frontiers in Climate

PERSPECTIVE
published: 04 December 2020
doi: 10.3389/fclim.2020.600998

Citizen Science and Environmental Protection Agencies: Engaging Citizens to Address Key Environmental Challenges

José Miguel Rubio-Iglesias[1], Triin Edovald[2], Robert Grew[3], Timo Kark[2], Ahmet Erkan Kideys[4], Taru Peltola[5] and Hester Volten[6]*

[1] European Environment Agency, Copenhagen, Denmark, [2] Estonian Environment Agency, Tallinn, Estonia, [3] Environment Agency, Exeter, United Kingdom, [4] Institute of Marine Sciences, Middle East Technical University, Erdemli-Mersin, Turkey, [5] Finnish Environment Institute (SYKE), Joensuu, Finland, [6] National Institute for Public Health and the Environment (RIVM), Bilthoven, Netherlands

Environmental Protection Agencies (EPAs) have been involved in citizen science initiatives for decades, engaging with citizens with the goal of protecting and restoring our environment. Yet the data and knowledge generated and the possibilities for engaging citizens have grown significantly in the last decades thanks to the recent developments in mobile technologies and the access to internet, resulting in a transformation of how environmental protection can be done. This perspective provides some examples on how European EPAs and their partners are currently addressing key environmental challenges and exploring new institutional approaches by bringing in citizen science data and methods. It also points out challenges that need to be addressed to fully realize the potential of citizen science as a complement to the monitoring efforts by these agencies. Finally, it presents the Interest Group on Citizen Science of the Network of the Heads of Environmental Protection Agencies (EPA Network), an informal forum where EPAs across Europe share examples and bring together strategic insights on citizen science approaches into their daily activities.

Keywords: environmental citizen science, environmental monitoring, environmental protection agency, biodiversity, air quality, marine litter, best practices, citizen engagement

Edited by:
Simon Wang,
Utah State University, United States

Reviewed by:
Sven Schade,
European Commission, Joint Research Center (JRC), Italy
Anne Bowser,
Woodrow Wilson International Center for Scholars (SI), United States

***Correspondence:**
José Miguel Rubio-Iglesias
jose.rubio@eea.europa.eu

Specialty section:
This article was submitted to Climate Services, a section of the journal Frontiers in Climate

Received: *31 August 2020*
Accepted: *16 November 2020*
Published: *04 December 2020*

Citation:
Rubio-Iglesias JM, Edovald T, Grew R, Kark T, Kideys AE, Peltola T and Volten H (2020) Citizen Science and Environmental Protection Agencies: Engaging Citizens to Address Key Environmental Challenges. Front. Clim. 2:600998. doi: 10.3389/fclim.2020.600998

INTRODUCTION

Citizen science has a longstanding tradition in the environmental domain, dating back to more than 200 years, with networks of volunteers carrying out phenological observations or collecting daily rainfall data. This wealth of information across spatial and temporal scales is extremely difficult to obtain in other ways and comes with increasing citizen engagement in environmental protection. Environmental Protection Agencies (EPAs) are not newcomers in the field of citizen science. In fact, several agencies coordinate or collaborate in long standing initiatives (Nascimento et al., 2018, Owen and Parker, 2018). Yet the growing number of citizen science activities, linked to the possibilities opened by mobile technologies, the pervasiveness of internet connection and the advances in data handling and storage, is a clear game changer. The knowledge generated and the possibilities for engaging citizens can grow exponentially, contributing to the transformation of environmental protection practices (Owen and Parker, 2018). Thus, the current landscape raises the question of how these institutions can best support these initiatives, not only benefitting from their data but also participating actively in the process, while addressing a more demanding citizen-agency dialogue, all in a time of financial difficulties, not the least due to the impact of the ongoing COVID-19 pandemic. In this perspective, we contribute to this discussion by providing some examples on how European EPAs and their partners are addressing key environmental challenges and exploring strategic approaches building on citizen science data and methodologies. We also discuss briefly the challenges faced by these institutions when integrating citizen science in their activities. We conclude by introducing the Interest Group of Citizen Science of the EPA Network, an informal forum where European EPAs share experiences and strategic insights on citizen science.

THE VALUE OF CITIZEN SCIENCE DATA–TACKLING KEY ENVIRONMENTAL CHALLENGES

While EPAs have diverse mandates and roles, with different national contexts, all of them share the primary goal of the protection of the environment, and are therefore in need of quality assured evidence about the ecosystems, pressures on the environment and the results of the implementation of environmental regulation (Owen and Parker, 2018). Ensuring data is quality assured helps maximize its utility, and besides the use of traditional methodologies and involvement of professional staff, can also be achieved by engaging properly trained citizens, provided with well-developed methodologies, appropriate technology and supported by a wider citizen science community and EPA staff, as we demonstrate below. Hence, the following cases highlight how European EPAs are building on the value of citizen science data and methods to address key environmental challenges of our time.

Tracking Biodiversity Loss—The Estonian Nature Biodiversity Database

Biodiversity monitoring is one of the areas with a long tradition in citizen science involvement, with time series, coverage and granularity that could not be achieved through official monitoring alone (McKinley et al., 2017). Given the current critical situation of ecosystem collapse and biodiversity loss, with a fall of 60% in the global wildlife populations in the last four decades (WWF, 2018), the need for more data to measure progress toward the relevant policy targets, including the calculation of biodiversity indicators, is more pressing than ever. From a European perspective, this is especially relevant in the context of the recently adopted Biodiversity Strategy for 2030[1], a core part of the European Green Deal[2], the flagship European Union (EU) ambition that inter-alia aims at making Europe a climate-neutral continent by 2050. Citizen science can be instrumental in this process.

In 2006, Estonian Environment Agency (Keskkonnaagentuur)[3], in collaboration with Estonian Naturalists' Society (Eesti Looduseuurijate Selts)[4], developed a platform called Nature Observations Database[5] for volunteers to keep track of their nature observations. The database has grown with each year and now, with more than 230,000 observations and 700 users, it has become a key reference on Estonian nature. Until 2015, all the observations were first recorded by the volunteers on paper before being submitted via an internet form. When this rather cumbersome procedure was replaced by a more user-friendly mobile application in 2015, there was a significant increase in the number of observations (see **Supplementary Figure 1**).

The current wide use of this data clearly demonstrates its value. The data submitted by volunteers to the Nature Observation Database is first checked and validated by specialists at the Estonian Environment Agency, with the help of pictures and descriptions provided by the volunteers. Once accepted, the data is integrated with the national monitoring data, which is then used by environmental officials, municipalities and by researchers.

Taking a step further, in 2019 the Environment Agency decided to launch a pilot project[6] with the objective of assessing the integration of volunteer nature observations into the actual national environment monitoring plan. For this pilot project, amphibians were chosen as they are a small group of protected species in Estonia which are already in a monitoring program. They are widely distributed, easy to find and identify. With 50 volunteers in the first year, more than 170 observations across the country covered mostly common species, but in a much larger area than a limited number of experts would have done in a traditional monitoring campaign. With the results of the second year being even more promising, the project has shown a four-times increase in the number of observations in relation to the previous campaigns. Based on these preliminary results, which also show a high data quality, the campaign is expected to be continued and extended to other species groups in the future, such as otters, dragonflies and pollinators.

Addressing Marine Litter—Marine Litter Watch

Since litter in general, and plastics pollution in particular, is one of the most prominent and visible problems in the marine and coastal environment, the involvement of citizens in beach litter collection and monitoring is becoming commonplace. The total mass of plastics waste in the ocean is expected to escalate from 50 million tons (Mt) in 2015 to 150 Mt by 2025 (Chamas et al., 2020) which is enormous when compared with the total global

[1]https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm
[2]https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[3]https://www.keskkonnaagentuur.ee/en
[4]https://www.elus.ee/
[5]https://lva.keskkonnainfo.ee/default.aspx?state=1;877954539;est;lvadb;;&lang=eng
[6]https://www.keskkonnaagentuur.ee/et/kahepaiksete-vabatahtlik-seire (in Estonian)

fish catch value of 96.4 million tons for 2018. Monitoring litter from aquatic environments is very important for generating data on the type and levels of macro and microliter pollution, hot spot areas, identifying threats to ecosystems, pinpointing sources and pathways, assessing the effectiveness of relevant legislation, as well as promoting public awareness (Zettler et al., 2017).

Academic and governmental monitoring efforts for litter data collection are often limited in space and time. Citizen science, especially when undertaken with some training and efficient support, is a cost-effective way to gather data over a large geographical range whilst increasing environmental awareness, spreading scientific knowledge among the general public (Rambonnet et al., 2019) and leading to demands for better and more effective legislation. Such monitoring activities or clean-ups involving large numbers of citizens also result in active clearing of substantial amounts of litter at source.

One of the most popular citizen science actions to tackle litter in Europe is Marine Litter Watch (MLW) coordinated by the European Environment Agency (EEA)[7]. Using a common mobile app developed by EEA, volunteers are collecting beach litter data, mainly from European seas but also rivers and lakes, since 2013. Communities and individuals from dozens of locally organized citizen groups across Europe apply a common protocol and receive permanent online support and training. Under this initiative, volunteers had collected and recorded by the end of 2019 almost two million litter items belonging to tens of types of debris, using a methodology developed by the Technical Group on Marine Litter set up within the scope of the EU Marine Strategy Framework Directive (MSFD) (JRC, 2013). The collected data is available through a dedicated web portal[8] maintained by the EEA (see **Figure 1**).

Despite continuous support from the MLW program, it was recognized that data collected by diverse groups or individual citizens could incorporate a higher margin of error than scientifically acquired data. Therefore, quality assurance through detailed data profiling was undertaken to remove inconsistencies (e.g., removing outliers) and other anomalies within the MLW database.

Recent analyses of MLW data show both spatial and temporal variations in litter composition among different aquatic systems and regions in Europe (Kideys and Aydin, 2020a). Furthermore, this data reveals the shares of certain dominant beach litter items change among distinct European seas (see **Supplementary Figure 2**). MLW data is thus useful for evaluating the efficiency of existing policies (such as the EU MSFD and the EU Strategy on Plastics) and for providing directions to future ones.

Measuring Air Pollution Together—Samen Meten

Although harmful emissions have decreased over the last decades, air pollution is estimated as causing hundreds of thousands of premature deaths across the EU (EEA, 2019a). Public awareness of this problem has increased in recent years, notably through many citizen science initiatives building on low-cost devices. However, up to very recently only government operated or traditional research networks with reference instruments measured air quality (EEA, 2019b).

Citizen science represents an opportunity to complement the official air quality measurements. Seeing this opportunity, around 2012 the Dutch National Institute for Public Health and the Environment (RIVM)[9], responsible for the official air quality monitoring network in the Netherlands, started to get involved in citizen science projects. The project iSPEX[10], initiated that very year, played a key role in changing RIVM's views on the contribution of citizen science (Volten et al., 2018). The project involved measuring aerosols using iPhones with a small add-on for the camera. More than 3,000 participants took part and over 10,000 observations were taken, demonstrating the value of this data in terms of spatio-temporal resolution, as well as the feasibility of engaging a large audience (Snik et al., 2014). However, the nature of the measurements made them unfit for monitoring purposes, and therefore did not lead to a sustained activity. To address this issue, RIVM turned its focus to low-cost sensors (e.g., nitrogen dioxide and particulate matter -PM- sensors).

In 2016, the RIVM launched the Samen Meten ("Measure Together") program. Samen Meten involves the development of a knowledge portal[11], where citizens can find information on air quality, sensors or citizen science initiatives to team up with, as well as an open data portal[12] (see **Figure 2**). Citizen scientists can either obtain data from the platform or upload it. Data can be exchanged through an Application Programming Interface (API) which is particularly convenient for larger citizen science programs such as Sensor.Community[13] or Hollandse Luchten[14]. Although these initiatives also have their own data platforms, the added benefit of the Samen Meten platform lies in the possibility to combine all available sensor data and to compare with nearby official data. Furthermore, and as the currently most used PM sensor, the Nova Fitness SDS011 sensor[15], is sensitive to relative humidity (RH), the data portal also provides a RH correction to the data (Wesseling et al., 2019). These additional functionalities attract a higher number of participants and boost the number of citizen science projects represented in the fast growing Samen Meten program.

To facilitate the use of the collected citizen science data by RIVM itself, additional efforts are necessary to enhance data by validation methods and corrections (e.g., for RH), using diverse approaches to incorporate the sensor data in monitoring procedures. Initial results show that this represents a valuable addition to traditional air-quality monitoring, providing much more spatial granularity than the official networks. In the case

[7]https://www.eea.europa.eu/
[8]https://marinelitterwatch.discomap.eea.europa.eu/Home.html
[9]https://www.rivm.nl/en
[10]http://ispex.nl/en/
[11]http://www.samenmeten.nl
[12]https://samenmeten.rivm.nl/dataportaal/
[13]https://sensor.community/
[14]https://hollandseluchten.waag.org/kaart/
[15]http://inovafitness.com/en/a/chanpinzhongxin/95.html

FIGURE 1 | Marine Litter Watch web application including the list of top 10 items collected, with cigarette butts and filters in the first place **(A)**, and the distribution of events in Europe **(B)**.

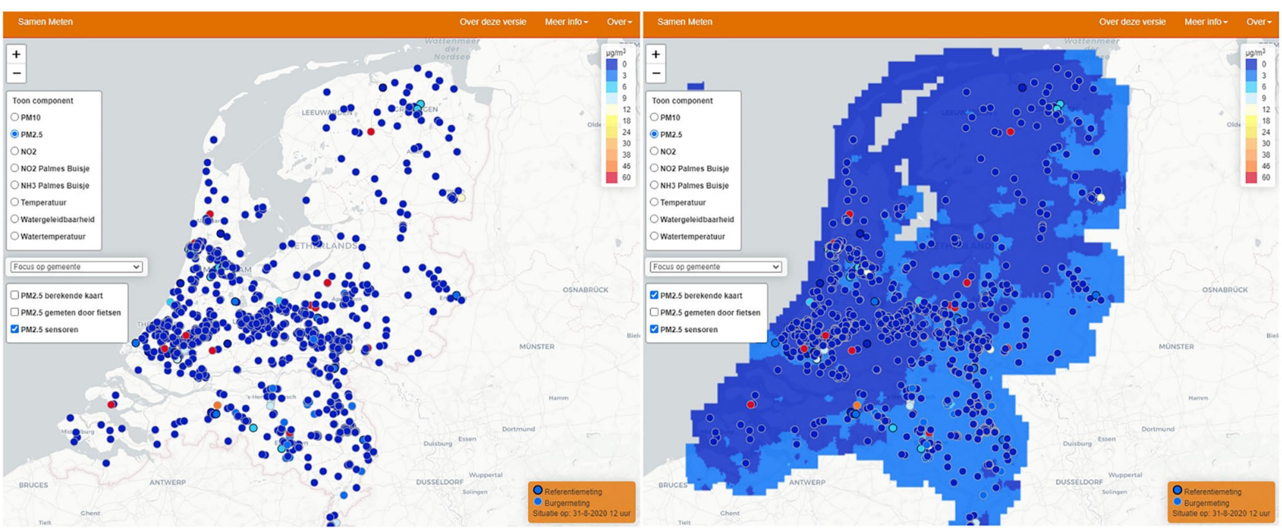

FIGURE 2 | Samen Meten data portal showing the density of the PM2.5 sensor locations and reference stations **(A)** on the map of the Netherlands, and the same against a backdrop of air quality model results **(B)**. Colors are an indication of the height of the PM2.5 concentrations.

of particulate matter, for example, the sensor data is now used in air quality models that attain a higher spatial resolution thanks to the many hundreds of sensors uploading to the data portal (Wesseling et al., 2019). Given its positive results, Samen Meten is now being expanded to other environmental areas such as noise and water quality, where the development of relatively low cost (sensor) measurement methods is also advancing at a fast pace.

THE VALUE OF CITIZEN SCIENCE DATA—FULFILLING OUR CORE MANDATE

EPAs are starting to consider citizen science as instrumental to achieve their core mandate, that is, environmental protection (Hindin et al., 2016, NACEPT, 2016, Owen and Parker, 2018). Many have launched platforms, catalogs and portals to have a better overview of the different initiatives (for example, Scotland's environment Citizen Science Portal[16]) and in some cases are adopting a more strategic approach toward citizen science—such as the Scottish Environmental Protection Agency (SEPA) (Nascimento et al., 2018), RIVM (Volten et al., 2018, Wesseling et al., 2019) or, outside Europe, the US Environmental Protection Agency (NACEPT, 2016). In this section we focus on two cases in Europe: the Finnish Environment Institute and the UK Environment Agencies.

Serving Our Institutional Goals—The Case of the Finnish Environment Institute (SYKE)

The Finnish Environment Institute (SYKE)[17], as a governmental research and expert institute, has as its main goal to build a sustainable society. In this role it has launched citizen science projects. The data from these projects are considered to contribute to the goals of SYKE in three significant ways.

First, citizen science has enormous policy value as it extends the monitoring capacity of environmental changes and problems. Citizen observations are invited through the Invasive Alien Species Portal[18], for example, to monitor the spreading of crab species (Rhithropanopeus harrisii) in the Baltic Sea (Lehtiniemi et al., 2020). Lake and Sea-Wiki[19] collects data on potentially problematic jelly fish invasions (Aurelia aurita). Data about algal blooms from citizens complements information from official sources, making the review of the cyanobacteria situation in coastal and inland waters more comprehensive.

Second, citizen science data serve innovation purposes. SYKE has developed a new nature-based solution to enhance abatement of diffuse pollution via ecological processes occurring on underwater wood surfaces (PuuMaVesi[20]). Addition of constructed wood bundles to ditches and sedimentation ponds increases simultaneously biological water purification efficiency, biodiversity and carbon storages of aquatic habitats. Collaboration with schools and private land-owners has enabled citizen monitoring of the effectiveness of the method. The results showed high reduction levels of pollutants as well as multiplication in the diversity of species.

Third, citizen science data have institutional service value. SYKE provides environmental information as a public service, enabling citizens, businesses and other public bodies to directly use and benefit from the data. For example, the data submitted by citizens to algal bloom watch can be utilized by everyone who is interested in and use local water bodies. The map-based internet service[21] offers information about locations where and when it is safe to swim, for example. Citizen-contributed data enhance the service making it more comprehensive.

Citizen Science in a Changing Environment—The UK Environment Agencies

The devolved governments and various environment agencies across the UK, including the England Environment Agency, Natural Resources Wales and Scottish Environmental Protection Agency have traditionally supported a number of well-established citizen science initiatives, especially in weather (e.g., Weather Observation Website[22]) and biodiversity (e.g., the National Plant Monitoring Scheme[23]). Data from these schemes are typically used in a wide range of applications, including reporting on the state of the environment, developing analytical tools and models as well as planning and regulatory activities.

Localness and devolved decision making are becoming increasingly important across the UK. The unique characteristics of citizen science mean it both engages people and empowers them. Citizen science can also augment traditional monitoring. Hence, people can become active in their local environment and it can support local decision-making (UKEOF, 2020a).

However, despite Environment Agencies in the UK supporting a number of longstanding initiatives and the growing importance of localness, there is still no coherent strategy for the development of these initiatives and numerous disparate methods and platforms. At a time of financial pressure, it is not possible to maintain so many different platforms. Government agencies are therefore working together to share information and expertise (e.g., UK Environmental Observation Framework[24]). They are also working with NGOs to develop a data sharing framework to collate and combine data from a wide range of sources (The River Trust, 2020).

Ensuring data is accessible is an important priority for any framework. This requires those involved in the planning, collection, storage or use of data to think about data management at the outset of the project (UKEOF, 2020b), and to develop a plan that considers the whole lifecycle. Data is often one of the lasting legacies of a citizen science project so it must be managed and stored effectively to improve the chance that the project has lasting impact (UKEOF, 2020b).

DISCUSSION

The previous sections show a snapshot of the rich landscape of citizen science initiatives involving environmental agencies in Europe. However, and despite the opportunities ahead, there are still challenges to be addressed before the potential of citizen science can be fully realized, especially in monitoring (Volten et al., 2018; Wesseling et al., 2019), their policy impact

[16]https://envscot-csportal.org.uk/
[17]https://www.syke.fi/en-US
[18]http://vieraslajit.fi/fi/content/invasive-alien-species-finland
[19]http://www.jarviwiki.fi/wiki/Etusivu?setlang=en
[20]https://www.syke.fi/hankkeet/PuuMaVesi (in Finnish)
[21]https://www.jarviwiki.fi/wiki/Valtakunnallinen_lev%C3%A4seuranta?setlang=en
[22]https://wow.metoffice.gov.uk/
[23]https://www.npms.org.uk/
[24]http://www.ukeof.org.uk/our-work/citizen-science

(Nascimento et al., 2018), but also in its integration at the institutional level.

A representative example of the complex context in which these agencies deal with citizen science is provided by RIVM. Managers at this institution are embracing citizen science as a much-needed way to getting closer to a society where environmental information become more and more available. Likewise, the participation of RIVM experts is warmly welcomed by the citizen scientists, who see them as a reference for questions about air quality. However, and although the participation in citizen science projects was occasionally very successful (e.g., iSPEX), RIVM technical staff expressed some reticence in this new approach. Their concerns referred to valid questions such as how to sustain public trust on official measurements, how to deal with expectation management or how to tackle discrepancies with citizen science measurements not meeting official procedures and regulations. These concerns, together with the perennial data quality discussion, are echoed by other governmental agencies as some of the greatest barriers for adoption (Blaney et al., 2016, Nascimento et al., 2018). While all this needs to be taken into consideration, and as demonstrated by the examples above, the potential of citizen science clearly outweighs the concerns, and in the case of RIVM the institution continues to support and expand the use of citizen science as we have seen with Samen Meten.

Many EPAs have identified common opportunities but also found similar challenges for a wider adoption of citizen science practices. The need for sharing experiences and identifying common approaches across EPAs crystalized in 2014 with the creation of an Interest Group on Citizen Science within the European Network of the Heads of Environmental Protection Agencies, EPA Network[25] The group, with members from 14 EPAs and the EEA, is a forum where EPAs share practical examples, follow policy developments, and bring together strategic insights on citizen science approaches into their daily activities. As a key stakeholder group, the Interest Group is in continuous dialogue with associations and institutions carrying out citizen science, networks such as the European Citizen Science Association (ECSA) and the European Commission. In particular, the group has been very active in contributing to the recently published Commission's "Best Practices in Citizen Science for Environmental Monitoring"[26] The list of recommendations and actions in this document aims at tapping into the potential of citizen-generated data and facilitating their use in environmental monitoring and policy-making, establishing a roadmap to facilitate its adoption and support its integration. Targeting inter alia public institutions such as EPAs and the EEA, these recommendations call for a reflection by the EPAs on further integrating and streamlining citizen science in their daily activities to better harness the potential of citizen science data and methods to make an even bigger and longer lasting impact.

[25]https://epanet.eea.europa.eu/

[26]https://europa.eu/!kk69mB

DATA AVAILABILITY STATEMENT

The original contributions generated for the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

TE and TK are the lead authors of section Tracking Biodiversity Loss—The Estonian Nature Biodiversity Database. AK is the lead author of section Addressing Marine Litter—Marine Litter Watch. HV is the lead author of section Measuring Air Pollution Together—Samen Meten, and Contributor to section Discussion. TP is the lead author of section Serving our Institutional Goals—The Case of the Finnish Environment Institute (SYKE) while RG is the lead author of section Citizen Science in a Changing Environment—The UK Environment Agencies. JR-I is the coordinator of the article, lead author of sections Introduction and Discussion and contributor to all the other sections. All authors have reviewed and commented on the full article.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2020.600998/full#supplementary-material

Supplementary Figure 1 | Number of observations registered in the Estonian Nature Observations Database over the last 10 years.

Supplementary Figure 2 | Comparison of the top ten items of litter collected by the regional sea beaches between 2014 and 2019 (Kideys and Aydin, 2020b).

REFERENCES

Blaney, R. J. P., Jones, G. D., Philippe, A. C. V., and Pocock, M. J. O. (2016). *Citizen Science and Environmental Monitoring: Towards a Methodology for Evaluating Opportunities, Costs and Benefits*. Wiltshire: Final Report on behalf of UKEOF.

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., et al. (2020). Degradation rates of plastics in the environment. *ACS Sustain. Chem. Eng.* 8, 3494–3511. doi: 10.1021/acssuschemeng.9b06635

EEA (2019a). *Air Quality in Europe - 2019 report, EEA Report No 10/2019*. Copenhagen: European Environment Agency

EEA (2019b). *Assessing Air Quality Through Citizen Science, EEA Report 19/2019*. Copenhagen: European Environment Agency

Hindin, D., Grumbles, B., Wyeth, G., Benedict, K., Watkins, T., Aburn, G. T. J., et al. (2016). "Advanced monitoring technology: opportunities and challenges. a path forward for epa, states, and tribes," in: *EM, The Magazine for Environmental Managers*, November 2016. Available online at: https://www.epa.gov/sites/production/files/2016-11/documents/article-adv-mon-technology.pdf

JRC (2013). *Guidance on Monitoring of Marine Litter in European Seas*. Ispra, VA: Publications Office of the European Union.

Kideys, A. E., and Aydin, M. (2020a). *Marine Litter Watch (MLW) European Beach Litter Assessment 2013–2019*. ETC/ICM Technical Report 2/2020: European Topic Centre on Inland, Coastal and Marine waters, 26.

Kideys, A. E., and Aydin, M. (2020b). "Preliminary analysis of marine litter watch data of the european environment agency with particular reference to the Black Sea," in *Marine Litter in the Black Sea,* eds U. Aytan, M. Pogojeva, and A. Simeonova (Istanbul: Turkish Marine Research Foundation (TUDAV)), 63–73.

Lehtiniemi, M., Outinen, O., and Puntila-Dodd, R. (2020). Citizen science provides added value in the monitoring for coastal non-indigenous species. *J. Environ. Manag.* 267:110608. doi: 10.1016/j.jenvman.2020.110608

McKinley, D. C., Miller-Rushing, A.J., Ballard, H. L, Bonney, R., Brown, H., Cook-Patton S. C., et al. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biol. Conserv*. 208, 15–28. doi: 10.1016/j.biocon.2016.05.015

NACEPT (2016). *Environmental Protection Belongs to the Public: A Vision for Citizen Science at EPA*. Washington, DC: NACEPT Report, NACEPT.

Nascimento, S., Rubio-Iglesias, J. M., Owen, R., Schade, S., and Shanley, L. A. (2018). "Chapter 11: Citizen science as input for better policy formulation and implementation" in *Citizen Science: Innovation in Open Science, Policy and Society* (Berlin: European Citizen Science Association), 219–240. doi: 10.2307/j.ctv550cf2.23

Owen, R., and Parker, A. (2018). "Citizen science in environmental protection agencies" (Chapter 20) in *Citizen Science: Innovation in Open Science, Policy and Society* (Berlin: European Citizen Science *Association)*, 284–300. doi: 10.2307/j.ctv550cf2.27

Rambonnet, L., Vink, S. C., Land-Zandstra, A. M., and Bosker, T. (2019). Making citizen science count: best practices and challenges of citizen science projects on plastics in aquatic environments. *Mar. Pollut. Bull.* 145, 271–277. doi: 10.1016/j.marpolbul.2019.05.056

Snik, F., Rietjens J. H. H., Apituley, A., Volten, H., Mijling, B., Di Noia, A., et al. (2014), Mapping atmospheric aerosols with a citizen science network of smartphone spectropolarimeters. *Geophys. Res. Lett*. 41, 7351–7358. doi: 10.1002/2014GL061462

The River Trust (2020). *First steps towards a Catchment Monitoring Cooperative v8*. Available online at: https://theriverstrust.maps.arcgis.com/home/item.html?id=634734556882421481e6652f3c9dd2a4 (accessed August 28, 2020).

UKEOF (2020a). *What is the Future of Citizen Science? What is UKEOF's role?* Available online at: http://www.ukeof.org.uk/resources/citizen-science-resources/cswg-horizon-scanning-flyer-web.pdf (accessed August 28, 2020).

UKEOF (2020b). *Data Management Planning for Citizen Science*. Available online at: http://www.ukeof.org.uk/resources/citizen-science-resources/cswg-data-guidance-booklet-web.pdf (accessed August 28, 2020).

Volten, H., Devilee, J., Apituley, A., Carton, L., Grothe, M., Keller, C., et al. (2018). "Enhancing national environmental monitoring through local citizen science" (Chapter 23) in *Citizen Science: Innovation in Open Science, Policy and Society* (Berlin: European Citizen Science Association), 337-352. doi: 10.2307/j.ctv550cf2.30

Wesseling, J., de Ruiter, H., Blokhuis, C.,Drukker, D., Weijers, E., Volten, H., et al. (2019). Development and implementation of a platform for public information on air quality, sensor measurements, and citizen science. *Atmosphere* 10:445. doi: 10.3390/atmos10080445

WWF (2018). *Living Planet Report - 2018: Aiming Higher*. Eds M Grooten, and R.E.A Almond. Gland: WWF,.

Zettler, E. R., Takada, H., Monteleone, B., Mallos, N., Eriksen, M., and Amaral-Zettler, L. A. (2017). Incorporating citizen science to study plastics in the environment. *Anal. Methods* 9, 1392–1403. doi: 10.1039/C6AY02716D

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.