Citizen Science & Ocean Resource Management in California

Guidance for forming productive partnerships.

California Collaborative Fisheries Research Program

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This document was developed by the Ocean Science Trust as part of our California Citizen Science Initiative, and in accordance with our principles of engagement. It is informed by research in California's Central Coast, including focus groups with participants in citizen science programs, interviews with citizen science coordinators, field visits, background research, and a workshop with citizen science program leaders and natural resource managers. We would like to acknowledge the time and thoughtful input generously contributed by staff and volunteers from many organizations working on citizen science related to California's oceans. We would also like to acknowledge that this work represents a snapshot of the Central Coast community, which is rapidly changing.

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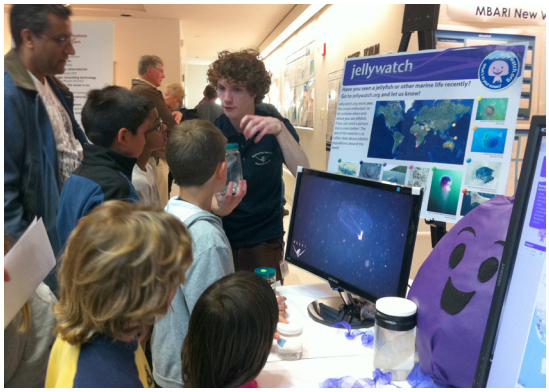
The Ocean Science Trust is a non-profit organization based in Oakland, California. We believe that science is an important foundation for ocean resource management decisions. We work with scientists, citizens, managers and policy-makers to build shared understanding and trust in science for healthy, resilient and productive coasts and oceans.

More information can be found at *www.oceansciencetrust.org*

cover: Scientists and volunteer fishermen team up to inform MPA monitoring and fisheries management through the California Collaborative Fisheries Research Program.

A volunteer diver collects data for REEF.

California Collaborative Fisheries Research Program



Jellywatch

MPA Watch

Citizen Science and Ocean Resource Management: Key Findings

CAN CITIZEN SCIENCE PLAY A ROLE IN OCEAN RESOURCE MANAGEMENT?

Yes. Citizen science programs are already informing managers through a wide range of partnerships, focused on issues ranging from oil spills, to water quality, to marine protected areas. There is great potential for increased collaboration between motivated volunteer scientists and managers. Citizen science isn't always the right approach, but opportunity exists to broaden citizen participation in research and monitoring.

WHY MIGHT MANAGERS WANT TO WORK WITH CITIZEN SCIENCE PROGRAMS?

A variety of potential benefits all add up to what one citizen science coordinator calls "Science Plus." There is often potential to promote education, awareness, and stewardship as a part of engaging citizen science programs. Citizen science is not free, but has the potential to generate large amounts of data very cost-effectively. In addition, citizen science offers one avenue for bringing a wider community of motivated individuals into the process of learning about and managing natural resources. Volunteers can be a tremendous source of local expertise, innovative ideas, and enthusiasm.

WHY MIGHT CITIZEN SCIENCE PROGRAMS WANT TO INFORM OCEAN RESOURCE MANAGEMENT?

Partnerships with managers are one way to show that the efforts of volunteers are feeding into something bigger—a key motivation for both citizen scientist volunteers and program staff. Relevance to managers may be attractive to funders. Partnerships with both science institutions and government agencies can give citizen science programs access to useful resources and expertise (e.g., lab space).

IS CITIZEN SCIENCE CREDIBLE?

Many citizen science programs are meeting and even exceeding traditional scientific standards. But citizen science often involves non-traditional approaches to generating data, which makes assessment or demonstration of credibility a challenge. We documented a range of strategies that citizen science programs use to build credibility and rigor. Transparency and shared expectations around these practices are important ingredients for productive partnerships between managers and citizen science programs.

WHAT ARE SOME CHALLENGES TO ESTABLISHING PRODUCTIVE PARTNERSHIPS?

Most of the challenges are surmountable through relationship building, shared understanding, and shared resources. Managers accustomed to working with academic scientists or agency scientists may be unfamiliar with the needs and programmatic realities faced by citizen science programs. They may view citizen science with suspicion because of stereotypes about the abilities of volunteers. Citizen science programs are often balancing multiple priorities, such as education and participation, alongside their scientific goals. Adding into this mix a partnership with a state agency can present a challenge. Citizen science groups may be doing good science, but lack the resources needed for effective data management and analysis, which managers need in order to make use of the data.

Golden Gate Raptor Observatory

Grunion Greeters

Limpets

MPA Watch demo at the CCSI workshop

Citizen Science in the Central Coast: Findings and Highlights

With an eye toward building and strengthening partnerships for MPA monitoring, we set out to learn about citizen science programs engaging with California's oceans in the Central Coast region, from Pigeon Point in the North to Point Conception in the South. Here are a few of our key findings about that community and highlights of our process, all of which are explored in more detail on *http://oceanspaces.org/community/citizen-science-oceanspaces/blog.*

OVER 30 CITIZEN SCIENCE GROUPS OPERATE IN THE CENTRAL COAST.

They are all different, covering a range of topics, inviting many different kinds of volunteers, and operating on different scales. The total number of Central Coast groups changes regularly as programs come and go, expand and contract.

CENTRAL COAST CITIZEN SCIENTISTS ARE ALREADY PARTNERING WITH NATURAL RESOURCE MANAGERS.

Every group we engaged with has at least identified one or more intended management audiences, and many of them are actively engaging with managers. Several of these groups, including Audubon California, the California Collaborative Fisheries Research Program, LiMPETS, MPA Watch, adnd Reef Check California are already actively partnering with the Ocean Science Trust to conduct MPA monitoring.

CENTRAL COAST CITIZEN SCIENCE AND MPA MONITORING ALREADY OVERLAP

For most of the topical areas covered by the Central Coast MPA monitoring plan there is at least some related citizen science activity in the region. There is great potential to build more and better partnerships between MPA monitoring and citizen science. This does not mean that citizen science can or should supplant academic and other scientific approaches but opportunity exists to strengthen the role of citizen science.

THE ROLE OF CITIZEN SCIENCE IN CENTRAL COAST MPA MONITORING

Through the California Citizen Science Initiative, citizen science groups are already actively shaping the next phase of MPA monitoring in the Central Coast.

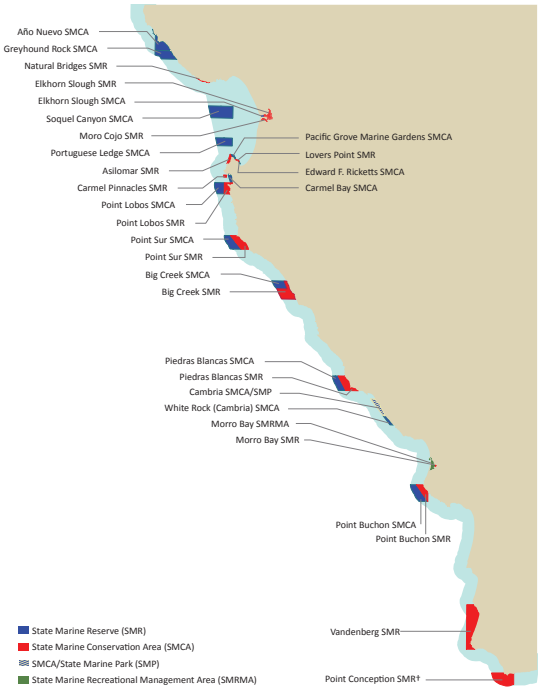
- Part of the plan. Insights from Central Coast citizen science groups are reflected in the updated Central Coast MPA Monitoring plan, which in early October, 2014, will be considered by the Fish and Game Commission for adoption as state policy. That document includes a section focused on partnering with citizen science (see Chapter 7).
- Informing implementation. We designed an online survey to characterize ongoing Central Coast monitoring efforts, and highlight opportunities for partnership and collaboration, which accommodates citizen science participation alongside other monitoring efforts. Results will inform the design and implementation of Central Coast MPA monitoring.
- Building community. An April, 2014 workshop built new connections and strengthened existing ones among the many citizen science groups who work in the Central Coast region. Groups have a strong desire to continue learning from each other at future events.

Introduction

THE OPPORTUNITY

Citizen scientists are out along California's Central Coast every day, collecting data, advancing knowledge, and engaging communities in a wide variety of coastal and ocean issues. At the same time, adaptive management and ecosystem-based approaches to natural resource issues are redefining best practices for environmental governance. Both of these worlds—citizen science and natural resource management—face opportunities and challenges as they advance their respective fields. There is great potential for citizen science programs and natural resource managers to forge lasting, mutually beneficial partnerships. However, citizen science cannot be all things to all people, and not every data need can or should be met through a citizen science approach. In this guidance document we lay out advice for managers and for citizen science programs to consider in thinking through opportunities for productive partnerships.

This document is a product of the Ocean Science Trust's California Citizen Science Initiative (CCSI). Our goal with the CCSI is to identify organizational models for citizen science that can contribute to sustained, useful and cost-effective MPA monitoring efforts, and to apply and test this knowledge through the process of implementing ongoing MPA monitoring in California's Central Coast region. The guidance in this document is intended to serve ourselves and our partners as we design and implement a monitoring program for MPAs in the Central Coast (see Box 1 for more information on this process). But while the specific opportunity of engaging citizen science in MPA monitoring has motivated this project, we also hope this guidance will be useful more broadly.



BOX 1. CITIZEN SCIENCE AND MPA MONITORING: WHY FOCUS ON THE CENTRAL COAST?

As a result of the Marine Life Protection Act, California is now home to the largest scientifically designed network of marine protected areas (MPAs) in the nation. This statewide network of MPAs is implemented and managed in four coastal regions. The Central Coast region stretches from Pigeon Point to Point Conception and contains 29 MPAs. Scientific monitoring, implemented through a partnerships approach, is an essential and mandated input to adaptive management of MPAs. Through partnerships we can leverage resources, avoid duplication of effort, expand the community of people and organizations involved in monitoring, and multiply opportunities for monitoring results to inform processes beyond MPA management.

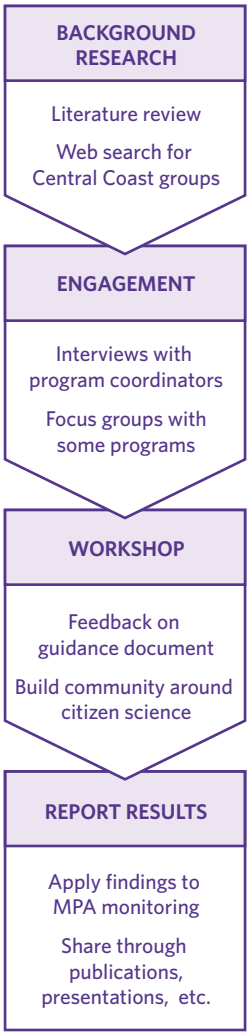
We can already point to MPA monitoring partnerships with citizen science groups throughout California. The groups range widely in their scientific approach, the volunteer communities, and their overall structure and mission. This diversity is part of what motivated us to investigate the citizen science opportunity further.

In the Central Coast region, we are learning from and building on these experiences. In designing and implementing a plan for long-term MPA monitoring in the Central Coast, we are explicitly acknowledging lessons learned from this and other regions, and building them into the design and implementation the next phase of monitoring. This guidance document is a key element of that process. Citizen science groups informed the updated Central Coast MPA Monitoring Plan, and are taking part in an online survey that puts their data collection efforts alongside those of other science organizations. This allows us to explicitly consider citizen science capacity, and partnerships opportunities, as we plan and implement the next phase of MPA monitoring in this region.

Learn more about MPA monitoring in the Central Coast and other regions at OceanSpaces.org.

Photo: Jim Wicker

Photo: Jim Wicker



DEVELOPING THE GUIDANCE

To develop this guidance, we conducted focus groups with participants in citizen science programs, interviews with citizen science coordinators, field visits, background research, and a workshop with citizen science program leaders and natural resource managers. Many of the results from these activities can be found on our blog at OceanSpaces.org/blog.

Throughout this process we have sought to better understand the ways in which citizen science can work, and use those lessons to think about how we can design MPA monitoring to be more inclusive of these different models. At the same time, we have looked for ways in which citizen science programs can learn from each other, and discover opportunities to broaden their impact. This document presents some important lessons learned that can guide us in building partnerships and implementing MPA monitoring. However, the collaborative learning process will continue in the Central Coast, other regions of California, and beyond.

IN THE CENTRAL COAST, "CITIZEN SCIENCE" MEANS MANY DIFFERENT THINGS

The term "citizen science" has many definitions. For us, citizen science refers to any scientific endeavor involving people who are not professional scientists. We used an intentionally broad and inclusive definition to discover the full range of citizen science programs operating in the Central Coast. Even so, we were surprised by the number of programs we found, and the sheer diversity represented by these efforts. Table 1 demonstrates that citizen science can be operationalized in many different ways; we must avoid the idea that all citizen science is the same. Table 2 lists citizen science programs operating in the Central Coast as of early 2014, their topical focus, and intended links to management. Many of these programs already work actively with natural resource managers in a range of organizations. We can learn from and leverage this experience.

Table 1. Citizen science in the Central Coast is highly diverse.

TECHNOLOGY	pencil & clipboard	⟷	cell-phone app
VOLUNTEERS	single participant	⟷	thousands
AGE OF PARTICIPANTS	grade school	⟷	retirees
SPATIAL COVERAGE	single beach	⟷	global
SAMPLING EFFORT	annual	⟷	daily
ORGANIZATION	local non-profit	⟷	global parent organization
TOPIC	Human uses, water quality, otters, rocky reefs, kelp forests, beach ecology, seabirds, shorebirds, marine debris, jellyfish, rocky intertidal, plankton, fisheries... and others!		

Science Plus: Benefits of partnerships with citizen science

Before we address the "how" and "when" of forming productive partnerships between citizen science and natural resource management, we should first review the "why." In other words, what would motivate these two groups to work together?

Citizen science may offer a variety of benefits, many of which might be of direct interest to natural resource managers. Scientific benefits include broad spatial and temporal coverage, data from hard-to-access private land, and labor-intensive data collection that would otherwise be prohibitively expensive to collect. In other words, citizen science can be an effective and efficient way to gather large amounts of data. (As noted in a later section, data collection is just one of the costs associated with citizen science.)

But the potential benefits of citizen science extend beyond low-cost data collection. Other potential benefits include increased scientific literacy, appreciation and stewardship of resources, strengthened community, and awareness of and support for management efforts. At our workshop with Central Coast citizen science groups, one participant dubbed this concept of multiple benefits "science plus." Managers may need to prioritize issues such as data quality and cost in their efforts to implement monitoring, but these additional benefits may also be worth consideration, particularly when adopting a long-term view of a sustainable, partnerships-based approach to monitoring.

There are also important motivations for citizen science groups to engage with natural resource managers. Such partnerships can open up new funding opportunities, motivate volunteers, increase reputation and public profile, and teach their volunteers how to participate in stewardship activities.

Guidance for Good Practice in Citizen Science Partnerships

STARTING THE CONVERSATION

Natural resource managers have a wide array of information and data needs. Some of these may be easier to meet through citizen science than others. Building a partnership requires multiple interactions—opportunities to ask questions and share information to build mutually held goals. For both sides, communicating about information needs, resource constraints, and available capacity is not always simple. The following questions can guide these conversations as resource managers consider working with citizen science groups to acquire useful data.

1. **Is capacity building needed?** Are citizen science groups already working on the subject? What changes might be needed for their work to meet your needs (e.g., expanded range of data collection, improved data management practices, or new analyses)? How much additional work would your task be for them?

2. **What's the task?** Is it dangerous? Will data collection involve complex technology or methods? Can the process be adjusted to match volunteer skills?

3. **Will people participate?** Is the method time-consuming or tedious? Is the subject of the study exciting or directly relevant to people?

None of the answers to these questions will rule out (or rule in) a citizen science approach to meeting data needs, but they can help to understand the challenge or opportunity.

Table 2. Snapshot of Central Coast citizen science programs

GROUP NAME	MAIN RESEARCH TOPIC	INTENDED MANAGEMENT AUDIENCE
Beach COMBERS	Beach-cast birds, mammals	CA Department of Fish and Wildlife, NOAA Marine Sanctuaries
Beach Watch	Beach-cast birds, mammals & human activity, tarballs	NOAA National Marine Sanctuaries
Beachkeepers (Save Our Shores)	Marine debris	City and county of Santa Cruz, Monterey County
Black Oystercatcher Monitoring (Audubon)	Black oystercatchers	Bureau of Land Management
CA King Tides	Sea level rise	Bay Conservation and Development Commission, National Estuarine Research Reserves
Collaborative Fisheries West	Fisheries (variety of projects)	CA Department of Fish and Wildlife
CA Collaborative Fisheries Research Program	Fisheries	CA Department of Fish and Wildlife
Elkhorn Slough National Estuarine Research Reserve Algae monitoring Friends of the Sea Otter Monitoring Bird Nestboxes Shorebird and Waterfowl Monitoring	 Algae mats Otter behavior Nestboxes Shorebirds	National Estuarine Research Reserves, CA Department of Fish and Wildlife
Coastal Watershed Council: First Flush Urban Watch	Water quality	CA EPA, regional Water Quality Control Board
Grunion Greeters	Grunions	CA Department of Fish and Wildlife
iNaturalist (California Academy of Sciences)	Biodiversity	Convention on Biological Diversity, Intergovernmental Platform on Biodiversity and Ecosystem Services
Jellywatch	Jellyfish	Harmful algal bloom management
Leatherback Watch	Sea turtles	NOAA
Lighthawk	Aerial perspective	Varies by project
LiMPETS	Rocky intertidal, mole crabs	CA Department of Fish and Wildlife, NOAA Marine Sanctuaries
Marine Debris Tracker	Marine debris	NOAA
Marine Debris Action Team (NOAA)	Marine debris	NOAA
Monterey Bay National Marine Sanctuary Areas of Special Biological Significance First Flush Regional Monitoring Program Urban Watch Snapshot Day	 Water quality Stormwater Watershed health Urban runoff Tributary health	NOAA Marine Sanctuaries
MPA Watch (Otter Project)	Human activity	CA Department of Fish and Wildlife
Phytoplankton Monitoring Program	Harmful algal blooms	CA Department of Health
Seabird Protection Network	Seabirds	NOAA Marine Sanctuaries, Bureau of Land Management
SPLASH (Cascadia Research Collective)	Humpback whales	National Marine Fisheries Service, NOAA Marine Sanctuaries, Department of Fisheries and Oceans Canada
Reef Check CA	Kelp forests and rocky reefs	CA Department of Fish and Wildlife
REEF	Fish and invertebrates	NOAA Marine Sanctuaries, United Nations Environment Program
Shorebird Monitoring (Morro Bay)	Shorebirds	National Estuary Program
Blue Water Task Force (Surfrider)	Water quality	Department of Health, county managers
Morro Bay National Estuary Program Volunteer Monitoring Program	Water quality, eelgrass transects, bioassessment, sediment	National Estuary Program

Beach Watch and BeachCOMBERS conduct a methods demo at the CCSI workshop

BALANCING MULTIPLE GOALS

All of the citizen science programs we engaged had multiple goals included in their mission, such as science, education, building a stewardship ethic among volunteers, informing management, and environmental advocacy. Managers can benefit from these parallel goals but they need to be explicitly recognized. For example, a citizen science program may offer valuable data, while its efforts in education and stewardship provide an opportunity to expand the community of citizens constructively engaged with natural resource management issues.

But a partnership with natural resource managers could present challenges to citizen science groups. A new use for existing data could, for example, generate pressure to increase the rigor of training or require new forms of data reporting, potentially limiting the pool of volunteers, and thus the program's reach in terms of, say, environmental education. It could also shift the balance of priorities within the program, raising management applications to a higher priority, and reducing resources available for things like outreach or curriculum development. Managers and citizen science programs must be sensitive to how those goals are prioritized and work to understand how a new partnership might interact – positively or negatively – with other goals and activities.

CREDIBILITY & RIGOR IN CITIZEN SCIENCE

Establishing scientific rigor and overall credibility of the program is extremely important for citizen science. Establishing credibility is also an issue faced by professional scientists, but the challenge for citizen science may be greater in some cases, because of widely held assumptions that citizen scientists are not experts, and the use of non-traditional approaches to data collection.

The challenge of establishing credibility and rigor was a recurring theme throughout our research and engagement process. For the purposes of this discussion, rigor refers to the technical merits of the methods that citizen science programs use to implement their programs. For example, experimental design, and the practices that volunteers use to gather data as part of implementing that design, would each be considered important determinants of the overall rigor of the program. Credibility includes these practices, but also refers to broader things that a program does to ensure the integrity of its science or build the program's overall reputation. For example, have the data been used in peer reviewed publications, and have the methods been adjusted based on new insights about the quality of the program's data? These and other practices can affect perceptions of credibility on the part of audiences such as managers and academic scientists.

There are many citizen science programs throughout the world, including in the Central Coast, that meet or exceed typical academic scientific standards. At our workshop, many Central Coast groups agreed that they want their scientific work judged by the same standards as any other scientific enterprise, even if their approaches to meeting those standards differ from those of their academic colleagues.

Of course, even within academic science, standards and expectations vary widely. Whether across journals or disciplines, or even within a very narrow discipline, individual scientists will have particular ideas about what constitutes credible, innovative, or useful scientific work. Science is a process with many components; credibility and rigor are often balanced across these components. Any partnership must be based on shared expectations around credibility and rigor.

Practices that Demonstrate Credibility and Rigor

There is no single formula for credible citizen science. Table 3 describes many strategies used by Central Coast citizen science programs in various combinations, along with examples linked to individual programs. Each strategy occurs during a different part of the research process, and has different implications for credibility and rigor. Almost all Central Coast groups use more than one of the strategies listed in Table 3. None of the Central Coast groups use all the strategies listed. This is partly due to resource constraints, but also due to the operational and organizational implications of some of the strategies. For example, required prior expertise may limit the pool of potential volunteers while in-person oversight could detract from the volunteer experience, if independence and flexibility are desired. The list in Table 3 provides a useful guide for thinking through approaches to improving credibility and rigor. But given the organizational and structural diversity of citizen science, it should not be thought of as a list of requirements.

Managers need to ensure that the data they rely on to make decisions are credible, sound science; they need to learn what common practices establish credibility in citizen science. Citizen scientists need to communicate the efforts they take to ensure sound science and help managers understand them. Transparency and shared expectations around these practices, and their organizational implications, are important ingredients for productive partnerships between managers and citizen science programs.

Rigorous methods and quality assurance only go so far without communicating such efforts to external audiences. We noted that some programs have a variety of informal, undocumented procedural checks or strategies for maintaining data quality. While these are useful internally, their value will not always be clear to an external partner.

Clear documentation of data verification, protocol implementation, data analysis techniques, and other practices is important for external perceptions of credibility. For most programs, the easiest means to achieve this kind of communication is through program websites, but staff can also communicate about their practices through individual relationships with scientists and managers. Programs also must responsibly communicate their results. Poor analysis, and/or unwarranted conclusions can jeopardize the credibility of an otherwise high quality monitoring program.

Structure and Sustainability of Citizen Science

The notion that citizen science is virtually free probably comes from the impressive accomplishments of large groups of volunteers working tirelessly without compensation. Their time does not constitute a direct cost to the program, but there are many resource needs associated with the mobilization of volunteers. We can learn about the realities of sustaining a citizen science program by examining the structure of the institutions that carry out citizen science, and what we heard from programs in the Central Coast about resource needs over time.

PROGRAM STRUCTURE

Table 4 lists Central Coast citizen science groups with some basic information about program structure and institutional setting. While the cases range widely, two thirds of the groups are based in the nonprofit (eNGO) world, with the others divided among government and academic organizations. Only five of the groups on this list are based primarily within academia, but many have formal or informal ties to scientists in academia or government (Table 4 lists only formal relationships).

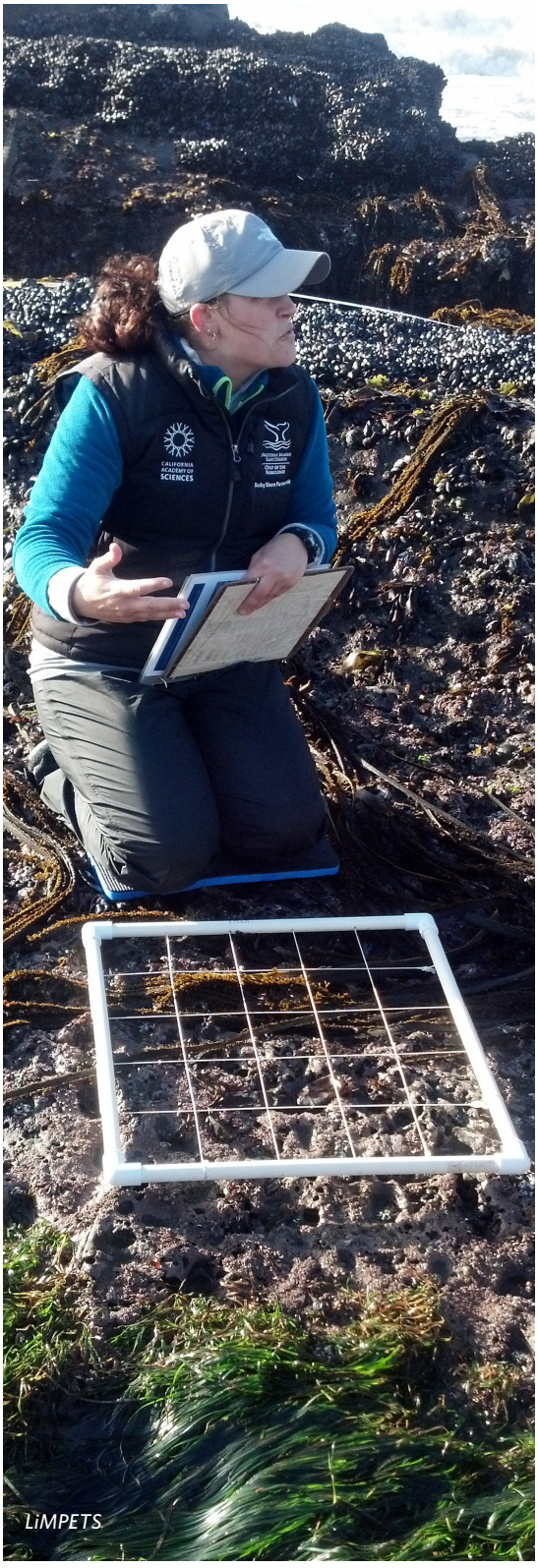
Table 3. Strategies for ensuring and demonstrating credibility and rigor.

STRATEGY	DEFINITION	EXAMPLE
PROJECT AND VOLUNTEER INITIATION		
Prior expertise	Particular knowledge or experience required in order for volunteers to participate	**Black Oystercatcher Monitoring:** Prior experience with bird-watching and research required.
Training	Required formal instruction before participation in the activity	**Beach COMBERS:** 80-hours of classroom instruction required before data collection begins
Science advising	Recognized experts provide guidance on the project design and implementation	**Elkhorn Slough:** Formal science advisory team drawn from academic institutions
DATA COLLECTION		
Ranking system	Volunteers advance through a hierarchy of roles, as they demonstrate improvement in skills and knowledge	**Reef Check California:** Volunteers graduate from seaweed and urchin surveys to more complex fish counts
In-person oversight	Professionals accompany volunteers in the field to keep an eye on data collection	**CCFRP:** Scientists oversee all measurements and species ID as they occur on the fishing vessel
Re-training	Instruction or testing for volunteers to refresh or gain skills	**LiMPETS:** Participating teachers review curriculum and methods each year
Technological aids	Technology that standardizes practices and/or reduces error	**iNaturalist:** Smartphones enable photos for validation and consistent GPS information
AFTER DATA COLLECTION		
Validated observations	A professional validates data once they have been collected	**Jellywatch:** Expert checks photos to validate species ID made by volunteers in the field
Cross-comparison	Compare program data with data generated by professionals	**Grunion Greeters:** Favorable comparisons with CA Dept of Fish and Wildlife data led to a partnership
Publication	Peer-review of data or results	**REEF:** New findings from program data published in a peer-reviewed scientific journal
Management use	Managers use program data for decisiton-making	**Blue Water Task Force:** Declaration of 'safe' swimming beach using volunteer-collected data
Quality assurance protocol	Periodic checks to independently verify method validity.	**Coastal Watershed Council:** Calibrate equipment using federal agency standards and equipment

LightHawk

Table 4. Structural aspects of Central Coast citizen science groups. Cases in bold are standalone organizations (as opposed to projects) formed solely to advance one or more citizen science efforts.

GROUP NAME	MAIN RESEARCH TOPIC	ORGANIZATIONAL STRUCTURE
CA Collaborative Fisheries Research Program	ACADEMIC	Part of CA Sea Grant research program
Grunion Greeters	ACADEMIC	Pepperdine University faculty research program
Jellywatch	ACADEMIC	MBARI faculty research program
SPLASH	ACADEMIC	Research program of Cascadia Research Collective
Marine Debris Tracker	ACADEMIC/ GOVT (fed)	Partnership between NOAA and University of Georgia
Elkhorn Slough National Estuarine Research Reserve (multiple programs)	GOVT (fed)	Part of the Elkhorn Slough NERR's broader set of volunteer programs.
Marine Debris Action Team (NOAA)	GOVT (fed)	Part of national network of NOAA volunteers
Monterey Bay National Marine Sanctuary (multiple projects)	GOVT (fed)	Part of the broader set of Sanctuary volunteer programs
Seabird Protection Network	GOVT (fed)	Network of chapters organized by Gulf of the Farallones National Marine Sanctuary
Phytoplankton Monitoring Program	GOVT (state)	Initiative of CA Department of Public Health
Leatherback Watch	INDEPENDENT	Personal project
Beach Watch	NP/GOVT (fed)	Part of Farallones National Marine Sanctuary
LiMPETS	NP/GOVT (fed)	Collaboration of NOAA Sanctuaries and Pacificw Grove Museum of Natural History.
Beach COMBERS	NP/GOVT (state)	Hosted by CA Department of Fish and Wildlife
CA King Tides	NP/GOVT (state)	chapter of international network, run partly on staff time from state agencies.
Beachkeepers	NP	Program of Save our Shores, a locally-based environmental nonprofit (eNGO)
Black Oystercatcher Monitoring	NP	Program of Audubon CA, chapter of a national eNGO
Blue Water Task Force	NP	Program of a international eNGO Surfrider Foundation
Coastal Watershed Council (multiple programs)	NP	Local eNGO houses chapters of larger data collection efforts
Collaborative Fisheries West	NP	State-supported and -created nonprofit
iNaturalist	NP	Hosted by the California Academy of Sciences
Lighthawk	NP	Independent international eNGO
Morro Bay National Estuary Program Volunteer Monitoring Program	NP	Collection of research programs directed by a local nonprofit with strong ties to government
MPA Watch	NP	Program of Otter Project, a local eNGO. Member of statewide network
REEF	NP	Standalone global eNGO; informal affiliation with UCSD
Reef Check CA	NP	Affiliated with Reef Check Worldwide, informal hosting by UC Santa Cruz.
Shorebird Monitoring (Morro Bay)	NP	Organized by Audubon California, part of national eNGO



LiMPETS

Most of the programs we examined in the Central Coast are run within nonprofit organizations, and there are very few programs that constitute standalone organizations devoted solely to advancing one or more citizen science efforts. The count of standalone organizations is difficult because some groups start as independent and become affiliated later or vice versa (for example, LiMPETS started as a faculty research program and is now a partnership of federal and nonprofit organizations, and California Academy of Sciences recently purchased iNaturalist). The relative absence of standalone organizations suggests that strong links to partner, host, or parent organizations are extremely important for Central Coast citizen science groups. These links can be a source of financial, human, or other resources. They also place data gathering in the context of a larger scientific or advocacy mission.

The overall picture of organizational structures among Central Coast citizen science groups suggests that partnerships and networks are the norm. Staff must be creative in leveraging resources across the various organizations involved in order to get things done. This may be quite promising for natural resource managers considering partnerships. But it is worth considering that each partnership comes with a set of priorities and expectations–transaction costs that must be balanced across the organization.

Reliance on partnerships and networks may mean that citizen science groups are particularly sensitive to shifts in the funding landscape. Relying on bits and pieces from multiple organizations can make it difficult to strategize and prioritize internally. There are clear examples of robust long-term monitoring within the Central Coast citizen science community. But we did not find evidence that long-term sustainability is any less of a challenge for citizen science than for monitoring efforts in other organizations.

TANGIBLE NEEDS

While funding is an ongoing need for many citizen science groups, some creative programs manage to sustain themselves largely on donations of equipment and in-kind support. Funding can come in a variety of forms, including government and foundation grants, crowd-funding, private donations, membership fees, and contracts with data users.

Below we describe some of the resources that groups use to maintain program capacity, drawn from our interviews, focus groups, and workshop with Central Coast citizen science groups. In asking people to reflect on their program, some of these resources are considered critical and others 'nice to have'. These designations vary in different programmatic contexts. The most urgent or critical needs groups expressed were most often support for volunteer coordinator staff and data management capabilities.

Physical Capital

Many of the physical needs of citizen science mirror those of academic science—equipment, student help, training materials, etc.—and are perhaps the easiest to acquire. However, there are some unique needs related to the structure of citizen science.

Existing outside of formal science infrastructure, for example, means that many citizen science programs must work to find laboratory space, do not have a grant and budget office, and do not have institutional subscriptions to data analysis software. Citizen science groups that perform ecosystem monitoring need large quantities of relatively simple items (like sample jars) to support many volunteers taking data year after year—a request that is not favorable to many funders.

Human Capital

The kinds of expertise required for citizen science are more diverse than in academic science. Program coordinators at the workshop stressed that while academic science uses graduate students to fill many roles within a scientific program, citizen science needs administrative, not scientific skills in some of its staff members. The volunteer coordinator, for instance, needs to be a professional skilled in dealing with people and maintaining strong lines of communication among all program members.

VOLUNTEER RECRUITMENT AND RETENTION

While tangible resources will keep a program running, citizen science still fundamentally relies on the energy of volunteers. This particular form of human capital deserves special attention.

Volunteer motivations can vary widely, even within a single program. For citizen science groups, volunteer recruitment and retention is every bit as important as maintaining financial resources, and should be documented similarly. For natural resource managers, volunteer energy should be considered in assessing a program's credibility and the potential for a long-term partnership. Managers should also consider what they themselves have to offer in terms of increasing volunteer motivation alongside any other resource contributions.

Natural resource managers may not be accustomed to worrying about whether science partners are reaping personal benefits while collecting data, but for the managers of citizen science projects, this is a central concern. To build a successful partnership, managers must understand how a program creates enjoyment for its participants. This may constrain or enhance the level of scientific complexity that the program can achieve. It also relates directly to the program's resource needs. This may mean that program support budgets need to include money for pizza for an annual dinner. It may also mean that partnering with a citizen science group involves providing support for the less-fun aspects of science, like data entry and analysis, in return for the extensive in-the-field capacity for data collection.

Looking Forward

When considering the challenge of implementing cost-effective, sustainable, and rigorous MPA monitoring, it is extremely encouraging to find that citizen science represents a range of motivated, capable, and experienced potential partners. Of course, we also found that citizen science is extremely diverse, and broad generalizations are dangerous.

Managers looking to partner with citizen science groups need to understand that getting citizen science done is a different practical and institutional problem than getting traditional academic science done. We can have good partnerships if we explicitly acknowledge that. And we must work to promote mutual understanding and shared expectations around issues such as credibility and operational needs.

In the months and years ahead, the Ocean Science Trust will continue to foster innovative partnerships, and explore the potential for many kinds of knowledge producers to play a productive role in MPA monitoring. This will mean continuing to engage the Central Coast citizen science community, while also translating what we have learned here to other regions.

RESOURCES THAT CITIZEN SCIENCE GROUPS AND THEIR VOLUNTEERS RELY ON TO SUSTAIN THEIR PROGRAMS.

Physical Capital

Aid for needy volunteers (e.g. for computer access and transport)
A data management system and storage*
Curriculum for teachers and informal educators to make use of the data
Training materials for data collection
Boat time, gas, and insurance
Resources for recruiting
Field supplies (like a slate, binoculars, camera, measuring tape, GPS)
Supplies for more complicated sample analysis (if not observation-based)
Quality assurance/quality control testing
Smartphones or tablets for direct data entry
Support for social events and community-building activities
Data analysis and visualization tools
Software licensing largely for data analysis and communication
Liability insurance

Human Capital

A professional science partner or science advisory team
A data manager, analyst or statistician
A communicator focused on education, outreach, and publicizing results
Event planning capacity (parties, campaigns, workshops)
A volunteer coordinator (regionally preferred to allow face-to-face time)*
A web and/or app developer
Substitute volunteers or staff flexibility to fill in holes in regular monitoring schedule
Program evaluation capacity

Volunteer Recruitment and Retention

Being connected with a community*
Knowing that the data is used to make a difference*
Charismatic leadership
Feedback from program staff to volunteers
Being part of new science, developing scientific information*
Expressing interest in the beach and ocean*
Taking ownership of local nature
Participating in a fun activity; making an enjoyable activity constructive
Fostering a connection to an animal
Educating others about the environment
Learning scientific skills; practicing methods
Maintaining a connection to science, especially field-based science
Helping the environment, participating in 'something bigger than myself'*
Answering a question from the community
Competition
Having an activity to do on your own

* *Items commonly deemed important by Central Coast citizen science groups*

High school students collect data with LiMPETS.