wohlin, C.** (2012). Systematic literature studies: Database searchers vs. backward snowballing. Paper presented at the international conference on Empirical Software Engineering and Measurement, ESEM'12, Lund, Sweden. Retrieved June 10, 2015, from <http://www.wohlin.eu/esem12a.pdf>
- Kelling, S., Johnston, A., Bonn, A., Fink, D., Ruiz-Gutierrez, V., Bonney, R., ... and Guralnick, R.** (2019). Using semistructured surveys to improve citizen science data for monitoring biodiversity. *BioScience*, 69(3), 170-179.
- Kieslinger, B., Schaefer, T., Heigl, F., Dörler, D., Richter, A., and Bonn, A.** (2018). Evaluating citizen science-towards an open framework. UCL Press.
- Kubicek, H., Lippa, B., and Westholm, H.** (2009). Media mix in citizen participation: the integration of online elements into participation processes at local level (Vol. 33). edition sigma.
- Kühl, H. S., Bowler, D. E., Bösch, L., Bruelheide, H., Dauber, J., Eichenberg, D., ... and Bonn, A.** (2020). Effective biodiversity monitoring needs a culture of integration. *One Earth*, 3(4), 462-474.
- Lindemann-Matthies, P. and Bose, E.** (2008). How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland. *Human Ecology* 36, 731-742.
- Mitlacher, G., and Schulte, R.** (2005). Increase of voluntary commitment in nature conservation associations. Federal Agency for Nature Conservation. <https://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/skript129.pdf>
- Mizrahi, Y.** (2004). Capacity enhancement indicators. Review of the Literature. Capacity Development for Improved Water Management, 301 <https://documents1.worldbank.org/curated/en/117111468763494462/pdf/286140Capacity0enhancement0WBI0WP.pdf>
- Moczek N, Hecker S, and Voigt-Heucke SL.** (2021). The Known Unknowns: What Citizen Science Projects in Germany Know about Their Volunteers—And What They Don't Know. *Sustainability*. 13(20):11553. <https://doi.org/10.3390/su132011553>
- Moczek, N.** (2018). Motivations for volunteering in the citizen science project "Wildkatzensprung. *Nature and Landscape* 4-2018.
- Moczek, N.** (2019). Freiwilliges Engagement für Citizen Science-Projekte im Naturschutz: Konstruktion und Validierung eines Skalensystems zur Messung motivationaler und organisationaler Funktionen. Pabst Science Publishers.
- National Academies of Sciences, Engineering, and Medicine.** (2018). Learning Through Citizen Science: Enhancing Opportunities by Design. Washington, DC: The National Academies Press. DOI: 10.17226/25183.
- Ng C.S, Duncan J.R and Koper N.** (2018). Who's "hooting"? Motivations and scientific attitudes of Manitoban citizen science owl surveyors. *Avian Conservation and Ecology* 13 (2). DOI: 10.5751/ACE-01265-130209.
- O'Brien, L., Townsend, M., and Ebdon, M.** (2010). 'Doing something positive': Volunteers' experiences of the well-being benefits derived from practical conservation activities in nature. *Voluntas: International Journal of Voluntary and Nonprofit Organizations*, 21(4), 525-545.
- Ockenden, N.** (2007). Volunteering in the natural outdoors in the UK and Ireland: A literature review. London, UK: Institute for Volunteering Research.
- Ostrom, E.** (2011). Which becomes more when we share. On the social value of the commons. Munich.
- Penner, L.A.** (2002). Dispositional and organizational influences on sustained volunteerism: An interactionist perspective. *Journal of Social Issues* 58(3): 447–67, DOI: <https://doi.org/10.1111/1540-4560.00270>
- Pocock MJO, Tweddle JC, Savage J, Robinson LD, and Roy HE** (2017). The diversity and evolution of ecological and environmental citizen science. *PLoS ONE* 12(4): e0172579. <https://doi.org/10.1371/journal.pone.0172579>
- Pocock, M. J., Chandler, M., Bonney, R., Thornhill, I., Albin, A., August, T., ... and Danielsen, F.** (2018). A vision for global biodiversity monitoring with citizen science. *Advances in ecological research*, 59, 169-223.
- Pocock, M. J., Newson, S. E., Henderson, I. G., Peyton, J., Sutherland, W. J., Noble, D. G., ... and Roy, D. B.** (2015). Developing and enhancing biodiversity monitoring programmes: a collaborative assessment of priorities. *Journal of Applied Ecology*, 52(3), 686-695.
- Pocock, M. J., Tweddle, J. C., Savage, J., Robinson, L. D., and Roy, H. E.** (2017). The diversity and evolution of ecological and environmental citizen science. *PLoS one*, 12(4), e0172579.
- Report NECR096.** Available at publications.naturalengland.org.uk/file/1995537 (Last accessed 21st August 2015)
- Richter, A., Dörler, D., Hecker, S., Heigl, F., Pettibone, L., Serrano Sanz, F., ... & Bonn, A.** (2018). Capacity building in citizen science. UCL Press
- Richter, A., Emmrich, M., von Geibler, J., Hecker, S., Kiefer, S., Klan, F., ... and Voigt-Heucke, S.** (2020). Citizen Science-Neues Beteiligungsformat für die Forschung zur Agrar-, Forst-, Fischereiwirtschaft und zu ländlichen Räumen? (No. 146). Thünen Working Paper.
- Richter, A; Dörler, D; Hecker, S; Heigl, F; Pettibone, L; Serrano Sanz, F; Vohland, K; and Bonn, A.** (2018). Capacity building in citizen science. In: Hecker, S; Haklay, M; Bowser, A; Makuch, Z; Vogel, J; Bonn, A (Eds.), *Citizen Science – Innovation in Open Science, Society and Policy*, 582; UCL Press, London; ISBN 978-1-78735-233-9
- Robinson, L. D., Cawthray, J. L., West, S. E., Bonn, A., and Ansine, J.** (2018). Ten principles of citizen science. In *Citizen science: Innovation in open science, society and policy* (pp. 27-40). UCL Press.

- Ryan, R.L., Kaplan, R., Grese, R.E.** (2001). Predicting volunteer commitment in environmental stewardship programs. *Journal of Environmental Planning and Management* 44(5): 629–648, DOI: <https://doi.org/10.1080/09640560120079948>
- Schemel, H. J.** (2004). Emotional nature conservation – on the importance of feelings in decision-making processes relevant to nature conservation. *Nature and Landscape*, 79(8), 371-378.
- Schmeller, D. S., Henry, P. Y., Julliard, R., Gruber, B., Clobert, J., Dziock, F., ... and Henle, K.** (2009). Advantages of volunteer-based biodiversity monitoring in Europe. *Conservation biology*, 23(2), 307-316.
- Schulemann-Maier, G. and Munzinger, S.** (2018). Analysis of the species knowledge of nature-loving people by means of the arten|pisa survey. *Nature Conservation and Landscape Planning* 50 (11), 412-417.
- Schulte, R., Jedicke, E., Lüder, R., Linnemann, B., Munzinger, S., and von Ruschkowski, E.** (2019). Eine Strategie zur Förderung der Artenkenntnis. *Naturschutz und Landschaftsplanung*, 51(5), 210-217.
- Schulte, R.; Lüder, E.J.; Linnemann, R. and Munzinger, S.** (2019). A strategy to promote species knowledge. *Naturschutz und Landschaftsplanung*, 51, 05.
- See, L., S. Fritz, Eduardo Dias, Elise Hendriks, Bas Mijling, Frans Snik, Piet Stammes... et al.** (2016). "Supporting Earth-Observation Calibration and Validation: A New Generation of Tools for Crowdsourcing and Citizen Science." *IEEE Geoscience and Remote Sensing Magazine* 4 (3): 38–50. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7570340>. doi:10.1109/MGRS.2015.2498840.
- Statista** (2018). Survey in Germany on the age of volunteers 2018. <https://de.statista.com/statistik/daten/studie/878709/umfrage/umfrage-in-deutschland-zur-berufstaetigkeit-von-ehrenamtlichen> (download 5.3.2020)
- Theobald, E.J., Ettinger, A.K., Burgess, H.K., DeBey, L.B., Schmidt, N.R., Froehlich, H.E., Wagner, C., Hille Ris Lambers, J., Tewksbury, J., Harsch, M.A., and Parrish, J.K.** (2015). Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation*, 181, 236-244.
- Trommer, G.** (2015). *Naturschutz und Umweltbildung. Natur, Emotion, Bildung—vergessene Leidenschaft*, 99-112.
- Tulloch, A. I., Possingham, H. P., Joseph, L. N., Szabo, J., and Martin, T. G.** (2013). Realising the full potential of citizen science monitoring programs. *Biological Conservation*, 165, 128-138
- Turrini, T., Dörler, D., Richter, A., Heigl, F., and Bonn, A.** (2018). The threefold potential of environmental citizen science-Generating knowledge, creating learning opportunities and enabling civic participation. *Biological Conservation*, 225, 176-186.
- Unell, J. and Castle, R.** (2012). Developing sustainable volunteering within the Natural Connections Demonstration Project: A review of evidence. *Natural England*. Commissioned
- van de Gevel, J., van Etten, J. and Deterding, S.** (2020). Citizen science breathes new life into participatory agricultural research. A review. *Agron. Sustain. Dev.* 40, 35 <https://doi.org/10.1007/s13593-020-00636-1>
- Vohland K, Häuser C, Regan E, Hoffmann A, Wetzel F** (2016). 2nd EU BON Stakeholder Roundtable (Berlin, Germany): How can a European biodiversity network support citizen science? *Research Ideas and Outcomes* 2: e8616. <https://doi.org/10.3897/rio.2.e8616>
- Walz, U., Bastian, O., Kästner, A., Wende, W. and H. Schwarze** (2013). Situation des Ehrenamts im Naturschutz- Ergebnisse einer Studie in Sachsen / Present state of nature conservation volunteering - Results of a study in Saxony. *Nature conservation and landscape planning*. 45. 233-240.
- Wehn, U., Ghasesifard, M., Ceccaroni, L. et al.** (2021). Impact assessment of citizen science: state of the art and guiding principles for a consolidated approach. *Sustain Sci* 16, 1683–1699 <https://doi.org/10.1007/s11625-021-00959-2>
- West, S. and Pateman, R.,** (2016). Recruiting and Retaining Participants in Citizen Science: What Can Be Learned from the Volunteering Literature? *Citizen Science: Theory and Practice*, 1(2), p.15. DOI: <http://doi.org/10.5334/cstp.8>
- Zukoski, A. and M. Luluquisen** (2002). "Participatory Evaluation: What is it? Why do it? What are the challenges?" *Policy & Practice* (5). http://depts.washington.edu/ccph/pdf_files/Evaluation.pdf

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