Citizen science as a valuable tool for environmental review

Corey T. Callaghan[1,*], Carly Winnebald[2], Blaze Smith[2], Brittany M. Mason[1], Laura López-Hoffman[2]

[1]Department of Wildlife Ecology and Conservation, Fort Lauderdale Research and Education Center, University of Florida, Davie, FL 33314-7719

[2]School of Natural Resources and Environment and Udall Center for Studies in Public Policy, University of Arizona, 803 East First Street, Tucson, AZ 85719 USA

*Corresponding author. email: c.callaghan@ufl.edu

Abstract

Human development and population growth are placing immense pressure on natural ecosystems, necessitating a balance between development and biodiversity preservation. Citizen science may serve as a valuable resource for monitoring biodiversity and informing decision-making processes, but its use has not been investigated within the realm of environmental review. We sought to quantify the extent to which citizen science data are currently being used, mentioned, or suggested in environmental impact statements (EISs) by analyzing a corpus of EISs (> 1,000) produced under the United States National Environmental Policy Act (NEPA), housed at NEPAccess.org. We found increasing incorporation of citizen science within the environmental review process, with 40% of EISs mentioning, using, or suggesting use of such information in 2022. Citizen science offers substantial potential to enhance biodiversity monitoring and conservation efforts within environmental review, but there are many considerations that need to be broadly discussed before widespread adoption.

Keywords: environmental management; citizen science; biodiversity; participatory science; environmental consulting; environmental impact statements; environmental review

Introduction

Human pressures on nature are pervasive (Bowler *et al.* 2020), with a growing human population inevitably leading to increased building and development projects (e.g., infrastructure, urban expansion, resource extraction). Maintaining biodiversity, and the associated benefits for humanity (Pimentel *et al.* 1997), should be a critical goal as future development projects are planned. And governments, developers, and society in general need tools that help reconcile future development and mitigate biodiversity loss (Simmonds *et al.* 2020).

Currently, many local, state, and federal governments around the world have laws and policies in place to help mitigate biodiversity loss from development projects. A key part of this policy process typically involves an environmental review of the potential socio-environmental impacts of a particular project, and the identification of strategies to mitigate impacts, such as minimizing biodiversity loss. Although such laws and policies tend to focus on threatened and endangered species, mandates exist for agencies to consider how actions will affect biodiversity as a whole (CEQ 1993). In the United States, for example, the National Environmental Policy Act (NEPA) mandates environmental reviews for any federal project with the potential for significant impact on the environment. Since it was enacted in 1970, NEPA has been emulated by more than 194 states, provinces, and countries around the world. In the US and many countries, environmental reviews are overseen by federal and state agencies, and much of the work of data collection and analysis involves professional consulting firms. This professional field, hereafter referred to as 'environmental consulting', plays a critical role in the goal of reducing impacts to biodiversity.

One of the first steps in developing an environmental impact assessment is to document and quantify the organisms present on the planned site of development. In an ideal world, given the potential for significant environmental impacts, each project would begin with thorough biodiversity surveys to ensure species are properly censused. However, such surveys can be expensive and time consuming, leading agency officials and environmental consultants to sometimes rely on existing sources of information about the presence of species.

Citizen science, or community or participatory science, now accounts for the majority of biodiversity data being collected globally (Callaghan *et al.* 2023). As such, citizen science is frequently touted as a potential mechanism for biodiversity monitoring (Tulloch *et al.* 2013; Chandler *et al.* 2017; McKinley *et al.* 2017), especially given the cost-effectiveness combined with broad spatial, temporal, and taxonomic scope of the data. But these calls most often revolve around government and 'public' entities, for example, monitoring progress towards Sustainable Development Goals (Fraisl *et al.* 2020), or the ability to use citizen science in governmental monitoring schemes (Hadj-Hammou *et al.* 2017).

In contrast, the role of citizen science in environmental reviews in general, and in the private sector in particular has been neglected. Anecdotally, we know that environmental consultants may use some citizen science data to inform their work. But a more comprehensive understanding of how citizen science data are being used in environmental reviews is critical, given the implications for policy-relevant decision making. As an example, citizen science data come with many types of spatial and temporal biases often influencing our understanding of biodiversity (Bowler *et al.* 2022). Are these biases properly accounted for as part of the

environmental review? Are citizen science data being used to provide documentation of endangered and/or threatened species at a site? And how often are these data being used to inform environmental review?

Here, we seek to answer these questions by highlighting a currently overlooked, but promising source of data—biodiversity data originating from citizen science (or participatory science) projects—that agency officials and environmental consultants may use to complement environmental review processes. First, we provide an overview on the potential value of citizen science for environmental reviews. Second, to quantify the extent to which citizen science data are currently being used or mentioned in environmental review, we analyzed a corpus of Environmental Impact Statements (EISs) produced under the US National Environmental Policy Act (NEPA) that is housed at NEPAccess.org (the largest and most comprehensive repository of US federal environmental impact statements). Third, we discuss some of the potential disadvantages of the widespread use of citizen science data in environmental reviews and by environmental consulting firms. And we conclude with some future avenues to broaden the potential of citizen science data in environmental reviews including some recommendations relevant for decision-makers and agency officials who oversee environmental review processes.

The potential value of citizen science for environmental review

There is much potential for expanded use of citizen science in environmental review. The use of citizen science in environmental review could include agencies and consultants interacting with volunteers directly or the use by agencies and environmental consultants of data originating from citizen science projects (i.e., indirectly working with volunteers). An obvious benefit of using citizen science data is the potential for increased data collection over many years and with broad

geographic extent. In many areas, citizen science participants are dedicated and exceptional naturalists with an ability and dedication to detect even the rarest species—arguably the species that can be most important for EISs.

Increasing public engagement in the environmental review process could have many flow-on effects, including more educated voters that support legislation for biodiversity-friendly development practices, as well as a more generally aware public about environmental decision-making processes and policies. In fact, the need for public engagement is recognized in the NEPA statute. By regulation, public participation is required at two points during the environmental review process: public input is requested during the early "scoping" stage of projects, and the public is asked to officially comment on draft EISs. The Council on Environmental Quality (CEQ) is currently proposing to enhance public participation by improving access to environmental review documents, making them electronically available on project or agency websites (CEQ 2023).

Quantifying the current use of citizen science data in environmental impact statements

To gain an understanding of the current use of citizen science data in environmental consulting we searched EISs for the following keywords: "citizen science"; "community science"; "eBird"; "iNaturalist". We constrained our search to eBird and iNaturalist as these are the most popular and widely used citizen science projects throughout the continental United States, matching the extent of our analysis.

We used NEPAccess.org, a platform for finding and analyzing decades of applied science and records of public participation in United States environmental decision-making processes, to find EISs completed between 2012–2022. Our search was conducted in February 2023. This platform covers the period from 1970 to the present, and includes full-text searchable PDFs of EISs, EPA metadata records since 2012, and additional metadata developed by the NEPAccess team.

To investigate how citizen science data was used in each document, we coded the mention and use of citizen science data as either direct use, indirect use, nondescript/inconclusive, or encouraged/suggested use (see Supplementary Text 1 for formal definitions). Direct use was coded for an EIS when citizen science played a pivotal role in directly influencing a decision within the analysis. This often involved using citizen science data to identify and document the presence or absence of species near the project area. Indirect use was coded when citizen science was utilized as a supplementary resource for the analysis, providing background or reference data without directly influencing a decision within the assessment. Nondescript/inconclusive was coded when we could not determine the reason citizen science was being used or it was mentioned in passing. Encouraged/suggested use was coded when citizen science data was not used in analysis but was being suggested to fill a knowledge gap or as a part of the project's objectives. In addition, we noted the lead agency of the EIS (e.g., the United States Fish and Wildlife Service or the Bureau of Land Management). We searched 1,355 EISs in the NEPAccess repository, and from these, 253 documents included references to our keyword searches, of which 25 were false positives and removed from analysis.

Since 2012, 17% of EISs mentioned or used citizen science data. When examined overtime, we found an increasing proportion of EISs mentioning or using citizen science data, with the highest proportion (40%) occurring in 2022 (Figure 1). And EISs using citizen science data were present across 45 agencies, with the most common being U.S. Army Corps of Engineers (n=38), U.S. Forest Service (n=26), and Bureau of Land Management (n=24) (WebFigure 1). A total of 147 EISs (64% of all EISs that mentioned citizen science) had direct use of citizen science data, with the most popular being eBird (87% of direct use cases) and only 6% using iNaturalist data (Table 1). For example, these were used to document the number of individuals and number of records for species of interest in the focal geographic area (see Box 1). We also found that 43 EISs (19% of all EISs that mention citizen science) had indirect use of citizen science data; for example, using iNaturalist species range to make a statement about animal biology. Importantly, we found that of the direct use cases, 28 EISs (12% of all EISs that mention citizen science) used no sighting of a species as evidence of absence of that species (see Box 1). Another 46 EISs (20% of all EISs that mention citizen science) suggested or encouraged future use of citizen science; for example, by aiming to increase local volunteerism and enhancing local interest in the natural resources (Box 1).

Our results highlight a previously undocumented use of citizen science data, relevant for environmental reviews and the field of environmental consulting. Our analysis points to the current, and increasing, use of citizen science since 2012, mimicking the popularity of citizen science in the broader biodiversity research field (Pocock *et al.* 2017). At the same time, our results also illustrate the future potential of citizen science data in environmental review, with an increasing number of EISs suggesting and encouraging future use of citizen science

participation. Yet, how citizen science is further implemented in environmental consulting is worthy of further discussion. Appropriate use of citizen science data, statistically accounting for the potential biases in the data is critical to make scientifically sound EISs. For example, data from iNaturalist are buffered for threatened species, where the precise coordinates are not known, but it wasn't always clear if, or how, this was taken into consideration. Nevertheless, the number of EISs using or mentioning citizen science in some way warrants further consideration of the future of how environmental reviews, and the policies that influence how reviews are conducted, should be implemented.

Further considerations of using citizen science data in environmental consulting

While there is much potential of using citizen science data to further advance and increase the power of decision making using EISs, there are further considerations worth discussing. First, to what extent participants of citizen science projects are willing for the data they collect to be used in a professional environmental consulting firm should be considered. A major motivation of citizen science participants is to contribute to conservation (Maund *et al.* 2020), and conservation-minded people may be opposed to development (McBeth and Shanahan 2004). Therefore, it might be difficult to get direct buy-in from potential citizen science participants to be willing to help contribute data to the environmental review process. In addition, environmental consulting is a for-profit business which then raises the question of whether participants would be willing to contribute data that a for-profit company uses.

Second, the use of citizen science data requires a nuanced understanding of the data and appropriate statistical analysis and thus conclusions about biodiversity. Of the EISs that directly

used citizen science data, 12% used citizen science data as evidence of species absence. However, there are many biases and gaps in organisms' presence associated with citizen science data. It is unlikely that project areas, and nearby adjacent areas, will necessarily have data from citizen science to provide sufficient evidence an organism was not there. Given the detectability and bias issues associated with citizen science data (Bird *et al.* 2014), we caution against concluding that an organism is not there based solely on an absence of records.

Future avenues for broadening the use of citizen science in environmental review

As illustrated, there are both potential benefits and drawbacks to the future use of citizen science data in environmental consulting. As such, we outline some potential research avenues that could help better understand and thus position the role of citizen science in the future of environmental review.

- **Broadening the scope of EISs included in analyses**. A further refinement of our understanding of how citizen science is used in EISs is necessary. We only focused on environmental reviews at the federal level under NEPA, but did not include state-level and county-level analyses, another area worthy of exploration in the future. Because our analyses focused on EISs at the federal level, we did not account for many environmental consulting projects that take place on private land, where citizen science data may be less likely available.
- **Encourage data sharing reciprocity whenever possible**. Whenever possible, we recommend reciprocity of data sharing, where environmental consulting firms share their data with citizen science repositories. For example, bird surveys commissioned by

environmental consulting firms could be submitted to eBird and information about other organisms could be submitted to iNaturalist. Sharing data with the community of scientists and the public could help ensure people are willing to help share data back and enhance reciprocity. However, we recognize the legal issues of who owns the 'data' by environmental consulting firms are often unclear and potentially problematic to data sharing.

- **Optimize sampling effort by citizen scientists**. Many citizen science participants are eager to help conservation efforts and protect biodiversity (Maund *et al.* 2020). One promising avenue of future research includes optimizing how and where citizen science participants collect data (Callaghan *et al.* 2019; 2021; 2023). If potential development plans are known, then citizen science participants could be mobilized to collect data from the locations in which observations would be most valuable, for example to better document the species of concern at a potential development site.
- **Produce policy-relevant guidelines on how citizen science should be used in EISs**. Here, we do not provide guidelines on how citizen science data could be used in environmental reviews, but the production of potential guidelines that include guidance on statistical analysis is an important avenue before citizen science data are commonly used in environmental review. For U.S. federal environmental reviews under NEPA, the guidelines would need to be produced by the Council on Environmental Quality, the agency within the Executive Office of the President that oversees NEPA implementation.

Conclusions

As the global population continues to increase and simultaneously urbanize, development and the policies surrounding development are increasingly important. Quantifying how and what biodiversity is present is essential to effective biodiversity loss mitigation. Citizen science is an increasingly valuable data source for biodiversity researchers and scientists. And environmental review is a critically important, but often overlooked, component of biodiversity monitoring and conservation. Our purpose here was to raise awareness of the potential advantages and disadvantages of the use of citizen science in EISs, using those previously submitted in the U.S. under the National Environmental Policy Act as a case study. It is our hope that our findings will spur further discussion about the relevance and value of citizen science data in the environmental review process. We believe that biodiversity monitoring, and biodiversity conservation more broadly, will benefit from increased use and participation of citizen science within the domains of environmental review and environmental consulting.

References

Bird TJ, Bates AE, Lefcheck JS, *et al.* 2014. Statistical solutions for error and bias in global citizen science datasets. *Biol Conserv* **173**: 144–54.

Bowler DE, Bjorkman AD, Dornelas M, *et al*. 2020. Mapping human pressures on biodiversity across the planet uncovers anthropogenic threat complexes. *People and Nat* **2:** 380–94.

Callaghan CT, Poore AG, Major RE, *et al*. 2019. Optimizing future biodiversity sampling by citizen scientists. *P R Soc B* **286**: 20191487.

Callaghan CT, Thompson M, Woods A, *et al*. 2023. Experimental evidence that behavioral nudges in citizen science projects can improve biodiversity data. *BioScience* **73:** 302–313.

Callaghan CT, Watson JE, Lyons MB, *et al*. 2021. Conservation birding: A quantitative conceptual framework for prioritizing citizen science observations. *Biol Conserv* **253:** 108912.

Chandler M, See L, Copas K, *et al*. 2017. Contribution of citizen science towards international biodiversity monitoring. *Biol Conserv* **213**: 280–294.

CEQ (Council on Environmental Quality). 1993. Incorporating biodiversity considerations into environmental impact analysis under the National Environmental Policy Act. Washington, DC: CEQ.

CEQ (Council on Environmental Quality). 2023. National Environmental Policy Act implementing regulations. Washington, DC: CEQ.

Fraisl D, Campbell J, See L, *et al*. 2020. Mapping citizen science contributions to the UN sustainable development goals. *Sustain Sci* **15**: 1735–1751.

Hadj-Hammou J, Loiselle S, Ophof D, Thornhill I. 2017. Getting the full picture: Assessing the complementarity of citizen science and agency monitoring data. *PLoS One* **12**: e0188507.

Maund PR, Irvine KN, Lawson B, *et al*. 2020. What motivates the masses: Understanding why people contribute to conservation citizen science projects. *Biol Conserv* **246**: 108587.

McBeth MK, Shanahan EA. 2004. Public opinion for sale: The role of policy marketers in Greater Yellowstone policy conflict. *Policy Sci* **37**: 319–338.

McKinley DC, Miller-Rushing AJ, Ballard HL, *et al*. 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. *Biol Conserv* **208**: 15–28.

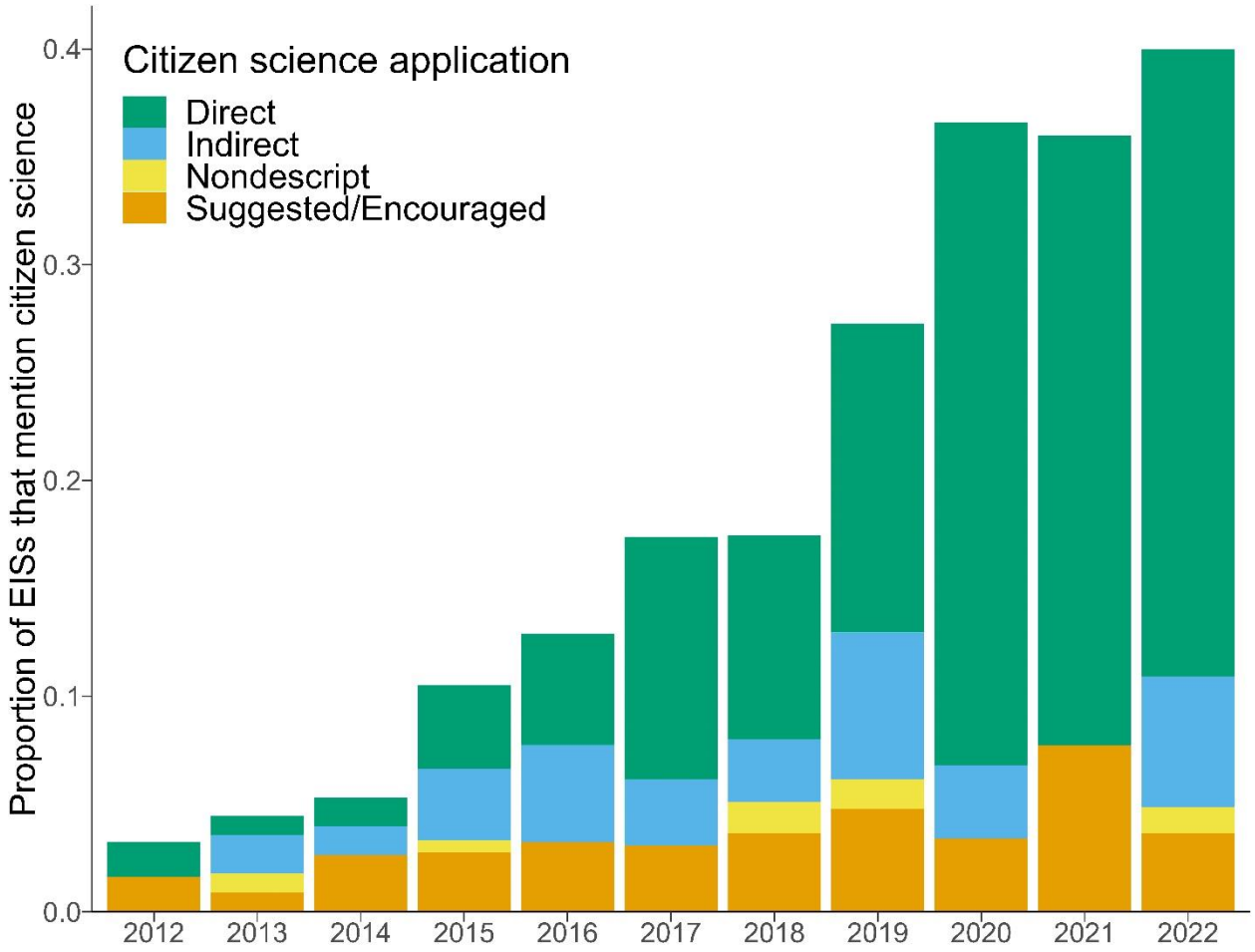
Pimentel D, Wilson C, McCullum C, *et al*. (1997). Economic and environmental benefits of biodiversity. *BioScience* **47**: 747–757.

Pocock MJ, Tweddle JC, Savage J, *et al*. 2017. The diversity and evolution of ecological and environmental citizen science. *PloS one* **12**: e0172579.

Simmonds JS, Sonter LJ, Watson JE, *et al*. 2020. Moving from biodiversity offsets to a target-based approach for ecological compensation. *Conserv Lett* **13:** e12695.

Tulloch AI, Possingham HP, Joseph LN, *et al*. (2013). Realising the full potential of citizen science monitoring programs. *Biol Conserv* **165**: 128–138.

Figure 1. Proportion of Environmental Impact Statements (EIS) returned from our search about citizen science between 2012 and 2022, categorized by use type.



Box 1. Quotes from Environmental Impact Statement publications mentioning citizen science data or platforms by use type. The references for these EISs can be found in Supplementary Text 2.

Direct Use

"In eBird, there are 687 records of 969 [olive-sided flycatcher] individuals on the Inyo National Forest" (Forest Service 2019).

"An eBird query, which documents the presence or absence of species using a real-time, online checklist, showed no reported sightings of [yellow-billed cuckoo] in Kittitas County (eBird 2012)" (Bonneville Power Administration 2017).

"No records of [Arkansas river shiner] have been submitted to iNaturalist (2021) from within or close to the landscape analysis area" (Rural Utilities Service 2022).

Indirect Use

"[Rufa red knot] is generally restricted to ocean coasts during winter and occurs primarily along the coast during migration . . . (eBird 2019)" (DOS 2019).

Nondescript

"Programs are offered across Mount Desert Island and on the Schoodic Peninsula. Programs focus on historical/cultural resources (e.g., Carrol Homestead Tours) and natural resources (e.g., iNaturalist Walk)" (National Park Service 2019).

Suggested/Encouraged Use

"National Park Service would engage communities in neighborhood partnership programs and citizen science activities with the goals of increasing volunteerism and developing local stakeholder interest in the preserve and its natural resources" (National Park Service 2014).

"The [National Bison Range] will use on-line, citizen science bird monitoring platform (eBird.org) for continued surveillance of occurrence using volunteers and the public to monitor population trends and inform management" (Fish and Wildlife Service 2019).

Table 1. Number of Environmental Impact Statements categorized by citizen science application, data usage, and data source. Data usage conveys whether citizen science data was used to document species presence or species absence and is only applicable for direct use citizen science application. The data usage and data sources categories are not exclusive (i.e., a paper that uses iNaturalist and eBird data will be included in both categories).

Category	n
Citizen Science Application	
Direct	147
Indirect	43
Nondescript	10
Suggested/Encouraged	46
Data Usage	
Presence	127
Absence	28
Data Source	
iNaturalist	9
eBird	129
Citizen/Community Science	36

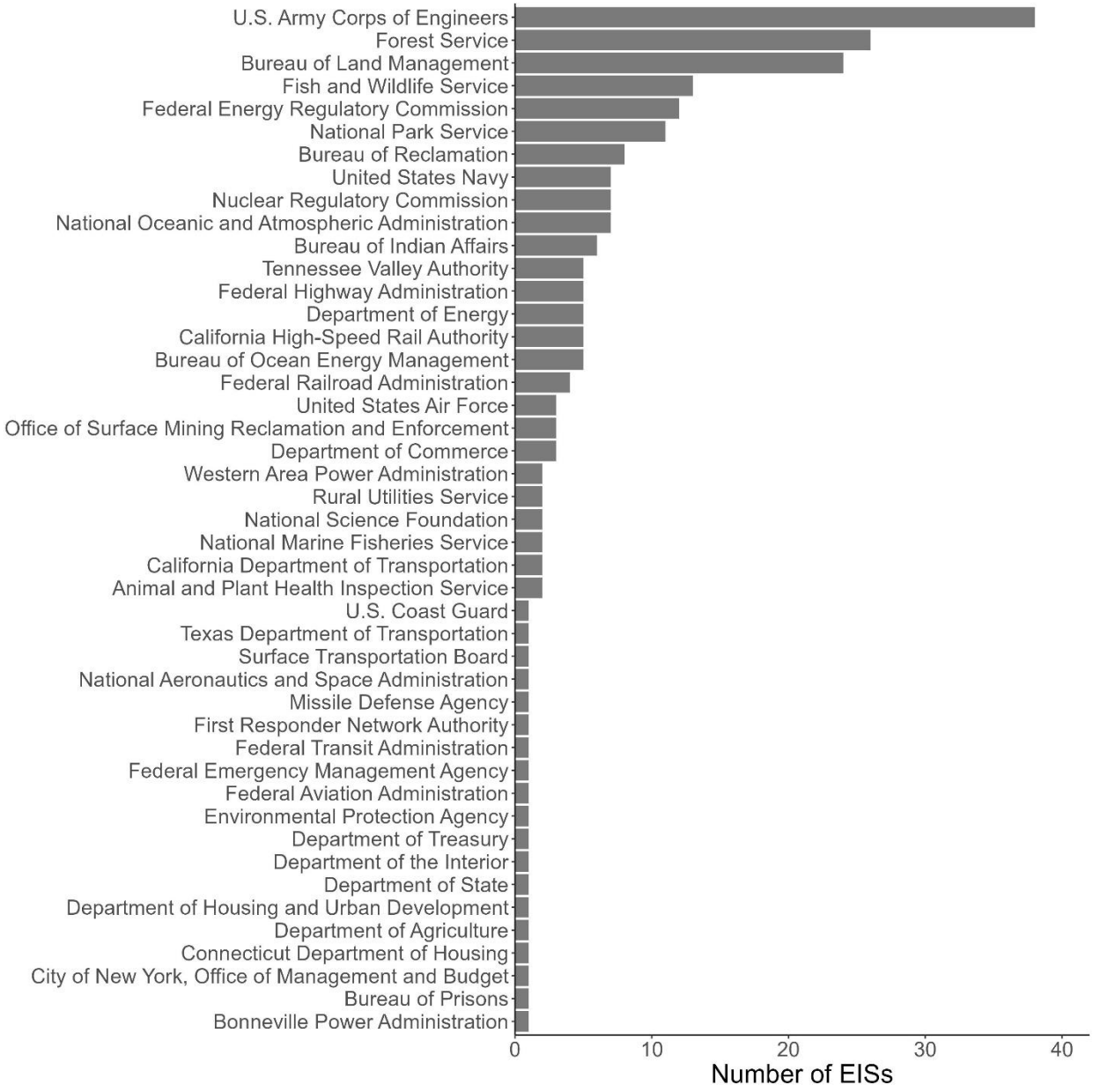


Figure S1. Number of Environmental Impact Statements from our search about citizen science by agency.

Supplementary Text 1. A detailed overview of our methods for the coding of EISs.

To facilitate the organization and categorization of the gathered data, formal definitions were established. These definitions were used to classify how citizen science was used in each Environmental Impact Statement (EIS).

The following formal definitions were employed for coding the data:

1. Direct Use: This category was employed to identify instances where citizen science methods were directly applied to identify species of interest in the project area. In the assessment's context, citizen science was used to gather evidence of the presence or absence of bird species in the project area. The direct use category was further classified into three subcategories: presence, absence, or both. "Presence" referred to cases where the species of interest were observed within the project area, "absence" indicated that there were no reports of the species of interest in the project area, and "both" indicated instances where one species was observed while another was not in the project area.

2. Indirect Use: This category encompassed situations where information obtained from mobile applications or websites, such as eBird or iNaturalist, was employed as background or reference data in an EIS. Such information served purposes such as providing reference materials for assessments, species information, or reviewing habitats.

3. Nondescript/Inconclusive: This category was utilized when the use of citizen science methods in the EIS was unclear or mentioned in passing without providing sufficient detail.

4. Encouraged/Suggested: This category denoted instances where citizen science methods were not directly used in the analysis but were recommended or suggested to bridge knowledge gaps. This category also encompassed situations where the project itself promoted the use of citizen science.

5. False Positive: This category specifically referred to cases where the search term resulted in an unintended result. For example, the search term “eBird” included documents with the term “shorebirds” (shor[ebird]s). These documents were removed from further analysis.

By employing these formal definitions and coding criteria, the data collected from the documents were effectively categorized, allowing for a systematic analysis of the utilization of citizen science methods in the EISs.

Supplementary Text 2. References for Box 1.

Bonneville Power Administration. 2017. Melvin R. Sampson Hatchery Yakima Basin Coho Project. Kittitas, Washington: Bonneville Power Administration.

DOS (Department of State). 2019 Keystone XL Project. Nebraska: DOS.

Forest Service. 2019. Revision of the Inyo National Forest land and resource management plan. California: Forest Service.

Rural Utilities Service. 2022. Skeleton creek solar and battery storage project. Oklahoma: Rural Utilities Service.

National Park Service. 2019. Aradia National Park final transportation plan and EIS. Maine: National Park Service.

National Park Service. 2014. Big Thicket National Preserve final general management plan. Texas: National Park Service.

Fish and Wildlife Service. 2019. National Bison Range final comprehensive conservation plan and environmental impact statement. Montana: Fish and Wildlife Service.