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PUTTING THE PUBLIC ON TRIAL: CAN CITIZEN SCIENCE DATA BE USED IN LITIGATION AND REGULATION?

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Projects, in which members of the public participate actively in environmental data collection and analysis, have exploded in recent years. These so-called citizen science initiatives have garnered high-level support from policymakers for their potential to provide a cost-effective means to fill pervasive gaps in our knowledge of baseline environmental conditions. However, as data collected by non-scientists begins to form the basis of regulatory decisions, significant concerns remain about the accuracy of this data. To date, the scholarly literature has effectively ignored the validity and impact of these concerns. This article attempts to remedy this gap, by first examining the current prevalence and reliability of volunteer data collection as a tool in environmental monitoring. This interdisciplinary analysis suggests that major concerns about publicly collected data are supported, but that these do not necessarily preclude its use in policymaking. This article then specifically explores the Clean Water Act's longstanding volunteer monitoring program to determine what design features may allow citizen science data to be effectively used in regulatory decision-making despite accuracy concerns. Finally, it argues that citizen science may have a particularly important triage role to play in the initial identification of potential environmental risks for further agency analysis.

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I. INTRODUCTION

In 2013, President Barack Obama formally called on executive agencies to increase the use of citizen science and crowdsourcing in their operations, aiming to both enhance the effectiveness of agencies and spur innovation.[1] Citizen science and crowdsourcing initiatives aim to directly involve non-scientists in the collection and analysis of scientific data.[2] Projects range from citizens monitoring the water quality of their local lakes to volunteers analyzing satellite images in search of black holes.[3]

While this was the first formal recognition of the potential role for citizen science in United States policymaking, President Obama's call reflects a growing global acceptance of data collected

1. Open Gov't Partnership, *Second Open Government National Action Plan for the United States of America*, THE WHITE HOUSE 1, 14 (Dec. 5, 2013), *available at* http://www.opengovpartnership.org/sites/default/files/US%20National%20Action%20Plan.pdf (explaining "[ ] [a]dministration will expand its use of crowdsourcing and citizen science programs to further engage [ ] public in problem-solving").

2. *See* Rick Bonney et al., *Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy*, 59 BIOSCIENCE 977, 977 (2009) (defining "citizen science").

3. *See* Case Studies, FEDERAL CROWDSOURCING AND CITIZEN SCIENCE TOOLKIT, https://crowdsourcing-toolkit.sites.usa.gov/case-study-overview/ (last visited May 2, 2017) (showing types of citizen science projects currently being carried out nationally).

by non-scientists in scientific and policy decision-making.[4] Historically, both the scientific and regulatory communities have viewed such data skeptically, preferring to leave scientific research to trained, professional scientists.[5] Technological advances, however, have made citizen involvement in arenas traditionally reserved for professional scientists more feasible in recent years; consequently, citizen science projects have burgeoned globally.[6]

Such volunteer participation in scientific research has been widely touted by both scientific and legal entities as a tool to fill data gaps that currently hamper effective regulation and policy decision-making.[7] Citizen science at its best can provide high-quality data on spatial and temporal scales that would be economically infeasible if professional scientists were used.[8] Additionally, projects that the local public motivate can provide information about small-scale problems that larger academic and legal institutions otherwise ignore.[9] Many have recognized that there may be a mismatch between "the knowledge science generates and the knowledge society needs."[10] Volunteers can fill these gaps, as their efforts are often

4. *See* Jonathan Silvertown, *A new dawn for citizen science*, 24 TRENDS ECOL. EVOL. 467, 467 (2009) (decribing growing acceptance and prevalence of citizen science).

5. Christine Overdevest and Brian Mayer, *Harnessing the Power of Information Through Community Monitoring: Insights from Social Science*, 86 TEX. L. REV. 1493, 1521 (2008) (illuminating that "[a]lthough citizen science is praised by [ ] growing number of academics and activists, it is frequently viewed with skepticism by industry and state agencies").

6. Abraham Miller-Rushing, Richard Primack & Rick Bonney, *The History of Public Participation in Ecological Research*, 10 FRONT. ECOL. ENV'T. 285, 289 (2012) (discussing how "[a]dvances in communications, transportation, and computing have made it easier for volunteers to contribute and for scientists and volunteers to manage and analyze [ ] resulting data").

7. *See e.g.* Bonney et al., *supra* note 2, at 977 (emphasizing educational benefits of citizen science); *see also* Barton H. Thompson, Jr., *The Continuing Innovation of Citizen Enforcement*, 2000 U. ILL. L. REV. 185, 223 (2000) (describing enforcement role citizen science can play).

8. Cathy C. Conrad and Krista G. Hilchey, *A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportunities*, 176 ENVTL. MONIT. ASSESS. 273, 280 (2011) (listing benefits of citizen science in environmental monitoring).

9. Overdevest and Mayer, *supra* note 5, at 1521 (differentiating problems that professional and citizen scientists investigate).

10. Scott Frickel, Richard Campanella & M. Bess Vincent, *Mapping knowledge investments in the aftermath of Hurricane Katrina: a new approach for assessing regulatory agency responses to environmental disaster*, 12 ENVTL. SCI. POL. 119, 119 (2009), *available at* http://richcampanella.com/assets/pdf/article_Frickel%20Campanella%20Vincent%20EnvSciPolicy-mapping%20science%20investment%20in%20New%20Orleans.pdf (discussing role of volunteers in generating environmental knowledge); *see also* Abby J. Kinchy & Simona L. Perry, *Can Volunteers Pick up the Slack? Efforts to Remedy Knowledge Gaps About the Watershed Impact of Marcellus Shale Gas De-*

direct responses to the failures of agencies to act in the face of perceived threats.[11] Even in cases where regulatory agencies are already engaging in monitoring activities, citizen participation in the scientific process may increase public acceptance of agency actions and strengthen community environmental understanding.[12]

Still, before citizen science can be effectively integrated into the legal system more broadly, further attention must be paid to the logistical realities of these projects.[13] Citizen science as a method of data collection and large scale problem solving has attracted widespread criticism from both the scientific and legal communities.[14] Concerns that the public may not be able to collect data that meets basic standards of accuracy and validity are particularly prevalent.[15] Coupled with this, sophisticated scientific instrumentation may be beyond the financial reach of many citizen science groups, rendering their data inherently less accurate than that of agency scientists and academic researchers.[16] There are also concerns that citizen science groups may choose to collect data that is ultimately not needed or is duplicative of that already available to agencies, bog-

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velopment, 22 DUKE ENVTL. L. & POL'Y F. 303, 306 (2012) (noting gaps in scientific knowledge about shale gas drilling).

11. Overdevest and Mayer, *supra* note 5, at 1510-11 (discussing role of citizen scientists in obtaining data to force EPA enforcement actions).

12. Dominique Brossard, Bruce Lewenstein & Rick Bonney, *Scientific knowledge and attitude change: the impact of a citizen science project*, 27 INTL. J. SCI. EDUC. 1099, 1099 (2005) (promising participation in citizen science project can increase pro-environmental attitudes); *see also* Dara O'Rourke and Gregg P. Macey, *Community Environmental Policing: Assessing New Strategies of Public Participation in Environmental Regulation,* 22 J. POL. ANAL. MANAG. 383, 383 (2003) (discussing how citizen science can increase acceptance of government actions); *but see* Christine Overdevest, *Volunteer Stream Monitoring and Local Participation,* 11 HUM. ECOL. REV. 177, 177 (2004) (finding community participation, not environmental knowledge, increased political participation and community connectedness).

13. *See* Janis L. Dickinson, Benjamin Zuckerberg & David N. Bonter, *Citizen Science as an Ecological Research Tool: Challenges and Benefits,* 41 ANNU. REV. ECOL. EVOL. & SYST. 149, 165 (2010) (describing practical challenges facing citizen science).

14. *See e.g.* Stefano Goffredo et al., *Unite Research With What Citizens Do for Fun: "Recreational Monitoring" of Marine Biodiversity*, 20 ECOLOGICAL APPLICATIONS 2170, 2171 (2010) (stating "use of nonspecialist volunteers is often criticized on [ ] grounds that [ ] information collected will be unreliable as [ ] result of either insufficient training or lack of consistency").

15. Eric Biber, *The Problem of Environmental Monitoring*, 83 U. COLO. L. REV. 1, 59 (2011) (voicing academic concerns with citizen science); *see also* Melissa Gedney, *An Exploratory Study on Barriers,* COMMONS LAB (Sept. 7, 2014), http://wilsoncommonslab.org/2014/09/07/an-exploratory-study-on-barriers/ (showing federal agency concerns); *see also* Kinchy and Perry, *supra* note 10, at 337 (discussing scientific concerns).

16. Biber, *supra* note 15, at 59 (discussing how funding concerns may limit effectiveness of citizen science).

ging agencies down with unnecessary information.[17] Even assuming that citizen scientists are able to contribute useful data, further questions arise regarding whether such data meets quality standards necessary for it to be used either by agencies or in court.[18]

These concerns present questions that the legal academy has given relatively little attention.[19] For instance, in the thirty years that the Environmental Protection Agency (EPA) has been basing major regulatory decisions under the Clean Water Act (CWA)[20] on volunteer-generated water quality data, only a handful of academics have attempted to address the role of citizen science in this process.[21]

This article works to fill this gap and explore the use of data that non-scientists generate in legal and policy contexts. Specifically, it examines citizen environmental quality monitoring as a case study to understand the barriers to the use of citizen science data more broadly in regulation, litigation, and policy decision-making.[22] Part I explores the history of public involvement in the scientific process and how this has informed the current efforts to incorporate citizen science data into policy-making.[23] Part II looks to the current use of citizen science data by agencies, and specifically examines the case study of volunteer monitoring under the CWA to understand how non-expert data may be used in regulatory contexts.[24] Part III builds on the increasingly widespread use of cit-

17. Douglas A. Kysar and James Salzman, *Foreward: Making Sense of Information for the Next Generation of Environmental Law*, 86 TEX. L. REV. 1347, 1354 (2008) (describing how federal agencies use information); *see also* Thompson, *supra* note 7, at 225–26 (discussing contributions of citizen enforcers).

18. *See generally* ROBERT GELLMAN, CROWDSOURCING, CITIZEN SCIENCE AND THE LAW: LEGAL ISSUES AFFECTING FEDERAL AGENCIES (2015) (giving overview of legal issues associated with citizen science).

19. *See* Gedney, *supra* note 15 (exploring barriers to citizen science use by agencies); *see also* Thompson, *supra* note 7 (explaining role of citizen scientists in enforcement actions).

20. The Clean Water Act of 1972, 33 U.S.C. §§ 1251–1387 (2012) (delineating purposes of Act).

21. *See generally* William V. Luneburg, *Where the Three Rivers Converge: Unassessed Waters and the Future of EPA's TMDL Program— A Case Study,* 24 J.L. & COM. 57 (2004) (providing excellent overviews and case studies); *see also* Charles Gottlieb, Keith H. Hirokawa & Kristin Keehan, *Bug Catching for the State: Gathering Baseline Ecological Information Under WAVE*, 32 VA. ENVTL. L.J. 61 (2014) (providing case study of biological stream monitoring).

22. For a further discussion of barriers to the use of citizen science data, see *infra* notes 129-207 and accompanying text.

23. For a further discussion on the background on citizen science, see *infra* notes 24-79 and accompanying text.

24. For a detailed look at the EPA's volunteer water monitoring program, see *infra* notes 80-209 and accompanying text.

izen science data by agencies to ask whether such data can ever be used in court.[25]

II. ANALYSIS

A. An Overview of Citizen Science

An examination of the current state of citizen science reveals that while use of non-scientists to collect environmental data is a growing trend, major reservations remain in the scientific community about the validity of volunteer data.[26] These concerns are similarly prevalent in the policy community, where significant concerns stem from the potential liability arising from the use of inaccurate publically collected data.[27]

1. *The History of Citizen Science*

The history of public involvement in the scientific process is a long and storied one, though this fact is often overlooked in today's culture of professional science.[28] Governments in the eighteenth and nineteenth centuries routinely turned to the public with contests and substantial monetary awards to try to develop answers to some of the most pressing scientific questions of the day.[29] These efforts built on a long tradition of "gentleman naturalists," who collectively made huge contributions to our understanding of the global environment.[30] In the United States, some of the earliest citizen science projects were those of amateur birdwatchers, traditions that began as early as 1900 and have continued to this day.[31]

25. For an analysis of citizen science data's admissibility in court, see *infra* notes 210-270 and accompanying text.

26. Conrad and Hilchey, *supra* note 8, at 281 (discussing "mistrust (by [ ] scientific or government community) in [ ] credibility and capacity of CBM data").

27. *See generally* Gellman, *supra* note 18 (giving overview of legal issues with citizen science).

28. *See* Miller-Rushing, Primack & Bonney, *supra* note 6 (detailing history of public participation in science over last two centuries).

29. Dickinson, Zuckerberg & Bonter, *supra* note 13, at 150 (describing British Government's use of amateur astronomers to help calculate distance from Earth to Sun as part of Transit of Venus project); *see also* DAVA SOBEL, LONGITUDE (2007) (describing Britain's establishment of monetary Longitude Prize for first person to develop system for accurately determining longitude at sea).

30. *See* John van Wyhe, *Charles Darwin: Gentleman Naturalist,* DARWIN ONLINE, http://darwin-online.org.uk/darwin.html (last visited May 2, 2017) (detailing biography of Darwin). Most notably in this class was Charles Darwin himself, whose theory of evolution is a cornerstone of modern biology. *Id.*

31. Dickinson, Zuckerberg & Bonter, *supra* note 13, at 150 (discussing storied citizen science work of Cornell Lab of Ornithology).

The prevalence of amateur scientists, however, declined greatly in the twentieth century, as science became increasingly professionalized.[32] Academic institutions and corporate research groups became the center of the scientific process, using technologies and specialized knowledge that left little room for the involvement of the untrained public.[33] This trend has started to reverse in the past two decades with an explosion of public participation in scientific projects.[34] The Cornell Lab of Ornithology, perhaps the most established citizen science institution in the United States, currently lists over six hundred ongoing citizen science projects, while the National Water Quality Monitoring Council estimates that as of 2014, over 1,700 volunteer groups were monitoring water quality nationally.[35]

The prevalence of volunteer environmental monitoring has followed this general trend.[36] Some of the oldest monitoring projects, established while amateur science was still a strong cultural institution, have continued uninterrupted to the present day.[37] Volunteer environmental monitoring, however, began its new rise to prominence in the 1970s, as communities became increasingly concerned about pollution in their local environments.[38] Volunteer monitoring efforts continued to steadily rise in both number and acceptance, until the past decade when community monitoring exploded over past levels.[39] Commentators have sug-

32. John T. Beer and W. David Lewis, *Aspects of the Professionalization of Science*, 92 DAEDALUS 764, 765 (1963) (discussing evolving professionalism of science in twentieth century).

33. *Id.* at 766 (describing institutionalization of science).

34. *See* Miller-Rushing, Primack & Bonney, *supra* note 6 (explaining rise of citizen science in recent years).

35. *Id.* (explaining rise of citizen science in recent years); *Volunteer Monitoring*, NATIONAL WATER QUALITY MONITORING COUNCIL, http://acwi.gov/monitoring/vm/index.html (last visited May 2, 2017) (providing overview of state of volunteer monitoring nationally).

36. *See* Miller-Rushing, Primack & Bonney, *supra* note 6 (explaining rise of citizen science in recent years).

37. Biber, *supra* note 15, at 58 (mentioning, among others, Audubon's Christmas bird count).

38. Ryan P. Kelly and Margaret R. Caldwell, *"Not Supported by Current Science": The National Forest Management Act and the Lessons of Environmental Monitoring for the Future of Public Resources Management*, 32 STAN. ENVTL. L.J. 151, 157-258 (2013) (documenting rise in environmental concern in 1970s).

39. Virginia Lee, *Volunteer Monitoring: A Brief History*, 6 VOLUNTEER MONITOR (1994), http://water.epa.gov/type/rsl/monitoring/upload/2004_10_13_monitoring_volunteer_newsletter_volmon06no1.pdf (last visited May 2, 2017) (showing five hundred volunteer monitoring programs existed in 1994); *see also Volunteer Monitoring*, *supra* note 35 (explaining 1700 volunteer monitoring programs existed in 2014).

gested many reasons to explain this rapid growth, ranging from decreases in governmental science funding to new technologies that make volunteer monitoring both cheaper and more accurate.[40]

2. *Citizen Science Defined*

Before delving deeper into the current role of citizens in environmental monitoring, it is helpful to understand the field of citizen science in more depth.[41] Citizen science fits into the broader world of public participation in scientific research (PPSR), which encompasses any project involving non-scientists in the scientific process.[42] PPSR has been divided into categories depending on the role of the public in the scientific process, ranging from contributory projects to co-created projects.[43] Contributory projects are those, in which professional scientists have established the methodology, goals, and structure of the research.[44] Volunteers are then used to carry out data collection according to established protocols.[45] Collaborative projects have the same basic characteristics, but volunteers may be involved to a greater extent in research design and result analysis.[46] In co-created projects, members of the public are involved in all stages of the process, including methodological design.[47] Differing volunteer–scientist relations in these projects have significant impacts on the perceived quality and uses of the data collected.[48]

Citizen science should be understood as a subcategory of PPSR.[49] In recent years, academic discourse and analysis of citizen science projects has grown rapidly.[50] Citizen science is defined in the scientific literature as any project that uses the public to collect

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40. Silvertown, *supra* note 4, at 467 (describing benefits of citizen science programs).

41. For a further description of citizen participation in environmental monitoring, see *infra* notes 53-58 and accompanying text.

42. ANNE BOWSER, ANDREA WIGGINS & ROBERT STEVENSON, DATA POLICIES FOR PUBLIC PARTICIPATION IN SCIENTIFIC RESEARCH: A PRIMER 2 (2013) (defining PPSR).

43. Ctr. for Advancement of Informal Sci. Educ., *Public Participation in Scientific Research: Defining the Field and Assessing its Potential for Informal Science Education: A CAISE Inquiry Group Report* 1, 11 (2009), *available at* http://www.birds.cornell.edu/citscitoolkit/publications/CAISE-PPSR-report-2009.pdf (creating typology of PPSR projects).

44. *Id.* at 18 (describing contributory projects).

45. *Id.* (explaining role of volunteers in contributory projects).

46. *Id.* (defining contributory projects).

47. *Id.* (defining co-created citizen science projects).

48. Ctr. for Advancement of Informal Sci. Educ, *supra* note 43, at 11 (describing how data from different types of projects is used).

49. *See* Bonney et al., *supra* note 2, at 978 (defining term "citizen science").

50. Silvertown, *supra* note 4, at 467 (discussing "new dawn" of citizen science).

data with standardized and accepted protocols.[51] Professional scientists are involved in the review and vetting of this data.[52] In this way, citizen science is distinguished from the broader world of PPSR projects by its emphasis on high quality, replicable scientific results.[53] While outreach and education goals are still critical in these projects, gleaning usable scientific data is the primary objective.[54]

Volunteer environmental monitoring specifically is an extremely diverse field, with projects that fit into all methodological categories of PPSR.[55] Cooperative extensions and land-grant schools have developed a wide network of largely contributory water quality monitoring projects, where projects are run, protocols are designed, and university scientists analyze data.[56] On the other end of the spectrum, community advocacy groups have created air quality monitoring programs to address specific pollution concerns in their communities.[57] Members of the public generally start and design these enforcement projects in loose consultation with local scientific experts.[58]

Despite the methodological differences that exist, volunteer environmental monitoring projects almost exclusively fall under the umbrella of citizen science.[59] The heavy emphasis on the use of approved and tested protocols for water quality data collection in volunteer monitoring is reflective of the strong emphasis on the scientific process in citizen science as a whole.[60] Moreover, required quality assurance programs and protocols subject volunteer

51. *See* Bonney et al., *supra* note 2, at 978 (explaining meaning of "citizen science").

52. *Id.* (discussing relationship between citizen and professional scientists).

53. *Id.* (noting citizen science by definition seeks to obtain replicable, valid scientific results).

54. *Id.* at 977 (articulating goals of citizen science).

55. *See e.g.* Conrad and Hilchey, *supra* note 8 (discussing types of volunteer environmental monitoring).

56. Bonney et al., *supra* note 2, at 977 (describing role of professional scientists in typical citizen science projects).

57. Overdevest and Mayer, *supra* note 5, at 1494 (exploring specific air quality monitoring programs).

58. *Id.* at 1510 (giving overview of volunteer environmental enforcement).

59. *See* Bonney et al., *supra* note 2, at 978 (providing definition of "citizen science").

60. *See generally* USEPA, *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (1996), *available at* https://www.epa.gov/sites/production/files/2015-06/documents/vol_qapp.pdf (setting out data quality requirements for volunteer water quality monitors).

monitoring data to review and vetting by professional scientists.[61] This emphasis on the scientific process and the collection of accurate results defines volunteer environmental monitoring projects as a subcategory of broader citizen science initiatives.[62]

Interestingly, in the scientific literature, volunteer environmental monitoring projects are almost universally referred to as citizen science.[63] This terminology has not been adopted by the legal academy, though, where volunteer monitoring is alternatively referred to as participatory action research, civil society research, or community policing.[64] In some cases exactly the same projects are referred to alternatively as citizen science in the scientific literature and as volunteer monitoring in the legal literature.[65] This is an illustration of the complete lack of interdisciplinary work that has been done on these initiatives.[66] For the purposes of this article, the conclusions about volunteer monitoring can be applied more broadly to "citizen science" projects as they seek to obtain results that can be used in policymaking.

3. *Views of Citizen Science*

a. *The Scientific Consensus: Widespread Quality Concerns*

The current explosion of citizen science has been met with mixed responses from the scientific community.[67] Citizen science proponents point to public data collection as an invaluably powerful method of supplementing existing data sets for professional

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61. *Id.* at 38 (explaining how EPA required QA programs include mandatory review provisions).

62. *See* Bonney et al., *supra* note 2, at 978 (articulating key characteristics of citizen science).

63. *See e.g.* Conrad and Hilchey, *supra* note 8 (describing "citizen science"); Dickinson, Zuckerberg & Bonter, *supra* note 13 (detailing rise of "citizen science"); Silvertown, *supra* note 4 (explaining all scientific publications referring exclusively to "citizen science").

64. Anne Bowser and Lea Shanley, *New Visions in Citizen Science*, 3 WOODROW WILSON INTL. CTR. COMMONS LAB CASE STUDY SERIES 45 (Nov. 2013) (showing participatory action research); *see also* Kinchy and Perry, *supra* note 10, at 304 (describing civil society research); *see also* O'Rourke and Macey, *supra* note 12, at 383 (discussing community policing).

65. *See* Biber, *supra* note 15, at 59 (referring to "volunteer monitoring" of water quality); *see also* Bonney et al., *supra* note 2, at 979 (describing same water quality monitoring as "citizen science").

66. *See* Eric Biber, *Which Science? Whose Science? How Scientific Disciplines Can Shape Environmental Law*, 79 U. CHI. L. REV. 471, 528 (2012) (discussing how "[i]nterdisciplinary debates might provoke [ ] broader range of creative solutions").

67. For a discussion of the scientific uncertainty surrounding citizen science, see *infra* notes 77-83 and accompanying text.

scientists, allowing analysis on previously unobtainable scales.[68] Still, many critics worry that data collected by non-scientists will never be able to reach the technical accuracy needed to be part of the peer-reviewed canon.[69] Moreover, professional scientists have expressed concerns that public groups may be motivated by external agendas that introduce unacceptable bias into their data.[70] These differing viewpoints illustrate the sharp divide that currently characterizes scientific attitudes towards citizen science.[71]

The lack of widespread scientific acceptance is both represented, and to some extent, likely driven by the relative lack of citizen science studies in the scientific literature.[72] Despite the explosion of citizen science projects nationally, very few of these projects have been used in peer-reviewed articles.[73] Numerous reasons have been hypothesized for this relative lack, notably the recent emergence of citizen science as a tool and the use of citizen scientists not for explicit hypothesis testing, as often required in published academic science, but for ambient monitoring and ecosystem surveying.[74]

Validation studies of citizen science projects comprise the bulk of published peer-reviewed articles on citizen science.[75] These validation studies provide a valuable basis for understanding exactly

68. *See generally* Bonney et al., *supra* note 2 (describing scientific uses of citizen science); *see also* Ctr. for Advancement of Informal Sci. Educ., *supra* note 43 (describing educational benefits of citizen science).

69. Conrad and Hilchey, *supra* note 8, at 281 (describing data quality challenges for citizen science).

70. *See id.* at 281 (explaining, in many cases, professional scientists are just as susceptible to external agendas and personal bias); *see also* Daniele Fanelli, *Do Pressures to Publish Increase Scientists' Bias? An Empirical Support from US States Data*, 5 PLOS ONE 1 (2010) (supporting publication pressure may lead to scientific bias); *see also* Sheldon Krimsky, *The Funding Effect in Science and its Implications for the Judiciary*, 8 J.L. & POL'Y 43, 48 (2005) (demonstrating external funding causes bias among scientists).

71. For a discussion of this divide in viewpoints, see *infra* notes 60-70 and accompanying text.

72. Silvertown, *supra* note 4, at 470 (noting lack of peer-reviewed citizen science studies).

73. Christopher Kullenberg and Dick Kasperowski, *What is citizen science? - A scientometric meta-analysis,* 11 PLOS ONE 1 (2016) (finding only fifty-nine studies explicitly citing citizen science existed in peer reviewed literature in 2009); *see also Mission: Citizen Science,* CORNELL LAB OF ORNITHOLOGY, http://www.birds.cornell.edu/page.aspx?pid=1664 (last visited May 2, 2017) (stating that 150 peer-reviewed studies have used CLO citizen science data since 1997).

74. Silvertown, *supra* note 4, at 470 (arguing that citizen science is rarely used for scientific purposes likely to be published in academic journals).

75. *See e.g.* Margaret Kosmala et al., *Assessing data quality in citizen science*, 14 FRONTIERS IN ECOLOGY AND THE ENVIRONMENT 551 (2016) (reviewing citizen science validation studies).

how susceptible these projects are to data quality issues by comparing data from volunteers directly with professionally collected data.[76] In looking at validation of citizen science broadly, accuracy of data collected by citizen scientists varies dramatically.[77] In some cases, data collected by volunteers has been shown to reach the same level of accuracy as that obtained by professional scientists.[78] There are a significant number of studies, however, showing just the opposite, that data collected by the public is substantially less accurate than that collected by professional researchers.[79] The variability in these results suggests that the accuracy of citizen science projects may be highly dependent on methodology, training, and even motivation of the volunteers.[80] In light of this uncertain data quality, many scientists express ongoing concerns about the use of citizen science as a viable research tool.[81] These reservations are widespread and may negatively impact the peer-review process.[82]

76. *See e.g.* David N. Bonter and Caren B. Cooper, *Data validation in citizen science: A case study from Project FeederWatch*, 10 FRONTIERS IN ECOLOGY AND THE ENVIRONMENT 305 (2012) (discussing validation used by citizen science bird watching programs).

77. Kosmala, *supra* note 75, at 551 (stating "volunteer accuracy varies, depending on task difficulty and volunteer experience. . . .").

78. *See* D. E. Canfield et al., *Volunteer Lake Monitoring: Testing the Reliability of Data Collected by the Florida LAKEWATCH Program*, 18 LAKE RESERV. MANAG. 1, 7 (2002) (finding that volunteer lake quality sampling data was "just as good [as that of] professional biologists"); *see also* Leska S. Fore et al., *Assessing the Performance of Volunteers in Monitoring Streams*, 46 FRESHW. BIOL. 109, 109 (2001) (finding stream water quality data collected by volunteers was same as that collected by professionals); *see also* Chris Newman et al., *Validating Mammal Monitoring Methods and Assessing the Performance of Volunteers in Wildlife Conservation—"Sed quis custodiet ipsos custodies?*", 113 BIOL. CONSERV. 189, 189 (2003) (showing volunteer mammal monitoring data was consistent with that of professional scientists).

79. Judy Foster-Smith and Stewart M. Evans, *The Value of Marine Ecological Data Collected by Volunteers*, 113 BIOL. CONSERV. 199, 199 (2003) (finding that volunteers often err in collecting abundance data); *see also* D.V. Obrecht et al., *Evaluation of Data Generated from Lake Samples Collected by Volunteers*, 14 LAKE RESERV. MANAG. 21, 21 (1998) (finding significant differences in lake phosphorous sampling undertaken by volunteers and professionals); *see also* Linda See et al., *Comparing the Quality of Crowdsourced Data Contributed by Expert and Non-Experts*, 8 PLOS ONE 1, 1 (2013) (showing volunteer inaccuracy in identifying land cover types).

80. Kevin Crowston and Nathan R. Prestopnik, *Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation*, 2013 46TH HAWAII INT. CONF. SYST. SCI. 450, 458 (2013) (showing impact of motivation on citizen science); *see also* J. F. Nerbonne and B. Vondracek, *Volunteer Macroinvertebrate Monitoring: Assessing Training Needs through Examining Error and Bias in Untrained Volunteers*, 22 J. NORTH AM. BENTHOL. SOC. 152, 162 (2003) (showing impact of training on citizen science data quality); *see also* See et al., *supra* note 79, at 1 (showing impact of methodology on data quality).

81. Kosmala, *supra* note 75, at 551 (stating that "scientists are often skeptical of [ ] ability of unpaid volunteers to produce accurate datasets. . . .").

82. Conrad and Hilchey, *supra* note 8, at 281 (explaining widespread concerns with citizen science data); *see also* H. Riesch & C. Potter, *Citizen Science as seen*

Even scientists who have participated in successful citizen science projects express ongoing concerns about data quality.[83]

The scientific literature also emphasizes the important point that, to obtain accurate and useful data, significant resources must be devoted to research design, volunteer training, and data analysis.[84] These resources may only be worth investing if it is clear that volunteer data is a useful tool in providing ambient environmental data on wider spatial and temporal scales.[85]

Current scientific reservations surrounding citizen science highlight that citizen science is far from a generally accepted scientific practice.[86] As policymakers strive to broaden the use and applicability of citizen science projects, this must be taken into account.[87]

b. The Policy Consensus: Agency Skepticism

As in the scientific community, major reservations exist in the regulatory and policymaking communities about the widespread use of data collected by volunteers.[88] A 2014 survey of federal agency staff found that data quality concerns prevented citizen science from being viewed as a viable means of data collection, with many considering it to be solely an educational exercise.[89] This preexisting bias is coupled with the overarching institutional failure to effectively integrate emergent information from non-traditional sources into policymaking decisions.[90] Together, these two factors create a situation, in which policymakers generally view citizen science with extreme skepticism.[91]

by Scientists: Methodological, Epistemological and Ethical Dimensions, 23 PUBLIC UNDERST. SCI. 107, 112 (2014) (discussing how professional scientists view citizen science).

83. Riesch and Potter, *supra* note 82, at 112-14 (describing data quality concerns of scientists who participated in citizen science projects).

84. *See generally* Bonney et al., *supra* note 2 (laying out methodological requiremests for successful citizen science projects).

85. *See generally* Conrad and Hilchey, *supra* note 8 (analyzing role of citizen science in environmental monitoring).

86. Kosmala, *supra* note 75, at 551 (describing lack of general acceptance by general scientific community).

87. *See* Dickinson, Zuckerberg & Bonter, *supra* note 13 (discussing challenges facing citizen science).

88. *See* Gedney, *supra* note 15 (discussing overview of opinions).

89. *Id.* (surveying agency views of citizen science).

90. Lynn E. Blais and Wendy E. Wagner, *Emerging Science, Adaptive Regulation, and the Problem of Rulemaking Ruts*, 86 TEX. L. REV. 1701, 1702–03 (2007) (stating "legal institutions may not always make good use of emergent information. . . .").

91. Gedney, *supra* note 15 (describing agency views of citizen science).

This skepticism is also present to some extent among legal academics.[92] Citizen science has been largely overlooked as a possible solution to monitoring problems.[93] Legal academics have recognized that volunteer monitoring may have a role to play in environmental management, but it is one that has limited applicability.[94] That citizen science is viewed as a relatively unimportant tool is supported by the dearth of published literature on this topic; a 2016 LexisNexis search showed that only fifty-five articles citing the term "citizen science," and twenty articles discussing "volunteer monitoring," have been published in the last twenty years.[95]

In light of the scientific and legal concerns with the widespread use of citizen science data, coupled with citizen science's recent shift to a more mainstream position championed by the President himself, this article explores whether data collected by citizens can in fact be used effectively in environmental regulation and enforcement.[96] Citizen science has the potential to provide information critical to the success of environmental enforcement actions.[97] However, significant questions remain regarding whether the data collected by citizens would be admissible in court or viable as the basis for agency rulemaking.[98]

B. Citizen Science in Agency Regulation

Concerted policy efforts are being made for the first time at the federal level to increase support and acceptance for citizen science projects and capitalize on the many benefits that are associated with public involvement in the scientific process.[99] President Obama led these efforts with the Open Government National Action Plan, calling for agencies to expand the use of "crowdsourcing

92. *See e.g.* Thompson, *supra* note 7 (describing important role citizen scientists can play in environmental enforcement).

93. Biber, *supra* note 15, at 54 (stating "citizen groups provide [ ] relatively overlooked option for improving monitoring").

94. *See id.* at 59 (noting that citizen science is often restricted by funding and technological shortcomings).

95. *See id.* at 54 (noting citizen science is "overlooked").

96. For a discussion of how specifically data collected by citizens can be used effectively in environmental regulation and enforcement, see *infra* notes 133-209 and accompanying text.

97. *See generally* Thompson, *supra* note 7 (explaining how citizen monitoring can motivate environmental enforcement).

98. For an analysis of citizen science in litigation, see *infra* notes 209-280 and accompanying text.

99. *See generally* Open Gov't Partnership, *supra* note 1 (calling on federal agencies to increase use of citizen science in operations).

and citizen science programs to further engage the public in problem solving."[100]

In September 2015, the Office of Science and Technology Policy expanded on this call by releasing a memo that required agencies to appoint an agency coordinator for citizen science projects and to create a catalogue of citizen science activities that the agency would undertake.[101] These requirements represent a dramatic and important shift in agency use of citizen science, which has, to date, been used only on a piecemeal basis in response to targeted problems and information deficits.[102] President Obama and OSTP's efforts represent a move towards broader and more coordinated implementation across the executive branch.[103] It could well be argued that this shift is the beginning of a new age of citizen science, as it becomes a mainstream and accepted method of data collection.[104]

Citizen science is being heavily pushed in the world of environmental monitoring and enforcement, a world in which data needs are vast and intensive.[105] Without adequate and ongoing understanding of ambient environmental conditions, it is impossible to effectively protect or restore ecosystems.[106] Highly detailed information is needed in these contexts to establish environmental baselines and design effective enforcement programs.[107]

While such common knowledge of the nation's environment might seem to be a basic prerequisite of environmental policy, in many cases, no such information exists.[108] As of 2000, for instance,

100. *Id.* at 13 (detailing steps agencies should take to incorporate citizen science more broadly).

101. Memorandom from Dir. Off. Sci. & Tech. Pol. John P. Holdren to the Heads of Executive Departments and Agencies 3 (Sept. 30, 2015) (stating "federal agencies shall improve coordination of and support for citizen science and crowdsourcing within and between agencies"). "Within [sixty] days of the issuance of this memo, each agency shall identify an agency coordinator for citizen science and crowdsourcing projects." *Id.*

102. *See* Gedney, *supra* note 15 (explaining how agencies use citizen science).

103. *See* Miller-Rushing, Primack & Bonney, *supra* note 6 (detailing history of public participation in science over last two centuries).

104. *See generally* Silvertown, *supra* note 4 (arguing that civilization is in "new dawn" for citizen science).

105. Biber, *supra* note 15, at 21 (describing data needed for effective ambient environemental monitoring).

106. *Id.* at 5 (arguing for importance of spatially and temporally continuous environmental monitoring).

107. Vincent Devictor et al., *Beyond Scarcity: Citizen Science Programmes as Useful Tools for Conservation Biogeography*, 16 DIVERS. DISTRIB. 354, 360 (2010) (explaining data needed to establish existing environmental conditions).

108. Kinchy and Perry, *supra* note 10, at 311 (describing current environmental data gaps).

only nineteen percent of the water bodies in the United States had been assessed for basic water quality.[109] For the remainder, agencies are forced to make regulatory decisions relatively blindly.[110] Lack of agency funding for monitoring creates these gaps and may be an area particularly susceptible to public choice failures.[111] Citizen science projects have the potential to remedy these failures by providing accurate monitoring at a fraction of the cost that would be incurred if professional scientists were used.[112]

It should not be overlooked that the use of citizen scientists represents a radical departure from the current model of professional institutionalized science.[113] Current efforts to broaden the use of citizen science must confront the fundamental reality that scientific and regulatory models are predicated on the use of trained, professional scientists to collect data.[114] Given the data quality concerns that are inherent in citizen science, this use presents a unique set of challenges that agencies must address before incorporating this data into their decision-making processes.[115] President Obama's directive to executive agencies to increase the use of citizen science seems then to be a step ahead of both the legal and scientific communities, where citizen science is still viewed with considerable skepticism.[116] Despite this skepticism, however, the reality is that citizen science has become an important tool, particularly in the realm of environmental monitoring.[117] As volunteer monitors are increasingly used to fill data gaps and contribute to effective regulation, this article seeks to understand whether the skepticism present in the legal community is well-founded, or whether citizen science should be more widely ac-

109. Luneburg, *supra* note 21, at 25 (discussing status of water body monitoring nationally).

110. Biber, *supra* note 15, at 8 (describing lack of information on environmental conditions).

111. *Id.* (discussing causes of environmental data gaps).

112. Conrad and Hilchey, *supra* note 8, at 28 (listing benefits of citizen science projects).

113. Miller-Rushing et al., *supra* note 6, at 286 (noting current status of professional science).

114. *See* Beer and Lewis, *supra* note 32 (describing role of professional scientists in twentieth century).

115. For a further discussion on scientific concerns with citizen science, see *supra* notes 45-64 and accompanying text.

116. For a further discussion of this skepticism, see *supra* notes 51-82 and accompanying text.

117. Conrad and Hilchey, *supra* note 8, at 28 (describing uses of citizen science).

cepted under existing standards for evaluating scientific evidence.[118]

Efforts to incorporate citizen science into currently existing systems must understand these constraints and the major questions that remain around the use of citizen science in legal and policy contexts.[119] Are untrained members of the public able to produce data that is comparable to that of professional scientists? Should such data be used to make regulatory and litigation decisions? What are the legal consequences if citizen-generated data is used in decision-making? To date, these questions have been largely ignored in the scholarly literature.[120]

1. *An Overview of Volunteer Monitoring under the TMDL Program*

One of the longest running and most robust examples of citizen science used in agency regulation is the volunteer water quality monitoring that takes place under the CWA.[121] The EPA has used data collected by members of the public for decades in formal water quality assessments and serves as a prime example of how citizen science data can be verified and integrated into decision-making by regulatory agencies.[122]

Under Section 305(b) of the CWA, states are required biannually to submit a report detailing the quality of their waters to Congress.[123] These 305(b) reports include listings of impaired waters in each state and are ultimately used to determine allowable Total Maximum Daily Loads (TMDLs) for various pollutants in these waters.[124] This reporting process thus requires states to routinely monitor and assess the environmental quality of all of the waters in their states.[125] Collectively, this represents a huge task, with over 3.5

118. For a further analysis on citizen science, see *infra* notes 138-215; 229-282 and accompanying text.

119. *See* Dickinson, Zuckerberg & Bonter, *supra* note 13 (discussing challenges that must be addressed before citizen science can be more widely adopted).

120. For a further discussion of the lack of legal study of citizen science, see *supra* notes 76-79 and accompanying text.

121. *See* Luneburg, *supra* note 21, at 25 (describing volunteer monitoring under CWA).

122. *Id.* (noting use of volunteers in Clean Water Act monitoring).

123. Clean Water Act of 1972, 33 U.S.C. §§ 305(b) (2012) (listing CWA reporting requirements).

124. *Id.* (describing impaired waters listing process).

125. *Id.* (requiring states to submit biannual reports).

million miles of rivers and streams requiring monitoring nationally.[126]

This widespread monitoring requirement has proved an incredibly difficult one to meet.[127] Initially, states and the EPA simply ignored this section of the CWA in favor of a focus on minimizing pollution from discrete industrial polluters as the main compliance aim.[128] In the wake of numerous losses in federal court for TMDL non-implementation, however, the EPA has, in recent years, become more vigorous about TMDL implementation.[129] Ultimately, less than twenty percent of the nations waters have been assessed to this day.[130]

In carrying out the gargantuan task of assessing and monitoring their waterways, states are statutorily required to use "all readily available and existing information."[131] Practically, this means that EPA and the states are actively reaching out to volunteer organizations, universities, and other potential data sources to ensure that they have obtained all relevant data on their state's water quality.[132] This mandate, and the scope of ambient monitoring required under the CWA, has set the stage for one of the broadest, and least talked about, citizen monitoring programs nationally.[133]

Volunteer water quality monitoring under the CWA began with a handful of programs in 1974, increased to over five hundred programs by 1994,[134] and by 2014, included over 1700 programs nationwide.[135] Early on, these programs were primarily community-led initiatives, intended to educate local communities, planning commissions, and health boards about possible health hazards and

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126. Luneburg, *supra* note 21, at 25 (describing water bodies in United States subject to CWA).

127. *Id.* (describing burden of CWA monitoring).

128. *Id.* at 5 (stating "from [ ] outset it was clear that EPA would put [ ] implementation on [ ] backburner in preference to BAT implementation for point sources through [ ] NPDES program").

129. *Id.* at 7 (describing history of court cases forcing EPA to enforce TMDL program).

130. *Id.* at 25 (noting current number of assessed water bodies nationally).

131. 40 C.F.R. §130.7(b)(5) (listing sources states must use in assessing water quality).

132. Luneburg, *supra* note 21, at 9 (discussing effects of available information mandate).

133. For a discussion of this program, *see* Lee, *supra* note 39, and accompanying text.

134. *Id.* (referencing evolution of volunteer monitoring programs over time).

135. *Volunteer Monitoring*, *supra* note 35 (describing results of statistical survey of monitoring programs).

pollution issues.[136] In a survey of water quality monitoring programs conducted in 1994 by the EPA, eighty-five percent of programs used their data for education.[137] Problem identification and local decision-making were the next two top data uses, with sixty-four percent and fifty-six percent of programs reporting these goals, respectively.[138] In contrast, very few programs at this time were using their data for litigation or 305(b) reports.[139]

Initially, the EPA-viewed volunteer data contributed to 305(b) reports in the category of "evaluated" data, comparable to land-use patterns, historical data, and predictive modeling.[140] While volunteer data was helpful in determining water-quality trends, the EPA considered this data to be less rigorous and reliable than "monitored" data obtained from professional scientific measurements.[141] Consequently, only "monitored" data was used in final regulatory decisions.[142]

In 1991, however, EPA recognized that data gathered by properly trained volunteers, that was collected according to established protocols and a clear quality assurance program, could be included in the "monitored" data category.[143] In shifting the classification of volunteer-collected data from evaluated to monitored, the EPA made a clear statement that it viewed volunteer data as equivalent to that collected by professional scientists.[144]

By 1994, twenty-seven states were actively using volunteer monitoring data to create their 305(b) reports.[145] It is worth noting that this acceptance of volunteer data in 305(b) reports happened long before the general acceptance of volunteer monitoring efforts in the scientific community.[146]

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136. Lee, *supra* note 39 (giving results of study of volunteer monitoring programs).

137. *See id.* (describing reported uses of volunteer monitoring data).

138. *See id.* (explaining further EPA survey data).

139. *See id.* (noting that relatively few programs had policy aims for data).

140. KENNETH H. RECKHOW ET AL., ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT 53 (2001) (discussing different types of data that EPA uses in CWA monitoring).

141. For a description of how volunteer data was viewed, *see* Lee, *supra* note 39, and accompanying text.

142. Reckhow et al., *supra* note 140, at 53 (referencing use of monitored data by EPA).

143. *Id.* (discussing shift of volunteer data from evaluated to monitored).

144. *Id.* (defining how evaluated and monitored data are viewed differently).

145. Lee, *supra* note 39 (noting uses of volunteer monitoring data over time).

146. For a further discussion of scientific concerns with citizen science, see *supra* notes 45-64 and accompanying text.

It is also significant to note that, in many cases, "volunteer" monitoring efforts are in fact receiving funding from the federal and state governments.[147] In 1994, approximately thirty percent of water monitoring groups received state funding, with an additional twenty-five percent receiving federal funds.[148] This, at the time, was an indication that government agencies recognized the benefits of obtaining water quality data from volunteer monitors.[149]

2. *Data Quality in Volunteer Water Monitoring*

Today, volunteer monitoring has become a key tool in EPA Clean Water Act monitoring.[150] The EPA has developed extensive protocols to manage this process and ensure that data used in 305(b) reporting meets required accuracy standards.[151]

EPA's only threshold quality requirement for data included in 305(b) reports is that it be "scientifically valid."[152] What data is considered valid may vary, however, based on the "consequences of the resulting water quality decisions."[153] Of these uses, enforcement actions generally require the highest quality data along with comprehensive regulatory grants to states.[154]

This flexible approach to data quality, and the recognition that different uses may support different quality standards, means that the EPA has no set data quality thresholds.[155] Instead, the EPA focuses on mandating proper methodology to ensure data validity.[156] Thus, in looking at data quality issues that may stem from volunteer data collection, it is important to note that there is no firm threshold that these programs must meet; instead, volunteer water quality

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147. Lee, *supra* note 39 (referencing results of survey indicating how volunteer monitoring programs were funded).

148. *See id.* (referencing specific survey results).

149. *See generally* USEPA, ELEMENTS OF A STATE WATER MONITORING AND ASSESSMENT PROGRAM (2003), https://archive.epa.gov/water/archive/web/html/statemonitoring.html (describing EPA's use of volunteers as integral part of CWA monitoring).

150. *See id.* (describing history of volunteer monitoring over time).

151. *See generally* USEPA, *supra* note 149 (setting out requirements for state monitoring programs under CWA).

152. *Id.* at 9 (describing what data can be used as basis for 305(b) reports).

153. *Id.* at 8 (detailing consequences of water quality decisions).

154. *See id.* (relating how data quality thresholds vary depending on how data will be used).

155. *See id.* (discussing case-by-case analysis of data quality).

156. *See generally* USEPA, *supra* note 149 (describing methodological requirements that states must meet).

monitoring data must simply meet the "scientifically valid" requirement.[157]

There are very few published validation studies of volunteer water quality monitoring programs.[158] Those that do exist suggest that with appropriate training and methodologies, there can be significant correlations between data that volunteers collect and data that professional scientists collect.[159] This is not always the case, however, as there are just as many examples where volunteer data is significantly different than that of data collected by scientists.[160] This is reflective of the general trend widely seen in citizen science validation studies more broadly: differing data accuracy depends on the methods used, and the training given to volunteers.[161]

There is strong reason to believe that data validity issues with water quality monitoring do currently exist.[162] The EPA has noted that "it is not uncommon for the reported quality of a water body (i.e. attainment or non-attainment) to differ on either side of a State boundary."[163] That this is a common scenario is likely indicative of systemic data quality issues.[164]

In sum, because of the general and deep-seated concerns with the scientific validity of citizen science data, the uncertainty in accuracy of volunteer water quality monitoring data, and the known water quality data issues, substantial questions about the quality of volunteer water quality data collected under the CWA are raised.[165]

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157. *See id.* (requiring data used by states be "scientifically valid").

158. For a further discussion of why there are scarce published validation studies, see *supra* notes 72-74 and accompanying text.

159. *See* D. E. Canfield et al., *supra* note 78, at 7 (explaining volunteers are reliable in assessing Florida lakes); *see also* Sarah R. Engel and J. Reese Voshell, *Volunteer Biological Monitoring: Can it Accurately Assess the Ecological Condition of Streams?*, 48 AM. ENTOMOL. 164, 164 (2002) (discussing how volunteer data is reliable in biological stream monitoring); *see also* Fore et al., *supra* note 78, at 109 (explaining that volunteer stream monitoring data matches data from professional scientists).

160. *See* Canfield et al., *supra* note 78, at 7 (noting instances where volunteer data was not accurate); *see also* Engel and Voshell, *supra* note 159, at 164 (discussing volunteer inaccuracy); *see also* Gottlieb, Hirokawa & Keehan, *supra* note 21, at 81 (describing hurdles to accuracy in ecologicas monitoring).

161. For a further discussion of variations in data quality, see *supra* notes 56-60 and accompanying text.

162. For a discussion of data quality issues associated with using volunteers to collect scientific data, see *supra* notes 67-87 and accompanying text.

163. Luneburg, *supra* note 21, at 8–9 (referencing problem of transboundary classification differences).

164. For a discussion on the importance of data replicability in citizen science, see Bonney et al., *supra* note 2, and accompanying text.

165. For a discussion of data quality questions that exist with citizen science as a whole, see *supra* notes 67-87 and accompanying text.

3. Designing Volunteer Monitoring to Ensure Data Quality

Despite these ongoing data quality concerns, volunteer water monitoring is widely recognized as a critical component of 305(b) water body assessment and monitoring.[166] The EPA's use of data collected by the public in impaired waters determinations under the CWA, illustrates two essential points about the use of citizen science. First, this data may be subject to non-trivial quality concerns.[167] Second, that this data may still, in many cases, prove to be an invaluable supplement to chronically underfunded environmental ambient monitoring programs.[168] Reconciling these points is critical if citizen science data is to be successfully used in regulation.[169] This article submits that attention to several citizen science project design features can ensure data, which non-scientists collect, is usable by agencies.[170] EPA's volunteer water monitoring program has accomplished this by including design mechanisms that work directly to reduce error where possible and to effectively include citizen science data in decision-making contexts, in which higher error rates may be tolerated.[171]

a. Quality Assurance/Quality Control

The first, and perhaps most important, mechanism allowing citizen science data to be used in regulatory decision-making is the creation of rigorous quality assurance/quality control (QA/QC) procedures for volunteer monitors.[172] Approved methodologies work to improve the data quality of citizen science projects across the board and reduce validity concerns to the extent feasible.[173]

The EPA and states have implemented QA/QC procedures by requiring that volunteer monitoring programs have approved Quality Assurance Projects Plans (QAPPs) before their data is used in

166. Luneburg, *supra* note 21, at 25 (describing role of volunteer monitoring in creating 305(b) reports).

167. For a discussion of data quality issues with citizen science, see *supra* notes 45-60 and accompanying text.

168. *See* Biber, *supra* note 15, at 4 (discussing data gaps in environmental monitoring).

169. *See* Dickinson, Zuckerberg & Bonter, *supra* note 13 (noting challenges that citizen science programs need to address).

170. For a discussion of these design features, see *infra* notes 139-209 and accompanying text.

171. For a discussion of the importance of flexible data quality standards specifically, see *infra* notes 161-170 and accompanying text.

172. USEPA, *supra* note 60 (discussing required QA methods for volunteer monitors).

173. *Id.* (relating goals of intensive quality assurance requirements).

303(d) listings.[174] QAPPs ensure that volunteer programs follow accepted protocols for training and data collection.[175] If they follow approved QAPPs, volunteer monitoring groups are allowed by most states to submit data that is used directly in 305(b) reports.[176]

Currently, approximately one-third of volunteer water monitoring programs use an EPA approved Quality Assurance Project Plan (QAPP), while an additional forty percent use a state approved QAPP.[177] Only thirteen percent of surveyed volunteer programs do not use QAPP.[178] Generally, state and EPA QAPPs work in very similar ways to establish methodologies that are most likely to achieve credible data.[179]

QAPPs are largely methodological tools that require volunteer programs to abide by accepted training and data collection procedures.[180] In general, QAPPs ensure that volunteer programs are engaging in quality assurance, and control and assessment steps throughout their projects.[181] These plans also require projects to create Data Quality Objectives (DQOs) that set out the accuracy goals for data collected by the project.[182] DQOs include measurements of precision, accuracy, representativeness, completeness, comparability, and measurement range.[183] Once projects have collected data, QAPPs require volunteers to review whether their gathered data meets stated DQOs and to establish procedures for updating methodologies if data standards are not met.[184]

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174. *See id.* (giving requirements for states to use volunteer data).

175. *Id.* (describing required training methodologies).

176. *See e.g.* VA Dept. of Envtl. Qual., *Levels of Citizen Water Quality in Virginia,* VIRGINIA DEQ, *available at* http://deq.state.va.us/Portals/0/DEQ/Water/WaterQualityMonitoring/CitizenMonitoring/Memo.pdf (last visited May 2, 2017) (listing how citizen data may be used in Virginia).

177. Linda Green et al., Assessing the Needs of Volunteer Water Monitoring Programs, EXTENSION VOLUNTEER MONITORING NETWORK 1, 8 (2012) (referencing number of monitoring programs using QAPPs).

178. *Id.* (referencing number of monitoring programs using QAPPs).

179. *Id.* (discussing relationship between state and federal QAPPs).

180. USEPA, *supra* note 60 (discussing methodological requirements of QAPPs).

181. Elizabeth Herron et al., *Building Credibility: Quality Assurance and Quality Control for Volunteer Monitoring Programs,* NATIONAL FACILITATION OF CSREES VOLUNTEER MONITORING 1 (2004), *available at* https://acwi.gov/monitoring/conference/2006/2006_conference_materials_notes/WorkshopsandShortCourses/QAQCWorkshop/E8_FINAL_QA-QC_workshop.pdf (elaborating on QAPPs).

182. USEPA, *supra* note 60, at 26 (introducing Data Quality Objectives as key piece of required QAPPs).

183. *Id.* (listing elements of DQOs).

184. *Id.* at 39 (establishing procedures programs must follow to successfully incorporate DQOs).

In addition to establishing DQOs, QAPPs require volunteer groups to adhere to approved methodologies and establish standards of review for collected data.[185] EPA does not mandate specific approved methodologies for water quality monitoring, but the majority of water quality monitoring programs look to the National Environmental Methods Index to determine accepted methodologies for monitoring various water quality parameters.[186] QAPPs require training of volunteers in these approved methods.[187]

In addition to methodological standardization, QAPPs require extensive quality control procedures.[188] EPA recommends that volunteer programs collect at least ten percent of their samples as Quality Control (QC) samples, or twenty percent for new programs still validating their methods.[189] These QC samples engage a variety of established scientific quality testing tools, allowing for comparisons between samples to ensure cleanliness, lab accuracy, the effect of transportation, and collection precision.[190] States, themselves, may impose additional quality control requirements for data to be used in 305(b) reports, such as external audits.[191]

QAPPs, therefore, hold volunteer monitors to an approved, and rigorous, methodological framework, by which it is possible for volunteers to achieve high data quality standards.[192] Ensuring methodological integrity is particularly important given that attacks on data generated by non-scientists are often aimed at perceived methodological flaws.[193] Eliminating this source of error creates a significantly stronger basis for regulatory action.[194]

Effective QA/QC procedures are a necessary component of citizen science data collection and may yield results that are on par with measurements by professional scientists.[195] These procedures, however, will never give assurance that data collected is sufficiently

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185. *Id.* (describing standards of review for volunteer programs).

186. *See Methods and Protocols,* NATIONAL WATER QUALITY MONITORING COUNCIL, http://acwi.gov/monitoring/methods.html (last visited Mar. 21, 2017) (describing use of NEMI by monitoring programs).

187. Herron et al., *supra* note 181, at 1 (discussing use of QAPPs).

188. USEPA, *supra* note 60, at 21–22 (establishing quality control requirements).

189. *Id.* (describing how programs should use quality control procedures).

190. *Id.* (listing elements of quality control methodologies).

191. VA Dept. of Envtl. Qual., *supra* note 115 (laying out Virginia's requirement of external audits as quality control measure).

192. USEPA, *supra* note 60 (discussing QAPPS broadly).

193. *See* Overdevest and Mayer, *supra* note 5, at 1519 (describing how volunteer data is attacked by others).

194. USEPA, *supra* note 60 (developing benefits of QAPPs).

195. *Id.* (noting outcomes of programs following QAPPs).

valid.[196] This is not a death knell to the use of volunteer monitoring data, though, as EPA demonstrates how additional procedural protections allow this data to be used effectively.[197]

b. Flexible Quality Standards

QAPPs, as implemented by the EPA, do not eliminate volunteer data quality concerns.[198] At no point in the QAPP process does the EPA require that volunteer monitoring be validated through comparison with professional measurements or other known baselines.[199] While QC samples may be able to pick out targeted problems in data collection or analysis, without comparison to known standards it is impossible to determine whether larger systemic differences exist between data collected by volunteers and professionals.[200] It is not a coincidence that validation studies of citizen science universally compare volunteer data to professional measurements to determine the quality of the data.[201] Data validation by comparison is the most useful metric of citizen science data quality, and ultimately the only real proof of data validity in these contexts.[202]

Without an overall validation requirement in QAPPs, there is ultimately no assurance that data gathered by volunteers meets data quality goals.[203] Given the lack of validation studies, for programs with or without QAPPs, it remains unclear whether the EPA's determination that volunteer data is of the same quality as that of professional scientists can be reasonably defended.[204]

Requiring, however, that all volunteer data used in environmental monitoring be validated through comparison with independent professional monitoring data would essentially defeat the

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196. *Id.* (describing data collection).

197. For a discussion of flexible quality standards, which is arguably the most important of these mechanisms, see *infra* notes 165-171 and accompanying text.

198. *See generally* USEPA, *supra* note 60 (establishing how EPA validates volunteer data).

199. *Id.* (discussing QAPP process in detail).

200. For a further discussion on the importance of validation studies in assessing volunteer data quality, see *supra* notes 75-83 and accompanying text.

201. *See generally* Bonter and Cooper, *supra* note 76 (discussing how citizen science is validated).

202. *See* Rebecca C. Jordan et al., *Evaluating the Performance of Volunteers in Mapping Invasive Plants in Public Conservation Lands*, 49 ENVTL. MGMT. 425, 431–432 (2012) (relaying importance of comparison validation studies).

203. *See id.* (emphasizing that validation is necessary to ascertain reliability of volunteer data).

204. *See* Conrad and Hilchey, *supra* note 8, at 280 (noting potential cost savings of using citizen scientists to collect data).

purpose of using volunteers to collect water quality data.[205] Professional scientists would need to monitor all areas sampled by volunteers to allow comparison to volunteer data.[206] This approach would then be subject to the same drawback that drives existing data gaps about ambient environmental conditions, essentially the lack of resources to carry out professional monitoring.[207]

Recognizing that perfect data accuracy, or complete confidence in data quality, may be impossible in environmental monitoring is a crucial component of citizen science data collection.[208] The EPA has codified this concept in their own volunteer water quality monitoring programs, noting that data quality needs vary based on the intended use of the data.[209] The understanding that imperfect data may be preferable to no data at all is a critical part of understanding the role of citizen science in the regulatory process.[210]

By recognizing the uncertainty inherent in the monitoring process, the EPA provides a framework that should be used for other citizen science projects going forward.[211] These projects may provide data that paints a broad and less finely grained picture of the state of the environment.[212] This data is no less useful for its lack of complete and perfect detail; understanding that there is a place for less than perfect data is effectively a prerequisite for including citizen science data in regulatory contexts.[213] The National Academy of Sciences recommended such an approach for TMDL listings, but the EPA never officially adopted it.[214]

205. *See* Kosmala, *supra* note 75 (describing validation process for citizen science projects).

206. *See generally* Bonter and Cooper, *supra* note 76 (discussing how citizen science is validated).

207. *See* Biber, *supra* note 15, at 4 (describing driven data gaps in environmental monitoring).

208. *See* RECKHOW ET AL., *supra* note 140, at 52 (recommending preliminary problem of identification role for citizen science).

209. *See* USEPA, *supra* note 149 (discussing data quality flexibility).

210. *See* Emily Hammond Meazell, *Super Deference, the Science Obsession, and Judicial Review as Translation of Agency Science*, 109 MICH. L. REV. 733, 748 (2011) (explaining how federal agencies use scientific information).

211. *See also* RECKHOW ET AL., *supra* note 140, at 52 (recommending preliminary of problem identification role for citizen science).

212. *See id.* (discussing data collected by citizen scientists).

213. *Id.* (arguing even flawed data from public has role to play in environmental monitoring).

214. For recommendations on volunteer monitoring data in TMDL listings, *see* Reckhow et al., *supra* note 140, at 52, and accompanying text.

Several states, however, currently use this tiered approach.[215] In Florida, monitoring of water bodies is split into several phases.[216] In Phase One, the state actively solicits volunteer data to develop a list of potentially impaired waters.[217] In Phase Two, state scientists monitor areas of potential concern to determine whether they are impaired or not.[218] This system allows the state to more readily determine monitoring priorities for their limited staff resources, while ensuring that listing decisions are based on sound science.[219]

A tiered approach is also largely used for enforcement actions.[220] In cases that are likely to go to court, citizen science data is generally not of high enough quality to be admissible.[221] In such situations, citizen science data is often used to identify particular areas of concern or exceedances.[222] Agency staff subsequently makes their own measurements, which ultimately form the basis for an enforcement action.[223]

One of the strongest uses of citizen science data is in the preliminary identification of potential environmental problems for further analysis and action by regulatory bodies.[224] This triage approach, as utilized to some extent in the TMDL program, capitalizes on the ability of volunteer monitors to provide data over vast scales while also ensuring that regulatory decisions are based only on high quality and defensible data.[225]

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215. For a discussion of Florida's process, see *infra* notes 216-219 and accompanying text.

216. FL Dept. of Envtl. Prot., *The Total Maximum Daily Load Program—Overview,* FL DEP 1, 1 (Jan. 20, 2003) http://www.dep.state.fl.us/water/tmdl/docs/TMDL_Program_Overview.pdf. (detailing Florida's water quality monitoring process).

217. *Id.* (describing different phases of TMDL data collection).

218. *Id.* (noting involvement of professional scientists in Phase Two).

219. *Id.* (describing state process).

220. Bailey Smith, *Agency Liabilty Stemming From Citizen-Generated Data*, WILSON CENTER 1, 5 (2015) (describing role of citizen scientists in enforcement).

221. *Id.* (discussing limitations on citizen science in litigation).

222. *See generally* Overdevest & Mayer, *supra* note 5 (describing role of citizen monitoring in identifying air quality problems).

223. SMITH, *supra* note 220, at 5 (noting that agency science is used in litigation).

224. RECKHOW ET AL., *supra* note 140, at 52 (recommending preliminary problem of identification role for citizen science).

225. *Id.* (balancing outcomes of citizen science).

c. Data Management for useable data

When it comes to environmental monitoring data, the belief that more is better is widespread.[226] To be usable, however, data must meet not only quality requirements, but must also include standardized formatting and metadata as well.[227] Ensuring that data is usable across platforms is a huge task, and is one that has received a great degree of focus in the scientific community as "big data" projects become more common.[228]

The EPA has mandated that states and volunteer groups report their data in uniform ways, ensuring usable data outcomes.[229] To this end, the EPA has created the STORET database to serve as a central clearinghouse for all water quality monitoring data submitted by state and volunteer groups.[230] This tool allows for water quality data to be standardized and shared across jurisdictions.[231] The importance for citizen science projects of creating such data management programs should not be underestimated.[232] Proper metadata and uniform sampling procedures often mean the difference between data being usable or not.[233] Effective data management is a critical tool in reducing the barriers that currently exist to citizen science data being used more broadly in decision-making.[234]

d. Direct Action Links

Lastly, volunteer monitoring should provide a clear pathway between monitoring results and regulatory action.[235] These link-

226. *See generally* Kelly and Caldwell, *supra* note 38 (recognizing trend towards gathering more environmental data).

227. Bonney et al., *supra* note 2, at 978 (discussing importance of ensuring cross-platform data usablitity through metadata).

228. Conrad and Hilchey, *supra* note 8, at 281 (also emphasizing need to ensure data usability).

229. USEPA, *supra* note 149, at 9 (laying out EPA's data reporting requirements).

230. *See Storage and Retrieval and Water Quality Exchange*, EPA, http://www3.epa.gov/storet/ (last visited Mar. 19, 2017) (describing STORET database).

231. *Id.* (describing uses of STORET database).

232. *See* Nerbonne and Vondracek, *supra* note 80, at 476 (finding that data management procedures were indicators of data quality).

233. Bonney et al., *supra* note 2, at 978 (discussing importance of ensuring cross-platform data usablitity through metadata).

234. *See* Conrad and Hilchey, *supra* note 8, at 281 (discussing barriers to use of citizen science data).

235. Overdevest, *supra* note 12, at 177 (assessing role of motivation in citizen science).

ages ensure that volunteer motivation in carrying out high-quality, ongoing data collection remains high over time.[236]

EPA's QAPPs, for example, depend highly depend on volunteer motivation to obtain accurate results.[237] By providing methodologies that enable iterative improvement in sampling procedures, QAPPs set the stage for accurate data collection over time.[238] This is dependent on volunteer programs being dedicated to effectively correcting any problems that are found in their monitoring procedures.[239] Volunteer motivation in citizen science projects, however, has been shown to be highly variable and an important predictor of data quality.[240] Showing volunteers that their data will be used directly in regulatory decision-making may motivate higher quality data and participation over the longer timescales that yield particularly useful data sets.[241]

4. *Design as a Means to Reduce Potential Liability*

The EPA's design of its volunteer water quality monitoring programs has evolved over the last 30 years into a system that works to reconcile the power of volunteer monitors to collect data over large scales with the potential quality issues inherent in data collection by non-scientists.[242] The strength of this system is particularly apparent in looking at how EPA has protected itself from any legal issues stemming from the use of inaccurate volunteer data.[243]

If the EPA relied on poor quality data in making regulatory decisions, there is a possibility that it could be held liable under the Federal Torts Claim Act if found to be acting negligently in a non-

236. *See* Overdevest and Mayer, *supra* note 5, at 1513 (highligting how volunteer motivation is important element in data quality); *see also* Overdevest, *supra* note 12, at 177 (maintaining volunteer motivation may be hurdle for citizen science projects).

237. *See* USEPA, *supra* note 60, at 28 (describing extensive scientific requirements volunteers must follow to abide by QAPPs).

238. *Id.* (emphasizing importance of QAPPs).

239. *Id.* (requiring that volunteer monitors gather feedback and seek to continually improve data collection methods).

240. S. Andrew Sheppard and Loren Terveen, *Quality is a Verb: The Operationalization of Data Quality in a Citizen Science Community*, PROC. 7TH INT. SYMP. WIKIS OPEN COLLAB. 29, 37 (2011) (showing importance of motivation in maintaining citizen science data quality).

241. *See* Biber, *supra* note 15, at 59 (discussing need for volunteer datasets over longer timescales).

242. USEPA, *supra* note 149, at 9 (laying out EPA's flexible data quality standards).

243. *See* SMITH, *supra* note 220, at 3 (discussing potential liability of federal agencies).

discretionary capacity.[244] In the case of 303(d) listings, the EPA is mandated under the CWA to collect data from states to determine impaired waters, a non-discretionary function.[245] The EPA, thus, may be held liable if courts were to find that it acted negligently in carrying out its mandate to oversee the 303(d) listing process.[246] This is unlikely, however, as the EPA's required QAPPs for all volunteer data used in 305(b) reports ensures that submitted data is not subject to major methodological flaws.[247]

If inaccurate volunteer-generated data was incorporated into an administrative rule or order, the EPA could be found liable under the Administrative Procedures Act (APA).[248] Under the APA, any party that has been adversely affected by an agency action may petition for judicial review.[249] Generally, judicial review of questions of fact, such as potentially inaccurate data, under the APA, is subject to arbitrary and capricious review, except in formal rulemakings or adjudications.[250] Arbitrary and capricious review is highly deferential to agencies, and courts tend to be particularly deferential when agencies are "making predictions in its area of special expertise, at the frontiers of science."[251] The EPA's existing methodological requirements for volunteer data likely preclude an arbitrary and capricious finding for reliance on inaccurate volunteer data, unless there is considerable evidence that the EPA should have known of these data deficiencies or if there was a case, in which TMDL listing decisions were based solely on inaccurate volunteer data.[252]

Lastly, the EPA could be held liable for the use of poor quality volunteer data under the Data Quality Act (DQA).[253] The DQA requires agencies to set out procedures "ensuring and maximizing the quality, objectivity, utility, and integrity of information" dissemi-

244. *Id.* (describing Federal Tort Claims Act).

245. *Id.* (noting difference between discretionary and non-discretionary functions).

246. *Id.* (describing when agencies may be held liable under FTCA).

247. USEPA, *supra* note 60, at 28 (establishing strict methodological requirments that all monitoring programs must meet).

248. Administrative Procedure Act § 10(c), 5 U.S.C. § 704 (2000) (setting out standards that all federal agencies must follow).

249. *Id.* (establishing judicial review of agency actions).

250. *Id.* (establishing standard of judicial review).

251. Baltimore Gas & Elec. Co. v. Natural Res. Def. Council, 462 U.S. 87, 103 (1983) (interpreting arbitrary and capricious standard).

252. *See* USEPA, *supra* note 60 (discussing methodology).

253. Data Quality Act, 44 U.S.C. § 3516 (2001) (establishing data quality requirements for federal agencies).

nated by them.[254] The DQA also creates a mechanism for parties injured by poor data quality to seek redress.[255] The EPA's citizen science data requirements likely meet the DQA's bar by ensuring that volunteers contributing data are trained and following appropriate methodologies.[256] Moreover, the public seldom uses the DQA to bring complaints against an agency, suggesting that this may not be a major avenue for potential litigation.[257]

There is a chance that citizen groups in the course of their monitoring may obtain data indicating that a particular entity is violating its permits, thereby leading to potential enforcement actions.[258] In these cases, however, the citizen science data is unlikely to be used in court proceedings.[259] Instead, the EPA generally carries out its own monitoring to ensure that data collected is accurate and viable as the basis for a lawsuit.[260] If this were not the case, citizen science data would have to meet the more stringent *Daubert* standard to be admissible in court.[261]

The EPA's CWA volunteer water quality monitoring program helps to illustrate key design features that allow citizen science to be used in regulatory contexts despite potential data quality concerns.[262] Such features are necessary to both prevent agency liability and to allow data to effectively contribute to environmental management.[263] Rigorous quality assessment and control procedures can ensure that volunteer data achieves high quality standards.[264] It is unlikely, however, that complete assurance in citizen science data validity can ever be achieved in the face of limited resources.[265] In light of this, volunteer environmental monitoring

254. *Id.* (listing data quality requirements for agencies).

255. *Id.* (creating redressability for damages from poor data quality).

256. *See* USEPA, *supra* note 60 (describing EPA's required volunteer methodologies).

257. Gellman, *supra* note 18, at 60 (relating limited role of DQA).

258. *See* Overdevest and Mayer, *supra* note 5 (describing enforcement actions taken on basis of volunteer data).

259. SMITH, *supra* note 220, at 4 (arguing that citizen science is unlikely to be admissible in court).

260. *Id.* (referencing role of agencies in enforcement actions).

261. *Id.* (discussing admissibility hurdles for citizen science). For more information on the *Daubert* standard, see *infra* notes 277-378 and accompanying text.

262. For a discussion of these design features, see *supra* notes 160-204 and accompanying text.

263. *See* SMITH, *supra* note 220 (discussing agency liability).

264. For a discussion of QA/QC protocols, see *supra* notes 172-197 and accompanying text.

265. For a discussion on how methodological controls can never offer complete assurance of data accuracy, see *supra* notes 196-198 and accompanying text.

data should be understood as a useful tool in providing a preliminary assessment of environmental conditions.[266]

The potential utility of volunteer environmental monitoring is one that extends far beyond the CWA alone.[267] Volunteer monitors may have an important role to play in ascertaining the broader state of the environment.[268] The EPA itself is beginning to initiate a more robust air quality monitoring program,[269] while scientists are increasingly calling for citizen monitoring of biodiversity, climate change impacts, and management regimes to fill critical data gaps.[270] Citizen petitions and environmental knowledge have already proven to be an important tool in Endangered Species Act listings.[271]

Still, these programs have not yet become widely used in other agencies outside of the EPA.[272] As citizen science develops as a tool and is increasingly used in the regulatory process, proper attention must be paid to the design of such programs to ensure that data obtained is both accurate and effectively used.[273] The EPA provides an example of how such programs can be structured to ensure that citizen science data is usable despite the existing legal constraints.[274] Efforts to ensure data of high quality is collected must recognize that data obtained may not be perfect, and should be coupled with design features that effectively utilize this less than

266. *See* RECKHOW ET AL., *supra* note 140, at 52 (recommending preliminary problem of identification role for citizen science).

267. *See* Conrad and Hilchey, *supra* note 8, at 281 (arguing that citizen science is critical tool for environmental monitoring).

268. Biber, *supra* note 15, at 54 (noting role volunteer monitors may play in ambient environmental monitoring).

269. *See Air Quality Toolbox for Citizen Scientists*, EPA, http://www.epa.gov/air-research/air-sensor-toolbox-citizen-scientists (last visited Mar. 19, 2017) (discussing EPA's new air quality monitoring "toolbox").

270. Conrad and Hilchey, *supra* note 8, at 273 (calling for increased use of citizen science); *see also* Stefano Goffredo et al., *supra* note 14, at 2170 (describing marine uses of citizen science); *see also* Jonathan Salter, John Robinson & Arnim Wiek, *Participatory Methods of Integrated Assessment—A Review*, 1 WILEY INTERDISCIP. REV. CLIM. CHANG. 697, 697 (2010) (describing climate change uses of citizen science).

271. Eric Biber and Berry Brosi, *Officious Intermeddlers or Citizen Experts? Petitions and Public Production of Information in Environmental Law*, 58 UCLA L. REV. 321, 326 (2010) (noting important role of citizen suits in Endangered Species Act listings).

272. *See generally* Open Gov't Partnership, *supra* note 1 (calling on federal agencies to increase use of citizen science in operations).

273. For a discussion of the importance of design features, see *supra* notes 150-209 and accompanying text.

274. For a case study of the EPA's monitoring program, see *supra* notes 150-209 and accompanying text.

perfect data.[275] If such programs are designed appropriately, they may be critical tools in identifying key areas for agency action and providing an avenue for citizen science data to be used effectively in agency action.[276]

C. Citizen Science in Court

Less than perfect data may have a role to play in agency regulation, but is there a place for it in the courts? Simple numbers would suggest perhaps not, as despite the increasing acceptance of citizen science data and its extensive use by agencies, citizen monitoring data has not, to date, been used in court.[277]

The absence of citizen data in court could simply be a functional disconnect; citizens often collect information about ambient environmental conditions, as in the EPA's CWA monitoring program.[278] Such information, while informative about the general state of the environment, is not the more targeted monitoring data needed to identify specific illegal activities and form the basis for litigation.[279] If the only data the public collected was ambient monitoring data, this might explain why there has been an absence of citizen data in court; it simply is not that helpful in making a case.[280]

Beyond the world of ambient monitoring and crowd-sourced data analysis that agencies are heavily involved in, however, a second type of citizen science has also recently been gaining ground.[281] This "community policing" involves members of the public directly in monitoring of local conditions to identify problems and mobilize litigation and enforcement.[282] These monitoring efforts have been particularly common in toxic tort litigation, with several non-profit organizations now existing for the sole

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275. For a specific look at QA/QC procedures, see *supra* notes 172-197 and accompanying text.

276. *See* RECKHOW ET AL., *supra* note 140, at 52 (discussing important preliminary role volunteers can play in agency assesment).

277. Michelle Nijhuis, *How the Five Gallon Plastic Bucket Came to the Aid of Grassroots Environmentalists,* GRIST (Jul. 23, 2003), http://grist.org/article/the19/ (noting that citizen data has not been used in court actions).

278. Biber, *supra* note 15, at 59 (discussing role of volunteers in environmental monitoring).

279. *Id.* (identifying difference between targeted and ambient monitoring).

280. *Id.* (defining ambient monitoring as inherently disconnected from targeted litigation).

281. *See* Silvertown, *supra* note 4, at 467 (describing growing prevalence of citizen science in environmental monitoring).

282. Overdevest and Mayer, *supra* note 5, at 1509 (discussing role of community policing).

purpose of providing low-cost air and water monitoring sensors for community environmental enforcement.[283] These groups have been successful in identifying previously undocumented pollution issues and initiating several major lawsuits.[284] These cases have motivated major settlement agreements: In 1994, low-cost air quality monitoring instruments placed in buckets were used by community members to track benzene exceedances from a local oil refinery; the community obtained an $80 million settlement.[285] Next, in 2002, the residents of Norco, LA won a settlement for complete relocation of their community from Shell Chemical after tracking chemical pollution in the air.[286] Finally, in 2002, Orion Refining settled with the residents of New Sarpy, LA after local community monitors tracked air pollution.[287]

The willingness of companies to come to major settlement agreements on the basis of data collected by citizens, and not professional scientists, suggests that these members of the public are able to collect accurate data.[288] It is probable that in most of these cases, companies already knew that they were discharging polluted matter based on their own internal practices and monitoring, and therefore, did not rely solely on the citizen monitoring data itself to discover these problems and decide to make settlement offers.[289] Even if this is the case, however, citizen-monitoring data is accurate enough to identify previously unidentified problems and spur enforcement actions.[290]

Despite being an important part of pre-trial litigation and forcing settlements, citizen data has not been used in the trial stage of litigation.[291] This absence could simply be a result of the notion that the majority of cases settle before trial and the opportunity for citizen data to be used in court has not yet arisen.[292] There is a prevalent belief in the legal community, however, that citizen sci-

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283. *Id.* at 1511 (describing advent of organizations providing air sampling buckets to communities).

284. *Id.* at 1508-10 (describing history of bucket brigades).

285. Nijhuis, *supra* note 277 (describing benzene enforcement actions).

286. *Victories,* GLOBAL COMMUNITY MONITOR, http://www.gcmonitor.org/about-us/victories/ (last visited May 12, 2016) (noting Norco settlement).

287. GWEN OTTINGER, REFINING EXPERTISE 2 (2013) (detailing Orion settlement).

288. *Id.* (arguing that citizen data was crucial in motivating settlements).

289. *Id.* (suggesting that companies were aware of polluting activities).

290. *Id.* (noting role of volunteer data in discovering compliance issues).

291. Nijhuis, *supra* note 277 (noting that citizen data has not been used in court).

292. For a discussion of why citizen science data may not be seen in court more broadly, see *supra* notes 222-224 and accompanying text.

ence data would not be admissible in court.[293] If this data is not admissible, litigation based on such data is more likely to settle before trial if plaintiffs believe that their data may not be admissible in court.[294] This presents a problem in cases where the only data source showing illegal activity is community monitors; if validation by professional scientists that illegal activity is occurring is unavailable, citizen groups may be forced into less favorable settlements based on the belief that their evidence will not be admissible in court and consequently that settlement is the only option.[295]

But is this belief that citizen science data is not admissible in court an accurate one? As of 1993, *Daubert* presents the standard that expert testimony must meet to be admissible in federal courts.[296] This standard poses a major hurdle for citizen scientists that may wish to have their data form the basis for a lawsuit that is tried in court.[297] The few academics, who have examined this issue, have immediately written off citizen science as extremely unlikely to be admissible under *Daubert*.[298] Ultimately, while in some cases citizen science data would probably meet Daubert's requirements for admissibility, these are also cases in which citizen data is no longer useful and is merely a redundant presentation of data that professional scientists also obtain.[299] For the majority of cases, and certainly the cases where citizen data is the only information available identifying illegal behavior, it is unlikely that such data would be admissible in court.[300]

Federal Rule of Evidence (FRE) 702 sets out the standard, under which experts may be qualified in court, noting that this rule applies to "a witness who is qualified as an expert by knowledge,

293. *See* SMITH, *supra* note 220, at 5 (elaboarinting on how "[m]any citizen science groups may have trouble getting [ ] data up to standard for court admissibility").

294. OTTINGER, *supra* note 287, at 2 (describing community members eventual willingness to accept settlement lower than they wanted); *see also Tonawanda*, CLEAN AIR COALITION OF WESTERN NEW YORK, http://www.cacwny.org/campaigns/tonawanda/ (last visited May 2, 2017) (showing that volunteer data identifying pollution problems instigated EPA investigation and EPA data was used in eventual enforcement litigation, resulting in large award).

295. *See* SMITH, *supra* note 220, at 5 (describing how citizen science is unlikely to be admitted in court).

296. *See generally* Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993) (describing standards for scientific evidence in courts).

297. *See* SMITH, *supra* note 220, at 5 (noting that citizen science is unlikely to be admissible in court).

298. *Id.* (describing difficulty of citizen science being admitted under *Daubert*).

299. *See* Kosmala, *supra* note 75 (discussing how citizen science is validated).

300. *See id.* (noting that citizen science is unlikely to be admissible in court).

skill, experience, or education. . . ."[301] This rule presents the first hurdle that citizen scientists face before their testimony may be admissible in court: do they qualify as experts under FRE 702?[302]

This raises an interesting question, as traditionally, educational credentials are a key factor in the process of qualifying witnesses as experts.[303] Citizen scientists, by definition, do not have a formal education that would solidify their status as experts.[304] However, FRE 702 also allows that experts can be qualified by "knowledge, skill, [or] experience."[305] These categories may then allow citizen scientists to be considered experts, even without formal scientific training.[306] Under FRE 702, witnesses as diverse as tire experts, and even drug dealers, have been qualified as experts on the basis of their specialized knowledge or experience.[307] There is an argument to be made that citizen scientists, through their knowledge of local environmental conditions and ongoing monitoring experience, might be considered experts under this standard.[308]

However, this is complicated by the fact that in fields where advanced education is available, courts generally look to this as a necessary precondition for qualification as an expert.[309] In *Kumho Tire v. Carmichael,* the United States Supreme Court asserted that the expert's "preparation is of a kind that others in the field would recognize as acceptable."[310] So while a drug dealer, who has not completed high school, may be qualified as an expert on drug trafficking, it is far less likely that an economist who has not completed high school, or obtained a PhD for that matter, would be considered an expert.[311] This presents complications for citizen scientists, as the scientific community generally views advanced degrees as a

301. FED. R. EVID. 702 (describing how experts can be admitted to testify in court).

302. *Id.* (describing standard that experts must meet to testify in court).

303. Joel Cooper, Elizabeth A. Bennett & Holly L. Sukel, *Complex Scientific Testimony: How Do Jurors Make Decisions?*, 20 LAW HUM. BEHAV. 379, 386 (1996) (discussing role of education in evaluating scientific testimony).

304. Bonney et al., *supra* note 2, at 977 (defining citizen science).

305. FED. R. EVID. 702 (describing admissibility of expert testimony).

306. *See* Bonney et al., *supra* note 2, at 977 (emphasizing importance of training for citizen scientists).

307. *See* Kumho Tire Co. v. Carmichael, 526 U.S. 137, 150 (1999) (admitting tire mechanic as expert on basis of experience).

308. *See generally* USEPA, *supra* note 149 (describing training and experience that volunteers must meet).

309. *Kumho Tire Co.*, 526 U.S. at 150 (noting importance of education in determining expert qualifications).

310. *Id.* at 151 (describing preparation needed for expert witnesses).

311. *Id.* (noting that what qualifies expert depends upon what field that expert seeks to be admitted in).

prerequisite of expertise.[312] Without these credentials, it may be difficult to argue that citizen scientists have the "reliable basis in the knowledge and experience of [the relevant discipline]" needed to be considered experts.[313]

In cases where citizen scientists do not have formal academic training, but have participated in training programs that introduce them to specific methodologies for data collection, there may be an argument that this training is sufficient to meet FRE 702's requirement.[314] Looking at the example of volunteer monitoring under the CWA, extensive training is required before the EPA can utilize public data.[315] These training programs must conform to EPA requirements and provide rigorous methodological training to volunteers.[316] While volunteers may not exit these programs with the wide range of knowledge that a professional biologist has, they arguably are just as knowledgeable about the specific technique being used.[317] In such cases, there is an argument that these volunteers should be considered experts under FRE 702.[318] When rigorous and formal training is combined with years of experience, there is an even stronger argument that citizen scientists may qualify as experts.[319] FRE 702 specifically points to experience as a factor that can establish expertise.[320] In the case of citizen scientists, many of whom participate in these projects over the course of many years, experience in combination with training may be sufficient to establish relevant expertise.[321]

If citizen scientists are able to illustrate, through their training, knowledge or experience that they may considered them to be experts, FRE 702 then allows opinion testimony if, *inter alia,* "the testi-

312. Jeffrey Pfeffer, *Barriers To the Advance of Organizational Science: Paradigm Development As a Dependable Variable.*, 18 ACAD. MANAG. REV. 599, 600 (1993) (discussing requirement of advanced degrees).

313. *Daubert*, 509 U.S. at 592 (laying out requirements for expert testimony).

314. See Bonney et al., *supra* note 2, at 977 (providing overview of typical training requirements).

315. *See* USEPA, *supra* note 149 (describing training requirements for volunteer monitors).

316. *Id.* (setting out procedures for training volunteers).

317. *Id.* (detailing specific training protocols).

318. For a discussion of Fed. R. Evid. 702's requirements, see *supra* notes 289-301 and accompanying text.

319. FED. R. EVID. 702 (allowing expertise on basis of "knowledge, skill, [or] experience").

320. *Id.* (asserting requirements of admissible expertise).

321. *See Kumho Tire Co.*, 526 U.S. at 150 (describing how tire expert may be admitted on basis of experience).

mony is the product of reliable principles and methods."[322] *Daubert* famously interpreted this requirement, setting out standards for judges to use in determining what scientific methodologies can be considered reliable.[323] Looking at the factors judges address under *Daubert,* there are significant hurdles for citizen scientists that may prove impossible to meet in most cases.[324]

In the case of citizen science, a *Daubert* inquiry can proceed in two different directions, depending on whether the use of volunteers to collect data is understood as the methodology being questioned, or whether it is the underlying protocols used by the volunteers that *Daubert* examines.[325] In some cases, only one of these will present a reasonable option for analysis; projects that use citizen scientists to classify different pictures of the galaxy, for instance, would likely only fall under the first option, as there is essentially no underlying methodology to examine and the only technique in question is the use of the public to carry this out.[326] In other cases, though, both of these options may be applicable.[327] Volunteer monitoring under the CWA, and in most other environmental cases, could be interpreted in either of these ways.[328] Volunteers are both using scientific techniques and methodologies that may be testable and are also subject to the question of whether the use of volunteers, and not trained scientists, as an overarching technique, is a viable one.[329]

The first inquiry under *Daubert* addresses whether the technique in question can be, or has been, tested.[330] In the case of inquiries into the specific methodology that citizen scientists use, these techniques are testable in the vast majority of cases, and as such, this *Daubert* factor should not pose a major problem to admissibility.[331] In following established scientific protocols and using in-

322. FED. R. EVID. 702 (describing what factors establish expertise).

323. *Daubert,* 509 U.S. at 592-94 (discussing requirements for scientific testimony).

324. *Id.* (setting standard to be admitted as scientific expert).

325. *Id.* (applying *Daubert* standard to scientific methodologies).

326. *See e.g.* Bowser and Shanley, *supra* note 64 (describing galaxy classification and other similar projects).

327. *Id.* (discussing environmental monitoring).

328. For a description of this program, see *supra* notes 99-149 and accompanying text.

329. For a discussion of specific techniques and viability questions, see *supra* notes 150-165 and accompanying text.

330. *Daubert,* 509 U.S. at 593 (discussing requirements for scientific testimony).

331. *See* USEPA, *supra* note 60 (showing testability of water quality monitoring methodologies).

strumentation that is accepted and widely used in the scientific community, citizen scientists comport with known, tested, and approved techniques.[332] These methodologies have been tested, and for the most part, citizen scientists are using the industry standard techniques.[333]

Satisfying this factor becomes more difficult, however, if courts choose to look at the broader question of whether using members of the public to collect data is the methodology under consideration.[334] Citizen science, as a broad methodology, is generally testable.[335] Data that volunteers obtain can be directly compared to the results that professional scientists obtain, directly testing the validity of citizen science.[336] Such validation studies are not infrequent, and ultimately, demonstrate that citizen science data can be comparable to that, which professional scientists collect.[337] Still, to carry out these validation studies, and in effect, "test" citizen science as a methodology, professional scientists must replicate the measurements of volunteers to determine whether there are any discrepancies.[338] This would require a great deal of time and money, and would render citizen science effectively useless; if professional scientists are needed to validate all data collected by citizen scientists, why bother with citizen-collected data in the first place?[339]

Daubert's second factor addresses whether or not the methodology has been subject to peer review or publication.[340] While some citizen science studies have been published in peer-reviewed journals, there are relatively few of these compared to the number of groups currently engaging in citizen science projects.[341] This is due to the controversy of the technique, rather than the simple fact that citizen science groups are generally collecting data for specific pol-

332. *See id.* (providing examples of methodologies).

333. *Id.* (discussing what protocols volunteer monitors follow).

334. For a further discussion on using members of the public to collect data, see *supra* notes 313-317 and accompanying text.

335. For additional examples of how citizen science studies are validated, see *supra* notes 56-60 and accompanying text.

336. *See e.g.,* Bonter and Cooper, *supra* note 76 (creating validation study comparing citizen scientists with professional scientists).

337. For a further discussion on validation studies and scientific views of citizen science, see *supra* notes 56-60 and accompanying text.

338. *See e.g.* Bonter and Cooper, *supra* note 76 (comparing citizen and professional science data).

339. For a discussion of the constraints on validation studies, see *supra* notes 201-202 and accompanying text.

340. *Daubert*, 509 U.S. at 593 (discussing requirements for scientific testimony).

341. Silvertown, *supra* note 4, at 470 (noting lack of peer-reviewed citizen science studies).

icy ends, coupled with the notion that publishing in academic journals is not a priority.[342] Consequently, the fact that citizen science studies are routinely, if not overwhelmingly, frequently published in peer-reviewed journals may be sufficient to meet this standard under *Daubert*.[343]

The only complication here stems from the fact that, generally speaking, each citizen science group is using different equipment, methodologies, and analyses.[344] Because of this, it may be difficult for courts to differentiate from peer-reviewed papers published by one specific volunteer group from another group operating in a different field.[345] Citizen science broadly has been subject to peer-review, but due to the relative dearth of these studies, it is unlikely that any specific project or technique can be supported by peer-review.[346] If citizen scientists are using methodologies that are widespread in the scientific community, as they often are, they may be able to point to peer reviewed studies that use these methodologies, and not necessarily in a citizen science context.[347] Thus, citizen scientists may be able to point to a range of different published studies, those supporting citizen science broadly and those supporting their methodology specifically, in order to satisfy this *Daubert* factor.[348] How convincing an argument this will be is likely subject to wide variation, depending on the specifics of the citizen science project, as well as the disposition of the judge in question.[349]

The error rate of the technique, the third factor that courts consider under *Daubert,* is one of the most important factors to consider for citizen science.[350] Fortunately, this error rate is relatively easily measured; validation studies both of citizen science equipment and methodologies commonly compare results from the pub-

342. *Id.* (arguing that citizen science projects generally do not have academic publication as one of objectives).

343. *Daubert*, 509 U.S. at 593 (requiring only that technique has been peer-reviewed).

344. *See e.g.* See et al., *supra* note 79 (discussing impact of differing methodology on data quality).

345. For a discussion of the variation within environmental monitoring groups, see *supra* notes 55-58 and accompanying text.

346. Silvertown, *supra* note 4, at 470 (noting lack of peer-reviewed citizen science studies).

347. Bonney et al., *supra* note 2, at 980 (describing how citizen science projects generally use established methodologies).

348. For examples of citizen science validation studies, see *supra* notes 75-80 and accompanying text.

349. *See e.g.* Conrad and Hilchey, *supra* note 8 (discussing different types of citizen science projects).

350. *Daubert*, 509 U.S. at 594 (discussing requirements for scientific testimony).

lic to those obtained by professional scientists.[351] Citizen science projects often conduct these validation studies when they are first starting in order to prove their legitimacy.[352] These error rates often show that results obtained by the general public are equivalent to those from professional, trained scientists.[353]

As with peer-review considerations, however, error rates are project- specific.[354] As such, validation studies for different projects are unlikely to be particularly useful in determining the potential error of another project.[355] To further analyze this factor under *Daubert* would then require validation studies of any citizen science data that was intended for use in court.[356] As discussed above, validation studies require professionals to effectively repeat the work of citizen scientists, which destroys the efficiency argument for volunteers collecting data.[357] This may be even more problematic for cases, in which the only data available is that members of the public collect; in such cases, completing validation studies would be impossible and thus, no error rate could be determined.[358]

Daubert's fourth factor addresses the existence of standards controlling the operation of the technique.[359] Citizen science projects generally have standards governing their methodologies, but how rigorous they are varies widely depending on the type of project and planned uses for the data.[360] Many projects contain extremely detailed QAPs, with associated training and validation requirements.[361] In fact, to submit data as part of the CWA 305(b)

351. *See, e.g.* GWEN OTTINGER, *supra* note 287, at 261 (explaining validation of air quality montioring buckets); *see also* David G. Delaney et al., *Marine Invasive Species: Validation of Citizen Science and Implications for National Monitoring Networks*, 10 BIOL. INVASIONS 117 (2007) (validating methods used by citizen scientists); *see also* See et al., *supra* note 79 (providing further validation of citizen science methodologies).

352. Bonney et al., *supra* note 2, at 981 (discussing use of validation studies).

353. *See e.g.* Delaney et al., *supra* note 153 (validating citizen science data); *see also* See et al., *supra* note 79 (demonstrating validity of citizen science project).

354. For a discussion on the variability in citizen science data quality, see *supra* notes 75-83 and accompanying text.

355. For examples of the impact of specific methodology on error rates, see *supra* notes 78-79 and accompanying text.

356. *Daubert*, 509 U.S. at 594 (discussing error rate requirement).

357. For a discussion of the practical limits of validation studies for citizen science projects, see *supra* notes 187-190 and accompanying text.

358. For a discussion on the practical limits of validation studies for citizen science projects, see *supra* notes 187-190 and accompanying text.

359. *Daubert,* 509 U.S. at 594 (discussing requirements for scientific testimony).

360. *See* USEPA, *supra* note 60, at 26-27 (relating how data quality thresholds vary depending on how data will be used).

361. *Id.* (describing QAPPs).

listing process, all volunteer monitoring groups must have QA plans approved by either state environmental departments or the EPA.[362]

Lastly, *Daubert* asks courts to look to whether the technique in question has gained widespread recognition within the relevant scientific community.[363] This is perhaps the highest hurdle for volunteer environmental monitoring to overcome, as the current explosion of citizen science has been met with mixed responses from the scientific community.[364] Citizen science proponents point to public data collection as an invaluably powerful method of supplementing existing data sets for professional scientists, allowing analysis on a scale that was previously unobtainable.[365] Many critics worry, however, that data collected by non-scientists will never be able to reach the technical accuracy needed to be part of the peer-reviewed canon.[366] Moreover, professional scientists have expressed concerns that public groups may be motivated by external agendas that introduce unacceptable bias into their data.[367] These differing viewpoints illustrate the sharp divide that currently characterizes scientific attitudes towards citizen science.[368]

Current scientific reservations surrounding citizen science call into question whether this can be considered a generally accepted scientific practice.[369] Still, a strong argument can be made that this is generally accepted in certain communities, specifically those of environmental monitoring.[370] The EPA's longstanding use of vol-

362. *Id.* at 26 (noting that QAPPs are required for volunteer monitoring groups).

363. *Daubert*, 509 U.S. at 594 (discussing requirements for scientific testimony).

364. For a discussion on uncertain attitudes in the scientific community towards citizen science data, see *supra* notes 67-87 and accompanying text.

365. *See generally* Bonney et al., *supra* note 2 (listing scientific benefits of citizen science); *see also* Ctr. for Advancement of Informal Sci. Educ., *supra* note 43 (noting education benefits of citizen science).

366. Conrad and Hilchey, *supra* note 8, at 281 (describing outside views of citizen science).

367. *See id.* (discussing how, in many cases, professional scientists are susceptible to external agendas and personal bias); *see generally* Daniele Fanelli, *Do Pressures to Publish Increase Scientists' Bias? An Empirical Support from US States Data*, 5 PLoS ONE 1 (2010); *see also* Sheldon Krimsky, *The Funding Effect in Science and its Implications for the Judiciary*, 13 J.L. & POL'Y 43 (2005) (discussing role of funding in impacting the scientific process).

368. For a further discussion of this divide, see *supra* notes 67-87 and accompanying text.

369. For specific examples of the extent of scientific reservations, see *supra* notes 81-83 and accompanying text.

370. *See Lee*, *supra* note 39 (describing longstanding and accepted use of volunteers to monitor water quality).

unteer monitors to obtain water quality data, for example, supports this idea.[371]

Ultimately, it appears that citizen science faces significant barriers to admissibility under *Daubert*.[372] The biggest of these hurdles are unknown error rates, lack of peer-reviewed publications, and uncertain acceptance.[373] In some cases, these hurdles have been effectively eliminated by the use of extensive training and quality assurance procedures, coupled with validation by professional scientists to determine error rates, but it is often these projects where citizen science data is least needed.[374] In the majority of cases, citizen science projects do not have the resources needed to conduct intensive error rate and validation analyses, nor do they have the motivation to submit their data to the peer-review process.[375] As more groups begin to look to community monitoring as a way to identify and litigate illegal activities, they should be aware that there is only so far that this data can take them.[376] If these groups hope to pursue a case beyond a settlement and in the courtroom, it may be necessary to look to trained scientists for data collection.[377]

III. CONCLUSION

Citizen science has become an increasingly important tool in certain segments of the legal and policy communities; agencies as a group, and environmental monitoring as a field, specifically, are early adopters and advocates for the utility of these projects.[378] Still, it remains unclear whether citizen science could ever be admissible in court.[379] It may be that the best future use of citizen

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371. For a discussion of the EPA's use of volunteer water quality monitors, see *supra* notes 121-176 and accompanying text.

372. For a further analysis of these hurdles, see *supra* notes 318-360 and accompanying text.

373. For details on these factors specifically, see *supra* notes 338-347, 352-360 and accompanying text.

374. For a discussion of EPA's use of volunteer water quality monitors, see *supra* notes 121-176 and accompanying text.

375. Biber, *supra* note 15, at 59 (discussing limits on volunteer monitoring programs).

376. *See* Thompson,, *supra* note 7, at 225–26 (detailing role of citizen scientists in enforecement actions).

377. *See* Smith, *supra* note 220, at 5 (noting that trained scientists may need to collect data for use in court).

378. For a discussion of those advocating for citizen science use, see *supra* notes 1-12 and accompanying text.

379. For an analysis of citizen science's likely hurdles to admissibility, see *supra* notes 276-377 and accompanying text.

science is in projects that inform agency regulation and identify compliance problems for agency enforcement.[380] Regardless, a further understanding of the limitations surrounding the use of citizen science data is crucial going forward in order to ensure that it can contribute effectively to legal decision-making.[381] As it stands, citizen science and crowdsourcing may not be the panacea pointed to by the executive branch, without considerable attention to the design of projects to ensure legal data quality standards are met.[382]

380. *See* RECKHOW ET AL., *supra* note 140, at 52 (recommending preliminary problem of identification role for citizen science).

381. For a further discussion on the concerns that must be addressed before citizen science can be more widely used, see *supra* notes 13-21 and accompanying text.

382. For a further discussion on how these design features play a role in EPA's CWA monitoring program, see *supra* notes 177-276 and accompanying text.