



## Capturing and communicating impact of citizen science for policy: A storytelling approach

Uta Wehn<sup>a,\*</sup>, Raquel Ajates<sup>b</sup>, Dilek Fraisl<sup>c,e</sup>, Mohammad Gharesifard<sup>a</sup>, Margaret Gold<sup>d</sup>, Gerid Hager<sup>c</sup>, Jessie L. Oliver<sup>f</sup>, Linda See<sup>c</sup>, Lea A. Shanley<sup>g</sup>, Michele Ferri<sup>h</sup>, Camden Howitt<sup>i</sup>, Martina Monego<sup>h</sup>, Ellen Pfeiffer<sup>a</sup>, Chris Wood<sup>j</sup>

<sup>a</sup> IHE Delft Institute for Water Education, Westvest 7, 2611, AX, Delft, the Netherlands

<sup>b</sup> Social Digital, University of Dundee, Dundee, DD1 4HN, UK

<sup>c</sup> International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, Laxenburg, Austria

<sup>d</sup> European Citizen Science Association (ECSA), Museum für Naturkunde Berlin, Invalidenstr. 43, 10115, Berlin, Germany

<sup>e</sup> University of Natural Resources and Life Sciences Vienna (BOKU), Gregor-Mendel-Straße 33, 1180, Vienna, Austria

<sup>f</sup> Australian Citizen Science Association (ACSA), University of Sydney, City Road, Darlingtown, NSW, Camperdown, 2006, Australia

<sup>g</sup> Nelson Institute, University of Wisconsin at Madison, Madison, WI, USA

<sup>h</sup> Alto-Adriatico Water Authority/Autorità di bacino distrettuale delle Alpi orientali (AAWA), Cannaregio 4314, 30121 Venice, Italy

<sup>i</sup> Sustainable Coastlines Charitable Trust, New Zealand

<sup>j</sup> Cornell Lab of Ornithology, Cornell University, Ithaca, NY, United States

### ARTICLE INFO

#### Keywords:

Impact assessment  
Storytelling  
Citizen science  
Citizen observatories  
Policy

### ABSTRACT

In response to the need for approaches to understand how citizen science is currently influencing environmental policy and associated decision making, we devised the Citizen Science Impact StoryTelling Approach (CSISTA). We iteratively designed instruments to be used as tools primarily for citizen science practitioners seeking to understand or communicate policy impacts. We then trialled the CSISTA and associated instruments on four exemplary citizen science initiatives, using different forms of inquiry and collaboration with respective initiative leaders. In this paper, we present CSISTA, with details of the steps for implementing inquiry and storytelling instruments. Additionally, we reflect on insights gained and challenges encountered implementing the approach. Overall, we found the versatility and structure of CSISTA as a process with multiple guiding instruments useful. We envision the approach being helpful, particularly with regards to: 1) gaining an understanding of a citizen science initiative's policy and decision-making impacts; 2) creating short policy impact stories to communicate such impacts to broader audiences; or 3) fulfilling both goals to understand and communicate policy impacts with a unified approach. We encourage others to explore, adapt, and improve the approach. Additionally, we hope that explorations of CSISTA will foster broader discussions on how to understand and strengthen interactions between citizen science practitioners, policy makers, and decision makers at large, whether at local, national, or international scales.

## 1. Introduction

### 1.1. Background and problem statement

Citizen science, or public participation in scientific research (Shirk et al., 2012), spans the globe and predominantly focus on ecological and environmental science topics (Kullenberg and Kasperowski, 2016; Pocock et al., 2017). For example, projects may investigate biodiversity, ecosystems, air, water, soil, or even sounds in landscapes. As a concept,

citizen science comes with many definitions, meanings and forms (Eitzel et al., 2017). While some definitions focus more on citizen science as a tool for collection and analysis of data (e.g. Oxford English Dictionary 2014), others define it as a multi-stakeholder process that aims at increasing democratization of science and policy, scientific citizenship, public engagement, transparency, equity, inclusiveness and justice (e.g. Irwin, 1995; Dickinson et al., 2012; Wehn et al., 2020a). Despite its rapid proliferation, evidence in the literature remains limited on the impacts of citizen science on policy or environmental decision making

\* Corresponding author.

E-mail address: [u.wehn@un-ihe.org](mailto:u.wehn@un-ihe.org) (U. Wehn).

<https://doi.org/10.1016/j.jenvman.2021.113082>

Received 17 February 2021; Received in revised form 18 May 2021; Accepted 12 June 2021

Available online 23 June 2021

0301-4797/© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

(Hyder et al., 2015). Impacts of citizen science on policy and decision-making processes (also referred to as governance impacts)<sup>1</sup> can be defined as “*impact on the processes and institutions through which decisions are made, both informal and formal (e.g. public policy), and on relationships/partnerships, as well as the governance of data generated*” (Wehn et al., 2021, p.3). Citizen science projects operate at different levels (local, regional, national or even global). Recent studies show that citizen science offers great potential to address data gaps for global initiatives too, such as the United Nations (UN) Sustainable Development Goals (SDGs). These data are crucial for providing decision makers with accurate insights on where more resources and policy changes or improvements are needed (Fraisl et al., 2020; Ajates et al., 2020; Fritz et al., 2019). Nevertheless, capturing the policy impacts of citizen science initiatives remains difficult.

This complexity in capturing impacts is often a reflection of the increasing complexity and opacity of policy-making processes, making it hard to claim causal relations. The time lag between the end of the project, which is largely a function of funding structures, and impacts becoming tangible or measurable due to the longer nature of the policy cycle (Shirk et al., 2012; Kieslinger et al., 2017; Gharesifard et al., 2019; Ferri et al., 2020; Wehn et al., 2020b), complicate teams' capacity to track impacts over time. It can also be difficult to track the various influences on a decision, such as the ongoing debate on hydraulic fracturing ('fracking') in the United States, and the role of the many small citizen science initiatives started by communities who are concerned about the health effects on their families, that are actively contributing data and evidence to the anti-fracking lobby (SCU, 2013).

In other cases, shortcomings on capturing policy impacts are a reflection of lack of resources and skills in the project groups. Evaluation typically happens at the end of projects, when resources are diminished and empirical evidence to back up emerging stories is still often lacking. Hence, sufficient proof to document impacts may be missing, with no remaining capacity to cover data gaps. Some citizen science initiatives have limited experience with policy or they do not have the capacity or resources to capture the impacts of their efforts (Hager et al., 2021). Community members of other initiatives may be explicitly motivated to create change and policy through advocacy with data or working in collaboration with decision makers. Such outcomes are not well represented in peer-reviewed publications, which are a regular output of academic research but not a primary goal of all citizen science initiatives. Overall, this has resulted in a limited number of policy impact assessments and evaluation of citizen science initiatives. It is therefore worth exploring new methodologies that support citizen science practitioners,<sup>2</sup> including project leaders, in capturing their own contributions to policy processes to demonstrate their potential to volunteers, funders, policy makers and potentially broader audiences.

Furthermore, poor understanding of how citizen science has an impact on policy, limits the availability of guidance on how to design such initiatives to achieve their desired impact (Hecker et al., 2018; Crow and Jones, 2018). Thinking through different pathways of change *ex ante* during the planning stage is increasingly required as part of results-based project design and management practice of large donor agencies (Prince et al., 2015). Moreover, lack of evidence on the impacts that citizen science initiatives have on policy hinders the mainstreaming

of citizen science, since raising awareness of the potential of citizen science among decision makers requires evidence.

The need and interest in methods to capture evidence of citizen science impacts has been expressed amongst citizen science practitioners from various realms, including research and grassroots activities. For instance, it is this interest that brought about the formation of the WeObserve Impact Community of Practice (CoP), which has resulted in the collaboration for producing this paper. This need was highlighted again during the requirements gathering step of the EU Horizon 2020 funded EU-Citizen Science platform when it was first being built.<sup>3</sup> The interest in the impact of citizen science projects was a recurring theme in the interviews with practitioners, who also requested that citizen science projects be searchable by the impacts they generated and not only by discipline (Sanz et al., 2019). Addressing this requirement proves to be challenging in practice, because there is no existing ontology to describe types of citizen science impacts, nor do citizen science projects typically include impact information in descriptions of their aims or outcomes.

Many citizen science projects aim to make positive contributions not only to science, but also to environmental governance and public policy (Kullenberg and Kasperowski, 2016). Citizen observatories are a particular form of citizen science initiatives that originated in Europe (European Commission, 2014). These citizen observatories complement earth observation approaches with tech-enabled and community-based environmental monitoring to deliver new data and information systems for decision and policy making. The access to information that citizen observatory infrastructures provide supports individuals and communities to take strategic actions in regards to local environmental concerns and priorities (Iglesias, 2013; Lanfranchi, 2014; Mazumdar et al., 2016; Liu et al., 2017). Citizen observatories are characterised by a focus on observing the environment, by the typically local scale of activities, and by the explicit (and early) involvement of relevant authorities and/or policy makers to enable two-way communication between citizens and decision makers (Wehn et al., 2019).

The most recent cohort of Horizon 2020-funded citizen observatories, where funding ended during 2019 or 2020, were assessed post funding for emerging macro level or policy impacts. Already there was evidence that improved communication between citizens and authorities was achieved, that scientific knowledge was enhanced, that useful data were collected (e.g., to augment the in-situ component of the Global Earth Observation System of Systems), and that tools and services were developed to improve decision making (Hager et al., 2021).

## 1.2. Capturing impacts via storytelling and narratives

Demonstrating impacts on policy is a more general and longer standing effort in the scientific community that has been tackled by studies that explore how science and policy interplay at the science-policy interface (e.g. Gibbons et al., 1994; Irwin, 1995; Hessels and van Lente, 2008). These efforts aim to understand the dynamics between knowledge production and its use by policy makers. Conceptual frameworks for analysis have been produced rather than 'ready to apply' impact assessment approaches. There is a global push for, and an often unwarranted assumption of the spread of 'evidence-informed' policy-making (Topp et al., 2018). However, there remains a major gap between evidence and policy, with climate change being a globally relevant example (Bäckstrand, 2003).

Storytelling and narratives in policy making has received attention in studies about public policy for a long time (Hajer et al., 1993; Stone, 1989; Sandercock, 2003; Ospina and Dodge, 2005), acknowledging the importance of the narrative lens, and how policy makers go beyond (or without) evidence to make decisions. How citizen science can inform global frameworks, such as the United Nations Sustainable Development Goals (Fritz et al., 2019; Fraisl et al., 2020) by developing 'success

<sup>1</sup> In the context of this paper, governance refers to the definition of goals by a range of actors on the thematic topics that a given citizen science initiative focuses on, e.g. water quality, soil, biodiversity, etc. as well as to related decision-making processes, e.g. decisions about the observed resource. Policy is understood as a specific instrument that guides decision-making processes.

<sup>2</sup> 'Citizen science practitioners' here refer to individuals involved in coordination and/or hands-on activities in citizen science initiatives. This builds on the definition of 'practitioner' by Göbel et al. (2019), and includes project managers, volunteer manager, project team members and those involved in designing project methodologies, as opposed to citizen scientists or volunteers.

<sup>3</sup> <https://eu-citizen.science/>.

stories' in cases where data from citizen science initiatives have been used for monitoring and achieving one or more SDGs is also encouraged (Fraisl et al., 2020). Additionally, there has been a growing interest in the scientific community to "learn to tell stories" with the goal to communicate findings to policy makers and other stakeholders to influence decisions (Green et al., 2018; Topp et al., 2018; Davidson, 2017; Wagenaar, 2011).

The value of stories in policy making is not a new idea. For decades, scholars have highlighted how stories enable participants in policy and administration to "predict, empower and even fashion change" (Boje, 1991, p.124). Also, stories can mediate reality and construct political space, as critical constitutive forces in politics and public policy making (Schram and Neisser, 1997). The universality of stories contributes to their potential to reach and move people, both in policy making circles as well as the general public (Davidson, 2017). These aspects are particularly relevant in the context of citizen science, where there is a push for the democratization of knowledge creation and science (Vohland et al., 2019). This is more so in the context of citizen observatories specifically, where there is an a priori intent to create policy impact, promoting a blueprint for making both science and policy with people, rather than for people. Citizen observatories can additionally play an important role in supporting evidence-based policy making, and thus democratising the evidence-making and policy-making process as well as the knowledge creation process. The emergence of citizen observatories with their remit to achieve not only science but also policy impacts is indicative of a trend within the field of citizen science - and indeed among actors in the quadruple helix<sup>4</sup> more broadly - towards making more transparent the use of evidence and to democratise processes of policy making as well as knowledge creation.

Wenger et al. (2011) introduced *value creation stories* as a special genre of story. These are narratives of "what value is created (or not)" (p.18) in communities of practice. The stories are intended to capture the experiences and aspirations of community participants. This highlights the usefulness of a storytelling approach that does not follow the format of well-known genres (e.g. thriller, romantic novel). Value creation stories instead incorporate the key elements of social learning in which the co-creation of knowledge leads not only to new understandings but also to the transformation of the contextual situation itself (Collins and Ison, 2009). Our study is embedded within this broader meaning of story genres and endeavours to create a practical approach to capturing and communicating the impacts resulting from citizen science and citizen observatories.

### 1.3. Objectives and structure

CSISTA is an approach that is primarily developed for use by citizen science practitioners, including project leaders. The main aim of this paper is to present and reflect on the development and piloting of the Citizen Science Impact Storytelling Approach (CSISTA) with citizen science practitioners in order to capture and communicate current and emerging citizen science impacts on policy.

The paper is structured as follows: in the materials and methods section, we present the details of developing the CSISTA. This includes theoretical and practitioner-focused rationale for the structure and content of the CSISTA data collection instrument for gathering data about citizen science impacts on policy and decisions. Additionally, we describe our criteria for case study selection and the evaluation process of the resulting outputs. Then, in the results section, we present CSISTA (the three main steps and the structure of the main instruments). We exemplify two ways that data acquired through use of CSISTA can be presented in different forms of storytelling to support communicating

about a citizen science initiative to audiences beyond those directly involved in a project. Lastly, we draw conclusions on the extent to which the proposed approach meets the needs for providing evidence of citizen science impacts to strengthen the sustainability of such initiatives and to the mainstreaming of citizen science more generally.

## 2. Materials and methods

In section 2.1, we describe the process of designing the CSISTA impact inquiry instrument, which is intended to support gaining insights regarding how particular citizen science initiatives have influenced environmental policies. Additionally, we detail the design of the CSISTA storytelling instruments. Section 2.2 details the selection and design of four case study citizen science initiatives to explore the use of CSISTA. In section 2.3, we present the approach for evaluating CSISTA in the case studies.

### 2.1. Development of the Citizen Science Impact Storytelling Approach

The work described in this paper was undertaken by the authors, most of whom have been actively engaged with the open WeObserve Community of Practice on 'Capturing Citizen Science Impacts on Governance'. WeObserve is a European Union funded 3.5-year initiative (2017–2021) that aims to tackle three key challenges that citizen observatories face: awareness, acceptability and sustainability.<sup>5</sup> One objective of the WeObserve initiative was to set up and run four globally-relevant communities of practice aimed to facilitate networking and explorations of four topics in citizen science: co-design and engagement, impacts, data interoperability, and alignment with UN Sustainable Development Goals. The community of practice (CoP) members include citizen observatory practitioners, citizen observers, policy makers, researchers and others with various levels of knowledge on citizen science as a practice. The members share practice-based knowledge, information and resources, and work together to develop best practice guidelines and toolkits for citizen observatories and citizen science more broadly. The so-called Impact CoP focused on understanding impacts has been working on exploring and improving the impact and value of citizen observatories in relation to policy and governance. As part of this effort, its members developed CSISTA to help capture and communicate current and emerging impacts of citizen observatories and citizen science initiatives more broadly.

The CSISTA Impact Inquiry Instrument was developed as a framework for qualitative data collection to understand impacts of citizen science and citizen observatory initiatives on influencing policy and decision making. Through two iterations, we found this inquiry instrument to be useful for collecting data via a range of methods, including interviews, self-completion, the review of project documentation and reports, or a combination thereof (for details, see Table 4). The first version of the data gathering instrument drew on the descriptive parameters contained in a case study interview questionnaire designed by Shanley and Azelton et al. (n.d.) to assess the impacts of earth observation and citizen science projects. After further development, the instrument was tested by four members of the CoP to explore interviewer and respondent experiences using the tool. The prototyping explorations and instrument refinement were discussed by the CoP members at a meeting in November 2018. Based on feedback from the CoP members, some of the questions were further simplified in the final version.

Given that the core purpose of the CSISTA Impact Inquiry Instrument is to capture data on the impacts that citizen science and citizen observatories have had on policy, relevant literature was consulted to operationalise the elicitation of such impacts during the data collection, via a sequence of relevant questions or prompts. These largely followed the STAR method for behavioural interviewing (Knight, 2017), focusing

<sup>4</sup> The quadruple helix stipulates knowledge-based interactions among academia, public sector, industry and civil society (Carayannis and Campbell, 2009).

<sup>5</sup> [www.weobserve.eu](http://www.weobserve.eu).

**Table 1**  
Descriptive features used as selection criteria of citizen science and citizen observatory initiatives.

Features Theme	Description
	Environmental focus of the initiative (e.g., biodiversity, air pollution, water quality, etc.)
<b>Age of the initiative</b>	Age of the initiative (either less than 3 years or more than 3 years old) at the time of this study's research
<b>Geographical scale</b>	Global, national or local scale of initiative
<b>Country</b>	Where the initiative is running
<b>Policy remit</b>	Explicit consideration at initiative inception, or serendipitous/incidental occurrences
<b>Lead organisation</b>	Non-governmental organisation, community group, agency, university, consortium, etc.
<b>Initiation process</b>	Bottom up, top down, co-created

**Table 2**  
Overview of the twenty-five citizen science initiatives.

Features Theme	Description
	6 biodiversity, 5 air quality, 4 natural resources management, 2 disaster management, 2 marine environment, 2 built environment, 1 ecology, 1 health, 1 climate, 1 noise pollution
<b>Age of the initiative</b>	13 More than 3 years 12 Less than 3 years
<b>Geographical scale</b>	2 Global, 6 regional, 5 national, and 12 local
<b>Country</b>	2 International, 14 Europe, 5 Oceania, 1 North America, 1 South America, 1 Asia, 1 Africa
<b>Policy remit</b>	21 explicit consideration at initiative inception, 4 serendipitous/incidental occurrences
<b>Lead organisation</b>	7 university, 4 research institute, 3 nonprofit organisation, 4 consortium, 3 NGO, 2 community-led, 1 Network, and 1 government organisation

on the (i) Situation/context (the why); (ii) Task/problem to be solved (or challenges along the way); (iii) Activities/strategies that overcame the challenges; (iv) Results/accomplishments; and (v) impact.

Specifically, the distinction of changes was broken down into regulatory changes at local to national scales. Another form is changes in practices (Shove et al., 2012) such as new practice arrangements or the re-design of use/distribution of physical spaces (Making Sense, 2018) or the creation of a committee to manage shared resources or issues (Ostrom, 1999). Moreover, the impact assessment literature was drawn upon (as summarised by Wehn et al., 2021) in terms of prompting for 1) planned or unexpected changes; 2) the actors involved in making changes happen and those left out of the process; 3) the perception of changes by different citizen science and citizen observatory stakeholders; and 4) whether there were any intentional efforts to formally measure such changes (quantitatively, qualitatively) using specific tools or methods.

We devised two CSISTA impact story instruments to provide guidance for the creation of simple impact stories, either as a narrative or a brief form. Authors elected to create the two storytelling instruments, with the view that storytelling is an effective model for quickly conveying information (Davidson, 2017; Richter et al., 2019). As suggested by Bontje and Slinger (2014), we also see stories as a suitable format to deliver to policy makers, and we hope they will be useful additional stakeholders, such as funders. These instruments are intended to communicate an initiative's influence on a policy or associated decision making. We selected two formats - narrative and brief approaches to storytelling - to accommodate for different preferences of target audiences, as well as the interests and competencies of the story writers.

## 2.2. Case study selection & design

In 2019, based on their own involvement in, or knowledge about, citizen science initiatives, members of the WeObserve Impact

Community of Practice identified twenty-five citizen science initiatives that have had an impact on public policy and decision making. The group then set out to describe each initiative according to a range of features identified from the literature on taxonomies of citizen science initiatives (Table 1) (cf. Gharesifard et al., 2019; Gharesifard et al., 2017; DITOs Consortium, 2018; Hecker et al., 2019; Haklay, 2015). These descriptive features include the theme, age of the initiative, geographical scale, country, policy remit, lead organisation and leadership.<sup>6</sup> Table 2 provides an overview of these features for the twenty-five citizen science initiatives.

To test CSISTA, and based on the available time and resources, we decided to select a sub-set of the twenty-five initiatives. We created a matrix structure for the above features (Table 1), and indicated where each project sits within the relevant criteria. We then made a selection of four cases that would represent a diverse range of citizen science projects around the globe and thematic areas, different geographic regions, at varying levels of geographical reach, and, whether or not policy impacts had been intended from the outset of the initiative (Table 3). Moreover, the selected cases differed in initiative age as well. One case was a long-established citizen science initiative that we hoped to see tangible manifestation of impacts; two medium term and one early-stage initiatives (to illustrate how and what emerging impacts on policy can be captured early on). Also, two of the four cases are citizen observatories (i.e. cases with a strong policy remit from the outset).

The CSISTA was then applied using the Impact Inquiry Instrument for learning about policy outcomes in each case study. In the four cases, different combinations of interviews with self-reporting by and feedback from the individuals directly involved in the initiatives, as well as secondary data sources such as project websites and publications were used by the authors of this paper. Table 4 provides an overview of the multiple applications of the inquiry instrument and the sequence of use of each source of information for all cases, along with the type of impact story created.

<sup>6</sup> In the leadership category, the citizen observatory cases could be described as top-down in leadership structure, since they were part of projects funded by the European Commission, actively creating demonstration cases of local citizen observatories. At the same time, the decision on what parameters should be monitored and/or the management of each citizen observatory might have had a bottom-up character.

**Table 3**  
Overview of selected case studies.

	Case study 1: eBird Tricolored Blackbird	Case study 2: Citizen Observatory of Water Alto Adriatico	Case study 3: Litter Intelligence	Case study 4: The National CBNRM Observatory Zambia
<b>Selection criteria</b>				
<b>Policy impact intended from the start</b>	No (CS)	Yes (CO)	Yes (CS)	Yes (CO)
<b>Start date of initiative</b>	2002	2013	2018	2016
<b>Lead organisation</b>	Cornell Lab of Ornithology at Cornell University and California Audubon	Alto-Adriatico Water Authority (AAWA)	Sustainable Coastlines	National CRB (Community Resource Board) Association
<b>Establishment mechanism (bottom up, top down, co-created)</b>	Top-down	Top-down	Bottom-up	Co-created
<b>Description</b>				
<b>Thematic focus</b>	Bird/Biodiversity	Flooding	Marine litter	Community-based natural resource management
<b>Geographic focus</b>	Global platform with a subproject in California, United States of America	Europe Northern Italy (Eastern Alps)	New Zealand	Zambia
<b>Geographical scale</b>	Regional (a sub-project of global eBird initiative)	Local (Brenta-Bacchiglione catchment)	National <sup>a</sup>	National

<sup>a</sup> National scope, with local areas in which they operate (with Samoa as an exception); global as the initiative extends to other countries in the meantime and due to the scale of the marine litter problem in general.

To reflect the versatile use of the inquiry instrument, we selected four case studies for which the respective initiative leaders engaged in populating the inquiry instrument in diverse ways. Some, for example, were interviewed first, others filled out the instrument directly, provided specific policy instances for the researcher to investigate, provided published references regarding policy outcomes, and one only provided feedback once the impact story had been written based on secondary data. Four authors of this manuscript used the storytelling instruments to craft one impact story each: two crafted Impact Narratives and two used the CSISTA Impact Brief format.

**2.3. Method for evaluating CSISTA**

To evaluate CSISTA, we considered and tested two aspects. Firstly, we explored the usability of the Impact Inquiry Instrument for the different information gathering applications or sequences. This was whether people collected information to populate the Impact Inquiry Instrument via remote interview; self-reporting, and reviewing available information for content (e.g. publications and websites). Secondly, we explored the suitability of the completed inquiry instruments for the

**Table 4**  
Overview of the applications of CSISTA instruments for Impact Storytelling.

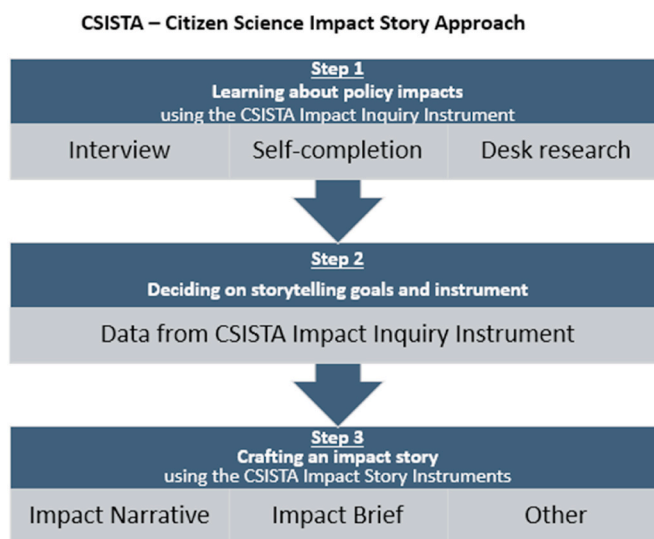
Case study	Use of CSISTA Impact Inquiry Instrument	CSISTA Impact Story Instrument
Case study 1: eBird Tricolored Blackbird	1 Self-reporting 2 Secondary data	Impact Brief
Case study 2: Citizen Observatory of Water Alto Adriatico	1 Interview 2 Check/additions to completed inquiry instrument by initiative contact 3 Secondary data	
Case study 3: Litter Intelligence	1 Secondary data 2 Check/additions to completed inquiry instrument by initiative contact	Impact Narrative
Case study 4: The National CBNRM Observatory Zambia	1 Secondary data	

creation of final communication products (i.e. the CSISTA Impact Narratives and Impact Briefs).

To understand the usability of the CSISTA Impact Inquiry Instrument for data gathering, we collected feedback from those co-authors who had populated inquiry instruments for the four respective initiatives individually, as part of an interview, or via collaboration with

interviewees. We adopted a qualitative approach to usability evaluation (cf. Bastien, 2010; Barnum, 2011; Rosenzweig, 2015) as follows. First, we collected feedback from the authors of this paper about both the content gathering stage and the use of the instruments for crafting impact narratives and impact briefs. The feedback on the inquiry stage included reflection on several predetermined use aspects of the instrument such as: length (time required to complete the template), terminology (comprehensibility of language and terms used), flow (sequence of questions), ease or difficulty of implementation (other handling aspects of the instrument), and duplicate information or missing fields. In addition, those co-authors who translated the gathered information into impact narratives and impact briefs, assessed this process by reflecting on ease or difficulty of transferring the information; availability and adequacy of information; and usefulness of the instrument structure and sequence of fields; as well as potential missing information.

To understand the suitability of the CSISTA Impact Inquiry Instrument for providing inputs towards creating stories, the Impact Inquiry Instruments were used to extract content to draft stories using either the brief or narrative forms. Content from inquiry instruments from case studies 1 and 2 was then used to create an impact story in the form of a brief using the associated storytelling instrument as a template. By contrast, content from inquiry instruments for case studies 3 and 4 was then used to create an impact story in the form of a narrative.



**Fig. 1.** Illustration of the CSISTA steps and instruments.

Experiences of the four co-authors who created the four impact stories in brief form or narrative form, also went through the same reflexive evaluation process applied for testing the usability of the CSISTA inquiry instrument.

### 3. Findings

Following the elaboration in section 2 of how we developed and evaluated CSISTA, here we summarise the final approach consisting of three main steps and final versions of the instruments (section 3.1). Next, we exemplify, for selected case studies, how the application of CSISTA results in an impact story (in section 3.2).

#### 3.1. The Citizen Science Impact Storytelling Approach

Implementing CSISTA involves three steps (Fig. 1), the use of the CSISTA Impact Inquiry Instrument and one form of impact story instrument:

**Step 1.** Learning about policy impacts using the CSISTA Impact Inquiry Instrument to gather qualitative data from citizen science initiative leaders about realised and potential policy and decision making impacts;

**Step 2.** Deciding on storytelling goals, the storytelling instrument, and relevant data. The storytelling instruments consist of guidance for writing short stories in an Impact Brief or Impact Narrative form.

**Step 3.** Crafting an impact story in a brief or narrative form, which can be used to convey policy impacts of a citizen science initiative to broader audiences (e.g. practitioners may provide stories to decision makers).

##### 3.1.1. Step 1: learning about policy impacts using the CSISTA impact inquiry instrument

The CSISTA data gathering instrument consists of four distinct sections designed to capture project, policy impacts, challenges encountered, and impacts beyond policy. The first section captures a description of the initiative, including title; start and end dates; aim; geographical scope; stakeholders involved; the role of the project participant completing the form; sponsor; and website. The second section captures impact details, including scoping the problem addressed by the citizen science initiative; scoping the (evolving) change; a title and a quote for the particular impact story; a quote and visual resources from the project; reflections and lessons learned; and key words for the impact story. The third section captures challenges faced during the entire initiative cycle, considering, for example, design, implementation, and evaluation; policy restrictions; further changes needed; and next steps in the project. The fourth section captures impacts beyond policy, such as monitoring approach and cost/benefit of the project; policy recommendations; and other impacts; as well as links with the SDGs and other international frameworks. The instrument is available as a resource on Zenodo.<sup>7</sup>

##### 3.1.2. Step 2: deciding on storytelling goals, the instruments, & relevant inquiry data

Depending on the impact story writer's preference and the target audience in mind (e.g. policy makers, volunteers, funders), one of the impact story instruments is selected (Impact Narrative, Impact Brief or a different format altogether). This is then completed drawing on the data collected in Step 1 using the CSISTA Impact Inquiry instrument. Ultimately, the choice of the impact story format is a combination of the writer's preferences (e.g. a citizen science project coordinator vs. researcher of citizen science) and the extent to which they have a good understanding of which format may be most suitable for the target

audience they are aiming to reach.

##### 3.1.3. Step 3: crafting an impact story in a narrative or brief form

The generation of an impact story requires crafting a congruent narrative as one flowing text.

Just as the Impact Inquiry Instrument, the overall structure of the story is also based on the STAR method (see section 2.1.1), albeit on a more aggregate level.

The CSISTA approach for crafting a *story in the form of an Impact Narrative* allows for presentation of key facts and impacts of an individual initiative in the form of a continuous text. The Impact Narratives could include facts and overview elements, such as project context, funding and stakeholders, with elements focused on impacts (on individuals, communities and policy) as well as storytelling elements such as quotes or images.

- Introduction -situation/context
- Challenge - Task/problem to be solved
- Activities/strategies adopted to overcome challenges - e.g. Volunteer and Stakeholder Engagement, Programme Evaluation, Funding and Partnerships, Data Quality Strategy
- Results/accomplishments - Policy impacts and beyond
- Next Steps
- Website and other project related web links (outputs, insights, press and other)

In contrast, the CSISTA instrument for crafting a *story in the form of an Impact Brief* does not follow a continuous text flow. Instead, it consists of building blocks, combining text with storytelling and visual elements.<sup>8</sup> This results in a simple format to grasp a summary relatively quickly that could be used for different audiences and purposes. The Impact brief building blocks are:

- Story title
- Project title
- In a nutshell (Topic; Location; Duration; Initiators; Stakeholders; Data)
- Project image
- The challenge
- Why does it matter?
- The action
- In numbers (Participants; data points; [other project dependent items])
- Effects on policy
- Other impacts
- What people say
- Facts and link list (Funding received; Project website; Open access data; We would like to thank; References; Please, cite as; To get in touch: email address)

#### 3.2. Impact stories of selected case studies

The stories that can be created using first the CSISTA inquiry instrument, and then one of the two impact storytelling instruments are exemplified by the two impact briefs and the two impact narratives we created for the four case studies we selected. These four impact stories are included in the supplementary material.

## 4. Discussion

In this study, we have shared CSISTA as an approach to investigate and communicate policy impacts of citizen science. We have described

<sup>8</sup> The CSISTA Impact Brief template is available in the supplementary material.

<sup>7</sup> <https://zenodo.org/record/4543603#.YcV1AZNKhTY>.

the CSISTA steps and its trailing of inquiry and storytelling instruments. CSISTA is primarily designed for use by citizen science practitioners, including project leads. Here, we share our reflections on opportunities, challenges, and future directions for using CSISTA to understand and communicate policy impacts.

#### 4.1. Feedback from filling in the CSISTA impact inquiry instrument

Overall, the co-authors considered the structure and the flow of the data gathering instrument to be of value. Those who filled in the instrument found it a very useful tool for a variety of purposes, including guiding semi-structured interviews, collating diverse information into a comprehensive project information document, as well as fleshing out and highlighting nuanced aspects of the projects. In addition, some of the interviewees or respondents found the questions intriguing and mentioned that this helped them to clearly think about how to formulate some project basics. For example, an interviewee mentioned “*this sounds like a great summary sentence, can I use this on our website?*”. Another benefit was that some of the information gathered using the CSISTA data gathering instrument had never been previously published about projects.

On the other hand, there was an overall consensus among the co-authors that filling in the CSISTA Impact Inquiry instrument is a time consuming process that may involve iterative information gathering from different sources (see examples in Table 4). It was evident that the process would work most effectively when the instrument is filled in collaboration among the interviewer and interviewee. If this is not possible, then it is recommended that representatives from the citizen science or citizen observatory projects fill in the instrument, rather than someone who is not from the project team. Nevertheless, in cases when the instrument is filled in by a project representative (e.g. a project coordinator or team member), the answers may be too abstract and there may be a need for follow up or to do further research to clarify the answers. Sometimes the interviewee did not have all the answers and had to check with a colleague or, because of time constraints, would refer the interviewer to additional resources. Moreover, some terminology used (e.g. governance impact) was not familiar to all respondents or belonged to a specific context (e.g. the term citizen observatories is well known in the European context, but not in the US or Australia). In these cases, the interviewer needed to further explain these terms. Additionally, some interviewees found it difficult or even inappropriate to categorise stakeholders into particular groups because they either did not find the classifications suggested by the instrument appropriate or simply because most stakeholders would not fit into one category. Overall, it seems important to obtain some form of input directly from citizen science project leaders, and ‘the more the better’ to support a collaborative community.

#### 4.2. Reflections on using the generated content to write an impact narrative or brief

The wealth of the information gathered using the CSISTA Impact Inquiry instrument was generally found adequate for writing the impact stories or impact briefs. Nevertheless, those who wrote the outputs encountered occasional redundancies or missing information in the filled-in instruments. Missing information sometimes concerned questions missing in the instrument (e.g. quantitative summary of number of volunteers or observations), and at other times incomplete answers to some questions in the instrument (e.g. incomplete quotes section). As a result, while writing, sometimes it was required to go back and forth through the completed answers to harvest appropriate/relevant information from other sections, or look for needed information elsewhere (e.g. the provided links or the project website).

#### 4.3. Limitations of CSISTA

By design, the CSISTA focuses on policy impacts of the projects and initiatives. Therefore, its application for capturing impacts in other domains of impact (e.g. social, environmental) requires adjustment of the instrument. Also, currently CSISTA does not provide the means to evaluate the ethical dimensions of citizen science initiatives such as inclusiveness, forms of participation, transparency and recognition of contributions.

Moreover, a certain affinity with qualitative methods and writing skills are needed for gathering data using the CSISTA Impact Inquiry instrument and for writing impact stories or impact briefs. In addition, the instrument works best if it is completed in collaboration with project representatives. Using the instrument by someone who cannot obtain the inputs from the initiative or project team, may result in an impact narrative or brief that misses or unintentionally misrepresents key information.

#### 4.4. Future directions for CSISTA

Future efforts can gather additional feedback on the use of the CSISTA instruments from a wider range of citizen science practitioners, particularly since the impact stories and the impact briefs developed here were written by academics, which is a limitation of the current study. In addition to citizen science projects and practitioners, the impact of the storytelling supported by the CSISTA instruments should be assessed with policymaking representatives to determine the effectiveness of this approach from their perspective. Over time, CSISTA and the impact stories and briefs generated using the instruments could have a contributory function for designing, influencing and guiding citizen science projects on the elements needed to achieve impacts on policy.

Specifically, the accumulating set of impact stories generated using CSISTA presents key insights for designing the pathways of change *ex ante* while planning the theory of change<sup>9</sup> of new citizen science initiatives (e.g. what kinds of impacts have been achieved and how). The CSISTA instruments serve to capture and generate impact stories during the life time of the citizen science initiative and *ex post*. The CSISTA could also be adapted in the future to address domains of impact other than just policy, such as impacts on governance more broadly, behaviour change, knowledge generation, costs and benefits of initiatives. Additionally, indicators could be developed about how the narratives helped to elicit policy impacts.

Future applications of CSISTA could also focus on improving the approach by inclusion of ethical dimensions of citizen science initiatives. Nevertheless, it is highly recommended that such improvements strike a balance between comprehensiveness and maintaining the light and less resource-intensive nature of CSISTA.

### 5. Conclusions

To date, the limited understanding of the policy needs and processes within the citizen science community has created a knowledge gap in how to communicate with policy makers and other stakeholders, such as funders, scientists and volunteers, about the impacts of citizen science and citizen observatories in a way that resonates with the policy community. Recent work in this field has reviewed the impact assessment tools to measure the impact of citizen science in various domains such as society, economy, science, governance and environment (Wehn et al., 2021). This shows that further advances are needed to turn the evolving metrics or instruments into actionable insights through impact stories that could demonstrate the value of citizen science to policy makers, funders, future initiatives, and other stakeholders.

<sup>9</sup> A theory of change is the currently most advanced evolution of the Log-Frame approach (Prinsen and Nijhof, 2015).

It can be argued that the academic community is expecting citizen science to provide the best of both worlds: the robustness and resource-rich approach of formal university-backed scientific approaches to capturing impact as well as bottom-up, volunteer-led projects with few resources to spare for ongoing evaluation. In terms of theoretical contribution, CSISTA is one of the first attempts to create a guided storytelling approach to capture and communicate the existing and emerging impacts of citizen observatories and citizen science initiatives on policy. It provides one data gathering instrument and two output instruments developed by the members of the WeObserve Impact CoP. Implications for practice are that these practical instruments can help capture impacts and communicate these impacts in versatile ways to policy makers and other potential audiences such as volunteers and funders, which could contribute to strengthening the sustainability and mainstreaming of citizen observatories and citizen science. As such, the theoretical and practical contributions of CSISTA help straddle the divide between comprehensive but resource intense impact assessment approaches, and the (limited) resources of community-led citizen science projects.

CSISTA also has a broader relevance in various contexts, including projects such as the EU-Citizen.Science platform, which pools the knowledge on citizen science and loops it back to the community to meet their needs of identifying best practices to inform policy. Overall, CSISTA offers a guided process that we hope is easier, faster and simpler than a comprehensive citizen science impact assessment (see approaches reviewed in Wehn et al., 2021). It holds promise to support citizen science practitioners by enabling them to capture and communicate the impacts of their initiative, whether early on and continuously, while unfolding, or at the end of their project. We see promise that CSISTA may offer a way to assess policy impacts using fewer resources, in terms of time as well as know-how, compared to traditional and more comprehensive impact assessment approaches. We are aware the uptake of CSISTA will require distinct dissemination efforts to ensure that citizen science practitioners are cognisant of its existence. Community is asking citizen science to provide the best of both worlds: the robustness and resource-rich approach of formal university-backed scientific approaches to capturing impact as well as bottom-up, volunteer-led project with few resources to spare for ongoing evaluation.

One way for citizen observatories and citizen science initiatives to be more effective, result-oriented and actionable, is to inform policy. Comprehensive frameworks have (recently) been developed and applied to measure impacts of citizen science (e.g. Wehn et al., 2020b), nevertheless, these require resources that many, if not most, citizen science initiatives do not have at their disposal. The aim of this paper is to bridge this divide and help capture selected impacts – namely those on policy – as they evolve in more manageable ways, not ruling out comprehensive impact assessment approaches in parallel or at a later stage. This can also increase the trust and accountability of both the initiatives and policy processes. Approaches such as CSISTA, that help capture impacts, have the potential to inform policies at the local level, where most of the citizen science initiatives take place. Additionally, it may support understanding impacts for large-scale projects and international frameworks, such as the SDGs and the Sendai Framework for Disaster Risk Reduction, with the potential of fostering global change.

#### Author credit statement

Uta Wehn, roles: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing, Raquel Ajates, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Dilek Fraisl, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Mohammad Ghareisifard, Conceptualization; Formal analysis;

Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Margaret Gold, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Gerid Hager, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Jessie Oliver, Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Linda See, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Lea Shanley, Conceptualization; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing, Michelle Ferri, Investigation; Writing – review & editing, Camden Howitt, Investigation; Writing – review & editing, Martina Monego, Investigation; Writing – review & editing, Ellen Pfeiffer, Investigation; Writing – review & editing, Chris Wood, Investigation; Writing – review & editing

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Acknowledgements

This research received funding from the EU Horizon 2020 research and innovation programme under the WeObserve project (No. 776740).

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2021.113082>.

#### References

- Ajates, R., Hager, G., Georgiadis, P., Coulson, S., Woods, M., Hemment, D., 2020. Local action with global impact: the case of the GROW observatory and the sustainable development goals. *Sustainability* 12 (24), 10518. <https://doi.org/10.3390/su122410518>.
- Bäckstrand, K., 2003. Civic science for sustainability: reframing the role of experts, policy-makers and citizens in environmental governance. *Global Environ. Polit.* 3 (4), 24–41.
- Barnum, C.M., 2011. *Usability Testing Essentials*. Morgan Kaufmann, Elsevier, Burlington, MA, USA. <http://repository.fue.edu.sg/xmlui/handle/123456789/3488>.
- Bastien, J.M.C., 2010. Usability testing: a review of some methodological and technical aspects of the method. *Int. J. Med. Inf.* 79/4, 18–23. <https://doi.org/10.1016/j.ijmedinf.2008.12.004>.
- Boje, D.M., 1991. The storytelling organization: a study of story performance in an office supply firm. *Adm. Sci. Q.* 36 (1), 106–126.
- Bontje, L., Slinger, J.H., 2014. Stories and storytelling in the pre-realization steps of the sand engine: analysis of personal narratives from pilot project stakeholders. *Wageningen*. In: 9th International Conference on Interpretive Policy Analysis, pp. 3–5. of July 2014.
- Carayannis, E., Campbell, D., 2009. 'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management* 2009 46 (3–4), 201–234.
- Collins, K., Ison, R., 2009. Jumping off Arnstein's Ladder: social learning as a new policy paradigm for climate change adaptation. *Environmental Policy and Governance* 19 (6), 358–373. <https://doi.org/10.1002/eet.v19.6>.
- Crow, D., Jones, M., 2018. Narratives as tools for influencing policy change. *Pol. Polit.* 46 (2), 217–234.
- Davidson, B., 2017. *Storytelling and evidence-based policy: lessons from the grey literature*. Palgrave Communications 3 (1), 1–10.
- DITOs Consortium, 2018. *Doing it Together Science: D6.6 Innovation Management Plan: "Making Citizen Science Work"*. UCL, London.
- Eitzel, M.V., Cappadonna, J.L., Santos-Lang, C., Duerr, R.E., Virapongse, A., West, S.E., Kyba, C.C.M., Bowser, A., Cooper, C.B., Sforzi, A., Metcalfe, A.N., Harris, E.S., Thiel, M., Haklay, M., Ponciano, L., Roche, J., Ceccaroni, L., Shilling, F.M., Dörler, D., Heigl, F., Kiessling, T., Davis, B.Y., Jiang, Q., 2017. Citizen science terminology matters: exploring key terms. *Citiz. Sci. Theory Pract.* 2 (1) <https://doi.org/10.5334/cstp.113>.



- Ferri, M., Wehn, U., See, L., Monego, M., Fritz, S., 2020. The value of citizen science for flood risk reduction: cost-benefit analysis of a citizen observatory in the Brenta-Bacchiglione catchment. *Hydrol. Earth Syst. Sci.*
- Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., Masó, J., 2020. Mapping citizen science contributions to the UN sustainable development goals. *Sustainability Science* 15 (6), 1735–1751.
- Fritz, S., See, L., Carlson, T., Haklay, M.M., Oliver, J.L., Fraisl, D., Wehn, U., 2019. Citizen science and the United Nations sustainable development goals. *Nature Sustainability* 2 (10), 922–930.
- Ghariesifard, M., Wehn, U., van der Zaag, P., 2017. Towards benchmarking citizen observatories: features and functioning of online amateur weather networks. *J. Environ. Manag.* 193, 381–393. <https://doi.org/10.1016/j.jenvman.2017.02.003>.
- Ghariesifard, M., Wehn, U., van der Zaag, P., 2019. What influences the establishment and functioning of community-based monitoring initiatives of water and environment? A conceptual framework. *J. Hydrol.* 579, 124033. <https://doi.org/10.1016/j.jhydrol.2019.124033>.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M., 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. SAGE, London.
- Göbel, C., Cappadonna, J.L., Newman, G.J., Zhang, J., Vohland, K., 2019. More than just networking for citizen science: examining core roles of practitioner organizations. In: *Crowdsourcing: Concepts, Methodologies, Tools, and Applications*. IGI Global, pp. 606–631.
- Green, S.J., Grorud-Colvert, K., Mannix, H., 2018. Uniting science and stories: perspectives on the value of storytelling for communicating science. *FACETS* 3, 164–173. <https://doi.org/10.1139/facets-2016-0079>.
- Hager, G., Gold, M., Wehn, U., Ajates, R., See, L., Woods, M., Tsiakos, V., Masó, J., Fraisl, D., Moorthy, L., Domian, D., Fritz, S., 2021. Onto new horizons: insights from the WeObserve project to strengthen the awareness, acceptability and sustainability of Citizen Observatories in Europe. *Journal of Science Communication (JCOM)*, forthcoming.
- Hajer, M.A., Hoppe, R., Dunn, W., Jennings, B., Healey, P., Dryzek, J., et al., 1993. *The Argumentative Turn in Policy Analysis and Planning*. Duke University Press.
- Haklay, M., 2015. *Citizen Science and Policy: A European Perspective*. The Woodrow Wilson Center, Washington, USA. Commons Lab.
- Hecker, S., Luckas, M., Brandt, M., Kikillus, H., Marenbach, I., Schiele, B., Sieber, A., van Vliet, A.J.H., Walz, U., Wende, W., 2018. 'Stories can change the world — the innovative potential of citizen science communication'. In: Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J., Bonn, A. (Eds.), *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press, London, U.K.
- Hecker, S., Wicke, N., Haklay, M., Bonn, A., 2019. How does policy conceptualise citizen science? A qualitative content analysis of international policy documents. *Citiz. Sci. Theory Pract.* 4 (1).
- Hessels, L.K., van Lente, H., 2008. Re-thinking new knowledge production: a literature review and a research agenda. *Res. Pol.* 37 (4), 740–760.
- Hyder, K., Townhill, B., Anderson, L.G., Delany, J., Pinnegar, J.K., 2015. Can citizen science contribute to the evidence-base that underpins marine policy? *Mar. Pol.* 59, 112–120.
- Iglesias, R., 2013. 'Citizens' observatories for monitoring the environment: a commission perspective'. In: *Proceedings of Workshop on Citizen's Involvement in Environmental Governance*. Arlon, Belgium. Directorate General Research and Innovation, European Commission.
- Irwin, A., 1995. *Citizen Science: A Study of People, Expertise and Sustainable Development*. Psychology Press.
- Kieslinger, B., Schäfer, T., Heigl, F., Dörler, D., Richter, A., Bonn, A., 2017. The Challenge of Evaluation: an Open Framework for Evaluating Citizen Science Activities.
- Knight, K., 2017. Exploring leadership conceptualisations in semi-structured interviews from multiple perspectives. In: *Challenging Leadership Stereotypes through Discourse*. Springer, Singapore, pp. 119–145.
- Liu, H.-Y., Grossberndt, S., Kobernus, M., 2017. 'Citizen science and citizens' Observatories: trends, roles, challenges and development needs for science and environmental governance'. In: Foody, G.M., See, L., Fritz, S., Fonte, C.C., Mooney, P., Olteanu-Raimond, A.-M., Antoniou, V. (Eds.), *Mapping and the Citizen Sensor*. Ubiquity Press, London, UK, pp. 351–376.
- Mazumdar, S., Lanfranchi, V., Ireson, N., Wrigley, S., Bagnasco, C., Wehn, U., McDonagh, R., et al., 2016. Citizens observatories for effective Earth observations: the WeSenseIt approach. *Environmental Scientist* 25/2, 56–61.
- Ospina, S.M., Dodge, J., 2005. It's about time: catching method up to meaning—the usefulness of narrative inquiry in public administration research. *Publ. Adm. Rev.* 65 (2), 143–157.
- Ostrom, E., 1999. Institutional rational choice. *Theories of the policy process* 35–72.
- Pocock, M.J.O., Tweddle, J.C., Savage, J., Robinson, L.D., Roy, H.E., 2017. The diversity and evolution of ecological and environmental citizen science. *PLoS One* 12 (4), e0172579. <https://doi.org/10.1371/journal.pone.0172579>.
- Prinsen, Gerard, Nijhof, Saskia, 2015. Between logframes and theory of change: reviewing debates and a practical experience. *Dev. Pract.* 25 <https://doi.org/10.1080/09614524.2015.1003532/>.
- Richter, A., Sieber, A., Siebert, J., Miczajka-Russmann, V.L., Zabel, J., Ziegler, D., Frigerio, D., 2019. Storytelling for narrative approaches in citizen science: towards a generalized model. *JCOM - J. Sci. Commun.* 18 (6), 24. <https://doi.org/10.22323/2.18060202>.
- Rosenzweig, 2015. *Successful User Experience: Strategies and Roadmap*. Morgan Kaufmann, Elsevier, Burlington, MA, USA. <https://doi.org/10.1016/C2013-0-19353-1>.
- Sandercock, L., 2003. Out of the closet: the importance of stories and storytelling in Planning Practice. *Plann. Theor. Pract.* 4 (1), 11–28.
- Sanz, Francisco, Gold, Margaret, Mazzonetto, Marzia, 2019. *EU-Citizen.Science, Platform Functionality Requirements & Specification Report*. <https://doi.org/10.5281/zenodo.3612807>.
- Schram, S., Neisser, Philip (Eds.), 1997. *Tales of the State: Narrative in Contemporary U.S. Politics and Public Policy*. Rowman & Littlefield Publishers Inc, New York.
- Science Communication Unit, 2013. *Science for Environment Policy In-Depth Report: Environmental Citizen Science, December 2013 (SCU)*. University of West England, Bristol, England. Available at: <http://ec.europa.eu/science-environment-policy>. (Accessed 7 November 2019).
- Sense, Making, 2018. *Making Sense: A Toolkit*. Amstredam, Making Sense Project Consortium. ISBN/EAN: 978-90-828215-0-5.
- Shanley, L.A., Azelton, K., Riesbeck, L., and Kommel, R. (n.d.). *The Integration of Citizen Science with Earth Observation: Best Practices and Success Stories*, Washington, DC: Secure World Foundation. (In progress).
- Shirk, J., Ballard, H., Wilderman, C., Phillips, T., Wiggins, A., Jordan, R., Krasny, M., 2012. Public participation in scientific research: a framework for deliberate design. *Ecol. Soc.* 17 (2).
- Shove, E., Pantzar, M., Watson, M., 2012. *The Dynamics of Social Practice: Everyday Life and How it Changes*. Sage.
- Stone, D.A., 1989. Causal stories and the formation of policy agendas. *Polit. Sci. Q.* 104 (2), 281–299.
- Topp, L., Mair, D., Smillie, L., Cairney, P., 2018. Knowledge management for policy impact: the case of the European Commission's Joint Research Centre. *Palgrave Communications* 4 (1), 87.
- Vohland, K., Weißflug, M., Pettibone, L., 2019. Citizen science and the neoliberal transformation of science—an ambivalent relationship. *Citiz. Sci. Theory Pract.* 4 (1).
- Wagenaar, H., 2011. *Meaning in Action: Interpretation and Dialogue in Policy Analysis*. ME Sharpe.
- Wehn, U., Ghariesifard, L., Anema, K., Alfonso, M., Mazzoleni, M., 2019. *Initial Validation and Socio-Economic Impacts Report, Ground Truth 2.0 Project Deliverable D1.11*. Delft, the Netherlands, September.
- Wehn, U., Goebel, C., Bowser, A., Hepburn, L., Haklay, M., 2020a. *Global Citizen Science Perspectives on Open Science. Short Paper for UNESCO Advisory Body on the Open Science Recommendation*, May.
- Wehn, U., Pfeiffer, E., Ghariesifard, M., Alfonso, L., Anema, K., 2020b. *Updated Validation and Socio-Economic Impacts Report, Ground Truth 2.0 Project Deliverable D1.12*. Delft, the Netherlands, February.
- Wehn, U., Ghariesifard, M., Ceccaroni, L., Joyce, H., Ajates, R., Woods, S., Bilbao, A., Parkinson, S., Gold, M., Wheatland, J., 2021. *Impact Assessment of Citizen Science: state of the art and guiding principles for a consolidated approach. Sustainability science* 1–17. <https://doi.org/10.1007/s11625-021-00959-2>.
- Wenger, E., Trayner, B., Laat, M., 2011. *Promoting and Assessing Value Creation in Communities and Networks: A Conceptual Framework*.