Conservation Biology

Special Section: *Moving from Citizen to Civic Science to Address Wicked Conservation Problems*

Citizen science networks in natural history and the collective validation of biodiversity data

Esther Turnhout,* Anna Lawrence,† and Sander Turnhout‡

*Forest and Nature Conservation Policy Group, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands, email esther.turnhout@wur.nl
†University of the Highlands and Islands, Inverness, IV2 5NO, U.K.
‡Institute for Science, Innovation and Society, SpeciesNL, Radboud University, P.O. Box 9010, 6500 GL, Nijmegen, The Netherlands

Abstract: *Biodiversity data are in increasing demand to inform policy and management. A substantial portion of these data is generated in citizen science networks. To ensure the quality of biodiversity data, standards and criteria for validation have been put in place. We used interviews and document analysis from the United Kingdom and The Netherlands to examine how data validation serves as a point of connection between the diverse people and practices in natural history citizen science networks. We found that rather than a unidirectional imposition of standards, validation was performed collectively. Specifically, it was enacted in ongoing circulations of biodiversity records between recorders and validators as they jointly negotiated the biodiversity that was observed and the validity of the records. These collective validation practices contributed to the citizen science character or natural history networks and tied these networks together. However, when biodiversity records were included in biodiversity-information initiatives on different policy levels and scales, the circulation of records diminished. These initiatives took on a more extractive mode of data use. Validation ceased to be collective with important consequences for the natural history networks involved and citizen science more generally.*

Keywords: amateurs, biodiversity recording, circulating reference, data validation, quality control

Las Redes de Ciencia Ciudadana en la Historia Natural y la Validación Colectiva de Datos sobre la Biodiversidad

Resumen: *Los datos sobre la biodiversidad tienen una demanda creciente para informar a las políticas y al manejo. Una porción sustancial de estos datos se genera en las redes de ciencia ciudadana. Para asegurar la calidad de los datos sobre la biodiversidad se han establecido estándares y criterios de validación. Usamos entrevistas y análisis de documentos del Reino Unido y los Países Bajos para examinar cómo la validación funciona como un punto de conexión entre las diversas prácticas y personas en las redes de ciencia ciudadana de historia natural. Encontramos que en lugar de una imposición unidireccional de los estándares, la validación se realizaba colectivamente. En específico, se promulgaba en circulaciones continuas de los registros de biodiversidad entre los registradores y los validadores, a la vez que ellos en conjunto negociaban la biodiversidad que era observada y la validez de los registros. Estas prácticas colectivas de validación contribuyeron al carácter de ciencia ciudadana o a las redes de historia natural y conectaron a estas redes. Sin embargo, cuando los registros de biodiversidad se incluyeron en las iniciativas de información de biodiversidad a niveles y escalas diferentes de política, la circulación de los registros disminuyó. Estas iniciativas se tornaron de un uso más extractivo de datos. la validación dejó de ser colectiva con consecuencias importantes para las redes de historia natural involucradas y en general para la ciencia ciudadana.*

Palabras Clave: aficionados, control de calidad, referencia en circulación, registro de la biodiversidad, validación de datos

Paper submitted February 28, 2015; revised manuscript accepted December 6, 2015.

DOI: 10.1111/cobi.12696

The Demand for Biodiversity Data

The demand for reliable biodiversity data to underpin conservation policies and planning decisions is increasing. Before data can be accepted as reliable, they must be shown to have been subjected to appropriate validation procedures (Porter 1995). In the case of biodiversity, a substantial portion of data is generated by volunteers in natural history organizations (Lawrence 2010). The study of natural history stems primarily from the formation of specialized learned societies focusing on a particular type of biodiversity (e.g., plants, birds, or insects) (Allen 1976). These societies brought substantial standardization to and validation of natural history data. They enhanced the publication of accurate and portable field guides, promoted the use of common systems of nomenclature, processed and stored records, and had observations checked by experts (Allen 1976). This shows that before policy and planning took an interest in biodiversity data, natural history organizations were already concerned with data validation. Thus, even though the current emphasis on the use of biodiversity data in policy might have shifted data-validation practices, validation cannot only be seen as a top-down phenomenon, where quality criteria are imposed to enable external scrutiny. In this article, we examined the role that validation plays in natural history organizations and networks.

Natural History, Citizen Science, and Validation as Collective Performance

Natural history has always been closely associated with science (Ritvo 1997). The volunteers in natural history are often highly respected as authoritative experts, and techniques for validating, presenting, and analyzing data have kept pace with scientific developments. Thus, we consider natural history a form of citizen science. Haklay (2013) distinguishes between community science and classical citizen science. Community science is citizen-driven: citizens use scientific methods to produce knowledge about a local issue and bring about change. In contrast, classical citizen science is science-driven, and the advancement of science is the primary objective. Other authors offer more complex typologies with multiple categories that distinguish between degrees of participation (Bonney et al. 2009; Shirk et al. 2012) or between the different kinds of activities citizens are involved in Wiggins and Crowston (2011); Newman et al. (2012).

The study of natural history is typical of traditional citizen science, where the mode of participation is contributory (Bonney et al. 2009; Shirk et al. 2012), because the primary role of the volunteers is to contribute to science by submitting records. However, contributing to science is not the only motivation or objective of volunteers. Although many of them care about the scientific character and quality of their work, the study of natural history is also a way for them to enact their personal relationship with nature (Ellis & Waterton 2004; Lawrence & Turnhout 2010).

In the field of natural history, different hierarchies distinguish between novices, experts, volunteers, and professionals (Waterton 2002; Bell et al. 2010). The relationships among these hierarchies are often precarious and tension filled (Meyer 2010; Toogood 2013). One area where tensions may become manifest is validation. Reasoned from a scientific perspective, validation and quality control are crucial, and there is much debate in the citizen science community about how to ensure the reliability of volunteer data (Bonney et al. 2009).

We considered validation as a point of connection in citizen science networks. Drawing on Latour (1999), we conceptualize validation as a process of translation during which an observation is transcribed onto a standardized form and becomes a record that is subsequently validated and digitized (Roth & Bowen 1999; Waterton 2002). However, rather than a progressive journey from observation to digital record, validation is networked and relational and involves ongoing interactions between recorders and validators. From this perspective, we addressed the question of how validation is done in practice; how it involves tools, field guides, and theoretical assumptions as well as relationships between people who record observations and people who negotiate the validity of biodiversity data.

Taking seriously the relational dimension of validation, we suggest that validation is a collective performance. Research suggests that collectivity does not require harmony, and that it thrives on ongoing questioning and scrutiny (Tsouvalis & Waterton 2012). However, collectivity does require a certain degree of reciprocity and interaction in the sense that the data, and the various translations of these data, are shared and distributed among the members of the network. As Latour (1999) explains, the ongoing circulation of these data translations, what he calls references, ensures the stability of the network and the data produced in the network. In our case, the reference is the biodiversity record that refers to a specimen observed in the field. Thus, we examined the collective character of validation by mapping the different translations of biodiversity records: how they circulate and how they are shared, distributed, and negotiated.

We focused our analysis on The Netherlands and the United Kingdom. Both countries have long traditions in natural history and are confronted with increasing demands for data to address policy concerns. As such, they offer good potential for studying a diversity of validation practices and the connections among them. All 3 of us have spent many years working and studying the field of natural history. For this article, we revisited our research and practical experiences in a new way with an explicit focus on validation. To analyze our data, we used an open coding process that focused on the organization of validation in practice, the different methods and techniques used, the different places in which validation takes place, and the different people involved.

The research of which this article is part includes numerous interviews and focus groups. However, not all of these focused explicitly on validation. The interviews we used were largely from 10 interviews with Dutch practitioners in natural history organizations and two interviews with U.K. practitioners because these interviews focused explicitly on this topic. We triangulated the data from these interviews with documents from the Netherlands and the United Kingdom, which we also analyzed with an open coding procedure and from the perspective of our own experiences and ongoing work. In that way, we have reflexively validated our analysis to ensure that it offers an accurate and grounded representation of validation practices in natural history.

We structured our findings on the basis of the variety of validation practices and the sites in which they took place. We examined validation practices that take place among the recorders themselves and within the natural history organizations. We also considered validation practices as they occur in biodiversity information initiatives that aim to generate policy-relevant and reliable biodiversity data on national and supranational scales. This provided the basis for our examination of validation as collective performance and for drawing conclusions.

Validation in the Field

Validation in natural history is as much about training volunteers to make correct observations and identifications as it is about socialization within tight-knit communities. Typically, the training of novices involves field trips guided by experts (Waterton 2002). Many natural history organizations provide instructions, offer courses, or use systems of regional experts to recruit and train volunteers. As one respondent explains:

> New volunteers are accompanied in the field ... Their level [of knowledge] is checked. And they never work alone in the beginning; they are always hooked up with a more experienced volunteer to learn. When the person is good enough, they go on with their own plots ... there is a quality check on the records [interview Dutch Society for Flora and Fauna].

Although often implicit, the hierarchical relations between novices and experts manifest themselves in practice in different ways. Experts lead the visits and trainings; they decide where to go, when to stop, and when to move on; and often they are authors of identification manuals or recording forms, or they are the contact person for the submission of records.

By doing their bit within the group and by gaining experience and expertise, novices can eventually become experts themselves. Acquiring expert status depends not only on expertise but also on how well a person performs in the organizations (Bell et al. 2010). The following quote illustrates this:

> You must earn your status. ... before you have expert status, you must show that you know your stuff. [Experts are also] very much appreciated, because they lead these groups [and] ... educate and transfer their knowledge [interview Dutch natural history organization for plants].

In the field, validation often involves guides providing images of ideal types of species and descriptions that focus on the characteristics considered vital for correct identification (Law & Lynch 1988). These guides help the recorder compare observed specimens with the ideal one. Identification also often relies on interaction with more experienced recorders who teach others how to look, what to look for, and how to handle specimens. Experts often rely on their affective experience and sensory interactions with the specimen (Roth 2005; Lorimer 2008; Ellis 2011) rather than on field guides.

The following interaction illustrates how identifications are often challenged, especially in the case of species that closely resemble each other but differ in rarity: Recorder A, "I just saw a Short-toed eagle." Recorder B: "Why wasn't it a buzzard?"

Recorder B's question demonstrates his knowledge that Short-toed Eagles (*Circaetus gallicus*) are rare and that mistaking a Short-toed eagle for a buzzard is a common mistake. This triggers recorder A to consult a guide and compare the features in the guide with what she or he saw. The eventual conclusion is informed by what is found in the guide and by her or his previous reasons to call the bird a Short-toed eagle. As such, the identification is validated through complex interactions between the specimen, the recorder, and her or his resources, including experience, field guides, and often binoculars.

Changing ideas about species identification further complicate the process of validation. An entomologist might say, "We used to look at the yellow spots on the sternum to determine the species, but now we know to look at the shape of the genitals." Such new understandings of what it is that makes a species have numerous consequences. They require new skills and ways of looking at specimens as well as new field guides and training methods. And they require critical scrutiny of old records to determine whether the names that were given earlier actually refer to same organism.

So far, we have shown that validation is never only about the observed specimen. It involves a trained eye, equipment, such as binoculars or magnifying glasses, experience, skill, field guides, and interactions with fellow recorders. Even then, identification can be problematic.

Some species are nearly impossible to distinguish in the field, individual specimens can be ambiguous, and classifications may have changed. In these cases, knowledge of the ecology of species is helpful. As Roth (2005) explains:

> [Fisheries scientists'] judgments of what the specimen is "in itself" relied upon their understanding of its place in an ecology; they did not determine its species classification *first* and *then* consider how it fitted into an environment. The classification took account of the weather, geography, and topography of the area.

The interactions that take place during validation in the field suggest considerable collectivity and ongoing interactions. However, there are clear hierarchies in which some volunteers are readily recognized and appreciated as experts.

Natural History Organizations as Centers of Calculation

An important step in validation is the transformation of an observation into a record by means of inscription onto standardized forms. These forms are provided by the natural history organizations and require the recorder to submit the date and time of the observation, name, sex, number, and behavior of the specimen observed, conditions of habitat and weather, and location coordinates. Inscription is important because observations need to become data before they can be transported to natural history organizations. These organizations resemble what Latour has called centers of calculation (Latour 1987); they are a crucial node in the network where all data are collected and subjected to new processes of translation. The larger and wealthier organizations employ professionals—who in most cases have expert status and are active as volunteer recorders—whereas the others rely solely on volunteers.

Inscription removes contingencies and uncertainties and what remains is a record stripped of much of the contextual knowledge that went into the identification of the organism. When a record arrives at the natural history organizations, it is digitized (increasingly, records are being submitted through the internet) and inserted into databases. Here, new practices of validation begin. As the following quote demonstrates, it is crucial to check the records:

> [Checking] is one of our roles. [. . .] That's part of the support that we give to recording groups. [. . .]. [Funders like local governments] recognise that they will get much better data out if they invest in the people who are collecting the data through us [interview Thames Valley Record Centre].

Many organizations start validation with an automatic check for so-called deviating records. The following is a typical explanation of the procedure in natural history organizations:

> All the digitised data are checked by our own automatic computer program. This compares the distribution of species in the forms with known data. So, if there are deviations, alarm bells start ringing, especially for rare species [interview Dutch natural history organization for plants].

Deviations can refer to the known distribution area of a species or to the known time periods (in a day or in a year) during which a species can be observed. Records of rare species, important species (e.g., species that are listed in policy documents and laws), or difficult-to-identify species are checked more intensively than species that are more common or easy to identify. As the following quotation indicates, these different kinds of records can be grouped in a formal classification: "We might define species generally as 1) not needing expert identification, 2) expert opinion desirable, depending on ability of recorder, and 3) expert opinion essential" (James 2005).

Deviating records are checked for several things, including the circumstances during which the observation was made and whether proof is available, in the form of, for example, a photograph, herbarium material, or a prepared and pinned specimen. The process of checking may entail asking a series of questions, such as:

> . . . [D]id you catch it, did you get a photograph, can you give a description, can you tell us why you came to the conclusion that it was that species, did you see the butterfly before, which guide did you use? All kinds of questions [are asked] that . . . give more background information . . . at the end a committee decides whether this is valid information or not [interview Dutch natural history organization for butterflies].

Such questions are an attempt to retrieve some of the information that got lost during inscription. This shows that validation practices in natural history organizations require not only information about the specimen but also about the context in which it was observed. Part of this involves the reputation of the recorder. Although anyone can mistakenly tick the wrong box on a species list, it matters who submits a record:

> "It makes a difference if [names of 2 very authoritative Dutch plant recorders] have found them or whether it was just any recorder" (interview Dutch natural history organizations for plants).

The following 2 quotes demonstrate that some recorders are known to be less reliable:

> I do know certain people who are more likely to let their imagination get the better of them [interview Dutch natural history organizations for plants].

> Of course you have information about unreliable recorders. You always have unreliable records, but at a certain moment [deviating records] cluster around specific locations and then you know, oh, they are from so and so [interview Dutch natural history organizations for birds].

The expertise of other recorders may not be known, particularly in large-scale surveys. The natural history organizations may therefore attempt to categorize recorders. One recorder, participating for the first time in the U.K. National Plant Monitoring Scheme, asked for advice on identifying a grass. Subsequently, she was asked to either send a photograph or choose an easier level of participation that did not include grasses. This attempt to pigeonhole recorders is risky. In this case, it led to a simplification of data and may have led to potential disengagement of the recorder.

The following exchange occurred between one of us (S.T.) and a validator relative to his record of a gatekeeper butterfly (*Pyronia tithonus*):

> Validator: "Are you sure? We have no information on *Pyronia tithonus* in that area."

> S.T.: "But I have distinctively seen the white spots in the black spots that are described in the field guide as the essential field marks."

> Validator (author of the field guide S.T. used): "The lucidity of orange in its wings is a better feature than the spots. Do you have some photographs?"

> S.T.: "I do not have photographs of this particular sighting, but I have some of previous sightings of butterflies that I identified as *Pyronia tithonus*. And I also have photos of the very similar meadowbrown (*Maniola jurtina*). Based on the lucidity of orange characteristic, I guess all my records of *Pyronia tithonus*, including older ones, should be *Maniola jurtina*."

> Validator: "Yes, you are right, they are all *Maniola jurtina*, I will correct your records."

The validation practices described so far treat different species differently, different recorders differently, and, as the exchange above shows, different records of the same species differently. The outcome of these validation practices can be quite conservative, making it next to impossible for recorders without strong reputations to get their records of rare or difficult species accepted.

The natural history organizations function as gatekeepers or obligatory points of passage (Callon 1986) that decide which records will be accepted. There is a clear demarcation between the work of the recorders and the work of the validators. In natural history organizations that employ staff, this demarcation is at the same time a demarcation between volunteers and professionals:

> The professional part is the coordination, making sure that people get the forms, that the data are processed, that they are analyzed . . . that they are communicated to the principals. From the moment that the data come in, from that moment it is a professional business [interview Dutch natural history-organization for birds].

This emphasis on coordination and quality control may lead to tensions with volunteers who do not always appreciate having their records checked and their identification skills questioned. One respondent was critical about natural history organizations only being interested in data:

> They are basically interested in gathering data and get as good an analysis on them as possible, to get the distribution [interview Netherlands European Invertebrate Survey).

Many natural history organizations are aware of this risk and emphasize the importance of taking care of the volunteers and ensuring a good relationship:

> The relationship of trust is key to making the records centre work [interview English Local Records Centre].

> The feeling [that the volunteers know that you are one of them] is very important. . . . They want to get to know you and they want to know that you know what you are doing. That you are not just a guy who puts data into the computer, but that you know your plants. . . . If they know that your heart is in the right place, that you will treat their data responsibly, then they will accept a lot from you [interview Dutch natural history organization for plants].

A *lack* of validation can also be risky and can result in disengagement. One U.K. volunteer experienced this when she submitted a record of a Great Northern Diver (*Gavia immer*) in Scotland in the breeding season and included a note that she could provide photos if required. She reported: "This felt really special to me—it is so unusual to see these birds this far south in summer." When the British Trust for Ornithology did not respond, which suggested that apparently the record was not as unique as she supposed, she experienced this as a lack of interest in the record and did not follow up with further records.

As we have demonstrated in this section, the natural history organizations play a central role in validation as centers of calculation (Latour 1987). What they work with is not biodiversity itself but the records that refer to and stand in for the actual observed specimens. However, in case of deviating records, validation involves the retrieval of information that got lost during inscription: the actual specimen, a photograph, the context of the observation, and the identity of the recorder are, at least temporarily, drawn back into circulation. Thus, the record has become a circulating reference (Latour 1999) that moves between the species it refers to, the recorder who made the inscription, and the validator who checks its reliability. As in the previous section, this interaction points to the collective nature of validation. And also here, validation is characterized by significant power differences and one-sided interactions between validators who are in charge of deciding on reliability and volunteers who are requested to deliver more proof for their records or are, in some cases, ignored.

Records Travel to National and Transnational Biodiversity Information Initiatives

Once records are accepted (even if acceptance is temporary as in the butterfly example), validation continues. Biodiversity records travel to other organizations and institutions, are included in different databases, and are used for a variety of purposes (Bowker 2005). For this movement to be possible, records are validated using new standards.

For example, the Global Biodiversity Information Facility (GBIF) aims to achieve an internationally distributed network of interoperable databases and applications in order to publish as much primary biodiversity data as possible. Before biodiversity records are entered into GBIF, they are validated. This validation involves standardization to guarantee interoperability and ensure that the records fit in the GBIF infrastructure. The standard that GBIF uses is called the Darwin core standard and consists of over a hundred >100 possible fields (Darwin Core Task Group 2014). To be included in GBIF, a record needs to have at least the following 5 fields: basis of a record (e.g., fossil, observation, or object); institutional code (owner of the data or objects); collection code (name of the data set); catalog number (unique number of the observation or collection); and scientific name (correct taxonomic name). Validation in GBIF is primarily procedural because the records are checked not for their correspondence with reality but rather for their compliance with the standard.

Statistics play a crucial role in the validation of biodiversity records. Statistical analyses are used to assess and, where possible, reduce standard error, and to upscale point data to full-coverage representations (Turnhout & Boonman-Berson 2011). In fact, statistics have become so important that many biodiversity recording and monitoring schemes are specifically planned to enable statistical analyses. In these cases, recorders survey a standardized area upon which a grid has been superimposed: a minimalist field laboratory (Latour 1999).

One example of the importance of statistical forms of validation is the Dutch Network of Ecological Monitoring (NEM). This network consists of a number of government-funded monitoring schemes executed by several natural history organizations that provide the government with relevant data about specific policy-relevant species and species groups. Statistics Netherlands, a governmental agency, plays an important role in the design of the schemes and in the validation of the records. It requires standardized methods for data collection in which volunteers systematically monitor a specific route or area at regular time intervals. Thus, as the following quotes demonstrate, participating in NEM implies new and strict standards for data quality:

> We have said: Pay attention, we now have a new situation. In the earlier days, it was all supply driven, and we were happy with your data, but now you have to professionalise. It is part of the game. . . . If you do it right you will get your money on a yearly basis. But the data have to meet with higher and more standards [interview Statistics Netherlands].

> This also means the volunteers have to be coordinated. We now say to the Butterfly Foundation for example, that there are white spots in certain parts of the country where no recording is being done. In that way we cannot calculate national trends. So we say to them that they have to try harder [interview Statistics Netherlands].

Part of the work of Statistics Netherlands is called "repairing the data." This repairing involves using estimates or proxies to fill holes in the data set and correcting for recorder bias and over- or undersampling. The validated data are subsequently used to calculate index figures that represent national trends and show whether a species is increasing or decreasing. The European Biodiversity Observation Network (EBONE) also uses statistical procedures to produce full-coverage representations of Europe's biodiversity (Turnhout & Boonman-Berson 2011).

The complicated statistical procedures make it difficult to trace the data back to original records. Such backtracing is also not considered necessary in some cases. The development of so-called proability maps (Nationale Databank Flora en Fauna 2015) is an example. These maps, heralded as prime examples of the policy-relevance of natural history, indicate the probability of observing a certain species at a certain location during a specific part of the year. Making these probability maps involves a significant change in the meaning of biodiversity data; such data are no longer records of actual observations but have become a probability, a potential future observation.

The validation practices discussed in this section involve new criteria imposed by new actors that are related to policy-relevance, database standards, or statistics. The ties between validators and recorders are significantly weaker here than in the validation practices discussed in the previous sections, and they are completely severed when the meaning of the record changes from observation to probability.

The Collective Performance of Validation

Our results point to the variety of sites, people, and organizations involved in validation practices in natural history. We found that these practices are networked and relational and involve interactions between species and recorders and between recorders and field guides, computer software, natural history organizations, etc. Thus, validation does not occur at a single center of coordination; rather, it is distributed and collective (Hutchins 1995). Our conception of collectivity was informed by recent work in the social sciences that shows collectivity does not require harmony (Latour 2004, 2010) and thrives on questioning and scrutiny (Tsouvalis & Waterton 2012). We saw this in the validation practices in the field, where experts train novices and check their identifications. Questioning and scrutiny continued in validation practices in natural history organizations for records that were not immediately accepted as reliable representations of observed biodiversity.

Validation is potentially precarious and recorders might take it as criticism of their knowledge, experience, and skills. We found, however, that validation plays a vital role in natural history networks. The notion of circulating reference is helpful for understanding how validation can assume this role. During validation, interactions between recorders and validators are sustained and the record continues to circulate between the species it refers to, the recorder who made the inscription, and the validator who checks its reliability. Thus, validation practices are key sites of connection, mutual recognition, and interaction and thus play an important role in guaranteeing the collective character of natural history networks.

At a certain point, however, interaction seems to diminish; then it becomes less clear whether and how reciprocity and circulation are maintained. The validation practices used in making probability maps and in biodiversity information initiatives, such as EBONE, GBIF, and NEM, involve practices that appear increasingly unidirectional. Validation no longer focuses on interactions between records, recorders, and biodiversity; rather, the focus is on preparing records for further travel, for inclusion in different databases, and for use by policy and other actors. When "knowledge crosses over from one context ... to another [it enters] new ... scientific and political configurations," where people have their own ideas about how that knowledge may be put to use (Waterton 2002). Although the validation of biodiversity data in these new configurations builds on the validation practices discussed previously, there is an important difference in that there is significantly less interaction between recorders and validators. Some of the statistical techniques used even sever the ties between recorders and validators in the citizen science networks.

This is not necessarily surprising; when data enter a new context, they must be geared toward new audiences and new criteria for usability apply. Moreover, it makes sense for biodiversity information initiatives to not have to redo the validation work done in the field and by the specialized natural history organizations. It is, however, important in light of the citizen science character of natural history.

Our analysis of validation practices sheds new light on natural history as a form of citizen science and on existing typologies of citizen science. We suggested above that natural history is a contributory form of citizen science with a relatively low degree of participation because the design of the recording process and the analysis of the data are initiated and primarily handled by the recording organizations. However, the interactions and reciprocities we observed between recorders and validators in the field and at the natural history organizations make clear that also in contributory forms of citizen science, validation practices that involve circulation, interaction, and mutual recognition are essential to ensure close ties between recorders and validators. The collective nature of validation strengthens the contribution of these natural history networks to the dual objective of citizen science to contribute to the needs of both science and citizens.

The validation practices in the biodiversity information initiatives we discussed differ from those in the field and at the natural history organizations. Although according to citizen science typologies, these initiatives are also best classified as contributory, they take on a more extractive mode of data use and validation in which the ties between recorders and validators are loosened or even severed. We suggest that this limits the contribution of these biodiversity information initiatives to the dual objective of citizen science and may even pose a threat to the citizen science networks on which they rely and of which they are part.

We are not advocating that natural history networks try to achieve a higher level of participation. As Lawrence (2006) has pointed out, sense of meaning, empowerment, and transformation on the part of the participants can also be accomplished at low levels of participation, and large differences in outcomes for participants can be identified among projects using the same level of participation. Rather, we argue that citizen science initiatives, even if those that are supranational or otherwise more remote from the daily practices of the citizens involved, will have to find ways to expand interaction and circulation in their validation practices. More generally, we suggest that validation practices that involve scrutiny and criticism as well as care, trust, and mutual recognition are crucial for citizen science collectives to thrive.

Literature Cited

Allen DE. 1976. The naturalist in Britain. Princeton University Press, Princeton, New Jersey.

Bell S, Marzano M, Podjed D. 2010. Inside monitoring: a comparison of bird monitoring groups in Slovenia and the United Kingdom. Pages 232–250 in Lawrence A, editor. Taking stock of nature: participatory biodiversity assessment for policy planning and practice. Cambridge University Press, Cambridge.

Bonney R, Cooper CB, Dickinson J, Kelling S, Philips T, Rosenberg KV, Shirk J. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience **59:**977–984.

Bowker GC. 2005. Memory practices in the sciences. The MIT Press, Cambridge.

Callon M. 1986. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. Pages 196–223 in Law J, editor. Power, action and belief: A new sociology of knowledge? Routledge, London.

Darwin Core Task Group. 2014. Biodiversity information standards. Available from http://rs.tdwg.org/dwc/ (accessed February 2015).

Ellis R. 2011. Jizz and the joy of pattern recognition: virtuosity, discipline and the agency of insight in UK naturalists' arts of seeing. Social Studies of Science **41:**769–790.

Ellis R, Waterton C. 2004. Environmental citizenship in the making: the participation of volunteer naturalists in UK biological recording and biodiversity policy. Science and Public Policy **31:**95–105.

Haklay M. 2013. Citizen science and volunteered geographic information: overview and typology of participation. Pages 105–122 in Sui D, Elwood S, Goodchild M, editors. Crowdsourcing geographic knowledge: volunteered geographic information (VGI) in theory and practice. Springer, Heidelberg.

Hutchins E. 1995. Cognition in the wild. The MIT Press, Cambridge.

James T. 2005. How real are your records? Exploring data quality. Summary report of the 4th NBN Conference for National Societies and Recording Schemes, 19 November 2004. National Biodiversity Network, The Natural History Museum, London.

Latour B. 1987. Science in action: how to follow engineers and scientists through society. Harvard University Press, Cambridge.

Latour B. 1999. Circulating reference: sampling the soil in the Amazon forest. Pages 24–79 in Pandora's hope. Harvard University Press, Cambridge, Massachusetts.

Latour B. 2004. Politics of nature: how to bring the sciences into democracy. Harvard University Press, Cambridge.

Latour B. 2010. An attempt at a "Compositionist Manifesto". New Literary History **41:**471–490.

Law J, Lynch M. 1988. Lists, field guides, and the descriptive organization of seeing: birdwatching as an exemplary observational activity. Human Studies **11:**271–303.

Lawrence A. 2006. 'No personal motive?' Volunteers, biodiversity, and the false dichotomies of participation. Ethics, Place and Environment **9:**279–298.

Lawrence A. 2010. The personal and political of volunteers' data: towards a national biodiversity database for the UK. Pages 251–265 in Lawrence A, editor. Taking stock of nature: participatory biodiversity assessment for policy planning and practice. Cambridge University Press, Cambridge.

Lawrence A, Turnhout E. 2010. Personal meaning in the public sphere: the standardisation and rationalisation of biodiversity data in the UK and the Netherlands. Journal of Rural Studies **26:**353–360.

Lorimer J. 2008. Counting corncrakes: the affective science of the UK corncrake census. Social Studies of Science **38:**377–405.

Meyer M. 2010. The rise of the knowledge broker. Science Communication **32:**118–127.

Nationale Databank Flora en Fauna. 2015. Kansenkaarten beschikbaar in de NDFF. Available from http://www.ndff.nl/kansenkaarten-beschikbaar-in-de-ndff (accessed February 2015).

Newman G, Wiggins A, Crall A, Graham A, Newman A, Crowston K. 2012. The future of citizen science: emerging technologies and shifting paradigms. Frontiers in Ecology and the Environment **10:**298–304.

Porter TM. 1995. Trust in numbers: the pursuit of objectivity in science and public life. Princeton University Press, Princeton.

Ritvo H. 1997. The platypus and the mermaid, and other figments of the classifying imagination. Harvard University Press, Cambridge.

Roth W-M. 2005. Making classifications (at) work, ordering practices in science. Social Studies of Science **35:**581–621.

Roth W-M, Bowen GM. 1999. Digitizing lizards. The topology of 'vision' in ecological fieldwork. Social Studies of Science **29:**719–764.

Shirk JL, et al. 2012. Public participation in scientific research: a framework for deliberate design. Ecology and Society **17:**29.

Toogood M. 2013. Engaging publics: biodiversity data collection and the geographies of citizen science. Geography Compass **7:**611–621.

Tsouvalis J, Waterton C. 2012. Building 'participation' upon critique: The Loweswater Care Project, Cumbria, UK. Environmental Modelling & Software **36:**111–121.

Turnhout E, Boonman-Berson S. 2011. Databases, scaling practices and the globalization of biodiversity. Ecology and Society **16:**35.

Waterton C. 2002. From field to fantasy: classifying nature, constructing Europe. Social Studies of Science **32:**177–204.

Wiggins A, Crowston K. 2011. From conservation to crowdsourcing: a typology of citizen science. Proceedings of the 44th Hawaii International Conference on System Sciences: 1–10.