Citizen Science in Fishery Stock Assessments: Review and Recommendations

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U.S. Department of Commerce
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Contents

Executive Summary

Citizen science, where individuals or groups voluntarily contribute to the scientific process, is a growing field of interest within fisheries science in the U.S. When designed and applied appropriately, citizen science has the potential to address data gaps limiting stock assessments while simultaneously building relationships with stakeholders like the commercial or recreational fishing communities. To better understand the extent to which citizen science is being used to support stock assessments and best practices for its successful application, we applied a mixed methods approach. The four methods included: (1) A literature review covering domestic and international studies; (2) semi-structured interviews with National Oceanic and Atmospheric Administration (NOAA) citizen science project leads; (3) analysis of stock assessment documents for mentions of citizen science; and (4) a survey of NOAA Fisheries stock assessment scientists. The results provide insights into how often data from citizen science projects are used in stock assessments, the types of data used and how they are applied, and an overall set of recommendations and best practices for both citizen science practitioners and end users (e.g., stock assessors) to guide the successful application of citizen science in stock assessments.

Based on our research and analysis, we can conclude that NOAA Fisheries currently uses some citizen science data in assessments, though there is potential to increase and improve the use of citizen science data by the agency. Some key recommendations in general for end users like NOAA are to recognize the scientific value of citizen science and to develop pathways for incorporation as appropriate. Some key recommendations for citizen science practitioners are to design projects in collaboration with an end user and for projects to target existing needs and data gaps. Generally speaking, agency managers and scientists are open and interested in citizen science, but there is still a need to improve the perception of citizen science as not just an outreach tool but also a viable source of data that could enhance or support assessments.

Introduction

In the U.S., the National Oceanic and Atmospheric Administration (NOAA) Fisheries is responsible for providing scientific advice in support of sustainable fisheries management. Fisheries stock assessments are the primary scientific tool used to advise fishery managers on catch targets and limits that prevent overfishing and achieve the optimum yield on an ongoing basis. The U.S. manages over 550 fish stocks and stock complexes (NOAA Fisheries, 2024) found within 3.4 million square nautical miles of federal waters (NOAA, 2007). Producing stock assessments requires large amounts of data on fishery population, harvest, and environmental dynamics, and the agency invests heavily in the data collection and analysis needed to produce these assessments. However, nearly 40 percent of those stocks either lack a stock assessment or are managed using simplified approaches due to data availability, processing, and/or analysis limitations (Blackhart and Oleynik, 2023). Citizen science, if designed and applied appropriately, could help NOAA Fisheries address data gaps limiting or preventing assessments for some stocks (Vianna et al., 2014), provide greater temporal and/or spatial coverages in support of stock assessments, and increase stakeholder engagement in the scientific enterprise.

Citizen science, as defined by the Crowdsourcing and Citizen Science Act of 2017, is where individuals or groups voluntarily contribute to the scientific process. Volunteer contributions can include data collection and/or analysis, project design, and the identification of research questions. NOAA Fisheries initiatives and guidance documents demonstrate a growing interest in harnessing the power of the crowd to address agency data gaps and support core science products, such as stock assessments. In 2021, NOAA designated citizen science as one of six NOAA science and technology focus areas (NOAA, 2021). This necessitated the development of a NOAA Citizen Science Strategy and Action Plan to guide the use of citizen science in support of NOAA's mission. In addition, the NOAA Fisheries National Saltwater Recreational Fisheries Policy recommended using citizen science to address evolving science, management, environmental, and climate-related challenges (NMFS, 2023).

Citizen science has made important contributions to the field of natural resource management (McKinley et al., 2017) and within the general field of fisheries science (Oremland et al., 2022). Fisheries science also has a long history of using citizen science programs. Fish tagging studies are perhaps the best known example, in which fish are captured, marked, and released in the hopes that they will later be recaptured and reported by fishers and/or anglers. With the expansion of cell phone use, there is an increased possibility for volunteers to collect and report data. However, while the efficacy of citizen science is increasingly recognized, its precise role in fisheries stock assessments remains unclear. Despite an enthusiasm among stakeholders to integrate citizen science into fisheries stock assessments, skepticism persists among both scientists and stakeholders. The scientific community can be skeptical of the scientific quality of citizen science projects, particularly citing its potential for biases (Brick et al., 2021). Citizen scientists can mistrust science and management when data they are asked to collect go unused (Bonney et al., 2021) or do not always show the desired outcomes. Bridging the gap between aspiration and apprehension is essential if the full potential of citizen science is to be realized by NOAA Fisheries' scientific programs.

Core Questions

In seeking to apply agency strategy and guidance to operational scientific products, our team sought to better understand the current and potential use for citizen science in fisheries stock assessments. We investigated the connections between citizen science data, fisheries stock assessments, and the fisheries management decision-making process with a focus on the implications for U.S. federally managed fisheries. However, aspects of the investigation considered a broader array of case studies and practitioners than just NOAA-managed stocks, though our recommendations are geared toward the U.S federal fishery management system.

The driving questions were as follows:

1. Are citizen science data being considered and/or used in fisheries stock assessments of U.S. federally managed fish stocks and stock complexes?
2. If and where citizen science data are used or being considered for use in stock assessments:
    a. What role are citizen scientists playing?
    b. What data are they collecting (e.g., life history data, abundance data, environmental data)?
    c. How were those data used and integrated into the scientific and management process?
3. What are the best practices for using citizen science to support stock assessments?

Methods

In order to understand the use and potential for use of citizen science data in stock assessments, we used a mixed methods approach. The four methods applied were as follows:

1. A literature review on the topic
2. Semi-structured interviews with NOAA citizen science project leads of projects with data of potential relevance to stock assessments
3. An analysis of stock assessment documents for mentions of use of citizen science data
4. A survey of NOAA Fisheries stock assessment scientists about current or potential use of citizen science

Literature Review

In 2022, we performed a literature review to find cases where citizen science was used in stock assessments. The research team worked with a NOAA librarian to perform a literature search using the SWIFT Active Screener (SCIOME, 2024) based on terminology associated with citizen science, fisheries, and stock assessments to identify relevant literature. An initial query produced 121 articles, which we then analyzed within EndNote (EndNote, 2024). Further screening by our research team reduced the pool of articles down to 73 articles, which included 82 cases of citizen science data in fisheries science, fisheries management, and/or fisheries stock assessments. Of the 73 publications, 35 were inside U.S. jurisdiction, 58 were marine-based projects, and 67 were fisheries-specific. We read and coded the articles for different elements including type of data collected, level of use or integration in an assessment, and elements of project design. As the level of integration or relation to an assessment was not always clearly described in the articles, the coding required some interpretation; however, no coding occurred for articles or elements where insufficient information was available. This literature review also served as a source of best practices or guidance on the topic.

Interviews with NOAA Citizen Science Project Leads

CitizenScience.gov (accessed 6 March 2025) hosts NOAA's inventory of over 60 NOAA and NOAA-affiliated citizen science projects. Using this list as a starting point, we identified 16 citizen science projects with data of potential relevance to stock assessments. Our team contacted the 16 project leads, some of whom were responsible for multiple projects of interest. We had two nonresponses, received two email responses (representing three projects), and conducted 10 interviews with program leaders (covering 11 projects) for a total set of information on 14 projects. Interviews were conducted in a semi-structured format by the same interviewer including the same base questions and structure and lasted between 40 and 60 minutes each. Questions (in Appendix A) centered on ascertaining the level of citizen science data use in stock assessments, the awareness of potential uses, and the engagement level of stakeholders and end users in the project (e.g., whether scientists participated in the project design or whether project data were accessible).

Stock Assessment Report Analysis

Stock Assessment Reports are documents summarizing the context, data, analysis, and review of fisheries stock assessments conducted for fish stocks and stock complexes produced by the regional U.S. Fisheries Science Centers. Our team downloaded the last "research," "benchmark," or "operational" stock assessment attempted for all federally managed stocks and stock complexes for which one was available. We ran a text-matching analysis on those documents to identify 14 pre-selected terms (analogs for citizen science) and their common synonyms and acronyms (Appendix C). The research, benchmark, and operational stock assessments were prioritized for this analysis because they generally include broader discussions of available data considered but not ultimately used in a stock assessment model.

A total of 261 stock assessment reports published between 2007 and 2024 were included in this text-matching analysis. The text in each stock assessment document was transformed into workable data using the R package tm (version 0.7.8; Feinerer et al., 2008) and returned 4,083 matches representing potential mentions of citizen science. Our team reviewed each of those mentions and identified 318 that were likely references to citizen science. If a reference contained an acronym or initialism, we conducted an additional search through the document for that abbreviation; however, this additional search did not yield additional citizen science references. Analysis was performed by looking for references both in the narrative portion of the document, which describes the data inputs, model development, and results, as well as in the research recommendations portion, which describes future data and research needs. We further classified those research recommendations according to their level of consideration or integration.

Survey of NOAA Fisheries Stock Assessment Scientists

This method focused on potential users of the data, specifically stock assessment authors in regard to their current or potential use of citizen science. A short questionnaire (Appendix B) was developed and sent to all six science centers. We distributed it through email using listservs and targeted dissemination through regional program leads in order to reach NOAA Fisheries stock assessment authors. The questions sought to discern respondents' awareness, consideration, use, and opinion of citizen science related to fishery stock assessments. All responses occurred within a 30-day response window. We received a total of 35 responses from across the six science centers with the highest response totals coming from the Southeast Fisheries Science Center (11) and the Northeast Fisheries Science Center (10). The responses represented individuals who self-identified as assessment authors in lead and contributing roles as well as data providers, analysts, and modelers for stock assessments.

Results

What Role Are Citizen Scientists Playing?

A consistent theme that emerged across our literature review and interviews with NOAA Fisheries' citizen science project leads was that citizen scientists primarily perform data collection types of activities. Their involvement could be divided into two general categories: data collection (providing direct observations, measurements, or experiences) and sample collection (providing specimens or images that researchers could process, collate, and analyze).

Literature review: The majority of cases in our literature review relate to citizen science projects where volunteers participated in data collection. In many of the international cases from the literature review, citizen scientists provided data such as catch, effort, fishing behavior (gear), species and length composition of catch, fishing logbooks, and location. They also collected and/or measured specimens or samples. These data are relevant to fisheries science and management, but within the U.S. fishery management system, they tend to come from mandatory reporting, not voluntary efforts.

Other examples of data collected by citizen scientists that could inform fisheries science and management that appeared in the literature included the following:

- Taking and submitting photographs (to provide species identification, presence/absence, and location)
- Reporting presence/absence information
- Sighting of spawning or aggregations
- Performing visual surveys while scuba diving and reef monitoring (species identification, presence/absence, counts, location)
- Characterizing habitat with species presence/absence
- Collecting biological samples: fin clips, otoliths, gonads, tissue samples, and so on
- Tagging species and reporting catch of tagged species

- Fishing reporting: catch and effort information, fishing behavior, discards, fish caught (and measurements)

Some of the cases we reviewed documented projects where citizen scientists performed data analysis and processing or provided their expertise to researchers. Most examples of data processing and analysis were related to reviewing photos or videos for species identification, counts, and/or measurements. Cases of experience-based knowledge gathering generally included the collection of specialized and/or localized ecological knowledge from public and industry stakeholders. Insights extracted from stakeholders' collective knowledge and experience then informed assumptions in stock assessment modeling activities.

Interviews with NOAA citizen science project leads and assessment scientists: The majority of the NOAA-led projects also involved citizen scientists participating in data collection. They included tagging programs, visual monitoring by divers, biological sample collection, collection of oceanographic data by commercial fishers, and voluntary reporting on discards and other types of fishing activity. Specific types of data that were incorporated into science or management from those projects included the following:

- Tagging data
- Genetic data from biological samples (such as fin clips)
- Fishing reporting: catch and effort information, fishing behavior (including gear, depth fished), discards, fish caught (and measurements)

Several projects involved citizen scientists in data analysis. Their role often centered on processing photos or videos to identify fish species, count observations, and take measurements. The results of their work provided catch composition and length data, supported reconstructions of historic catch levels, provided records of species presence, and helped train machine learning algorithms.

In some instances, citizen scientists helped to identify research questions or contributed to project design. For example, the California Collaborative Fisheries Research Program in which citizen scientists participate in fishing activities as part of a fisheries independent survey was designed in collaboration with recreational fishermen and stock assessment scientists.

Feature: Tagging Highly Migratory Species (HMS)

Tagging programs are common ways to involve the public in data collection and research, and have been used by NOAA Fisheries, as well as other government agencies and nonprofit groups and academia, for many years. In these programs, volunteer anglers may help to catch and tag fish, and/or they may report fish that they catch that are already tagged. The simplest form of tagging is mark-recapture studies, but there are also examples of deploying more advanced tags, such as satellite tags, which can track movement and other information. The cooperative tagging program for HMS currently run by NOAA began in 1954 in New England and expanded to the Southeast region in the 1980s. As such, this long-running program has a long time series of data and a long history of working with volunteer angler participants.

HMS tagging data do not contribute to a regular index or dataset used in an assessment, but data from the tagging program have contributed to multiple elements of an assessment. Tagging data have been used to define stock structure and have been used to validate growth assumptions and model growth parameters used in stock assessment models. Tagging data also have some limited capabilities to contribute to knowledge about mortality and movement. Some challenges include variable participation and unequal distribution in the program by sector and by geography. The experience of the HMS tagging program also highlights the need for active management by the implementing agency. Managing a tagging program and getting reliable data require participant recruitment, quality control of the data, and high levels of familiarity with the fisheries. The experience of the program in record keeping on tag deployments, reporting tools, and overall data quality assurance has contributed to the utility of the data collected to scientists and managers.

What Information Is Being Used and How Is It Used?

All of our data collection methods yielded examples of citizen science data receiving consideration in the fisheries stock assessment and/or management decision-making process. The most direct and impactful connections between citizen science data and stock assessments were those where citizen science projects produced an index of abundance that was incorporated into an operational stock assessment model. Though instances of this were rare, indices of abundance are critical sources of information in both basic and advanced stock assessments, and provide relative trend information assumed to be proportional to the abundance of a fish stock (Lynch et al., 2018).

We also identified instances where citizen science datasets informed elements of stock assessments. Examples include cases where data derived from tagging studies informed estimates of natural mortality and those where data derived from logbooks informed estimates of catch and effort, discard rates, and/or discard mortality rates. In addition, citizen science data informed fisheries management decisions outside the stock assessment in several instances, for example, through the provision of information on resource users, fishing practices, and/or fish habitat use and distribution.

Literature review: In the literature review, the reader of each article estimated the level of integration of citizen science data into an assessment across six categories (Table 1). We found that the most common categorization was a lack of sufficient information, with 31 of the 82 cases (from the 73 articles) making no mention about use in science or management. Among those that did provide information on outcomes, 21 described use informing management, and 19 described partial or full inclusion of the data in an assessment (Table 1).

Table 1. Literature review results showing level of citizen science integration into a stock assessment.

Level of Integration	Definition of Level of Integration	Number of Cases	Percent of Cases
N/A	No information available	31	38%
NO	No effort made to use data	9	11%
MANAGEMENT	Used to support fisheries management outside the stock assessment process	21	26%
ATTEMPTED	Attempted but not used	2	2%
PARTIAL	Partially used in an assessment	9	11%
FULL	Data from the citizen science project was fully incorporated into an assessment	10	12%

All of the cases included in our literature review that fully incorporated data into a fisheries stock assessment occurred outside the United States. They included self-reported fishing data projects, syntheses from angler apps, and fishers contributing by sending in biological samples or participating in data collection. Examples in which citizen science data informed management included those where it provided information about habitat use and/or angler behavior, records of species sightings, or evaluations of marine protected areas.

Stock assessment report analysis: Our analysis of stock assessment reports screened for 14 terms related to the use, consideration, or availability of citizen science data. Out of the 261 analyzed stock assessment reports, 89 (34 percent) contained one or more of those terms in their narrative sections describing data inputs, model development, and assessment results (Figure 1). We further reviewed each term match to discern whether the data were ultimately used in the final stock assessment model.

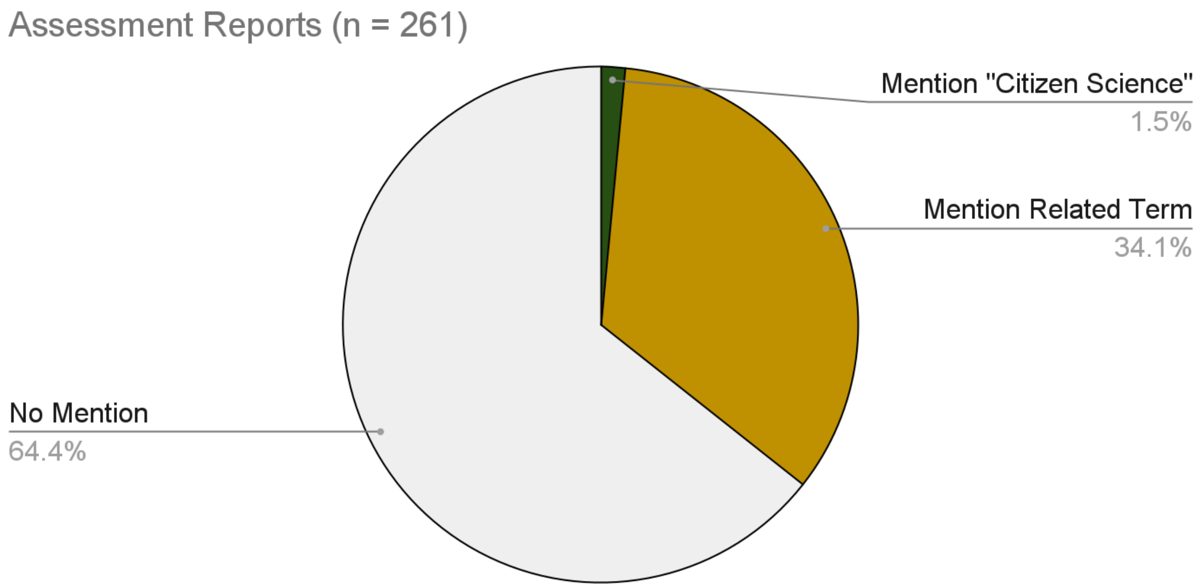

Figure 1. Results of frequency in word query in stock assessment reports.

Tagging data were the most common reference, with 152 mentions across 68 stock assessment reports covering all five regions (Table 2). Of these, 33 reports documented the direct or indirect use of tagging data in the statistical stock assessment model. Local and traditional knowledge were the second most common terms, referencing cases where scientists collected the experience-based knowledge and insights of fishers to inform their assumptions about a fish stock. One of those terms appeared in 28 reports across all five regions (Table 2), with 17 of those documenting its direct or indirect use in the stock assessment model.

Mentions of the remaining terms were rare. Voluntary and volunteer reporting appeared in 11 stock assessment reports, with at least one report in each region. However, only two reports, both from the Northeast, documented either term's use in the final stock assessment model (Table 2). Citizen science was referenced in eight reports from the Southeast and West Coast regions, though none indicated the utilization of the data in final models. References to angler diaries, surveys, and phone applications appeared in four reports from the Northeast and Southeast regions. Two Northeast reports described the use of those data in the final model (Table 2).

Table 2. Counts of the total number of stock assessments reports with references to the availability, consideration, or use of citizen science data for each NOAA Fisheries region.[1]

	Fish Tagging Program	Citizen Science	Voluntary/ Volunteer Reporting	Local/ Traditional Knowledge	Public Participation	Angler Diary/ Survey/ Phone App
Northeast	8 (4)	-	5 (2)	5 (1)	3 (0)	3 (2)
Southeast	20 (8)	6 (0)	3 (0)	8 (5)	1 (0)	1 (0)
West Coast	21 (7)	2 (0)	1 (0)	10 (9)	4 (0)	-
Pacific Islands	7 (5)	-	1 (0)	1 (1)	1 (1)	-
Alaska	12 (9)	-	1 (0)	4 (1)	-	-

Most stock assessment reports include sections discussing priority research and data collection needed to improve model accuracy, support model development, or enable first-time assessments. We examined those recommendations and found that 53 (20 percent) identified citizen science data collection and/or its consideration as a priority. Among those reports, most recommendations focused on initiating new (26 reports) or expanding existing (14 reports) citizen science data collection programs or datasets. A handful of the recommendations we reviewed targeted the consideration (7) or incorporation (5) of citizen science data in stock assessment models. Tagging data were most frequently recommended, representing 67 percent of all references, with local and traditional knowledge (22 percent) and volunteer data collection (5 percent) being the only others appearing more than twice.

Interviews with NOAA citizen science project leads: Among the 11 citizen science project interviews, four described direct use of citizen science data in stock assessments. Three used tagging data to define stock structure and validate growth assumptions. The others used citizen scientists to help collect data within a fisheries independent survey and probability-based design to create an index of abundance and provide age and growth data (Figure 2).

Three described indirect data use in stock assessments or mechanisms through which citizen science data informed the stock assessment process or fishery managers' decisions. They included cases where citizen science data informed, provided a point of comparison, or provided validation for inputs into an assessment such as catch composition, size/length estimation, stock structure and identification (e.g., genetics), recruitment, or species movements and distribution.

[1] Reports detailing the use of citizen science data (e.g., tagging data) are also provided in parentheses.

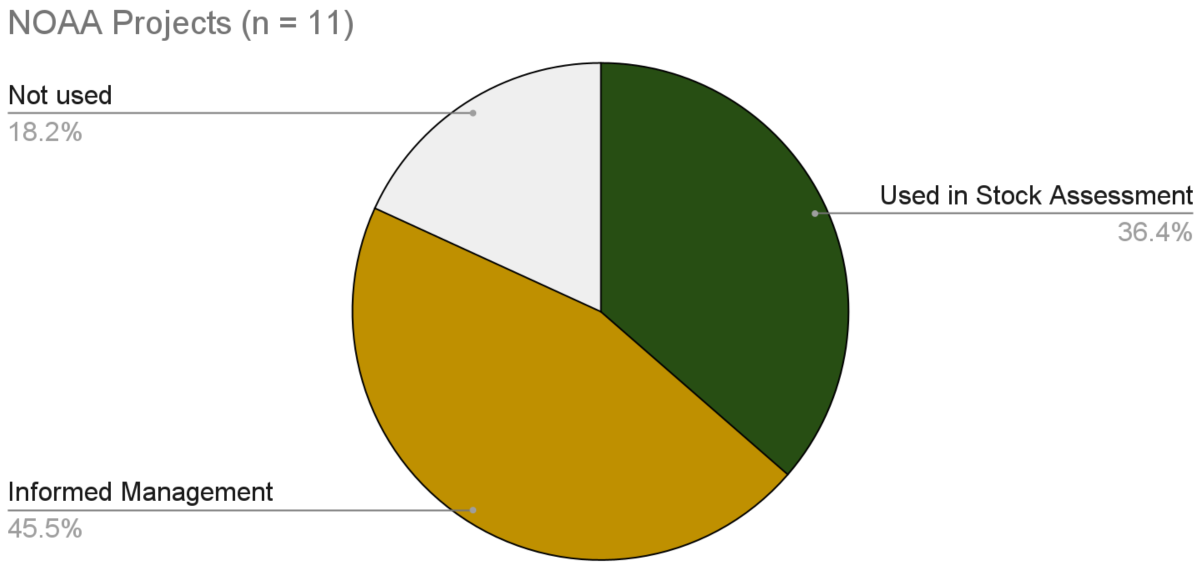

Figure 2. Use of citizen science in NOAA projects whose project leads were interviewed.

Survey of NOAA Fisheries stock assessment scientists: Across our sample, 19 (54 percent) of the 35 NOAA Fisheries stock assessment scientists reported considering a citizen science dataset in an assessment. Of them, four reported that the data did not end up being used. Five reported that the data informed the assessment or management decisions but were not directly incorporated (Figure 3). In those cases, citizen science data provided a better understanding of discards, information on larval connectivity, information on the severity of a red tide event, stakeholder input to develop management strategy evaluation frameworks for harvest control rules, and interviews with fishermen that could inform management strategies.

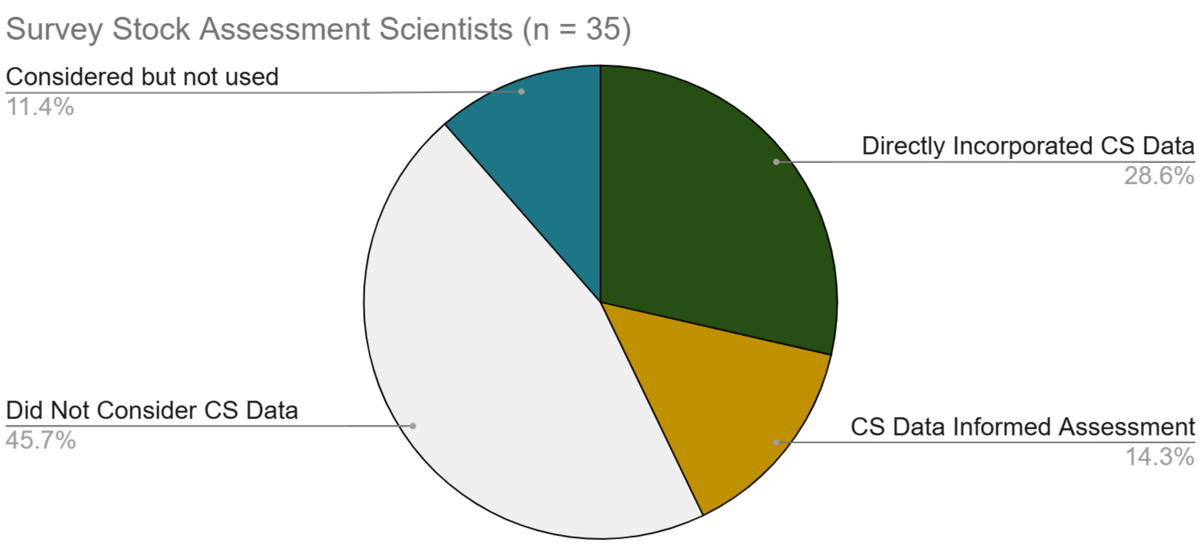

Figure 3. Use of citizen science in the survey of stock assessment scientists

Ten authors reported that data were directly incorporated into an assessment (or had plans to incorporate it in the next assessment) through a variety of mechanisms and pathways. In some cases, citizen science data helped to increase the quality of assumptions made about population-level processes such as the lengths of recreational landings and discards or fish catchability and growth patterns. In others, they provided the samples necessary to extract the data used in estimates of stock life history parameters such as maturity, fecundity, and/or growth. Data collected through tagging programs had especially broad utility and helped define stock boundaries, inform estimates of growth and natural mortality, and document fish habitat preferences.

Stock assessment scientists highlighted recreational fishing data collection as something that could benefit from citizen science. Recreational discards, in particular, are not currently captured by NOAA Fisheries' surveys of recreational fishing effort.

Case Study: OceanEYES

Many citizen science projects focus on incorporating volunteers into collecting data, but there are also examples of using volunteers to assist with elements of data analysis or processing. One example of this is the OceanEYES project in the Pacific Islands region, and its use of the Zooniverse platform for analyzing video data.

In Hawaii, the primary survey which supports the stock assessments for the Deep 7 bottomfish complex is the BFISH survey, which collects various types of at-sea data, including the use of stereo cameras to record underwater video. Currently this video is analyzed by professional annotators for species identification and counts using a MaxN methodology (a method for estimating the maximum number of individuals) and this data is combined with the other data collected in the multigear survey to produce abundance estimates.

The Center is currently investigating the use of automated image analysis and machine learning to improve analysis of the video data, but also created the OceanEYES project, using the Zooniverse platform, to recruit volunteers to analyze the videos. Volunteers, after undergoing some basic training, annotate videos from the BFISH survey to mark presence/absence, identify species and count fish in video frames, in addition to marking the position (which can be used for training the machine learning algorithm).

The project has shown great potential in the ability to process large amounts of video. Current methods with professional annotators only look at select frames, and often produce more conservative counts. Using OceanEYES, it is possible to annotate every frame of the video. Quality checks show Zooniverse annotators to have high accuracy. In addition, while

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professional annotators are not being replaced by volunteers, their bandwidth is currently full so the use of volunteers has allowed the Center to analyze more data more quickly. Since the project's launch in 2020, over 27,000 volunteer citizen scientists have completed more than 5.3 million annotations of over 435,000 underwater images.

In addition, the popularity of volunteer participation in this project using Zooniverse has been a great outreach tool, allowing participants to learn more about the scientific processes and the various species studied in Hawaii. The project shows there are various ways that citizen scientists can contribute to NOAA Fisheries science, including from the comfort of their homes.

Discussion of a Multimethod Approach

Our research team employed multiple methods to explore a diverse portfolio of citizen science projects focused on producing data to support fisheries population modeling and management decision-making. We identified various pathways through which these data were incorporated into or informed fisheries stock assessments and/or influenced related management decisions.

Each method had both strengths and weaknesses that factored into our analysis. Our literature review captured a broad array of pathways through which citizen science informed and influenced fisheries stock assessments and fisheries management. However, many of the case studies considered occurred outside of the United States or focused on freshwater or estuarine systems. Their frequent focus on projects that included voluntary contributions of catch and/or fishing information complicated direct comparisons to the U.S. because that reporting is frequently either mandatory or led by government surveyors in the U.S. In addition, many cases provided limited information on the ultimate use or nonuse of citizen science data in fisheries stock assessments or fisheries management.

Our review of U.S. stock assessment reports provided a broad sense of the current role of citizen science data in fisheries stock assessments. However, our results were based on a text matching algorithm. We did not investigate the specifics of datasets or data collection programs referenced within reports, resulting in two key assumptions. First, our analysis assume that all relevant datasets captured in the query fall entirely under the umbrella of citizen science, potentially overinflating our counts for incorporation. For example, not all tagging programs are entirely voluntary, and some local and/or traditional knowledge-gathering activities might not meet the requisite criteria to be considered citizen science (e.g., data collection or analysis might not include volunteers). Second, we were unable to capture citizen science datasets only referenced by their name, which might have led to us undercounting the number of stock assessments referencing citizen science. For example, the most recent stock assessment of red grouper off the South Atlantic coast used photo histories collected through citizen science to inform some of its analyses, but our query did not capture that because reference to the data focused on the collection program name, MyFishCount (SEDAR, 2021).

Our internal surveys and interviews of NOAA Fisheries stock assessment scientists and NOAA Fisheries citizen science projects provided details and insights into the production, use, and perceptions of citizen science within the agency. However, both pools of respondents have potential biases to consider. We distributed our survey of stock assessment scientists through several listservs and internal communication channels. As responding was voluntary, it is possible that only staff with stronger opinions or experience related to citizen science participated. Information provided by NOAA Fisheries' citizen science project leads likely included higher rates of consideration in fisheries stock assessments than similar, external projects. It is possible that their associations with internal staff and agency research lent them additional credibility, increased their visibility, and helped them to better identify high-impact opportunities for citizen science data collection.

All methodologies show the incorporation of citizen science data into stock assessments is minimal in the United States, with the potential exception of tagging data. Furthermore, the pathways for the use and consideration of data and insights derived from citizen science by fishery managers are poorly documented. This reveals a significant gap between current operations and the aspirations outlined in the forward-looking NOAA Citizen Science Strategy (NOAA, 2021).

Conclusions

The Potential for Citizen Science to Inform Stock Assessments

We found many examples where data were collected or analyzed by citizen scientists for stock assessments, including at NOAA Fisheries. NOAA aspires to expand its use of data and/or insights derived from citizen science in fisheries stock assessments over time (NOAA, 2021). While the future impact and uptake of citizen science data in stock assessments are uncertain, perceptions of their potential often center on data quality or data needs and assessment priorities.

Data Quality: Our literature review included several meta-analyses that recommended best practices for collecting reliable citizen science data (Cooke et al., 2000; Cigliano et al., 2015; Garcia-Soto et al., 2017; Wolf et al., 2019). They generally focused on the importance of training participants, keeping data collection activities simple, and including mechanisms for tracking and evaluating participation and data quality. Many of the case studies that our team reviewed followed those best practices.

We also reviewed several studies that statistically compared data collected using citizen science against data collected through traditional fisheries-independent or fisheries-dependent sampling (Gerdeaux and Janjua, 2009; Hassell et al., 2013; Jiorle et al., 2016; Johnston et al., 2021). None of them identified significant differences between the two data sources. While these findings demonstrate the potential of citizen science in data collection, they represent best-case scenarios where data quality and comparability were prioritized, leaving their broader applicability uncertain. This duality highlights both an opportunity and a challenge for citizen science. It demonstrates that well-designed and executed citizen science projects can produce high-quality data suitable for fisheries stock assessments. However, *if such projects merely replicate data already collected by agencies, their likelihood of uptake and/or utilization is low*. To address this, practitioners must ensure that their methods and quality assurance protocols yield data that can be independently evaluated for representativeness to support their inclusion in fisheries stock assessments.

Data Needs and Assessment Priorities: NOAA Fisheries published a 2023 report that established target data levels across five categories (abundance, catch, size and age composition, life history, and ecosystem considerations) for all of its managed stocks, censused current data levels for those stocks, and identified existing gaps (Blackhart and Oleynik, 2023). It reported that 86 percent of U.S. stocks had a data gap in one category and that more than 50 percent of stocks had a data gap across four or five categories. Thus, while the agency maintains robust data streams for some stocks, data gaps and/or limitations persist for most.

Citizen science offers a potential avenue for addressing stocks' data limitations to enable a basic stock assessment or the development of more advanced statistical models capable of providing improved scientific guidance. In general, our methods identified two main areas where citizen science can help support data. One is to address identified data needs. Examples in the literature include instances where citizen scientists' efforts could help by collecting data on low-catch fisheries or fisheries without retained harvest, including recreational fisheries (Guindon et al., 2015); by contributing data on remote areas, nearshore areas, or areas that are infrequently sampled by traditional surveys (Kontoes et al., 2017); or by contributing biological samples, which can increase the sample size in a cost effective way (Wilmoth et al., 2020). An analysis done by the Environmental Defense Fund reviewed stock assessment reports to identify data needs with high suitability for citizen science projects. They identified numerous suitable types of data but highlighted life history information, particularly for less commercially valuable species, as being highly suitable for citizen science projects (Carroll et al., 2024).

Our review of stock assessment reports identified areas where citizen science could help NOAA address research needs that it lacks the capacity or resources to address. For example, the 2016 stock assessment of goliath grouper off the Southern Atlantic Coast and Gulf encouraged anglers to provide fish lengths using the Snook and Game Fish Foundation's mobile phone application (SEDAR, 2016). Similarly, the 2022 research stock assessment of bluefish off the Atlantic Coast identified recreational discard lengths as a high-priority data need and recommended expanding and promoting volunteer angler surveys programs to help address the gap (NEFSC, 2022). Stock assessment scientists who responded to our survey also identified citizen science data with high potential for uptake in stock assessments. Examples they provided included recreational fishing data (especially discard information), biological samples, data on nearshore or shore-based fisheries, information on species interaction or depredation, sightings of spawning aggregations, and diving surveys.

Another avenue through which citizen science could supplement existing NOAA Fisheries data collection efforts would be to expand sampling coverage or cover missing surveys. For example, most agency surveys occur only once or twice a year, but citizen scientists are capable of providing observations throughout the year. Such efforts could bolster ongoing operations by providing more "eyes on the water" observations or information to "ground truth" other scientific information collected (Schemmel et al., 2016; Obaza et al., 2021; Carroll et al., 2024), for example, as most agency surveys occur once (or twice) a year. The value of those data could be even greater in the event that NOAA Fisheries faces funding or execution challenges that restrict its ability to conduct its routine sample. This occurred during the COVID-19 pandemic, when federal and state surveys were unable to operate in 2020. At that time, the California Collaborative Fisheries Research

Program was the only fisheries-independent survey conducted, which helped maintain an important time-series of nearshore groundfish along the West Coast (White House Office of Science and Technology Policy, 2022).

The examples provided above and this Technical Memorandum are not meant to be an exhaustive analysis of gaps. Moving forward, each region could encourage the exploration or initiation of more projects by examining its stocks' data gaps and research priorities and indicating which ones might be addressed by citizen science. Uptake and inclusion of those data could be expedited by ensuring that any index of research priorities also captures stock assessment urgency for targeted stocks. This can also highlight that citizen science projects will likely experience the most success when targeting an identified data need, on one or a few species, versus broad projects targeting many species (e.g., catch or abundance). While not exhaustive, Appendix D highlights some resources that could facilitate such an examination.

Elements of Success

Our research team considered citizen science efforts successful if the data they produced were incorporated into a stock assessment or influenced fisheries management decision-making. While our review did not investigate or consider causality, we observed a number of common elements among successful projects, which generally mirrored those identified in the meta-analyses and best practices literature (Cooke et al., 2000; Cigliano et al., 2015; Garcia-Soto et al., 2017; Wolf et al., 2019).

One element was the *targeting of specific, discrete, or continuous data needs.* As previously stated, duplicative datasets for stocks with robust and reliable data sources have limited utility. Successful projects often address known data gaps, for example, a study that saw anglers providing specimens to scientists from which they could extract age, length, and/or genetic information (Fairclough et al., 2014) or one where volunteers provided catch records of inshore species not well captured by other traditional sampling methods (Smith et al., 2013).

Another feature common among successful projects was a *collaborative approach to project design and execution*. Specifically, providing opportunities for data collectors, scientists, and other end users to co-create or collaborate on methods development (Bonney et al., 2009). This approach enables projects to leverage all participants' knowledge and experiences. For example, scientists can inform data requirements, while participants can provide knowledge about fishing methods, practices, or areas (when they are anglers) (Yochum et al., 2011; Schemmel et al., 2016). This collaborative engagement best contributes to project success when sustained throughout a study (Page et al., 2021).

Sampling design was another area where broad engagement among citizen science project leads, volunteers, scientists, and end users led to higher success rates. Scientists' expertise helped *ensure that data collection guidelines and standards were sufficiently rigorous and that project sampling designs met the statistical needs of their intended end users* (Yochum et al., 2011; Venturelli et al., 2017). Furthermore, collaboration ensured that adequate data quality assurance measures (e.g., participant training programs and data quality checks) were in place to ensure data fitness for use. The trustworthiness of data collected by citizen scientists often depended upon the presence of and adherence to quality assurance and control protocols. As an added benefit, this collaborative approach to sample design improved the collective understanding of its purpose and importance as well as how, where, and when the resulting data might be incorporated into future scientific stock assessments and/or fisheries management decisions (Bieluch et al., 2017).

Successful citizen science projects also had adequate resources. *Designing and implementing citizen science projects requires staff, funding, and hard work*. Furthermore, recruiting and maintaining well-trained volunteers requires extensive, consistent outreach that must be adaptive to changing needs throughout a project. In our interviews with NOAA Fisheries citizen science project leads, all of them relayed the importance of permanent, dedicated agency staff who work closely with participants and ensure data quality and program funding to supply materials and support logistics.

Obstacles and Barriers

Nearly half of the case studies in the literature review did not indicate whether the data they produced were used and/or included in fisheries stock assessments or related decision-making. Additionally, in most of the cases across our methods, we were not able to thoroughly investigate the reasons that data may not have been used or incorporated. As such, our conclusions and observations related to the obstacles and barriers preventing the uptake and/or use of citizen science data in U.S. fisheries stock assessments are predominantly drawn from our own inferences, survey responses from stock assessment scientists, and the existing literature.

Sampling design has a significant influence on the utility and uptake of data collected by citizen scientists. Many citizen science projects utilize an opportunistic approach to data collection, having participants report data during their normal course of activity (diving, fishing, walking a beach). This varies from more formal and probability-based sampling designs where volunteers sample at specific locations or times. Because many citizen science data utilize an opportunistic approach to sampling, their data products can vary in spatial and temporal distribution of sampling effort. Those variations introduce biases associated with nonprobability sampling (Brick et al., 2021) and are challenging to confront in fisheries stock assessments that often rely upon standardized, long-term time series and a probability-sampling, systematic framework. The scientists we spoke with highlighted the limited circumstances under which opportunistic datasets might improve or inform their assessments in the context of stocks with extant, reliable long-term time series data. Overall, data collected opportunistically can be used but must be considered differently than systematically collected data.

Data biases also led to skepticism among potential end users. Their concerns often centered on the challenges associated with self-selection, avidity, and response biases and limitations related to quality control. Self-selection biases where participants volunteer, rather than being randomly selected, can lead to participant pools that are not representative of the broader population. Avidity and response biases deal with the tendencies of avid participants to be over-represented in datasets and of all participants to under-report “zeroes” (e.g., fishing trips with no catch events). Citizen science volunteers are likely to be more “avid” participants, and as such, their fishing behavior or skill may not be representative of the entire fishery. While the problems and challenges resulting from these biases are well documented (Brick et al., 2021), they are exacerbated when metadata is also lacking. Information such as who collected a particular sample and when they collected it are critical for quality control and addressing bias. Citizen science data often lack sufficient metadata, undermining efforts to conduct data quality analyses or reviews. Other types of bias may relate to citizen science projects often centering on specific towns, fisheries, or participant groups. There may be strong scientific protocols and participation of the various volunteers;

however, the fishing or diving groups are generally not representative of the range and behavior of the entire fishery.

Another type of potential bias that affects the utility of some citizen science projects is a *lack of information about effort data* (Scyphers et al., 2014). For tagging programs, knowing the number of tags distributed, then deployed, and eventually recovered is critical. Additionally, information about "zero" values including the total number of trips, including trips with no sightings is also important. There are types of data that do not require effort information (observations, life history information like length or weight), but a lack of effort data inhibits the ability to use data to produce any sort of estimates of abundance or total catch.

Concerns over the quality of nonscientists collecting data and making observations were also common among potential data users. The stock assessment scientists who responded to our survey expressed concerns over the quality of individual observations. While citizen science efforts generally include some level of training for participants and maintain standardized, scientific sampling protocols, there can be challenges if scientists do not always trust that the training and protocols are consistently followed over time and space.

One potential obstacle inhibiting the uptake of citizen science into fisheries stock assessments is the *existence of spatial and/or temporal mismatche*s in study scope. Stock assessments rely on long time series of data and survey large regions in order to estimate population dynamics. Many citizen science projects focus on small, local areas. Additionally, projects need years of sustained funding in order to develop long time series. It is understandable, based on citizen science logistics, why they may have more local focus, but it does make it more difficult to incorporate the data into existing models when the scope is much smaller than other datasets.

Data management also arose as an obstacle preventing the use of citizen science in fisheries stock assessments. Citizen science projects have the potential to collect large amounts of data, and there need to be processes to collect, clean, and share the data in formats that are useful to assessment scientists. If a scientist is delivered a dataset that will take a large amount of time to understand, process, and calibrate, they are unlikely to put in the effort to consider or incorporate it. Other challenges relate to processing, storing, and sharing the data. There are cases where data may just be collected by one program manager and stored in their computer for analysis. One potential way to address this concern in the U.S. would be to cooperate with data clearinghouses, such as the Atlantic Coastal Cooperative Statistics Program and Fishery Information Networks, which could address data quality, consistency, and accessibility issues.

A final key obstacle preventing the broader uptake of citizen science is *the cost and resources required.* Citizen science is not free. While citizen science project use of volunteers may seem like a more cost-effective alternative when compared to agency-run data collection programs, it still requires substantial resources. Staff will still be needed to develop the program, recruit, train, and work with volunteers and perform quality checks. Recruiting and retaining participants are also necessary to collect useful data (having too few participants or high attrition can cause projects to fail). Additionally, samples or data collected by volunteers will need to be processed. There is little sustained funding for citizen science projects; many have to continually apply for grants.

Recommendations and Best Practices

Based on our research and analysis, we can conclude that NOAA Fisheries currently uses some citizen science collected data in assessments, though there is great potential to increase and improve upon the use of citizen science data by the agency. To date, most projects have been small, directed projects. With the exception of a few long-running tagging programs, there is a need for improved and consistent support for citizen science. Generally speaking, agency managers and scientists are open and interested. In order to improve the perception of citizen science as not just an outreach tool but also a source of data that could be used by scientists and managers, we have various recommendations.

For Groups or Individuals Interested in Developing Citizen Science Projects

1. **Design a Project with an End User:** When initiating a project, it is crucial to include scientists and managers in project design and implementation. This can help identify and refine needs, as well as develop a roadmap for the uptake of information.
2. **Communicate Often:** Consistent communication and collaboration throughout the project among volunteers, project managers, and end users of the data are critical to support project goals, maintain engagement, and build trust.
3. **Address Data Gaps:** Developing a citizen science project needs to strategically address data gaps. There are many ways to identify data gaps. The councils often identify research priorities for assessments, and these documents are publicly available on council websites. The best way would be to speak to scientists and assessment authors directly. In Appendix D, we have some examples of additional resources that could be useful in identifying data gaps.
4. **Proactive Engagement:** In our survey with stock assessment scientists, many (~75 percent) mentioned first becoming aware of a citizen science project through the council process or previous work with the organizations. A level of coordination and outreach through the typical fisheries management processes would be useful to bring attention to citizen science datasets.
5. **Know Your Audience:** In addition to speaking with scientists, working closely with participants to get their feedback is also important to project design. Is it feasible to collect this data using volunteers? What level of training would be necessary? Are there platforms to recruit participants? Maintaining long-term projects requires enthusiastic, committed, and well-trained participants.

For the Agency

1. **Recognize the Value:** The agency should recognize the value of citizen scientists in data collection and analysis. While realistic expectations are necessary and it may take work to participate in designing and implementing a project, there are many benefits, including increased data in addition to stakeholder engagement.
2. **Integrate and Coordinate with Similar Programs:** The agency currently invests heavily in data collection and also has additional programs that fund projects with stakeholders, including Cooperative Research, Saltonstall-Kennedy grants, and many projects that are funded at universities, cooperative institutes, and partner organizations. It is recommended that the agency consider how citizen science could support and play a role in these various programs

3. **Data Infrastructure:** NOAA Fisheries is undergoing various efforts to improve its data management infrastructure. These improvements should also include investments in digital infrastructure to facilitate the use of citizen science collected data, including storage and accessibility.
4. **Increase Funding:** Funding directed toward citizen science projects should be increased. Currently, there is no directed funding for these projects. They can contribute useful data but need consistent support to increase their utility. This could be similar to agency support for cooperative research projects.
5. **Lead with the Science:** Citizen science should be viewed by the agency as a data collection program within the scientific enterprise. While citizen science also has outreach and education benefits, projects should be centered and led from the science side.
6. **Develop and Facilitate a Clear Process:** Science centers and councils should develop and document a clear process for reviewing citizen science data prior to incorporation into an assessment. This could include a standardized framework of guidelines. In addition, the centers or councils could facilitate outreach and assistance to groups in designing studies and connecting groups with scientists. This can include developing and outreach regarding data needs and data collection programs.

General Strategic Considerations

1. **Target Existing Needs:** Citizen science projects may be at their most effective when they are developed to address specific management issues or data collection problems (de Jesus, et al. 2009). It is not necessary for citizen scientists to develop an entire index of abundance to estimate changes in a stock's abundance. The projects can be set up to collect certain types of data (e.g., biological samples, settlement information) that can complement existing datasets.
2. **Citizen Science Is Not Truly "Free:"** While participants may not be compensated, there are costs to program management staff, supplies, training, and data management. Also, the value of the data increases with longer-term datasets. Some citizen science projects may be short-term, but others will likely require multiple years to develop sufficient datasets. It is crucial to identify sufficient long-term funding for projects. While projects may adjust and shift to respond to scientific or management needs and questions, constantly applying for grants or shifting focus to find funding can challenge project design.

Case Study: Rockfish Settlement

Many fishery species managed by the agency can be considered “data-limited.” There are many reasons a species may be data limited, but species that are hard to sample (such as those that live in rocky environments), or species that are not frequently caught have higher likelihood to be data limited, with limited fishery dependent and independent data for use in assessments. There are numerous west coast rockfish species that can be considered data limited, and some are even classified as threatened or endangered. As managers in the west coast started searching for data on some such species, they considered ways that volunteers and citizen science could contribute to data collection.

Beginning in 2015, the Young of the Year (YOY) Settlement project works with volunteer recreational divers to collect data on rockfish settlement in the Puget Sound. Most divers purposefully look for settlement events. Settlement refers to larvae settling into rockfish habitat and can lead towards recruitment into the population in later years.

This data is not currently used directly in assessments (and many species lack assessments). The understanding between settlement and recruitment cannot currently be directly shown. But the measure of settlement can be used as a sort of “red flag” or indicator approach to show trends in the population. Current work to monitor these species may take place sporadically and use remotely operated vehicles (ROVs), which may miss many fish or larval settlement. As population assessment of these species is currently operating in a data scarce environment, information on settlement can be informative on population status.

The project was motivated to work with volunteers due to budget limitations. The use of volunteer divers expanded the ability to monitor and collect data about settlement events by increasing the number of divers, as well as the time frame for collecting data. Volunteers are trained by a NOAA Fisheries contract staff member and have protocols for collecting and submitting data. To date, the activity has proven popular with diving communities, who enjoy the motivation to collect this type of data while diving.

There are plans to incorporate the data along with some recreational catch data and limited fishery survey data to develop a generalized linear model which could provide information on abundance and distribution. To date, the program has been successful at collecting data in a data limited scenario, in addition to engaging the diver community.

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Appendices

Appendix A: Questions for Interviews with Project Leads

- To your knowledge, has data collected by this project been analyzed or used to support stock assessment or fisheries management? If so, please describe (provide references if applicable).
- We're interested in cataloging the level of engagement among stakeholders and end users:
    - Were end users involved in project design? If so, who?
    - How did you raise awareness about the project? Who did those efforts target?
    - How can potential users discover and access the project data?

Appendix B: Survey Questions for Stock Assessment Scientists

- Science Center
- Role in Assessment Process
- What assessments are you the primary author or contributor to?
- Have you considered the use of citizen science data in a stock assessment?
- Did you use the citizen science data in a stock assessment?
- What were the data?
- How did you learn about these data?
- How were the data incorporated into or used to inform the stock assessment?
- Why were the citizen science data not used?
- Are you aware of any citizen science project datasets that could be appropriate for stock assessments in your region? If yes, please list
- Have you been involved in designing a citizen science project to support a fisheries stock assessment or inform management?
- What projects were you involved in? Did you use data from the project(s)?
- Thinking about some of the data gaps and research needs in your assessment(s), do any have potential where citizen science projects could address those needs?
- What are the greatest opportunities for citizen science to contribute to your assessments?
- What are the biggest challenges and barriers you see to using citizen science data in your stock assessments?
- Please share any additional thoughts.

Appendix C: Text-matching Terms

Confirmed mentions of citizen science, with the total count of matches provided in parentheses. Alternative terms used in the query are displayed below.

Term	Northeast		Southeast		West Coast		Alaska		Pacific Islands		TOTAL	
citizen	0	(0)	2	(3)	2	(2)	0	(0)	0	(0)	**4**	**(5)**
community	0	(16)	2	(38)	0	(86)	2	(43)	2	(24)	**6**	**(207)**
civic	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	**0**	**(0)**
participatory*	3	(28)	3	(179)	0	(25)	0	(34)	2	(20)	**8**	**(286)**
crowd	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	**0**	**(0)**
action	0	(25)	0	(227)	0	(232)	0	(16)	0	(1)	**0**	**(501)**
traditional	0	(49)	1	(48)	0	(42)	4	(21)	0	(12)	**5**	**(172)**
knowledge	10	(45)	15	(157)	3	(38)	7	(30)	2	(20)	**37**	**(290)**
volunteer	9	(13)	5	(10)	10	(12)	0	(1)	0	(0)	**24**	**(36)**
public	1	(41)	1	(206)	0	(79)	1	(21)	0	(3)	**3**	**(350)**
app	0	(98)	2	(7)	0	(3)	0	(7)	0	(2)	**2**	**(117)**
voluntary	3	(7)	5	(40)	1	(15)	1	(12)	4	(5)	**14**	**(79)**
angler#	8	(39)	1	(410)	2	(376)	0	(1)	0	(0)	**11**	**(826)**
tagging+	27	(76)	52	(526)	64	(326)	32	(108)	29	(128)	**204**	**(1,164)**
TOTAL	**61**	**(437)**	**89**	**(1,901)**	**82**	**(1,236)**	**47**	**(294)**	**39**	**(215)**	**318**	**(4,083)**

* Alternate term included: participation

\# Alternate terms included: angler diary, angler survey, angling survey

\+ Alternate term included: tag data

Appendix D: Additional Resources

The team did not do exhaustive analysis of all research needs with citizen science, though listed below we have a few resources that could be considered when thinking of data gaps. These can serve as examples, or as a starting point in identifying data gaps with potential for citizen science.

Example Research Recommendations with Citizen Science potential: Our team has reviewed documents including: Council Research Priorities, Research Recommendations found in Stock Assessment Reports, and Scientific and Statistical Committee research recommendations. These different documents make recommendations of needed research, often on specific species or stocks, which could improve an assessment. The following table, while not exhaustive, highlights some examples that mention citizen science, or could have citizen science potential.

Region	Stock	Recommendation	Source
North Pacific FMC	Skate	Monitor skate egg concentrations	Council Research Priorities
North Pacific FMC	Pacific cod - Bering Sea	Tagging studies are encouraged	Stock Assessment Author
North Pacific FMC	Sablefish - Eastern Bering Sea / Aleutian Islands / Gulf of Alaska	Seek out local knowledge regarding fishery CPUE, in particular regarding any issues with the performance of slinky pots that may affect CPUE.	Scientific and Statistical Committee
Mid Atlantic FMC	Black Sea Bass	Estimate discard mortality rate of BSB in offshore recreational rod and reef fisheries	Council Research Priorities
Mid Atlantic FMC	Bluefish - Atlantic Coast	Obtaining better data on recreational discard lengths would be valuable. NMFS should consider developing an app that can be used by anglers to report discard lengths. Because self-reporting can introduce bias, the statistical issues should also be explored.	Stock Assessment Author & Scientific and Statistical Committee
New England FMC	Red Hake	Document fishermen's ecological knowledge (knowledge of previous fisheries)	Council Research Priorities
New England FMC	Red deepsea crab - Northwest Atlantic	Design a successful tagging study to explore red crab growth rates, fishing mortality rates and molt frequencies in situ?	Stock Assessment Author
New England FMC	Silver hake - Gulf of Maine / Northern Georges Bank	To address the uncertainties about migration in silver hake, the development of conventional, data storage tag or hook-based tagging studies to provide information about migration, should be considered.	Center for Independent Experts
New England FMC	Witch flounder - Northwestern Atlantic Coast	Conduct tagging studies designed to decrease the uncertainty of estimates/assumptions for M, if feasible.	Stock Assessment Author

Region	Stock	Recommendation	Source
Western Pacific FMC	Troll Fishery	Obtain proof of shark depredation events	Council Research Priorities
Western Pacific FMC	Green jobfish - Main Hawaiian Islands	Better understand stock structure, population connectivity, and adult movement of fishes using genetic analysis and tagging experiments.	Center for Independent Experts
Western Pacific FMC	Spanner crab - Main Hawaiian Islands	Tagging program to estimate harvest rates, along with movement, and other aspects of the stock dynamics.	Center for Independent Experts
Western Pacific FMC	Skipjack tuna - Central Western Pacific	Given the difficulties with aging skipjack using traditional methods (i.e., otoliths and spines) we recommend an exploration of the epigenetic aging approach using samples from individual tag-recapture skipjack	Stock Assessment Author
Pacific FMC	Sablefish - Pacific Coast	Anecdotal information, such as the large 1947 recruitment reported by central California sport fisherman, along with historical records could be investigated to provide additional information on historical patterns of recruitment.	Stock Assessment Author
Pacific FMC	Cabezon - Southern California	Consider developing a tagging program to understand the spatial extent of the localized populations at different stages of their life cycle.	Center for Independent Experts
Pacific FMC	California scorpionfish - Southern California	A tagging study to estimate natural mortality for scorpionfish should be considered. This project could be designed as a cooperative research project with the charter fleet in southern California.	Stock Assessment Author & Center for Independent Experts
South Atlantic FMC	Black sea bass - Southern Atlantic Coast	For this assessment, the age-dependent natural mortality rate was estimated by indirect methods. More direct methods, e.g. tag-recapture, might prove useful. Some tag-recapture studies have demonstrated relatively high tag return rates for black sea bass, at least compared to those of other reef fishes of the southeast U.S.	Stock Assessment Author

Region	Stock	Recommendation	Source
South Atlantic FMC	Gray triggerfish - Southern Atlantic Coast	Examine the time series of Gray Triggerfish captured, tagged, released and recaptured by the Virginia Game Fish Tagging Program, to determine if a useful index might be generated.	Stock Assessment Author
South Atlantic & Gulf FMCs	Goliath grouper - Southern Atlantic Coast / Gulf of Mexico	Use visual data from the REEF survey, NMFS-UM Reef Visual Census (though they do not sample artificial reefs and wrecks), and expand the Great Goliath Grouper Counts from once a year in June to twice a year (June and September) to help identify locations with larger fish to sample.	Stock Assessment Author
Gulf FMC	Red drum - Gulf of Mexico	Investigate self-reported discards to determine if there is bias or misidentification in the data.	Stock Assessment Author
Gulf FMC	Gulf of Mexico Jacks Complex	Investigate self-reported discards to determine if there is bias or misidentification in the data.	Stock Assessment Author
Gulf FMC	Lane snapper - Gulf of Mexico	Estimation of current stock abundance from tagging studies (e.g. Red Drum), which could be used in methods such as the Beddington and Kirkwood (2005) approach.	Stock Assessment Author

South Atlantic Fishery Management Council: The SAFMC has spent multiple years developing a citizen science program. This has included a workshop bringing together fishermen, scientists, managers, and citizen science practitioners to come up with potential applications of citizen science to fisheries management. Program Blueprint and guidance have been developed, and a few pilot projects have also been supported by the Council. Resources developed by the Council are very relevant and informative about designing citizen science programs to meet fishery science and management needs.

- General website: https://safmc.net/citizen-science/
- https://safmc.net/citizen-science/program-development/
- Program priorities: https://safmc.net/documents/appendixc_safmccitsciresearchpriorities_adoptdec2023/

Data Gap Analysis: In 2023, NOAA Fisheries published a Tech Memo on Setting data targets and Analyzing Data Gaps. Detailed analysis was done in all regions across 554 fishery stocks and stock complexes to identify target data levels in 5 categories: catch, abundance, life history, size/age composition, and ecosystem linkages (on a 0-5 scale). In addition to identifying target levels, current data levels were also identified and the gaps identified. This resource can be helpful in identifying particular stocks with data gaps in particular categories: https://spo.nmfs.noaa.gov/content/tech-memo/setting-targets-and-analyzing-data-gaps-us-fish-assessments

Environmental Defense Fund Report: A recent study by the Environmental Defense Fund titled "Citizen Science to Support Climate-Ready Management of United States Fisheries" reviewed information gaps in a selection of 80 U.S. Federal stock assessments (across all Council regions) to identify gaps with potential to be filled by citizen scientists. The report includes a more complete table, but some examples of data identified as "high suitability" includes: Species growth (tag recapture), Recruitment (length/weight in catch sample), Rec fishery release length data (discards), Commercial fisheries release length data, Depth distribution (on gear depth from catch location), Effect of temp on distribution (collecting temp and catch together), HAB dynamics from visual tracking of red rides, Survey fishermen to get demand, and Surveys to get fishermen demographics: https://library.edf.org/AssetLink/rt4ch86ocgyo466wm5io038370et6w36.pdf