NOAA Science Advisory Board Report

Potential for Citizen Science in Support of Data Needs for Ecosystem-Based Science

November 2018

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The term "Citizen Science" (CS) has been broadly defined as a collaboration between agencies and science-based entities and the general public. A wide range of activities may be considered Citizen Science, from cooperative research to citizen-based data collection programs (Silvertown 2009; Dickinson et al. 2012). Because ecosystem based management requires collection of data over broad spatial and temporal scales, many scientists have embraced citizen science as a way to enhance our understanding of local and regional processes by working with people in communities, fishing cooperatives, tribes, and other entities (McKinley et al 2017). Citizen scientists have provided NOAA with useful data on ecological and physical processes, from early weather records of lighthouse keepers to more recent records of fish abundance by SCUBA divers. However, as with all data collection, protocols and quality control are essential to ensure accurate and useful information that can be integrated with data collected by the agency.

The Crowdsourcing and Citizen Science Act (2016)[1] encourages support of citizen science "to advance agency missions and stimulate and facilitate broader public participation in the innovation process". The Act provides agencies with direction on what to do if they undertake citizen science and crowdsourcing activities. For example, agencies *shall* 1) make public and promote projects to encourage broad participation; 2) determine appropriate level of consent, registration, or acknowledgement of terms of use required from participants; 3) disclose privacy, intellectual property, data ownership compensation, service, other terms of use; and 4) make data collected available to the public. NOAA has embraced Citizen Science in many ways, but could benefit from a review of "best practices" for CS programs that can contribute to the agency's data needs, as well as consideration of the types of citizen-collected data that lend themselves well to ecosystem-based management, interests of coastal communities, and careful matching of technical ability with research project needs.

The Ecosystem Science and Management Working Group (ESMWG) was tasked with development of a brief report on the current use and potential value of citizen science to enhance data collection and monitoring needs for ecosystem-based management. We discussed this topic at our meetings in May 2017, November 2017, and briefly in May 2018, with guest speakers from NOAA Office of Education (John McLaughlin), NOAA Fisheries Office of Science and Technology (Laura Oremland), University of Washington (Julia Parrish), and the National Marine Sanctuary Program (Claire Fackler and Julie Bursek). The focus of our discussion was on the use of citizen science programs for data collection and monitoring that can be integrated with agency-based science efforts.

For this report, we consider citizen science efforts that are designed by scientists for the purpose of collecting data that can be used for monitoring and evaluating biological, physical, and social processes. Typically, these would include trained volunteer programs that regularly collect data for monitoring environmental conditions or phenomena and mentored community science projects that enhance sample size or scope of data collection under the supervision of a professional scientist. Other forms of CS, including Cooperative Research and Indigenous and Local Ecological Knowledge, are discussed in other EMSWG reports.

[1] https://www.congress.gov/114/plaws/publ329/PLAW-114publ329.pdf

What are the potential benefits of CS to augment NOAA's Ecosystem Management data needs?

Ecosystem-based science and management is complex and requires a high level of spatially-explicit information over space and time to capture both complexity and variability in coastal ecosystems. While advances in instrumentation and remote sensing can provide some of that baseline information, mainstream scientists are, for the most part, spatio-temporally restricted in their sampling. Many researchers are now recruiting the public to assist with data collection needs and standardized monitoring, particularly as a means to understand the effects of climate change (Dickinson et al. 2012). If projects are well designed, monitored, and coordinated, CS can enhance mainstream science and our coastal observing networks through the provision of high volume and fine-grain, location-specific information (Theobald et al. 2015, Buckland-Nicks et al. 2016).

Many mainstream scientists see citizen-based data collection programs as useful for outreach and education, but are skeptical about the use of these programs for scientific monitoring and assessment (Burgess et al 2017). This is primarily due to concerns about data quality and control, a lack of scientific sampling methodology or standards, and/or bias that can arise from data collection by "untrained eyes" (Ottinger 2010). In spite of these concerns, data from large spatial scale programs such as COASST, REEF, and eBIRD have been used in NOAA studies that have resulted in peer reviewed publications, and smaller scale programs have contributed to a wide array of publications on coastal ecosystem condition and recovery (Follett and Dresev 2015). If NOAA expands its support and use of citizen-collected data, continued development of best practices to ensure data quality and consistency, robust sampling designs, and careful documentation of sampling effort and control will be needed[2].

Regular, cost-effective monitoring that is critical for data time series development can be maintained through well-designed citizen science programs (Conrad and Hilchey 2011). A few examples related to NOAA's needs for ecosystem-based science and management include:

a) Providing baseline information on the quantity and diversity of animals or plants in a region to monitor trends and help distinguish extreme events from natural spatio-temporal variation;

b) Water quality sampling to enable rapid and targeted response to pollution events and harmful algal blooms;

c) Large scale "groundtruthing" of information derived from remote sensing or model extrapolations with *in situ* measurements;

d) Documentation of human response to destructive events such as floods and hurricanes, including migration;

e) Monitoring erosion, precipitation, pH, wave height and other physical factors in coastal systems with the help of simple instruments and protocols.

For a recent review of the diversity of citizen science programs related to environmental and ecological monitoring, see Pocock et al. (2017).

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[2] https://www.citizenscience.gov/toolkit/howto/#

How is NOAA using CS now, and what is needed to enhance existing programs?

NOAA has been involved with CS for many years. The NOAA Citizen Science and Crowdsourcing site includes a number of programs and resources connected to coastal systems that can be reviewed and potentially linked and/or coordinated[3]. NOAA participates actively in the development of best practices and coordination among federally sponsored programs through the Federal Community of Practice for Crowdsourcing and Citizen Science[4], including contributions to the Federal Crowdsourcing and Citizen Science Toolkit that provides basic steps for designing CS programs that can contribute to agency missions[5]. The programs examined by the ESMWG through the database had variable applications and often integrated with mainstream science needs, particularly in the areas of water quality monitoring and beach-watch programs. For a large number of programs in the database, the emphasis was on outreach and education, rather than data collection and science-based monitoring for research and management.

Coordinated sampling programs can be leveraged across larger landscapes and inform multi-scale modelling efforts. A number of monitoring programs have taken advantage of CS to expand the geographical scope of their sampling, including:

- the Alaska Ocean Acidification Network, which includes CS water sampling by local residents to monitor pH, allowing development of large-scale condition and prediction maps,[6] and
- the Southern California Coastal Water Resource Project (SCCWRP) program coordinates water, sediment, toxicology, and animal sampling among many different local agencies at the scale of the Southern California Bight[7].

NOAA can continue to serve as a facilitator for program development and the sharing of resources across federal, state and private partnerships. Additional work on protocols to ensure high quality data standards is needed, and coordination among CS programs and NOAA science centers may increase CS programs' connectivity and analytical power.

Development of "best practices" for quality-control and review

Data from CS programs can be integrated with information from surveys, cruises and sensors deployed by agencies and academic scientists. However, there is a need for careful program design, data review, and quality control to ensure that citizen science efforts produce valuable data that is accepted by the mainstream scientific community (Burgess et al. 2017; Parrish et al. 2018). Programs that are largely designed for outreach and education that lack oversight, standards and data control are unlikely to provide information that can be used in environmental evaluation.

A CS program can be designed to increase its likelihood of generating data that meets the requirements for rigor, repeatability, and quality. There are a number of steps required for this, as outlined in the citizenscience.gov toolkit and review papers. To illustrate, the following table outlines some of the steps used by the Coastal Observation and Seabird Survey Team (COASST), a beach monitoring program that

[3] https://oceanservice.noaa.gov/news/citizen-science/welcome.html
https://www.noaa.gov/office-education/citizen-science-crowdsourcing
[4] https://digital.gov/communities/crowdsourcing-and-citizen-science/
[5] https://www.citizenscience.gov/about/toolkit/#
[6] https://www.aoos.org/alaska-ocean-acidification-network/monitoring/shore-based-stations/
[7] http://www.sccwrp.org/ResearchAreas/DataManagement/CEDEN.aspx

has contributed data to a number of peer-reviewed studies (Parrish et al. 2018 and *personal communication*):

Best Practice	Example from COASST
Know your scientific questions and data needs *a priori*, and match them to the interests, lifestyles and needs of your target participants.	Question: what is species composition, magnitude and variability of beachcast marine birds on US West coast and Alaskan beaches?
Determine the scope of the project needed to collect meaningful data that can contribute to monitoring or management needs, and consider value of data from different scales	Broad spatial scale (Northern CA to Aleutians, coordinated with British Columbia and central CA) and fine grain (~600 sites) allows evaluation of patterns that may be caused by oceanographic events as well as local events; program has run long enough to create a baseline of natural variability.
Develop scientifically rigorous protocols that can adapt to data collection and participant needs, and that allows for independent verification of deductions.	Dichotomous key identification manuals for bird parts have been developed and distributed across the survey area; index beaches with strong participant support identified; simple measurement and photo identification protocols developed, along with detailed survey data sheets.
Develop a strong training program that details why the data are needed as well as the protocol	Volunteer Training meetings scheduled regularly, include research updates. Program leaders visit participant communities to give talks, trainings and refreshers.
Verify information collected by participants through complete review, spot-checking, and/or outlier checks	All data including photos are uploaded to the central data site and all identifications are verified by experts on staff; uncertain IDs or rare reports are verified by outside experts.
Recognize that improvements in data collection, identification, or rigor are likely to improve over time	All data submissions are attached to the data collector in the database, allowing tracking of individual performance and appropriate feedback.
Support IT and data management specialists to visualize data and make it accessible to scientists, participants and the public	Program applies for continued funding to employ IT specialist and a post doc for data visualization, analysis and manuscript preparation.
Provide feedback to the participant community to show how their data are used and compare over broader spatio-temporal scales	Real-time web app presents interactive spatial and time series graphics showing participants how bird numbers have changed through time in their area and coastwide; e-newsletter includes skills practice quizzes; science blog presents interesting data stories and infographics.
Create community by rewarding volunteers and keep them engaged and enthusiastic about the work they do	Website regularly features stories about participants, and acknowledgement of data collection milestones. Annual Holiday card with humorous theme and thank-you letter sent out to all participants each year. Usable "thank-yous" (water bottle, sun hat, message bag, sweatshirt) with COASST logo sent to long-term participants.
Establish regular program review	Science Advisory Board meets annually to discuss data results, program modifications, and new initiatives.

To meet these recommended best practices and provide NOAA with quality data, resources committed to citizen science programs need to be broader than simple “one-off” project funding. Partnerships with other management agencies, states, NGOs, the National Science Foundation, and other entities may enable start-up and continued support funding to support programs. However, the time and effort to foster these collaborations should not be under-estimated.

Here is a list of support needs that could enhance the use of CS in NOAA ecosystem research:

- Design and Development. Continued work on the best practices in the design and development of citizen science programs, participant recruitment and retention, community engagement, data quality assurance and control, integration of citizen science with mainstream science, and dissemination of results to scientific and layperson audiences. Creation of processes and templates that can be utilized across regions, projects, and disciplines with guidance for how to tailor programs to fit local conditions and needs.
- IT support. Computing resources and expertise for data storage, management, and integration. Technical assistance with web design, maintenance, and hosting. Development of mobile applications and/or web-based interfaces for reporting and dissemination of results.
- GIS support and data visualization. Resources and expertise to map information and identify patterns over broad geographic areas. Develop platforms for integrating local knowledge, data collected through citizen science programs, and data collected through mainstream science, and to coordinate multiple projects in a region.
- Communication tools and public engagement training for scientists to "report back" to communities.[8] Incentives to retain volunteers and encourage continued participation.
- Extended program support to maintain programs that are providing valuable data.

Added value to Ecosystem-based Management Needs = Public Participation in Research

Researchers who are invested in CS as a tool for data enhancement also laud its value for community engagement and broadening participation in science. For example:

- Citizen science programs can establish and grow long-term relationships between mainstream science and the coastal communities.
- Locally specific science programs can support and further actionable science, i.e. locally relevant and accessible investigations that support decision making.
- Citizen science programs can build relationships around observing environmental change and working together to understand the drivers of events and change over time, and can invite all people to be a part of the science "team".
- With local involvement of coastal community residents, multiple sources of knowledge and data types can be combined to enhance stewardship and restoration of coastal ecosystems.

Cost effective data collection and the benefits of community engagement are not independent and can be a common goal of NOAA-supported programs. Well-designed community science programming will maximize both benefits by focusing on issues of importance to participants while illustrating the importance of standardized methods and the value of integrating locally collected data over broad spatial scales (Haywood et al. 2012).

[8] Note that scientists who use citizen-collected data may not always provide sufficient feedback.

Findings and Recommendations

CS is likely an underutilized tool for environmental data collection and monitoring in coastal systems, and well-designed programs have potential to contribute cost-effective information that can be used in scientific investigation

Further review of existing programs that already have valuable data for ecosystem monitoring is warranted, and additional support, standardization of data storage and sharing, and enhancement of data collection protocols or trainings in those programs may improve their utility.

Citizen science doesn't just happen – it requires intention, consideration of community and participant needs, interests and abilities, and careful planning to ensure data quality and control. For programs to contribute meaningful data for NOAA ecosystem science and management, they need to be built over time and receive ongoing support for multi-entity collaborations.

Commitment of resources and expertise from NOAA Regional and Science Centers can improve the quality and integration of data generated by citizen science and contribute to participatory research that enhances public awareness of science and its value to coastal communities.

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