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# Leveraging the power of place in citizen science for effective conservation decision making

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## ABSTRACT

Many citizen science projects are place-based -built on in-person participation and motivated by local conservation. When done thoughtfully, this approach to citizen science can transform humans and their environment. Despite such possibilities, many projects struggle to meet decision-maker needs, generate useful data to inform decisions, and improve social-ecological resilience. Here, we define leveraging the 'power of place' in citizen science, and posit that doing this improves conservation decision making, increases participation, and improves community resilience. First, we explore 'place' and identify five place dimensions: social-ecological, narrative and name-based, knowledge-based, emotional and affective, and performative. We then thematically analyze 134 case studies drawn from CitSci.org ( $n = 39$ ), The Stewardship Network New England (TSN-NE;  $n = 39$ ), and Earthwatch ( $n = 56$ ) regarding: (1) use of place dimensions in materials (as one indication of leveraging the power of place), (2) intent for use of data in decision-making, and (3) evidence of such use. We find that 89% of projects intend for data to be used, 46% demonstrate no evidence of use, and 54% provide some evidence of use. Moreover, projects used in decision making leverage more ( $t = -4.8$ ,  $df = 117$ ;  $p < 0.001$ ) place dimensions ( $\bar{x}=3.0$ ;  $s = 1.4$ ) than those not used in decision making ( $\bar{x}=1.8$ ;  $s = 1.2$ ). Further, a Principal Components Analysis identifies three related components (aesthetic, narrative and name-based, and social-ecological). Given these findings, we present a framework for leveraging place in citizen science projects and platforms, and recommend approaches to better impart intended outcomes. We discuss place in citizen science related to relevance, participation, resilience, and scalability and conclude that effective decision making as a means towards more resilient and sustainable communities can be strengthened by

leveraging the power of place in citizen science.

Keywords: Citizen science, Power of place, Place-based citizen science, Integrated citizen science, Social-ecological systems, Conservation decision making, Open science, GIS, Open data

## INTRODUCTION

Citizen science is a phenomenon born out of a long history of public participation in scientific research (Miller-Rushing et al., 2012) enacted through many approaches (e.g. contributory, collaborative, and co-created) that can involve crowdsourcing, community-based monitoring, and participatory action research (Bonney et al., 2009; Danielsen et al., 2009; Ballard and Belsky, 2010; Shirk et al., 2012). Some projects extend the spatial and temporal scale of data available for scientific investigations (Loss et al., 2015; Theobald et al., 2015) while others improve the coupling of natural and human systems data collection (Crain et al., 2014). Regardless of approach or goal, citizen science projects often focus on a particular topic of interest to the scientific community such as bird diversity, precipitation, phenology, astronomy, or public health; not necessarily on multi-faceted conservation decisions, issues, or actions relevant to specific place(s). Moreover, empirical reviews of citizen science reveal that its contribution to decision making and, ultimately, social-ecological resilience, can often be relatively trivial (Conrad and Hilchey, 2011; see also Gray et al. this issue). There is a need to understand the barriers to use of citizen science data in decision making and examine factors and circumstances influencing success (Conrad and Hilchey, 2011). We do not fully understand how knowledge gained from citizen science translates into conservation decision making processes -processes often requiring integrated knowledge across many topics related to particular places.

Indeed, little is known about the possibility and implications of leveraging aspects of 'place' in citizen science to impart applied solutions through informed conservation decision making (Haywood, 2014). The stewardship of any particular place ideally relies on scientifically

informed decision making rooted in place in conjunction with continuous monitoring, evaluation, reflection, and management by diverse stakeholders (McGinnis, 2016).

Stakeholders influencing decisions include governmental agencies, non-profit organizations, private landowners, county planning offices, collaborative conservation initiatives, concerned citizens, and similar actors. For those becoming involved in citizen science, recent technological advances can streamline traditionally time consuming tasks such as data entry and volunteer coordination. For example, support platforms such as ebird, iNaturalist, CitSci.org, and SciStarter are empowering more people to create (and connect with) place-based efforts. Here, we hypothesize that projects leveraging the power of place strengthen their influence on conservation decision making. In this paper, we define these terms, identify and test one indication of leveraging the 'power of place,' and recommend ways citizen science practitioners (both project and platform designers) can better leverage place to make their efforts more likely to inform conservation decision making.

## Citizen science

Citizen science is a process where citizens become involved in science (Kruger and Shannon, 2000) or, more generally, public participation in scientific research (Bonney et al., 2009; Shirk et al., 2012). A growing number of projects are motivated by local conservation issues. These projects are considered community-based monitoring and represent "...a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track and respond to issues of common community concern" (Whitelaw et al., 2003, p. 410). Some projects might even be construed as

community-based management, where citizens and stakeholders are included in management of (and hence decision-making regarding) natural resources (Keough and Blahna, 2005; Conrad and Hilchey, 2011). When done thoughtfully, these projects can transform the relationship between humans and their environment and have been implicated in increasing community social-ecological resilience through improved conservation decision making (Shirk et al., 2012).

### Conservation decision making

Conservation decision making is a difficult process to define. For this paper, we focus on a few core components: decisions about land-use and/or natural resource management made either by institutions or by individual private landowners regarding the stewardship of property. These decisions can be about policy changes or about how to work and act within existing policy, and can be made at any scale from local to global. Decisions beyond those of the individual landowner involve some degree of political interaction. Public participation in decision making is seen as critical to sustainable development (WCED, 1987; Kates et al., 2001), is integrated in the Rio declaration of 1992 (UNEP, 1992) and is now considered an important pillar of environmental democracy (Mauerhofer, 2016). It is therefore assumed to be normatively good (Haklay, 2003, Miller, 2013), but some maintain that this is true only when managed fairly and effectively (Reed, 2008). In practice, effective participation in decision making involves establishing rules in advance; creating a culture of empowerment, equity, trust, transparency, and learning; continual (and early on) opportunities; institutionalization; inclusion of local and scientific knowledge(s); presence of experienced moderators; integration of stakeholders; and organizational cultures that foster continual goal negotiation and



outcomes assessment (Reed, 2008; Luyet et al., 2012). Involving participants in participatory modelling has also been shown to improve participation experiences and group decision making (Gray et al., this issue).

### Leveraging the power of place

Although most field-based citizen science occurs at, and is grounded in, specific places, little research has extensively explored the affective interactions and relationships among volunteer participants and the places in which they participate in citizen science (Haywood, 2014). The place literature historically emphasizes the “lived experiences” of humans within specific social-ecological contexts (Allen, 2004; Casey, 1993; Hubbard et al., 2002). For example, the phenomenological geographers Relph, (1976) and Tuan (1975, 1977) claim that the concept of place is much more particular and nuanced; it is linked to life histories, social processes, and individual experiences (e.g., race, age, gender, sexuality, and spiritual orientation) that, in turn, influence our understanding of place (Haywood, 2014).

We define the ‘power of place’ by combining material and symbolic perspectives which together create the capacity for citizen science to foster sustainable place-making. Our concept of place draws on interdisciplinary approaches developed over the last several decades in place studies (see Lewicka, 2011; Manzo and Devine-Wright, 2013 for comprehensive reviews of place studies), environmental communication (Cantrill and Oravec, 1996; Spurlock, 2009; Druschke, 2013), and human geography (Massey, 2005). An early definition of place defined it as a type of affective relationship or attachment that connects people to specific physical locales (Irwin Altman and Low, 1992; Lewicka, 2014). Much like the discussions that have

occurred within citizen science, studies of place have explored this concept through quantitative and qualitative approaches that use a variety of methods. Although the 'sense of place' concept has been used to explore how citizen science participants make connections between embodied experiences, thoughts, ideas, interactions, and behaviors (Haywood et al., 2016), there is a clear need to build upon conceptualizations of 'place' and explore how use of place concepts may affect the decision making outcomes of citizen science (Haywood, 2014).

For us, the phrase 'power of place' embodies actions motivated by the emotional, cultural and material connection that many people have for the place in which they live, sometimes expressed as 'love' or 'attachment to place'. It also includes actions guided by the interconnected understandings which can come with this intimate connection (McGinnis, 2016). Hence, citizen science projects and platforms that 'leverage the power of place' are those that connect with these motivations and understandings. There are many means towards this end. Here, we explore one in detail specifically use of place dimensions in project materials as an indicator of leveraging the power of place - and test it against our hypothesis that doing this improves a project's influence in conservation decision making.

## METHODS

Our goal is to explore the connections between citizen science, conservation decision making, and how projects that leverage the power of place influence data use in decision making. We focus our analysis on projects, but return to the scope of platforms in our recommendations, discussion, and conclusion. We first identify and describe five dimensions of place as one indication of leveraging the power of place and then use qualitative, quantitative,

and statistical techniques (mixed methods) to explore this potential relationship.

## Place dimensions

Our characterization of the power of place is consistent with qualitative and phenomenological approaches (Seamon, 2013), but the place dimensions we identify and test can also be measured quantitatively. We identify place dimensions that are both symbolic and material, whereby place is socially constructed (agreed upon by people and existing within local and global cultures) and related to an actual physical reality. For us, 'place' includes (1) the physical location and ecological life support system ( i.e., a Social-Ecological System or SES); (2) the narratives and place names that people ascribe to a place (narratives and place names); (3) the local knowledge(s) people have about a place (knowledge-based); (4) the emotional attachments people feel (emotional and affective); and (5) the ever changing dynamic of active place-making (performative) (Table 1). Clearly, these dimensions intersect and overlap. For example, we come to know a place through place-names and stories that can also influence how we materially shape that place, or conversely, how that place shapes us. In this paper, we tease apart these dimensions to guide our analyses and recommendations. Considering them as distinct, but still connected and mutually influencing, allows a richer perspective of the many ways in which practitioners may leverage these dimensions in project design and implementation.

Our first dimension refers to an actual physical location, a social-ecological system, which literally sustains everything we do, including our citizen science programs. This dimension is akin to 'locale' as per Agnew and Duncan (1989) and Haywood (2014). As Stedman (2003)

argues, although perceptions of place can be socially constructed, there is an actual physical world that exists that influences our felt attachments to it (Stedman, 2003). Approaching place as an SES recognizes the flow of materials and energy that shape and sustain human and natural communities. The human body is a tangible example, as we could easily consider ourselves ecosystems with legs. In fact, citizen science projects are now being called upon to collect SES data to study complex socio-ecologies (Crain et al., 2014). For citizen science projects, it matters whether and when birds appear, planets orbit, companies pollute, species invade, amphibians migrate, and algae bloom. Those who coordinate projects documenting events such as these know that these events are very real and fundamentally shape our activities. The power of place, from this perspective, recognizes our dependence on, and connections within, social-ecological systems.

Our second, third, and fourth dimensions all refer to different ways in which the concept of place can also be symbolic. Massey (2005) describes the complex intersections between material and symbolic constructions of place as relational and resulting from material and social-cultural flows. These flows include stories and discussions between people, but also increasingly the production of information (especially digital) that includes geographic locations (e.g., latitude and longitude coordinates). The result of these flows is a shared understanding of place and its importance locally and globally. As a result, we have places that have different cultural and physical realities (e.g., Jerusalem) and some that are specific and that act as global icons (e.g., the Eiffel Tower as an icon of Paris). Place narratives and naming is an important dimension then in shaping human relationships to place (Cantrill and Oravec, 1996; Druschke, 2013).

In addition to the names we ascribe, the multiple forms of knowledge that influence our understanding of place can have a dramatic impact on our activities in relation to place. Science produces one form of empirical knowledge, and can be compared with Traditional Ecological Knowledge (TEK) as a related yet also distinct way of knowing a place. As Berkes (2012) identified, within TEK, place and the relationship to specific locations and the land are central to the organization and functioning of human societies. TEK may enact a form of empiricism or systematic, question-driven inquiry without necessarily relying on more post-positivistic assumptions about what the world is, how we fit in, and how we come to know what we know that characterize modern science. Our epistemologies (e.g., our claims about how we produce knowledge about a place) shape our activities within a place.

Our fourth dimension is recognizable to anyone who has experienced the “wow” factor in a place, an intensity of emotion that goes beyond words and dramatically shapes relationships with environments (Conley and Mullen, 2008). The emotional and affective dimension of place refers to two levels of experience. On the first level, people fall in love with places and feel a deep sense of connection to specific locales. Individuals define their ‘sense of place’ at different scales and locations and may be willing to invest more time and energy into the places they connect with if they believe their efforts will be valuable in conserving the intrinsic and extrinsic values of the places they love (Rolston, 1988, 1994). On the second, there is a space of attachment that transcends the felt emotion where the connection is more intuitive. When people describe being drawn to a place, this is an affective response that operates on a more intuitive level. This form of attachment occurs in a space that precedes the naming and labeling of emotion, like love, and can be experienced with places that may not be quintessentially beautiful, but rather degraded or impaired.

The fifth and final dimension is similar to Massey's (2005) discussion of flows and 'relationality'; it highlights the continual performance of place (McGill, 2006; Spurlock, 2009). The material and symbolic dimensions described above are in a continual process of flux, whereby SESs are constantly dynamic, names change and stories evolve, knowledge is produced and also forgotten and emotional attachments grow stronger and also fade. Place as a performance recognizes the active and continual production of place in and through activities (McGill, 2006; Spurlock, 2009) like citizen science. By attending to these dimensions, citizen science may begin to more fully realize its potential for active place-making and, perhaps, ultimately influence conservation decision making processes (Haywood, 2014). Such 'place-making' may occur through citizen science and associated stewardship activities and the informed and empowered involvement of individuals in social-ecological decision making.

#### Thematic analysis of case studies

We use a case study methodology (Yin, 2013) to analyze three separate contextual sources of citizen science projects: the CitSci.org ([www.citsci.org](http://www.citsci.org)) platform, The Stewardship Network: New England (TSN-NE; <http://newengland.stewardshipnetwork.org/>), and Earthwatch (<http://earthwatch.org/>). We selected these sources of project information because each serves as a hub for connecting and organizing multiple projects operating across local to global scales. Because each source contains nested cases, we were able to conduct a cross case comparison and engage in explanation-building that informed our place framework (Yin, 2013). Each source represents a different context for projects examined. CitSci.org is a global platform supporting citizen science projects. The TSN-NE is a regional network of citizen science and

community based monitoring efforts, and Earthwatch is a global organization supporting vetted projects led by scientists who do research with volunteers who pay to participate. Using a shared rubric (Table 2), we thematically analyzed 134 case studies drawn from CitSci.org ( $n = 39$ ), TSN-NE ( $n = 39$ ), and Earthwatch ( $n = 56$ ). We restricted our sample size within each source based on four criteria: (1) # participants > 25, (2) # observations > 50, (3) # years running > 3, and (4) availability of high quality written materials describing the project. We used these criteria to ensure mature projects and to standardize projects and materials across contexts.

Three team members, each familiar with one of our three sources, compiled and drew insights from available forms of evidence for their cases. Available forms of evidence included: direct observations based on personal conversations, leadership involvement, general participation, and a host of physical materials such as documents, reports, websites, data management platforms, photographs, news articles, and more (Yin, 2013). We created a shared spreadsheet including information about how the project self-describes, the project purpose, and any impacts observed in the materials. Team members then coded these materials independently with regard to intent for data to be used to inform decisions, whether data were used, and the degree to which they leveraged the power of place as evidenced by our five place dimensions (Table 2). For each project, we asked: ‘Does the project intend to inform decision making?’, ‘Does the project generate data used in decision making?’, and ‘To what degree does the project leverage the power of place based on our five place dimensions in their materials?’ We coded materials for these variables based on an ordinal scale of 0 to 2 (0 = no intent/use; 1 = some intent/use; 2 = high degree of intent/use). We then calculated binary ‘intent’ and ‘use’ variables as yes/no where 0 = no intent/use and either a 1 or 2 = intent/use in decision making.

We also calculated the total number of dimensions evident by summing the number of dimensions coded as either a 1 or 2 (Table 2) to capture the breadth of place dimensions leveraged. To gain consistent interpretations of materials, we triangulated our observations through iterative verbal and written discussions and discussed emergent themes stemming from our analysis (Lindlof and Taylor, 2002; Patton, 2002; Yin, 2013).

#### Inter-coder reliability and statistical analysis

To test for inter-coder reliability, we identified 10 projects from each context ( $n = 30$ ) and independently coded them. We convened twice to discuss discrepancies in project material interpretations focusing on five projects having disparate interpretations. We calculated Krippendorff's alpha using the "kalpha" macro in SPSS for the independently coded 30 project subsample (Hayes and Krippendorff, 2007 - [www.afhayes.com/public/kalpha.pdf](http://www.afhayes.com/public/kalpha.pdf)). Final inter-coder reliability statistics were as follows: intent ( $\alpha = 0.64$ ), use ( $\alpha = 0.60$ ), social-ecological ( $\alpha = 0.61$ ), narrative and name-based ( $\alpha = 0.44$ ), knowledge-based ( $\alpha = 0.63$ ), aesthetic and emotional ( $\alpha = 0.65$ ), performative ( $\alpha = 0.54$ ), and number of place dimensions ( $\alpha = 0.75$ ). Coding the number of place dimensions evident in project materials had the greatest reliability, whereas the narrative and name-based dimension had the least reliability. We used an independent t-test in SPSS to compare the number of place dimensions used between projects with use and those with no use to assess the relationship (if any) between use of place dimensions and use in decision making. Finally, we conducted a Principal Component Analysis (PCA) to further examine place dimension groupings.

## RESULTS



## Thematic analysis

Results are summarized in Table 3. The majority of projects analyzed across all contexts (89%) intended for data to be used in conservation decision making. Of all projects analyzed (134 projects), 46% had no evidence of use while 54% demonstrated some evidence of use. These percentages varied across contexts (Table 3). Earthwatch projects showed the greatest percent of projects used (79%), CitSci.org had the least (21%), and TSN-NE showed a moderate percentage (54%; Table 3). Across all contexts, only 7% of projects leveraged all five place dimensions and 34% made use of only one or no place dimensions (Table 3).

Moreover, projects influencing decision making used more ( $t = -4.8, df = 117; p < 0.001$ ) place dimensions ( $\bar{x} = 3.0; sd = 1.4$ ) in materials than projects not influencing decision making ( $\bar{x} = 1.8; sd = 1.2$ ) (Fig. 1).

## Principle component analysis

A PCA of place dimensions identified three dimensions (social-ecological, narrative and name-based, and knowledge-based) as primary components. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.64 and Bartlett's test of sphericity was significant ( $\chi^2(10) = 173.877, p < 0.001$ ). The communalities were all above 0.3, confirming that each dimension shared common variance with other dimensions. These three place dimensions together explained 87% of the total variance (Fig. 1). Initial Eigen values indicate that these first three factors explained 46%, 24%, and 17% of the variance, respectively, suggesting that similar

analyses in the future may only need to code these three dimensions.

#### A framework for leveraging the power of place in citizen science

Given our thematic analysis, several conceptual relationships emerge between the phenomena of citizen science and conservation decision-making and the inherent capacity of the power of place in a given social-ecological system. It is apparent, for example, that some projects focus explicitly on decision making, some focus on engagement and environmental education, some are long-term monitoring programs aiming to provide monitoring data for eventual use in science and/or decision making, some emphasize strong ties and emotional attachments to specific places, and still others do not leverage the power of place in any way and would not be considered place-based. In our experience, we find that citizen science support platforms also share these conceptual relationships.

To conceptualize how citizen science projects and platforms can (and in some cases do) leverage the power of place, we devised a framework (Fig. 2) that situates citizen science and conservation decision making with how the power of place affects these two phenomena. This framework allows us to understand that citizen science overlaps decision making and place and that place overlaps citizen science and decision-making. Here, we place special emphasis on examining the areas of overlap, namely Zones One, Two, Three, and Four as labeled in Fig. 2a.

The areas of overlap identify four zones of influence between citizen science, conservation decision making, and the power of place. Zone One represents a sweet spot where all phenomena intersect; we consider this integrated citizen science. Zone Two can be

thought of as citizen science based decision making that informs policies not strongly linked with the stewardship of a particular place. Zone Three can be seen as collaborative conservation (land-use/natural resource management/social-ecological resilience efforts including effective participation by people with attachments to a place but lacking the science aspect of citizen science). Zone Four represents citizen science inquiry -scientific programs that leverage the power of place but lack direct linkages with decision making – perhaps due to a scientific focus on topics not tied to decision maker needs.

Given our results and this framework, how might citizen science project coordinators expand the influence of their projects in conservation decision making? How can practitioners better leverage the power of place to help inform decisions? Conceptually, how can we increase the size of Zone One and the proportion of projects in Zones One, Two, Three, and Four as conceptualized in Fig. 2b?

## RECOMMENDATIONS FOR LEVERAGING THE POWER OF PLACE IN CITIZEN SCIENCE

We draw upon our thematic analysis and both our quantitative and qualitative results to recommend additional ways projects and support platforms might alter their design and implementation to better leverage the power of place and become more relevant to decision making. We group our recommendations into three sections, (1) Design & Implementation, (2) Data Decisions, and (3) Collaboration.

- 1) Explicitly incorporate 'place' into project design and implementation

Use power of place to co-identify issues, goals, and objectives.

Co-identifying place-specific issues and needs -along with continual reinforcement of the specific project purpose -is an effective strategy for many well-established projects uncovered through our analyses. For example, the New Hampshire Annual Loon Count plays a strong policy role in New England advocating for loon conservation. The census engages volunteers on lakes across the state to count and observe loons for 1 h during the breeding season. The project makes explicit the purpose of the census for informing stewardship and policy: “Data are used to guide the sighting and construction of loon nesting rafts [and for] state policy changes... New Hampshire was the first state in the nation to restrict the use of small lead fishing tackle in lakes and ponds, which was extended to all freshwaters in NH (2005) and the ban of the sale of this tackle (2006). A new law was also passed in 2013 restricting larger lead sinkers. The Loon Preservation Committee data... also inform[s] legislation restricting mercury emissions from coal-fired power plants.”

Tie citizen science to identified priority stressors, phenomena, and baseline needs.

Once data and needs are co-identified, take care to tie your project to them. There is a great opportunity for citizen science projects to reach out early on in design to collaboratively identify data needs and scientific questions that citizen science can help address together with decision makers. For example, the Front Range Pika Project engages volunteers in American pika (*Ochotona princeps*) conservation by collecting baseline data necessary to guide regulation policies and species listings and contribute data for studies of climate change and species

distribution changes (Beever et al., 2010). The project emphasizes the importance of local alpine refugia as a connection to the regional place for this sensitive species and is guided by these priority stressors and baseline data needs.

Make decisions regarding changes based on initial data.

When citizen science projects are co-designed together with decision makers to meet their needs, initial data can be generated to inform decisions. For example, the Maine Brook Trout Survey engages volunteer anglers to survey remote ponds and coastal streams to find and document new populations of wild and sea run brook trout. Data use and action is explicit in program goals: “Data collected [are] verified by biologists and used to inform future fisheries management decisions and to conserve brook trout in Maine.” Survey locations and results are made available as a recruitment tool and to share results with volunteers ( e.g., “look where we found new populations of trout and where we can expand fishing opportunities for anglers”).

Bring in citizen science to evaluate impacts of interventions and progress towards goals.

Once decisions are made based on best available data, how do decision makers know if implementing initial decisions generates desired results? Here is another great opportunity to leverage integrated citizen science via adaptive management. Citizen science projects can collect monitoring data pre-and post-intervention to provide data and evidence for the success or failure of initial decisions. For example, Virginia Master Naturalist volunteers measure e-coli in riparian areas fenced off from cattle and in those having continuous grazing (Jordan et al.,

2016) to evaluate the impact of this management decision by gathering evidence regarding the effect of the buffers on e-coli abundance.

Promote identification with place as a motivator for volunteer recruitment and retention.

Strong identification with a place can be a powerful motivator for recruiting and retaining volunteers. For example, the New Hampshire-based Lakes Lay Monitoring Program involves volunteers from lake associations who live around and have deep connections to “their” lakes. Volunteer-collected data are submitted for analysis and shared with each lake association for use in lake management and policy making. According to program staff, volunteer retention and commitment is very high, with the majority of volunteers monitoring their lakes for >5 years, and >25% for >15 years (Pervier, 2013).

Consider ‘place’ in project and platform design, especially related to data

As recommendations, we see several technical aspects critical to spatially enabling integrated citizen science, including data creation, discovery, interoperability, and sharing, which can be addressed through collaboration with geographers and geographic information scientists. In this way, citizen science can become “geographical citizen science” (Haklay, 2013) - part of Volunteered Geographic Information (Goodchild, 2007).

Include ecological interconnections of place

One way to leverage place is to enable people with a great affection and understanding of place to participate in citizen science. The way that projects or platforms are designed affects how local knowledge and expertise is engaged. In some cases, local or traditional ecological experts may hold unique, long term, intimate knowledge about the social and ecological landscape of a place that can be somewhat dissimilar from environmental indicators that data scientists or observing systems often measure (see Punawai et al., 2016). Often the knowledge of local and traditional experts is less about specific variables within a local environment and more about entire landscape systems. Yet, many citizen science project and platform designs focus on a particular issue or taxa. Platforms and protocols that allow for greater breadth of “data” collection are needed to capitalize on local knowledge (see CitSci.org as one example; Newman et al., 2011). MentalModeler.org (Gray et al., 2013) is another example that partially addresses this issue by allowing local experts to share their understandings of the complex interactions of a place as conceptual models in a systematic and structured format that can be folded into the scientific process for hypothesis development, scenario exploration, and in co-identifying needs and issues (e.g., recommendations 4.1.1 and 4.1.2).

#### Document protocols and data following metadata standards

Part of leveraging place in citizen science is predicated on making data more discoverable and useable by others. Stakeholders and decision makers should ideally be able to easily mine and use all available citizen science data to complement the plethora of traditional geographical information system (GIS) data easily accessible on the web and in use in decision making. Such mining is enabled by good metadata, standardized geospatial protocols, and effective data

sharing APIs. Good metadata describes important information such as protocols, sampling designs, geospatial projections, datums, and data formats (Wang et al., 2015). When well documented, data from projects can be interoperable with other data layers such as those derived from remote sensing. Given that citizen science organizations often are faced with limited resources, there is a fine line between complex standards cumbersome to implement and more loose standards that still ensure some metadata is documented (Brown et al., 2013).

We recommend that integrated citizen science projects and platforms use protocols that facilitate data to be used in governmental analyses. Projects should identify a priori end user databases to guide which export formats will most easily facilitate the sharing of data with these desired systems. Fortunately, the CitSci.org platform is developing metadata documentation tools to assist coordinators in automating the documentation of protocols and improve data reuse in decision-making (see Wang et al., 2015). Finally, the Citizen Science Association, in conjunction with CitSci.org, SciStarter, The Commons Lab at the Woodrow Wilson Center, and the Federal Community of Practice on Citizen Science and Crowdsourcing are developing a data exchange protocol and metadata standard for both program and observational metadata (and data). These standards are an answer to the conflict between burdensome metadata beyond the capability of most small organizations and the risk of losing data when metadata are not well documented. One success already to this end is iNaturalist: a data platform that cuts across taxa and that has adopted metadata standards for sharing biodiversity observations. This platform shares “research grade” observations with the Global Biodiversity Information Facility.

Ensure data are geo-located and use geospatial analysis and GIS



The proliferation of GIS, including the ability of volunteers to now more easily access and create geographic information and share it, indicates that GIS plays an important role in integrated citizen science (Haklay, 2013). Beyond the integration of base layer information, there are also many spatial analysis methods that take into account heterogeneous data provided by citizen science. The areas of geo-visualization and human-computer interaction within GIS are developing more effective and useful applications for citizen scientists and people using these data. The visualization of place-based information can play a role in motivating volunteers who can now immediately see data they collect being shared and used. Web-based spatial applications also allow volunteers to use sophisticated visualization and analysis tools online (e.g. in [arcgis.com](http://arcgis.com) and [databasin.org](http://databasin.org)) to carry out their own analyses. These tools allow users to make web-maps that contain citizen science data from many projects and platforms all in one place and viewable at once with transparency, or by clicking on and off layers. Thus, we recommend that all citizen science data be tied to place geospatially and contain documentation of basic spatial metadata. Further, to be easily discoverable and usable, citizen science data should be provided in a common format, such as ESRI shapefiles and/or KML files. Finally, we also recommend making as many attributes available as possible and uploading data to data repositories to make citizen science data machine-discoverable.

#### Make data open and promote open science

The rise of citizen science complements the emerging paradigm of open science, and there are merits to linking the field to this broader context. Though the trend has been towards

more collaboration as the field of ecology evolves from short term, individual-led projects to long term, large-scale investigations, its legacy still favors closed data (Reichman et al., 2011). The premise of “open science” and related cultural norms of sharing, transparency, and peering across the Internet can improve the rate and quality of scientific progress (Nielsen 2012; Tapscott and Williams, 2010; Waldrop, 2008). However, barriers exist for open data sharing, including awareness of appropriate repositories and questions about proper data management (Sayogo and Pardo, 2011). Significant effort has been put into policies to encourage open access to well curated data (Data ONE, 2012) and infrastructures to do so (e.g. <http://www.datadryad.org>), though the process of managing the deluge of data remains difficult (Strasser and Hampton, 2012). Access to data collected in a region should ideally only be limited by sensitivities such as concerns about revealing precise locations of critically endangered species and privacy. Enabling local data efforts to track their contributions (and reuse of them) incentivizes them to make their data discoverable and accessible. It also motivates participants to further spatially qualify their efforts to benefit local and scaled-up initiatives.

#### Increase place-based collaboration in citizen science

One of the strongest motivations for environmental volunteers is the desire to give back to their community (Independent Sector, 2001). This connection is a unifying force for volunteers. We suggest that programs can increase volunteer participation, cross-fertilize programs with “multi-interest” volunteers, develop a more skilled pool of volunteers, engender a more engaged community of programs and volunteers, create program efficiencies, and better connect the citizen science community to policy decision makers by increasing

collaboration within a particular place.

### Create place-based networks for collective impact

Recent efforts to connect citizen science programs, staff, and researchers at national and international scales (e.g. the Citizen Science Association) offer new opportunities for networking, sharing, and the building of a strong and robust community of practice. Advances in digital infrastructure systems make the mechanics of networks easier. However, citizen science networks that capitalize on a shared sense of place may offer special opportunities for face-to-face or digital connections and collaborations. Lessons from the concept of collective impact (SSIR) can inform creation of new place-based networks. We recommend that projects develop a shared agenda; share measurement data; mutually reinforce activities such as complementary volunteer opportunities and trainings across organizations, topics, and scales; communicate continuously (e.g., collaborate on a shared e-newsletter or social media to promote stories and opportunities across organizations, topic areas, and scales, and seek backbone support organizations that support the network as a whole that can evaluate and promote the collective needs of network members. The Stewardship Network: New England is an example that provides a shared infrastructure for a group of projects in New Hampshire, Vermont and Maine and.

### Pool citizen science information & resources

Citizen science networks that capitalize on a shared sense of place offer an opportunity to

collaborate to showcase, cross-promote, and catalogue volunteer opportunities across organizations and topics. Collaborative practices might include web portals of all citizen science projects for a place (SciStarter is working towards this by spatially enabling its database of projects), communication tools that pool stories about a place and promote local events, and collaborative communities that bring together staff and volunteers from the same place but different programs in face-to-face events. Integrated citizen science efforts offer a special opportunity for new models of efficiency. Physical proximity to programs and volunteers allows collaboration among programs on volunteer training, management, recognition, and engagement. For example, The Coastal Research Volunteers (CRV) program uses pooled resources -in the form of a single coordinator. A pool of trained volunteers conduct science and stewardship projects funded by university researchers, state and federal agencies, and local communities who partner with CRV to coordinate and train volunteers for seasonal, one-time, and on-going projects. The program hosts a volunteer newsletter and social media channels, hosts face-to-face events to connect volunteers and researchers, and provides technical assistance to researchers.

### Connect with decision-makers

Networks offer opportunities for conferences, meetings, and events that expand the citizen science community to not only those affiliated with citizen science, but also decision-makers, agencies and stewardship organizations who can use citizen science data. Conferences and/or events designed to include volunteers offer a welcoming learning environment for decision-makers who may also be non-scientists. This offers a promising

opportunity to connect citizen science programs, data, and volunteers to policy, stewardship and decision-maker communities.

#### Collaborate with small-scale projects

Place-based citizen science also offer advantages for researchers involved in smaller-scale research projects who need volunteers seasonally, for a limited time, or in small numbers. In these cases, a single “time-share” coordinator can support and train a pool of volunteers who are drawn together through a sense of place, such as in southwest New Hampshire and the Ashuelot Valley Environmental Observatory. In this program, volunteers participate in a variety of place-based citizen science projects such as bird banding, culvert assessments, mapping invasive plants, nighthawk monitoring, amphibian monitoring, and vernal pool mapping, in collaboration with different agencies and researchers. Researchers gain access to both a well-trained cadre of skilled volunteers and a professional citizen science coordinator who has experience training and communicating with volunteers and performing data quality assurance and quality control tasks.

#### DISCUSSION

We hope that this paper provides ideas and motivations for practitioners to consider when designing and implementing citizen science projects and support platforms. One pathway for citizen science to affect conservation decision making is for it to affect the conservation science that is in turn influencing decision-making. A related study found that citizen science is

not being used to its full potential in biodiversity science (Burgess et al., this issue). The recommendations of that paper are similar to the ours, and are mutually reinforcing. Despite these emerging recommendations, it is important to note that we found qualitative coding of project materials difficult (obtaining good inter-coder reliability metrics proved challenging and required three iterations and numerous discussions). However, we feel that our mixed methods approach uncovered an important relationship between one indication that projects leveraging place might be better able to inform decision making. Our analyses also uncovered differences among projects contexts. The Earthwatch context is unique in that all projects are designed and implemented by scientists and are vetted by Earthwatch staff through a proposal review process. Additionally, Earthwatch templates summary reports and asks lead scientists for explicit explanations of use and/or outcomes. The TSN-NE network is unique in that it focuses on collaboration and communication and consists of loosely affiliated citizen science programs who connect through this regional network. CitSci.org is unique in that it empowers people to design and implement their own projects; it does not require nor vet project scientist oversight through any proposal review process. Instead, it is up to project coordinators to reach out in this way and connect with scientific expertise. Thus, here is an opportunity for platform designers to integrate processes that afford greater flexibility while simultaneously guiding and encouraging best practices that promote quality and utility for decision makers.

Besides the uniqueness of our three contexts, other caveats to consider center around obtaining comparable project materials. This caveat (different projects provide different levels of quality materials) illustrates the need for projects to provide solid materials that describe their efforts in great detail. It also illustrates an opportunity in citizen science to provide templates for project and platform designers to use that ensure quality project descriptions and

that prompts designers to leverage place. Additionally, our analyses show that defining what constitutes use in decision making is a concept that requires further examination.

Moving beyond coupled social and ecological systems (Crain et al., 2014), this goal can be broadened to resilient systems, and the particular characteristics of resiliency that require learning and feedbacks. Many people care about the social aspects of resilience more than mere ecological aspects. This brings them into the conversation. For instance, when a City Council offers a new app that allows you to document potholes with your smartphone, the people participating should be part of the same overarching framework, and doing this as citizen science will inevitably help when the factions end up on opposite sides of an issue, such as whether or not to develop an open space. If the factions are already working together, it is more likely that a wise decision will ensue. A key strategy towards social-ecological resilience is to have boundary institutions, such as citizen science projects and platforms that effectively navigate across spatial scales from fine to coarse (Cash et al., 2006). Many of the recommendations put forth earlier, especially those pertaining to data (Section 4.2), will help with this challenge. For instance, data collected from a suite of fine scale projects, if easily shared, can combine to inform coarse scale management agreements and policies. Cash et al., (2006) also recommend that these boundary institutions navigate across and between scales of other themes, such as time and/or social networks. Our recommendations related to enabling citizen science to help foster knowledge co-production, mediation, translation, and negotiation processes should help with this grand challenge.

## CONCLUSION

With the advent of the Internet, citizen science is experiencing an explosion in growth, but it is not impacting conservation decision-making to its full potential. Now is the time to address this issue while we are still in the exploration and development phase of this newly reborn phenomenon. We hypothesized that if citizen science better leverages the power of place, namely people's affinity for, understanding of, and connection to their home, this will improve the influence of citizen science on conservation decision making. This is especially expected at the local scale where much land-use and management actions are decided. We also expect an increase in the degree to which projects and platforms leverage place to increase participation, retention, and data utility. There are many ways projects and platforms can leverage the power of place. We used use of place dimensions in project materials as an indicator that projects are leveraging the power of place to assess our hypothesis and found preliminary support. A resulting vision is that we should make it easier for people who love their home to easily find, create, choose among, and participate in a suite of citizen science projects which are subsequently seamlessly translated into useful data that are easily used by decision-makers affecting a given place through science-based decision making processes. We also provide a variety of specific recommendations for leveraging the power of place. We are confident these will help, but the relative degree and importance among them is unclear and requires further research. Many of these best practices need further structure, experimentation and evaluation. Towards these ends, we close here by making a call for projects and platforms to better document themselves (especially with regard to the recommendations made herein, as well as their intent and influence in conservation decision-making) and learn from each other as a community of practice focused on more integrated citizen science.



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## FIGURES

**Table 1**

A description of the place dimensions identified, guiding questions used for our thematic analysis, and various example forms of evidence used in support of the dimensions identified.

| Place dimension                        | Guiding questions for analysis   | Example forms of evidence   |
|--|--|---|
| Socio-ecological                       | In what types of social-ecological systems does the project take place and to what extent does the program emphasize connectedness to natural and human communities?   | Project materials emphasize interlinked human communities and ecosystems with specific details about SES components, relations, and patterns.   |
| Symbolic through narratives and naming | What stories, local histories, and unique place names does the project include about place?  | Testimonials that share stories related to the place and/or to the citizen science activity within a place are featured.  |
| Knowledge-based                        | Does the project seek to include diverse forms of knowledge (local, traditional, scientific, and/or arts-based)?   | Project embraces multiple ways of knowing that include local/traditional knowledge. The project includes local people's inherent knowledge regarding their place and/or allows participants to collect/discover such local knowledge.   |
| Aesthetic and emotional                | How does the project promote emotional attachments to place?   | The project uses terms like love and beauty to describe itself.   |
| Performative                           | Is there a sense that the project is dynamic, seeking creativity and innovation, and including multiple ways in which participants can help shape the project and the place, build relationships, and engage in active place-making? | Project leaders demonstrate a commitment to building relationships as a key strategy to promote active place-making. Project activities performed are encouraged that shape the project and/or the place. The project offers and encourages activities that allow participants to shape the project and/or the landscape and build a sense of ownership towards the project and/or place. Activities are explicitly tied to the project (versus calls to action and/or best practices). |

**Table 2**

Rubric used for coding projects and compiling data for our thematic case study analysis, including the name of each item and brief description.

| Information   | Description   |
|---|---|
| ID  | Unique number created for analysis and assigned to each project.  |
| Description   | Either self-described by organizers or compiled using available evidence.   |
| Number of Participants <sup>a</sup>                     | Total number of volunteers or contributors in the project (total or annual).  |
| Number of Observations <sup>a</sup>                     | Total number of observations made by volunteers.  |
| Years running <sup>a</sup>                              | Number of years project has been active.  |
| Intent for decision-making <sup>b</sup>                 | Whether or not the program describes an intent to connect to decision-making such as stewardship, policy, or other users of data.   |
| Use in decision-making <sup>b</sup>                     | Whether there is evidence that the program has an explicit connection to decision-making such as stewardship, policy, or other uses of data   |
| 1 - Socio-ecological <sup>c</sup>                       | Project materials emphasize interlinked human communities and ecosystems with specific details about SES components and relationships.  |
| 2 - Symbolic through narratives and naming <sup>c</sup> | Testimonials that share stories related to the place and/or to the citizen science activity within a place are featured.  |
| 3 - Knowledge-based <sup>c</sup>                        | Project embraces multiple ways of knowing that include local/traditional knowledge and includes local people's inherent knowledge regarding their place and/or allows participants to collect/discover such local knowledge.  |
| 4 - Aesthetic and Emotional <sup>c</sup>                | The project uses terms like love and beauty to describe itself.   |
| 5 - Performative <sup>c</sup>                           | Project leaders demonstrate a commitment to building relationships as a key strategy to promote active place-making. Project activities performed are encouraged that shape the project and/or the place. The project offers and encourages activities that allow participants to shape the project and/or the landscape and that build a sense of ownership. Activities are explicitly tied to the project (versus calls to action and/or best practices). |
| # Dimensions  | Calculated/derived value summing the number of place dimensions coded as either a 1 or 0. Indicates breadth of use.   |

<sup>a</sup> These metrics were obtained and used to determine project maturity and for inclusion in our thematic case study analysis.

<sup>b</sup> These metrics were coded using an ordinal scale of 0 to 2 (0 = no intent/use in decision making; 1 = some intent/use in decision making; 2 = high degree of intent/use in decision making).

<sup>c</sup> These metrics represent our 5 place dimensions and were also coded using an ordinal scale of 0 to 2 (0 = no use in project materials; 1 = some use in project materials; 2 = high degree of use in project materials).

**Table 3**

The percent of projects in our thematic case study analysis demonstrating evidence for each construct. Sources include the [CitSci.org](http://CitSci.org), The Stewardship Network: New England (TSN:NE), and Earthwatch (EW).

| Construct                     | CitSci.org             | TSN: NE                | EW                     | All                    |
|-------------------------------|------------------------|------------------------|------------------------|------------------------|
| No intent for decision making | 10% (4/39)             | 18% (7/39)             | 7% (4/56)              | 11% (15/134)           |
| Intent for decision making    | 90% (35/39)            | 82% (32/39)            | 93% (52/56)            | 89% (119/134)          |
| No use in decision making     | 79% (31/39)            | 46% (18/39)            | 21% (12/56)            | 46% (61/134)           |
| Use in decision making        | 21% (8/39)             | 54% (21/39)            | 79% (45/56)            | 54% (73/134)           |
| # Place-based dimensions      | $x = 1.64, sd = 1.224$ | $x = 1.59, sd = 1.208$ | $x = 3.45, sd = 0.952$ | $x = 2.38, sd = 1.429$ |
| No dimensions used            | 18% (7/39)             | 13% (5/39)             | 0% (0/56)              | 9% (12/134)            |
| 1 dimension used              | 33% (13/39)            | 49% (19/39)            | 4% (2/56)              | 25% (34/134)           |
| 2 dimensions used             | 26% (10/39)            | 15% (6/39)             | 7% (4/56)              | 15% (20/134)           |
| 3 dimensions used             | 13% (5/39)             | 15% (6/39)             | 45% (25/56)            | 27% (36/134)           |
| 4 dimensions used             | 10% (4/39)             | 5% (2/39)              | 30% (17/56)            | 17% (23/134)           |
| 5 dimensions used             | 0% (0/39)              | 3% (1/39)              | 14% (8/56)             | 7% (9/134)             |

Fig. 1. (a) Comparison of the mean number of place dimensions leveraged by projects exerting no influence in decision making ( $\bar{x} = 1.8$ ;  $s = 1.2$ ) and projects influencing decision making ( $\bar{x} = 3.0$ ;  $s = 1.4$ ) ( $t = -4.8$ ,  $df = 117$ ,  $p < 0.001$ ) and (b) graphical depiction of principal components identified using PCA illustrating five place dimensions with respect to three component axes.

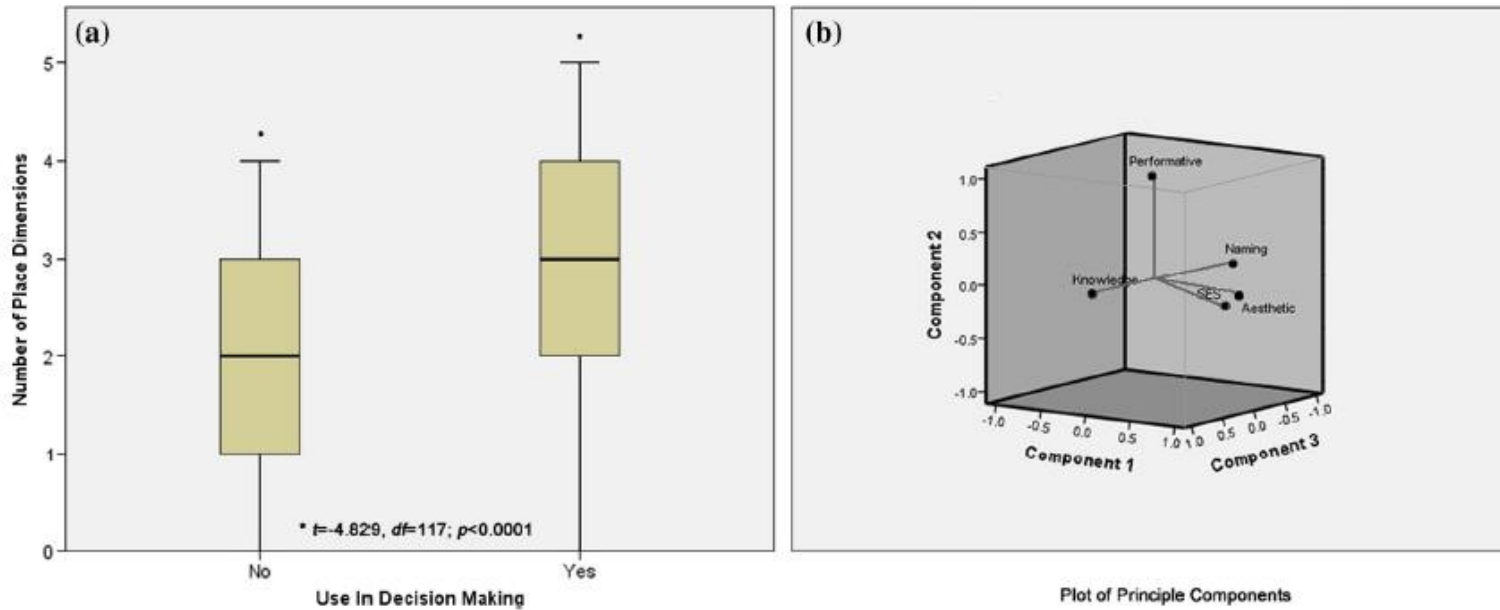
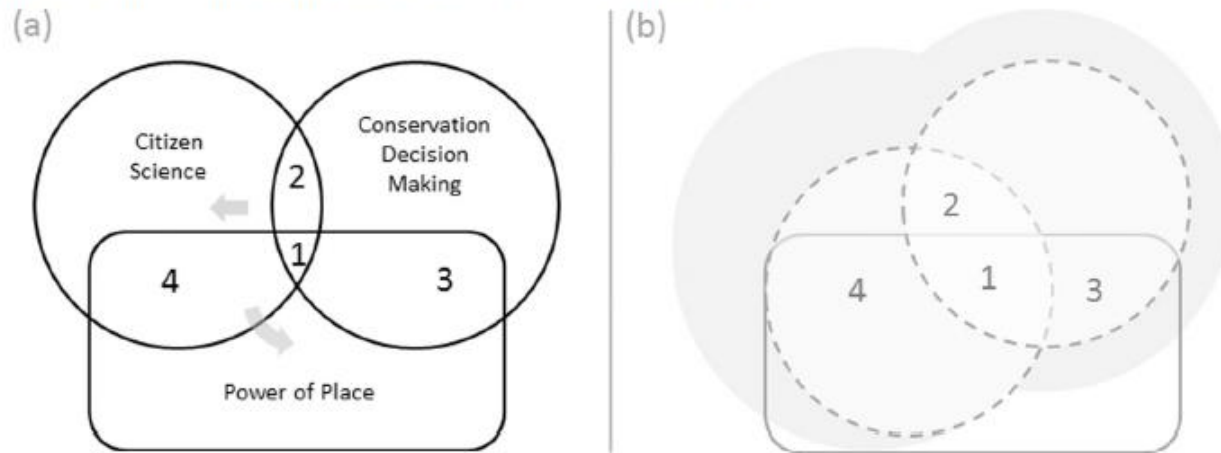


Fig. 2. Place-based citizen science framework (a) before and (b) after leveraging the power of place. Note that after leveraging the power of place, the citizen science circle is enlarged to reflect a potential increase in participation, data collection, and quality of conservation decision making and that the overall influence of decision making also grew. Note also that the relative size of Zone One increased while the inherent capacity of the power of place remained the same size.



## REFERENCES

- Agnew, J., Duncan, J. (Eds.), 1989. *The Power of Place: Bringing together Geographical and Sociological Imaginations*. Unwin Hyman, Boston, MA.
- Allen, C., 2004. Merleau-Ponty's phenomenology and the body-in-space encounters of visually impaired children. *Environ. Plan. D: Soc. Space* 22, 719–735.
- Ballard, H.L., Belsky, J.M., 2010. Participatory action research and environmental learning: implications for resilient forests and communities. *Environ. Educ. Res.* 16, 611–627.
- Beever, E.A., Ray, C., Mote, P.W., Wilkening, J.L., 2010. Testing alternative models of climate-mediated extirpations. *Ecol. Appl.* 20, 164–178.
- Berkes, F., 2012. *Sacred ecology*. 3rd Edition. Routledge, New York.
- Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., Wilderman, C.C., 2009. *Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education (A CAISE Inquiry Group Report)*.
- Brown, M., Sharples, S., Harding, J., Parker, C.J., Bearman, N., Maguire, M., Forrest, D., Haklay, M., Jackson, M., 2013. Usability of geographic information: current challenges and future directions. *Appl. Ergon.* 44, 855–865.
- Cantrill, J.G., Oravec, C.L., 1996. *The Symbolic Earth: Discourse and our Creation of the Environment*. University Press of Kentucky.
- Casey, E., 1993. *Getting back into place*. Indiana University Press, Bloomington.
- Cash, D.W., Adger, W., Berkes, F., Garden, P., Lebel, L., Olsson, P., Pritchard, L., Young, O., 2006. Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecol. Soc.* 11, 8.
- Conley, D.S., Mullen, L.J., 2008. Righting the commons in red rock canyon. *Communication and Critical/Cultural Studies* 5, 180–199.
- Conrad, C., Hilchey, K., 2011. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environ. Monit. Assess.* 176, 273–291.
- Crain, R.L., Cooper, C., Dickinson, J.L., 2014. Citizen science: a tool for integrating studies of human and natural systems. *Annu. Rev. Environ. Resour.* 39, 641–665.
- Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldsa, J., Holt, S., Hubertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Ngaga, Y., Poulsen, M.K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jorgensen, E., Yonten, D., 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conserv. Biol.* 23, 31–42.
- Data ONE, 2012. *DataONE: A Distributed Environmental and Earth Science Data Network Supporting the Full Data Life Cycle*.
- Druschke, C., 2013. Watershed as common-place: communicating for conservation at the watershed scale. *Environmental Communication: A Journal of Nature and Culture* 7, 80–96.
- Goodchild, M.F., 2007. Citizens as sensors: the world of volunteered geography. *GeoJournal* 69, 211–221.
- Gray, S., Gray, S., Cox, L., Henly-Shepard, S., 2013. *Mental Modeler: A Fuzzy-Logic Cognitive Mapping Modeling Tool for Adaptive Environmental Management*. Proceedings of the 46th International Conference on Complex Systems. pp. 963–973.
- Haklay, M.E., 2003. Public access to environmental information: past, present and future.

- Comput. Environ. Urban. Syst. 27 (2), 163–180.
- Haklay, M., 2013. Citizen science and volunteered geographic information: overview and typology of participation. *Crowdsourcing Geographic Knowledge*, pp. 105–122.
- Hayes, A.F., Krippendorff, K., 2007. Answering the call for a standard reliability measure for coding data. *Commun. Methods Meas.* 1 (1), 77–89.
- Haywood, B.K., 2014. A ‘sense of place’ in public participation in scientific research. *Sci. Educ.* 98 (1), 64–83. <http://dx.doi.org/10.1002/sce.21087>.
- Haywood, B.K., Parrish, J.K., K., J., Dolliver, J., 2016. Place-based and data-rich citizen science as a precursor for conservation action. *Conserv. Biol.* 30, 476–486 (<http://doi.org/10.1111/cobi.12702>).
- Hubbard, P., Kitchin, R., Bartley, B., Fuller, D., 2002. *Thinking geographically: Space, theory and contemporary geography*. Continuum, London.
- Independent Sector, G. a. V. i. t. U. S, 2001. *Giving and Volunteering in the United States*. Publication of Independent Sector (Independent Sector).
- Irwin, A., Low, S.M., 1992. *Place Attachment*. Springer.
- Jordan, R., Gray, S., Sorensen, A., Newman, G., Mellor, D., Newman, G., Hmelo-Silver, C., Ladeau, S., Biehler, D., Crall, A., 2016. Studying citizen science through adaptive management and learning feedbacks as mechanisms for improving conservation. *Conserv. Biol.* 30 (3), 487–495. <http://dx.doi.org/10.1111/cobi.12659>.
- Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Joachim, H., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grüber, A., Huntley, B., Jäger, J., Jodha, N.S., Kaspersen, R.E., Mabogunje, A., Matson, P., Mooney, H., Iii, B.M., Riordan, T.O., Svedin, U., 2001. Sustainability science. *Science* 292, 641–642.
- Keough, H.L., Blahna, D.J., 2005. Achieving integrated, collaborative ecosystem management. *Conserv. Biol.* 20, 1373–1382.
- Kruger, L.E., Shannon, M.A., 2000. Getting to know ourselves and our places through participation in civic social assessment. *Soc. Nat. Resour.* 13, 461–478.
- Lewicka, M., 2011. Place attachment: how far have we come in the last 40 years? *J. Environ. Psychol.* 31, 207–230.
- Lewicka, M., 2014. Place inherited or place discovered? Agency and communion in people-place bonding. *Estud. Psicol.* 34, 261–274.
- Lindlof, T.R., Taylor, B.C., 2002. Observing, learning, and reporting. In: Lindlof, T.R., Taylor, B.C. (Eds.), *Qualitative Communication Research Methods*. Sage Publishers, Thousand Oaks, California, pp. 132–169.
- Loss, S.R., Loss, S.S., Will, T., Marra, P.P., 2015. Linking place-based citizen science with large-scale conservation research: a case study of bird-building collisions and the role of professional scientists. *Biol. Conserv.* 184, 439–445.
- Luyet, V., Schlaepfer, R., Parlange, M.B., Buttler, A., 2012. A framework to implement stakeholder participation in environmental projects. *J. Environ. Manag.* 111, 213–219.
- Manzo, L.C., Devine-Wright, P., 2013. *Place Attachment: Advances in Theory, Methods and Applications*. Routledge.
- Massey, D., 2005. *For Space*. Sage Publications, Thousand Oaks, CA.
- Mauerhofer, V., 2016. Public participation in environmental matters: compendium, challenges and chances globally. *Land Use Policy* 52, 481–491.
- McGill, K., 2006. Reading the valley: performance as a rhetoric of dimension. *Text Perform.* Q. 26, 389–404.



- McGinnis, M., 2016. *Science and Sensibility: Negotiating an Ecology of Place*. University of California Press, Oakland, CA.
- Miller, T.R., 2013. Constructing sustainability science: emerging perspectives and research trajectories. *Sustain. Sci.* 8, 279–293.
- Miller-Rushing, A., Primack, R., Bonney, R., 2012. The history of public participation in ecological research. *Front. Ecol. Environ.* 10, 285–290.
- Newman, G., Graham, J., Crall, A., Laituri, M., 2011. The art and science of multi-scale citizen science support. *Econ. Inf.* 6, 217–227.
- Nielsen, M., 2012. *Reinventing Discovery: The New Era of Networked Science*. Princeton University Press, Princeton, New Jersey.
- Patton, M.Q., 2002. *Qualitative Research and Evaluation Methods*. (3rd ed.). Sage Publications, Inc., Thousand Oaks, CA.
- Pervier, H., 2013. The New Hampshire citizen lake monitors survey: The distribution, reception and influence of citizen science in lake communities. Conference presentation presented at the 33rd international symposium of the North American lake management society, San Diego, CA Retrieved from <http://www.nalms.org/home/conferences-and-events/past-nalms-symposia/2013-symposium/nalms-33rdannual-symposium.cmsx>.
- Punawai, N., Gray, S.A., Severance, C., Lepczyk, C., 2016. Mapping ocean currents through human observations: insights from Hilo Bay, Hawai'i. *Hum. Ecol.* 1–10.
- Reed, M.S., 2008. Stakeholder participation for environmental management: a literature review. *Biol. Conserv.* 141, 2417–2431.
- Reichman, O.J., Jones, M.B., Schildhauer, M.P., 2011. Challenges and opportunities of open data in ecology. *Science* 331, 703–705.
- Relph, E., 1976. *Place and placelessness*. Pion Limited, London.
- Rolston, H.I., 1988. *Environmental Ethics: Duties to and Values in the Natural World*. Temple University Press, Philadelphia.
- Rolston, H.I., 1994. *Conserving Natural Value*. Columbia University Press, New York (259 pages).
- Sayogo, D.S., Pardo, T.A., 2011. Exploring the Determinants of Publication of Scientific Data in Open Data Initiative. *ACM Press*, p. 97.
- Seamon, D., 2013. Place attachment and phenomenology. In: Manzo, L.C., Devine-Wright, P. (Eds.), *Place Attachment: Advances in Theory, Methods and Applications*. Routledge, New York, New York.
- Shirk, J.L., Ballard, H.L., Wilderman, C.C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B.V., Krasny, M.E., and others, 2012. Public participation in scientific research: a framework for deliberate design. *Ecol. Soc.* 17:29.
- Spurlock, C.M., 2009. Performing and sustaining (Agri)culture and place: the cultivation of environmental subjectivity on the piedmont farm tour. *Text Perform. Q.* 29, 5–21.
- Stedman, R.C., 2003. Is it really just a social construction?: the contribution of the physical environment to sense of place. *Soc. Nat. Resour.* 16, 671–685.
- Strasser, C.A., Hampton, S.E., 2012. The Fractured Lab Notebook: Undergraduates and Ecological Data Management Training in the United States. *Ecosphere* 3:art116.
- Tapscott, D., Williams, A., 2010. *Macrowikinomics: New solutions for a connected planet*. Portfolia/Penguin Press, p. 428 pages.
- Theobald, E.J., Ettinger, A.K., Burgess, H.K., DeBey, L.B., Schmidt, N.R., Froehlich, H.E., Wagner, C., HilleRisLambers, J., Tewksbury, J., Harsch, M.a., Parrish, J.K., 2015. Global change and local solutions: tapping the unrealized potential of citizen science for biodiversity

- research. *Biol. Conserv.* 181, 236–244.
- Tuan, Y.-F., 1975. Place: An experiential perspective. *Geogr. Rev.* 65, 151–165.
- Tuan, Y.-F., 1977. *Space and place: The perspective of experience*. The University of Minnesota Press, Minneapolis.
- UNEP, 1992. United Nation Environmental Programme 1992 Rio Declaration on Environment and Development.
- Waldrop, M., 2008. Big data: Wikiomics. *Nature* 455, 22–25.
- Wang, Y., Kaplan, N., Newman, G., Scarpino, R., 2015. CitSc.org: a new model for managing, documenting, and sharing citizen science data. *PLOS Biology* October 22, 1–5.
- WCED -World Commission on Environment and Development, 1987. *Our Common Future*. World Commission on Environment and Development Oxford University Press.
- Whitelaw, G., Vaughan, H., Craig, B., Atkinson, D., 2003. Establishing the Canadian community monitoring network. *Environ. Monit. Assess.* 88, 409–418.
- Yin, R.K., 2013. *Case Study Research: Design and Methods*. Sage publications, Thousand Oaks, CA.