Citizen science as a valuable tool for environmental review

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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). 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; compared with just 3% in 2012. 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

In a nutshell

- Under the United States National Environmental Policy Act, Environmental Impact Statements are mandated for development projects that have the potential for significant impact on the environment.
- Environmental Impact Statements are increasingly incorporating citizen science data to document and quantify the organisms present or absent on the planned site of development in lieu of expensive and time-consuming thorough biodiversity surveys.
- While citizen science data has potential for informing decisions, its use in Environmental Impact Statements must be scientifically sound and statistically rigorous, in accordance with general ecological and conservation science practices.

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. 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 (Glasson and Therivel 2013). 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 (Morris and Therivel 2001; Glasson and Therivel 2013). Although such laws and policies tend to focus on threatened and endangered species, mandates generally exist for agencies to consider how actions will affect biodiversity as a whole (CEQ 1993, 2021). 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 (Emerson et al. 2022). 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 sometimes 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 (Glasson and Therivel 2013).

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 (Morris and Therivel 2001). In an ideal world, given the potential for significant environmental impacts, each project would begin with thorough biodiversity surveys to ensure species are properly documented. 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. 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, the scientific community knows that environmental consultants may use some citizen science data to inform their work. 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, including proportionally more sampling nearer regions with high human population density or more observations in recent years compared with historical records, 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. 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.

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

To gain an understanding of the current use of biodiversity-focused (e.g., plants and animals) citizen science data in environmental consulting (i.e., with a focus on biodiversity) 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 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 (Figure 1; see Panel S1 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 (see Panel S1) and removed from analysis. The remaining EISs span across the United States and cover all states except Nebraska, with the most EISs covering California (n=75; Figure S1).

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 2). 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) (Figure S2). 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 — use in the environmental review and regulatory process, forming a data contribution to EISs. 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. Another example included statistically accounting for the number of records within the region of interest, which is related to whether or not a given species would be detected. There are also differences in the likelihood a species would be detected, for example driven by body size of that species (Callaghan *et al.* 2021). Such biases need to be considered when thinking about potentially using citizen science data in an environmental review process. 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.

The potential value of citizen science for environmental review

We identified an increase in usage of citizen science data in environmental review. However, there remains 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, for example working with local volunteers to collect data at a specific site or hosting a bioblitz at a site of planned development. Or, citizen science can be used indirectly by agencies and environmental consultants by using 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. Citizen science participants tend to participate in projects because they want to contribute to science, and specifically, conservation (Domroese and Johnson 2017; Larson *et al.* 2020). Because of this intrinsic interest citizen science participants tend to be dedicated and exceptional naturalists (Cooper 2016) with an ability and dedication to detect even the rarest species—arguably the species that can be most important for EISs, where only a single occurrence can be meaningful from a regulatory standpoint.

Increasing public engagement in the environmental review process could have many flow-on effects. Research in the field of citizen science has shown that participation in citizen science projects can influence knowledge gain and behavioral change (Jordan *et al.* 2011) and that engagement can lead to increased scientific literacy (Phillips *et al.* 2019). Therefore, it is likely that direct participation in the environmental review process could lead to 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 (Glucker et al. 2013; Ulibarri et al. 2019). Nevertheless, currently public comments appears to have minimal effects on the final EISs (Ulibarri et al. 2019), suggesting that other approaches, such as citizen science, may be able to provide a more engaged public participation in the process. 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).

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 is possible that citizen science participants could feel empowered knowing that they are potentially directly contributing to conservation policy, for instance by detecting and documenting a rare species that could influence a NEPA outcome. In contrast, however, 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 if those data collected are contributing to a for-profit business such as an environmental consulting firm.

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, including human preferences (e.g., people are more likely to observe and report bright charismatic species than dull obscure species), and time of sampling (e.g., observations are more likely to come from periods of the year when it is more convenient to sample). 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 that species can sometimes go undetected and that there are varying densities of citizen science records, often associated with human population (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. 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.

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Figures

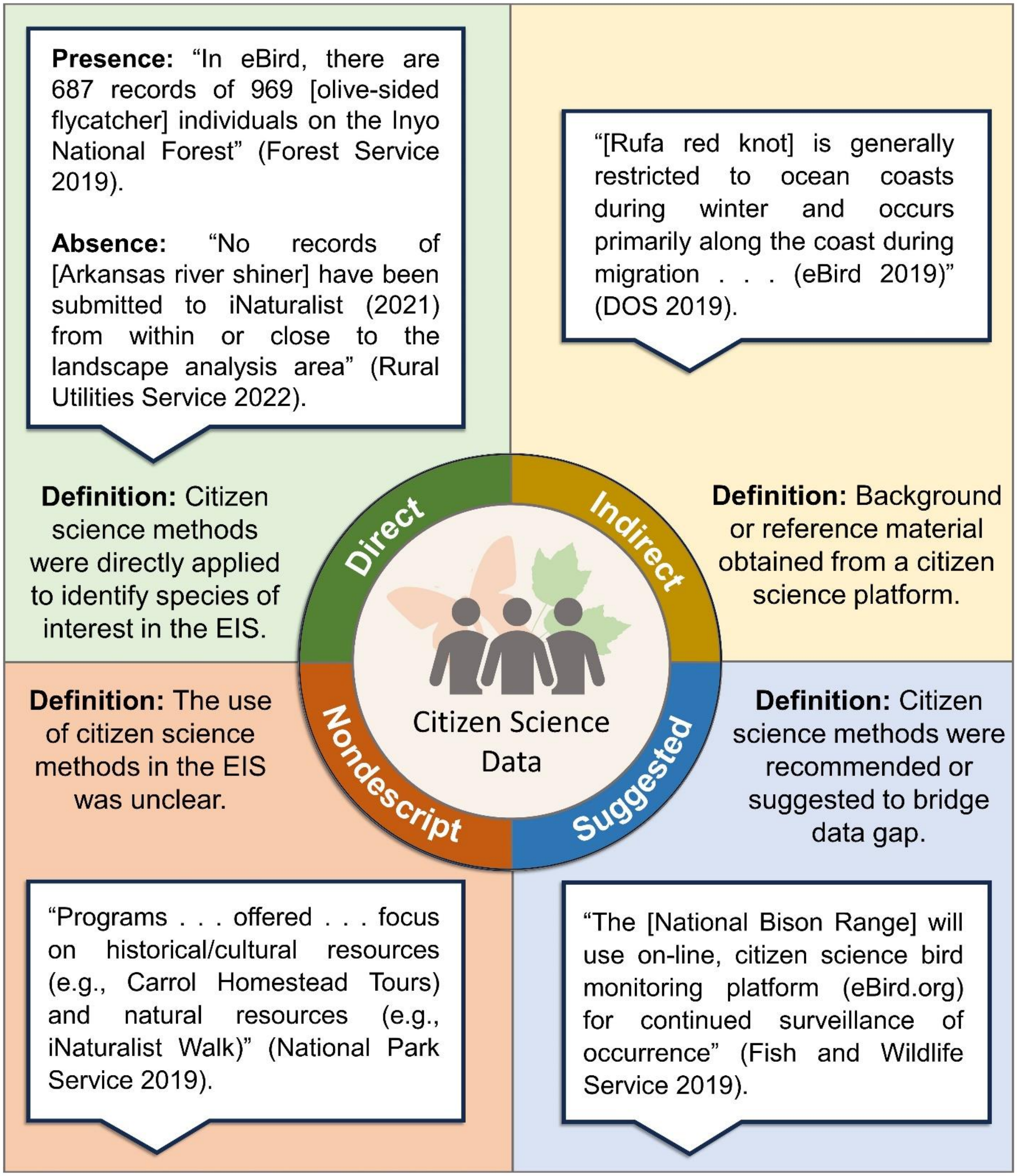


Figure 1. Defined citizen science data usage types observed in Environmental Impact Statements (EIS). Contained in the white boxes are quotes from EIS documents by use type. The references for these EISs can be found in Panel S2.

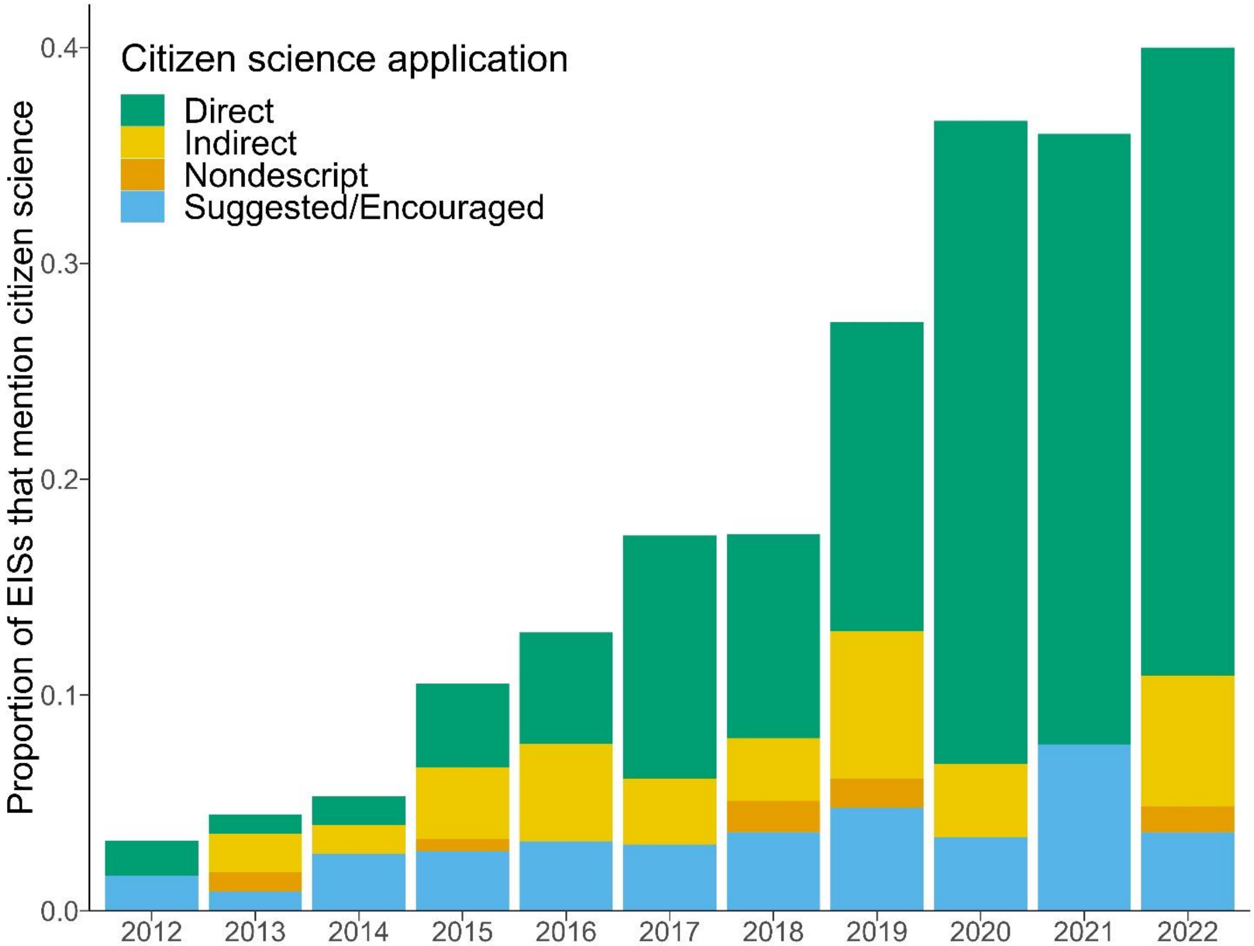


Figure 2. Proportion of Environmental Impact Statements (EIS) returned from our search about citizen science between 2012 and 2022, categorized by use type.

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

Panel S1. 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.

Figure S1. Number of EISs by state.

Choropleth map depicting the number of Environmental Impact Statements (EIS) that mentioned "citizen science", "community science", "iNaturalist", or "eBird" by state. The scale is log transformed to better illustrate the differences by states. The state with the most EDIS documents was California (n=75). One state, Nebraska, had no EISs that mentioned citizen science.

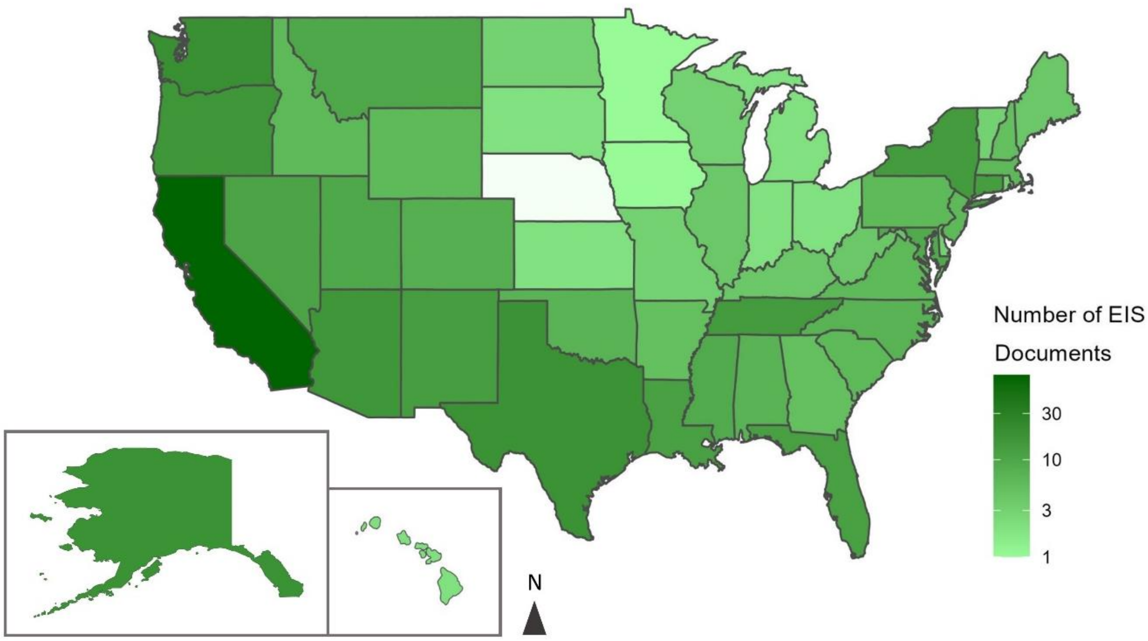
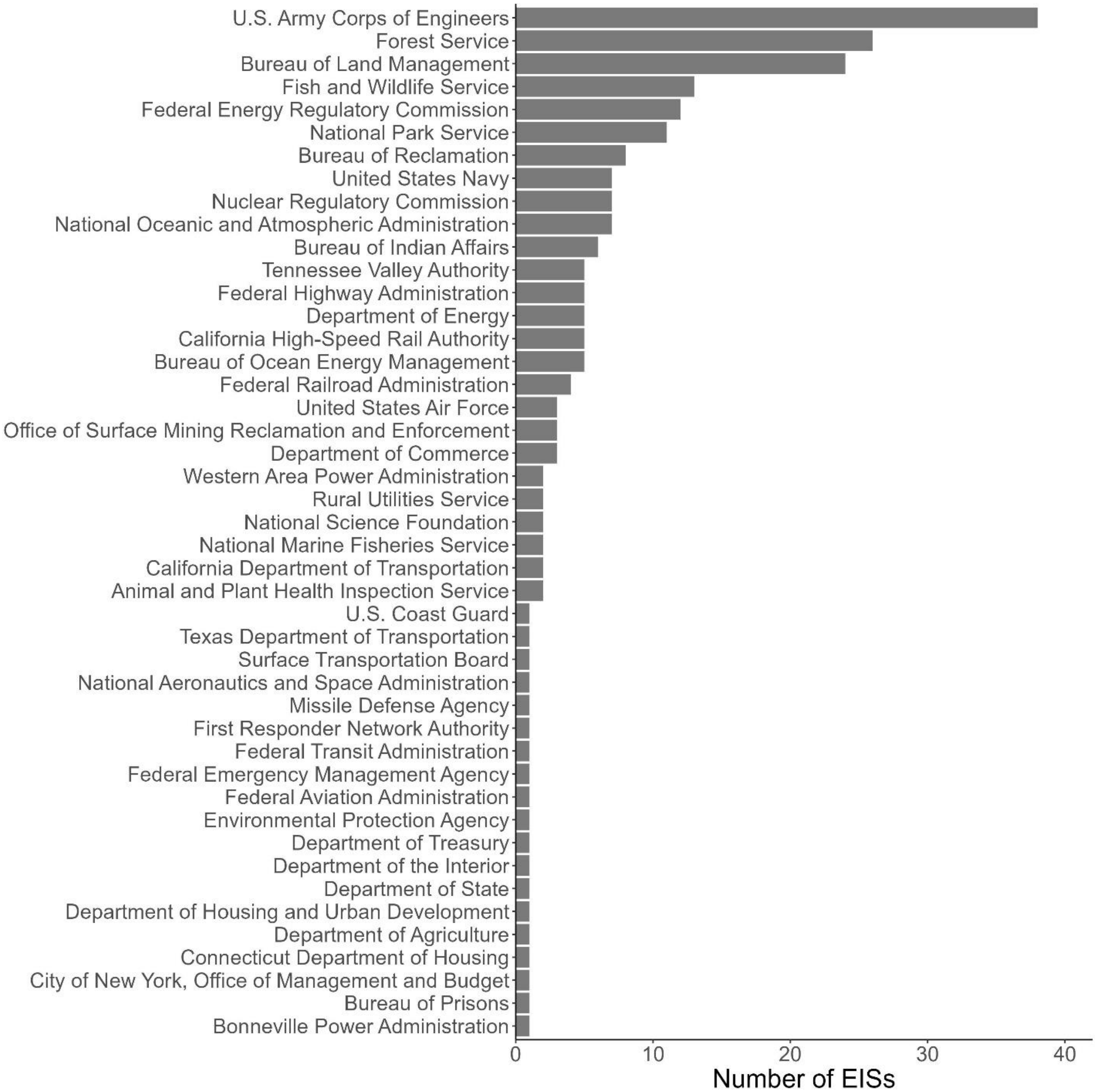


Figure S2. Number of EISs by agency.

Count of Environmental Impact Statements (EIS) that mention “citizen science”, “community science”, “iNaturalist”, or “eBird” by agency.



Panel S2. References for Figure 1 in the main text.

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