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# How establishing a marine protected area network has shaped community and citizen science along California's coast

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Community and citizen science (CCS), the involvement of non-professional scientists in research and monitoring, has emerged as a key approach in tackling marine conservation issues. This has been evidenced especially in various monitoring efforts of marine protected areas (MPAs) with increasing involvement of CCS programs in contributing data used by MPAs in their adaptive management processes. Having recently engaged in its decadal management review process, this study focuses on the implementation of California's MPA Network through an examination of the diverse impacts to CCS programs. Through an analysis of survey and interview data provided by leaders representing 12 CCS programs in addition to 13 members of the MPA State Leadership Team, we report on the varied impacts to a diverse set of CCS programs and explore how the relationships between MPAs and CCS in California have evolved over the past 10+ years. We found that regardless of State funding eligibility or receipt to participate in MPA monitoring, all 12 CCS program leaders reported overall increases or growth to their programs across all six focal impact type categories (participants, data, programmatic elements, finances/funding, and staff/partners). Additionally, MPA leaders shared perspectives on the evolving role of CCS, emphasizing the importance of collaboration and data alignment. These findings suggest that continued support for the collaborative MPA-CCS relationships could yield further mutual benefits for both the growing use and utility of CCS and its role in MPA implementation and marine conservation more broadly.

# 1 Introduction

The need for sustained monitoring in support of adaptive management has been a persistent challenge in marine conservation. To meet this challenge, many have pointed to community and citizen science (CCS) as a promising approach (Cigliano and Ballard, 2017; Aceves-Bueno et al., 2015; McKinley et al., 2012). We use the term community and citizen

science to refer to a broad range of ways in which people who do not self-identify as professional scientists may become involved in research and monitoring, often as volunteers. CCS can take many forms, from global technology-enabled crowdsourcing to hyperlocal community-led projects (Bonney et al., 2014). Though it has lagged behind the terrestrial domain (Theobald et al., 2015), marine-focused citizen science has been increasing rapidly across a wide range of topics (Cigliano and Ballard, 2017; Cigliano et al., 2015; Garcia-Soto et al., 2021).

Beyond the obvious appeal of volunteers collecting data, which may be cost-effective, CCS may help to meet other conservation goals related to outreach and education, or encouragement of stewardship behavior (Jordan et al., 2011; Ballard et al., 2018). Furthermore CCS can help to strengthen connection to place (Newman et al., 2017), and expand the network of partners working together on conservation issues. CCS projects – especially those based outside of academia – may face particular challenges in developing and maintaining technical capacity for practices such as data quality assurance and quality control, and data management and analysis (Freitag et al., 2016). However, there are also many examples, including in the marine environment, where such obstacles have been overcome, and CCS programs have contributed highly rigorous and useful data (McKinley et al., 2017; Aceves-Bueno et al., 2015; Cigliano and Ballard, 2017).

The insights described above point to a broad appeal, and great potential for using CCS in support of marine conservation and adaptive management. The study we report on here inverts this perspective by focusing on how CCS has been impacted by the implementation of marine protected areas (MPAs). In other words, when conservation partners explicitly include CCS as part of a monitoring strategy, what does this mean for CCS capacity in the coastal areas where such policies are taking effect? Identifying and addressing the unique challenges and best practices for supporting CCS as part of a larger marine conservation strategy is a crucial, but seldom acknowledged issue. An empirical focus on the ways in which CCS capacity evolves in response to policy, funding and other forms of support can yield practical insights for conservation managers and policy makers, and for CCS practitioners themselves, about how best to best leverage the opportunity of public participation in research and monitoring.

Our study focuses on California's MPAs in state waters, which in 2023 underwent an official decadal management review, marking the ten year anniversary of the full implementation of the network of 126 MPAs. As we describe in further detail below, California's MPA network has from the beginning included CCS as one component of a broader monitoring strategy. Our study looks back at 10+ years of the network's implementation leading up to the decadal management review and asks: what has the existence of MPAs meant for marine and coastal CCS in California? How have CCS programs changed in response to California's MPA monitoring approach, and what opportunities and challenges does that raise for long-term implementation? Our study

addresses these questions by hearing directly from people responsible for implementing and managing MPAs as well as CCS project leaders. Our mixed methods approach, involving surveys and interviews exploring the perspectives of CCS project leaders and partners involved directly in MPA implementation offers nuanced understanding of the relationship between MPA and CCS, and has broader implications for funders, practitioners, and other research focused on CCS in conservation.

## 1.1. Background on Community and Citizen Science and Marine Protected Areas in California

Since 2007, under the auspices of the Marine Life Protection Act (MLPA), the California Department of Fish and Wildlife (CDFW), California Ocean Protection Council (OPC), and the California Fish and Game Commission have collaborated to manage California's MPA Monitoring Program. The MLPA also points to the crucial role of collaborative work with state and federal agencies, private funders, and other organizations (Kirlin et al., 2013), and the core implementing agencies pursue this work through mechanisms such as public-private partnerships, funding for monitoring and other initiatives, and a high-level Statewide Leadership Team.

The MLPA calls for adaptive management of the full network of MPAs, for the benefit of ocean health (as opposed to individual targeted species), both inside and outside of MPAs. Monitoring has been a crucial component of the highly complex task of measuring progress toward these objectives. The state has invested millions of dollars in monitoring projects across a wide range of disciplines and focal areas, during an initial Baseline Monitoring phase and subsequent Long-Term Monitoring program (CDFW, 2022). A notable feature of the state's approach to MPA monitoring has been the emphasis – from the beginning – on CCS approaches that can integrate with, or supplement traditional professionalized approaches.

The advent of MPAs in California, with CCS as a key feature of the monitoring strategy, has created a valuable opportunity for learning about the interactions between CCS projects, policy and management, and other partners such as universities and advocacy organizations. CCS has played a prominent role in monitoring the California coast for many years preceding MPA implementation. Programs such as LiMPETS, Beach Watch, Grunion Greeters, and others have been mobilizing volunteers to collect high quality data about diverse ocean-related topics, in some cases for more than a decade before implementation of California's MPA network. Other CCS projects, such as MPA Watch and Snapshot Cal Coast, were created specifically to aid in the implementation of MPAs. Many programs received state funds, and others organized their activities around MPAs, even without receiving state funds. In a recent assessment prepared for state management agencies, it was found that at least 84,000 people contributed roughly half a million volunteer hours to state-funded CCS projects. CCS contributed large amounts of data, but also to other management objectives such as outreach and education, policy and permitting, and enforcement and compliance (Meyer et al., 2022). Although the MLPA does not include explicit language regarding individual or

community involvement in MPA monitoring or other conservation efforts and activities, CCS has emerged as a reliable solution to address and satisfy capacity-related needs for data collection.

The above-mentioned assessment (Meyer et al., 2022) focused on CCS contributions to MPA management in California. Here we report on our study of how MPAs have impacted CCS. We theorized that the advent of California's MPAs would impact CCS programs in ways that extend well beyond a simple opportunity to expand in response to increased funding. Some programs received funding, while others did not. Some were directly partnered with academic institutions, while others operated more independently. Some were created specifically in response to MPA monitoring plans, while others pre-dated the program. This provides for a variety of cases, under the single policy umbrella of the MLPA. In our surveys and interviews of agency personnel and program leaders, we investigated both qualitative and quantitative measures of impact, aiming to understand how things have evolved during the period leading up to the Decadal Management Review (DMR) of MPAs, which occurred in 2023.

# 2 Methods

We utilized a mixed-methods approach to obtain a comprehensive understanding of the nature and extent of policy impacts observed by CCS program leaders, and by MPA leaders involved in planning and decision-making. We conducted an online survey of CCS program leaders followed by semi-structured interviews to qualitatively deepen our understanding of survey results. MPA leaders also participated in a set of semi-structured interviews. This research was declared exempt indicating minimal risk to participants by the Institutional Review Board of the University of California, Davis (IRBNet #1740875-2).

## 2.1 Study participants

### 2.1.1 CCS program leaders

To gain a broad understanding of how MLPA has impacted CCS programs, we wanted to hear from CCS program leaders with varying degrees of formal ties to state-funded MPA monitoring, and diverse structures of CCS implementation. Drawing from Meyer et al. (2022), we identified leaders of marine and coastal CCS programs active within or near California MPAs (Table 1). Six programs were identified as having received funding from State agencies to participate in baseline and/or long-term MPA monitoring activities, three of which were newly created or initiated along with MPA implementation. The other six were among a list of identified program contacts involved in coastal/marine CCS that did not receive any MPA-related funding from State agencies, but which conducted monitoring activities within MPA boundaries. We invited all twelve to participate in the study, and all accepted.

TABLE 1  Overview of CCS program leader participants' affiliated programs.

| | | Program Name | General Description of CCS Activities |
|---|---|---|---|
| State — Funded Programs New with MPAs | | Snapshot Cal Coast | Volunteers attending bioblitz events share observations of biodiversity in sandy beaches and rocky intertidal ecosystems. |
| | | California Collaborative Fisheries Research Program (CCFRP) | Commercial passenger fishing vessel captains and recreational anglers conduct hook and line surveys of fish communities. |
| | | MPA Watch | Volunteer surveyors monitor the human uses of coastal and marine resources. |
| State — Funded Programs Pre — Existing MPAs | | Long-term Monitoring Program and Experimental Training for Students (LiMPETS) | Middle and high school students monitor Pacific mole crabs (sandy beach) and key invertebrate and algae species (rocky intertidal). |
| | | Beach Watch | Trained volunteers survey live and dead species of birds and marine mammals along with human activities along the coast. |
| | | Reef Check California | Experienced divers monitor rocky reef and kelp forest communities. |

*(Continued)*

**TABLE 1  Continued**

| | Program Name | General Description of CCS Activities |
|---|---|---|
| Non State – Funded Programs | Grunion Greeters | Trained volunteers monitor beaches at night to observe and report grunion spawning. |
| | Crystal Cove Conservancy | Students monitor the Crystal Cove State Marine Conservation Area aboard a fishing vessel. |
| | Black Oystercatcher & Snowy Plover Monitoring Project (Monterey Audubon) | Volunteers monitor breeding Black Oystercatchers and nesting Snowy Plovers throughout Monterey Bay. |
| | BeachCOMBERS | Trained volunteers survey beaches from Santa Cruz to LA County to track seabird and marine mammal mortality. |
| | Stewards of the Coast and Redwoods | Volunteers monitor seabirds and pinnipeds throughout Sonoma Coast State Park. |
| | Multi-Agency Rocky Intertidal Network (MARINe) Seastar Wasting Disease Observations (SSWD) | Volunteer observers document and report the distribution and health of sea stars along the West Coast. |

## 2.1.2 MPA leaders

The statutory authority for implementing MPAs lies formally with the California Department of Fish and Wildlife, with regulatory oversight by the California Fish and Game Commission. However, as described above, a much broader coalition of partners is involved in MPA implementation. To ensure we obtained a broad perspective from across these agencies, MPA leaders were identified from within the MPA Statewide Leadership Team (MSLT) Working Group, which is composed of representatives from key partner organizations, agencies, and Tribes central to the successful implementation of California MPAs. The MSLT Working Group coordinates closely with the MSLT Executive Committee to identify and assess MPA-related tasks, projects, and priority work areas and outcomes, making recommendations to decision makers as appropriate. A list of moderate to highly engaged MSLT Working Group representatives was provided by the (now former) Senior MPAs Program Manager with the OPC. This list included contacts from 16 partner organizations, agencies, and Tribes, all of whom were invited to participate in an interview. Based on timing and availability, a total of 13 MSLT Working Group representatives participated in interviews.

## 2.2 Data collection

### 2.2.1 Survey and interviews with CCS program leaders

#### 2.2.1.1 Survey design and data collection

In order to investigate the nature and extent of the impacts of California MPAs on CCS programs, we developed a survey to elicit CCS program leaders' perceptions of this question. We used the survey to identify some impacts that could be quantified and compared across programs, and lay groundwork for semi-structured interviews that could draw out additional qualitative insights about policy impacts. The survey questionnaire was developed and shared between May and July 2022 using Qualtrics software. The instrument contained 19 to 20 items depending on the logic and branching of items based on responses of participants. The questionnaire included primarily closed response items and a

few open response items exploring the goals of CCS programs, the relationships between CCS programs and the MPA Network, and the ways CCS programs were impacted by California MPAs. In order to examine directly impacts that the key goals of the MPA program might have on CCS, survey items were developed largely based on the context of the MLPA Goals and pillars of the MPA Program in addition to common CCS activities and practices prevalent in California coastal and ocean monitoring as characterized by Meyer et al. (2022). The four pillars of the MPA Program focus on Research and Monitoring, Enforcement and Compliance, Outreach and Education, and Policy and Permitting while the six MLPA Goals include:

1. Protect the natural diversity and abundance of marine life, and the structure, function and integrity of marine ecosystems.
2. Help sustain, conserve and protect marine life populations, including those of economic value, and rebuild those that are depleted.
3. Improve recreational, educational and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.
4. Protect marine natural heritage, including protection of representative and unique marine life habitats in CA waters for their intrinsic values.
5. Ensure California's MPAs have clearly defined objectives, effective management measures and adequate enforcement and are based on sound scientific guidelines.
6. Ensure the State's MPAs are designed and managed, to the extent possible, as a network.

Additionally, the survey included questions and items about impacts related to participants, data, programmatic elements and protocols, financials, and program staff and partners.

#### 2.2.1.2 Interviews with CCS Program Leaders

As a follow-up to the survey to provide more depth on the reasons and ways CCS Program Leaders work with the MPAs, semi-

structured interviews were conducted with the 12 CCS program leaders who completed surveys and were available to participate. This step helped to contextualize survey responses, drawing out additional detail about the reported impacts, and information about other potentially confounding factors that might be at play, beyond the implementation of California MPAs. Interviews took place between July and September 2022 and were conducted remotely via Zoom video conferencing software. Interviews lasted 45 to 90 minutes, and involved questions regarding both individual and programmatic engagement with CCS and MPA monitoring. Other questions focused on specific examples and targeted follow-up questions to their specific responses to survey items about how their programs were impacted by California MPAs. For example, each participant was reminded about their survey responses and then probed to share more about how their CCS program had been impacted by MPAs in three key areas: People (staff, participants, partners), Programmatic Elements (methods, QA/QC, reporting, funding), and Applications (MPA monitoring, informing other conservation management processes).

### 2.2.2 Interviews with MPA leaders

In order to hear the perspectives and detailed explanations about how they view CCS programs and data, we conducted interviews with the 13 MSLT Working Group representatives (MPA Leaders) who were available and agreed to participate. These were conducted between June and August 2022, and lasted approximately 45 to 120 minutes. Interview questions focused on involvement in various aspects of MPA monitoring and decision-making as well as perceptions of how different CCS programs were impacted by California MPAs. Some examples of interview questions asked include:

- Can you describe the State's strategy for including CCS in funding for baseline and long-term monitoring, and how that has evolved?
- How have the relationships between CCS programs and MPA management changed over the last decade?
- What specific changes have you seen CCS programs make as they contribute to MPA monitoring?

## 2.3 Data analysis

### 2.3.1 CCS program leader survey data analysis

Trustworthiness measures of validity of the survey instrument were determined by internal measures (Creswell, 2017). Internal validity was determined by an expert review panel performed by six social science researchers who specialize in community and citizen science research. The survey was shared with 74 CCS program leaders and received 27 responses for a response rate of 36.5%. However, our goal was to generate a single authoritative response from each of the programs representing recipients of our survey request. Of the 27 responses, six were removed from analysis for being incomplete with less than half of the items being addressed

and one was removed as no CCS program was named or identified by the individual who completed the survey. An additional five responses were removed from analysis as they were identified as replicates from within the same CCS programs. That is, only one response per program from the leader identified to have the broadest spanning purview of program and organizational impacts within a given CCS program was considered and used for analysis. This included a total of 15 responses that were analyzed, however, the present study focuses on data provided by 12 program leader respondents based on their availability to participate in a follow-up interview (as described in the subsequent section) in order to keep samples consistent across data sources. Survey data were analyzed quantitatively using Microsoft Excel to calculate descriptive statistics across survey item responses. The reliability of Likert-type items was determined by calculating Cronbach's alpha values for each item as well as the overall Cronbach's alpha values for each impact type category. Cronbach's alpha is a commonly used statistical calculation that examines the internal consistency of reliability of summated rating scales, such as Likert-type items, based on a function of the number of items and the average inter-correlation among the items (Cronbach, 1951).

### 2.3.2 Interview data analysis

Interviews with both CCS program leaders and MPA leaders were audio recorded in addition to detailed notes taken during the interview. All interview notes were analyzed qualitatively following a codebook thematic analysis approach as described by Braun et al. (2019) via Dedoose 9.0.107 (a qualitative data analysis software). This approach involved a largely targeted coding process using a set of predefined impacts as described in Table 2. These impact type categories were reflective of the thematic categories of survey instrument items that were posed to CCS program leaders. The codebook was developed to align closely with the impact-type categories that were included in the survey instrument with an additional code of an impact type category being identified during the coding process. The coding process included reviewing the detailed interview notes documents for each interview to apply relevant codes from the codebook of impact types based on participants' responses to the interview questions. The same codebook was used to analyze interview notes for both CCS program leaders and MPA leaders, and the process was completed with each set of interview notes documents being reviewed and coded twice. To ensure validity and reliability, all three co-authors collaboratively developed the survey instrument and interview guides, and two of the co-authors collaboratively developed the codebook. These two co-authors then conducted an initial round of coding the same three sets of interview notes to check for and ensure agreement of consistent and appropriate coding.

## 3 Results

Analyses of data obtained via interviews with MPA leaders along with the interviews with and surveys completed by CCS Program Leaders revealed a number of trends and themes regarding the varied

TABLE 2 Codebook of impact type categories.

| Impact type category | Definition |
|---|---|
| Participants | Any changes regarding participants, including number of participants, participant recruitment training and retention, or roles that participants play in research/monitoring. |
| Data | Any changes in the scope of data collection (e.g. number of phenomena such as species, parameters) observed or measured by participants, total amount of data collected, QA/QC (measures taken to ensure credibility and high quality of data), and/or peer-reviewed products generated by or making use of a program's data. |
| Program | Any changes in the number of monitoring sites, geographic scope or range of activities, depth of initial training required for participants, number of follow-up participant trainings or refreshers, and/or marketing and communication about a program. |
| Finances/Funding | Any changes in the dollar amount of funding received, number of funding opportunities eligible to receive, and/or program operating costs. |
| Staff/Partners | Any changes in the number of staff required to implement the program and/or the number of program partners and partnerships. |
| Other | |
| Additional Codes | |
| Forces Causing Changes | Discussions of changes (past, present, or future) that are relevant to CCS, but not linked explicitly to an impact for a specific program. |

ways that California's MPA Network has impacted CCS programs and their participants. As indicated in the survey findings and elaborated upon during interviews, CCS program leaders indicated no decreases to program-related elements or factors across all impact types. Interviews conducted with MPA leaders revealed perspectives from those involved in statewide MPA policy and activity planning processes on the varied ways they saw California MPAs impact CCS programs over time. Some of these insights aligned well with the data provided by CCS Program Leaders, while others raised new points or suggested gaps in mutual understanding, which are highlighted in the following sections.

## 3.1 CCS program leaders' perspectives on impacts of MPAs on CCS

### 3.1.1 CCS program leader survey findings

We found through our analysis of survey data that CCS Program leaders report overall positive impacts of working with MPAs across the broad categories we asked about (impacts on participants, on data quality, on programs, on finances, and on staff/partners) (Table 2). Overall results regarding the extent different program-related elements or factors were impacted in terms of increasing or decreasing as a result of California MPA implementation are summarized in Figure 1. Notably, none of the CCS program leaders reported any decreases, or what could be perceived to be negative impacts, to elements of their CCS programs as a result of the introduction of California's MPA Network. All of the responses provided by program leaders indicated either no change, or an increase or expansion of activity across all categories. Looking more closely, we saw that leaders of CCS programs that received State funding reported proportionally more increases across impacts compared to those that did not receive State

funding as highlighted in Figure 2. Finances/Funding and Staff/Partners were the two categories that program leaders believed had been impacted the most in terms of increases to aspects related to these programmatic elements based on a proportional comparison across categories. That is, these two categories had proportionally fewer respondents indicating no change (neither increases or decreases) compared to the other impact categories. More detailed findings of individual survey items associated with each impact type category can be found in Supplementary Material A.
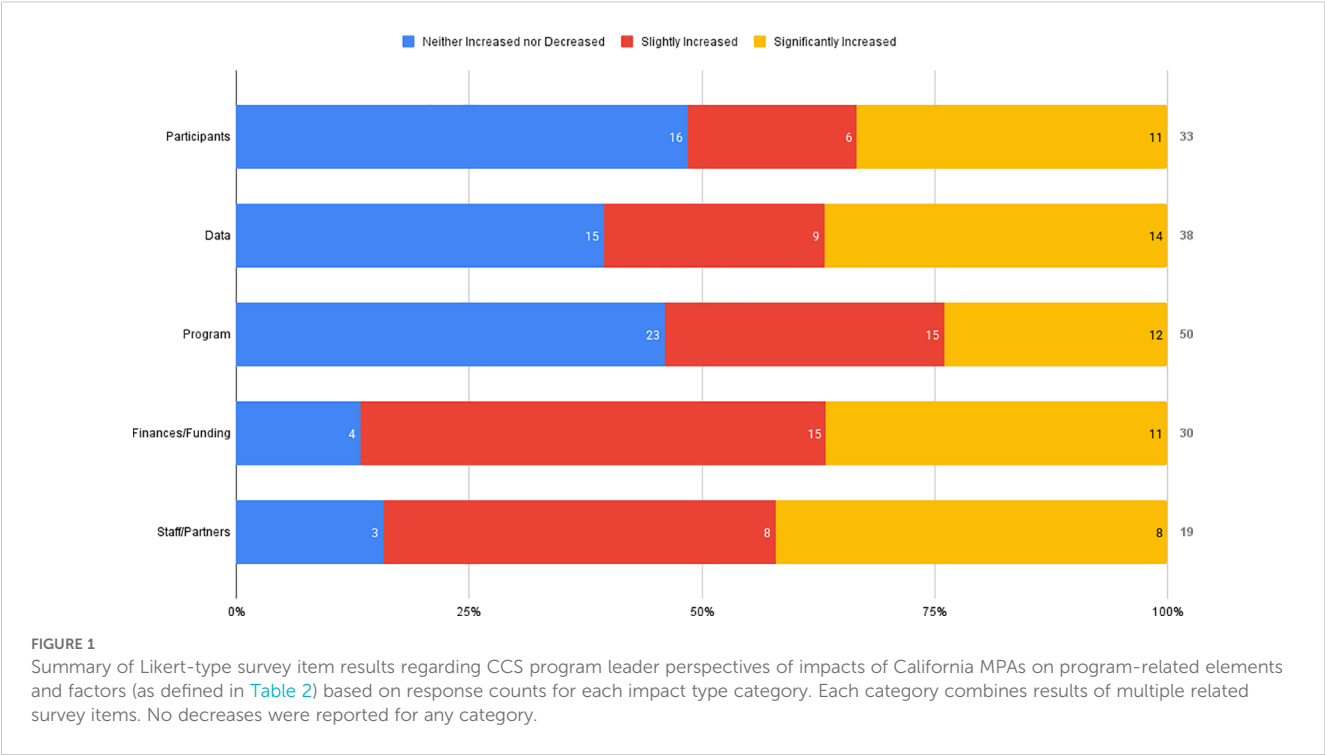
### 3.1.2 CCS program leader interview findings

Interviews with a subset of CCS program leaders who filled out the survey provided additional information, context, and examples of the ways their programs were impacted by California MPAs, adding nuance to the quantitative survey results. In some cases, interview responses expanded our understanding of the types of impacts that resulted from MPA implementation around the 4 main categories of participants, practices, finances, and staff and partnerships.

#### 3.1.2.1 Impacts of MPAs on participants

When asked if and how their program's participants had been impacted by California MPAs, some program leaders felt that increased awareness of and interest in the MPAs helped their programs attract, recruit, and work with more participants. For example, the leader of Reef Check California, a program that engages experienced SCUBA divers to monitor rocky reef and kelp forest communities, noted that since their establishment MPAs generally received a lot of notice and interest from the diving community, which helped to add numbers to their network of participants:

"There was just a lot of public attention on MPAs, which I think also has kind of subsided a bit. That definitely helped in recruiting volunteers and demonstrating to them the need and usefulness of

**FIGURE 1**
Summary of Likert-type survey item results regarding CCS program leader perspectives of impacts of California MPAs on program-related elements and factors (as defined in Table 2) based on response counts for each impact type category. Each category combines results of multiple related survey items. No decreases were reported for any category.
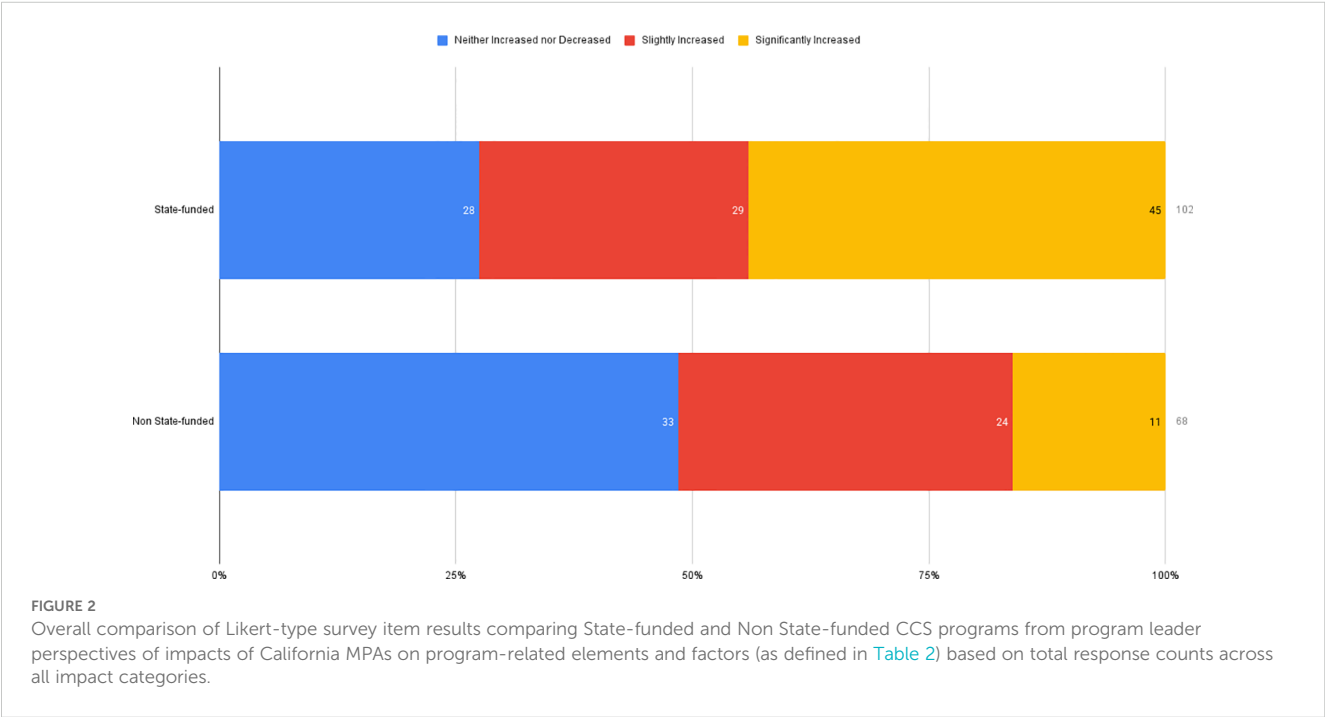
the information they collect. I think that has changed since now the MPAs are not that big of a story anymore, and other things have become more important." -Reef Check California Program Leader

This insight points to both the power of MPAs as a potential driver of CCS participation apart from direct funding, and the reality that this may ebb and flow over time.

### 3.1.2.2 Increasing capacity and evolving practices

Many program leaders pointed out the correlations among different measures of capacity and activity. With many programs expanding their geographic scope, and/or adding more participants, this of course led to, for example, the collection of a higher overall quantity of data. Interviews helped to uncover instances where



**FIGURE 2**
Overall comparison of Likert-type survey item results comparing State-funded and Non State-funded CCS programs from program leader perspectives of impacts of California MPAs on program-related elements and factors (as defined in Table 2) based on total response counts across all impact categories.

programs, in addition to increasing their activities, also adapted their activities in response to MPAs.

For example, MPA implementation appears to have had data-related impacts beyond the scale of data collection. CCS program leaders described ways in which California MPAs caused them to internally review and update some of their own practices regarding data management and data integrity. A leader with MARINe Seastar Wasting Disease Monitoring, a program that involves volunteer observers documenting and reporting the distribution and health of sea stars along the west coast, described how their program reviewed and improved the attention they gave to metadata and overall data integrity:

"Being involved with the MPA Program really forced us to create good metadata for all of our data because there was that requirement to do that in a systematic way for all our groups. So that's something again that probably would have happened anyway, but it's nice to be forced to do something on some timescale. I think that was kind of another key bit in terms of data integrity." -MARINe Seastar Wasting Disease Monitoring Program Leader

Another example is in training of participants in a CCS program. For some programs, updated and more frequent training sessions were necessitated due to changes made to data collection methods, protocols, and instruments. The leader of Beach Watch, a CCS program that began in the early 1990s and trains volunteers to survey live and dead species of birds and marine mammals along with human activities along the coast, described what some of these programmatic changes looked like within their program:

"We had an increase in training specific to state MPAs. Our data sheets changed pretty dramatically with different codes but also just continually bringing in that awareness [of MPAs]. You know, [participants] are volunteering for a federal monitoring program as well as contributing to a state monitoring program, so we have more evening lectures that engage our volunteers and some of them may focus on one subject area or the other, and obviously there's overlap." -Beach Watch Program Leader

### 3.1.2.3 Impacts on finances

Funding impacts, referenced to some extent by all program leaders interviewed, extended well beyond the MPA-specific funding provided by state agencies. Some explained that the establishment of the MPAs introduced a topical focus with which their programs could align to attract private or external funders. For example, the LiMPETS program, in which middle and high school students monitor Pacific mole crabs on sandy beaches and key invertebrate and algae species within the rocky intertidal, noted:

"We were more enticing to funders. That was mostly when we were applying for different grants, like B-WET grants or like a Packard Foundation grant. You become more enticing when you say 'oh we are using this funding to monitor MPAs and compare data in and around MPAs.' So that also helped." -LiMPETS Program Leader

This points to a potential positive feedback loop between state funding and other sources of funding, all feeding into capacity that is brought to bear on MPA monitoring. Another program leader

mentioned that their program, and the budget line for the leader's specific position, received funding support from federal government agency-level partners wanting to support monitoring activities benefitting California MPAs:

"As far as funding, BOEM [Bureau of Ocean and Energy Management] is probably the largest single contributor of funding to the BEACHCombers program, and they paid for a portion of my salary to manage that … so if they're seeing contributions of citizen science programs to the priorities of the MPA Program, then they're probably more inclined to maintain or potentially increase funding." -BeachCOMBERS Program Leader

### 3.1.2.4 Impacts on staff and partners

Along with examples of increased funding and opportunities for funding, a number of program leaders also noted the ways their personnel and partnerships had grown due to MPAs. Some programs and teams were able to increase the capacity of paid staff, and most described how their networks of partner organizations, communities, and agencies had continued to grow and broaden along with the implementation of the MPA Network. The leader of the Multi-Agency Rocky Intertidal Network (MARINe) Seastar Wasting Disease monitoring, which employs the efforts of volunteer observers to document and report the distribution and health of sea stars along the west coast, said, "[We have seen] retention of staff, and in a broader sense an expansion of MARINe partners. I know up on the North Coast there was more engagement of at least one Tribe."

Another program leader described more specifically the ways in which their program's team and broader network was afforded to grow alongside MPAs. In the context of the Crystal Cove Conservancy, whose CCS activities involve students heading to sea aboard a fishing vessel to monitor the Crystal Cove State Marine Conservation Area along the coast in Southern California, the leader shared these impacts to staff and partners:

"Our numbers are naturally rising as we grow our staff, as we grow the support that we need on the back end to be able to finance things. But also as we grow our network between not just teachers but also our partners that we kind of meet through the MPA Network … I think where our strength lies is the fact that we have partnerships not just in academia or out in our fields through informal education and educators in schools" -Crystal Cove Conservancy Program Leader

## 3.2 MPA leader interview findings

In contrast with the specific, concrete examples described above, the interviews conducted with MPA leaders understandably yielded high-level insights about the evolving role of CCS in MPA implementation, and the impacts that MPAs have had on CCS programs. For the most part, MPA leaders indicated they were not involved in (or aware of) the day-to-day implementation of CCS projects, and learned about CCS through sources such as project reports, comments at public meetings, or in some cases through applications for funding. They seemed to express that much of their

relationships with CCS programs were fostered through the alignment of data collection methods/protocols for their specific needs, sharing of data, and/or applications and awards of funding, and over time, the relationships with specific programs have greatly deepened and strengthened while others remain more peripheral or indirectly related to the MPA Program.

### 3.2.1 Increased funding and stronger relationships

Many MPA leaders referenced the role that funding has played in the growth and success of CCS involvement in MPA monitoring. One member of the MSLT described the role of State funding in not only contributing to successful monitoring programs, but also aiding in the strengthening of relationships and partnerships between CCS programs and MPA leadership, which is a core value of the MPA program writ large:

"[The program] has worked with the State to really improve how they contribute to MPA monitoring, and a lot of funding has come from OPC to do so ... it's also a situation where we are like 'hey, we need you to do this, so here's funding to do so'...so the relationship there has really blossomed."

### 3.2.2 Protocols and data reporting

In a few interviews, MSLT members focused on data integrity and reporting, describing active efforts to ensure CCS program data collection methods and protocols were sound. Beyond data quality and rigor, MSLT members also felt that data utility could be enhanced through improvements in how data are displayed and reported. One MPA leader described their general role in working with CCS programs to gather and provide relevant data:

"We've made suggestions to them and they've changed some of the things they do ... their reports and their data ... we've had this interaction like 'well, if you were to create a certain graph or show the data like this, that would be much more informative'...and the number of sites inside and outside [of MPAs] being replicate ... we kind of talked in the past a lot about going over the same sites outside the MPAs as they were inside."

This notion of CCS programs making changes or updates to protocols and data collection and reporting instruments was similarly noted by other MPA leaders who were not necessarily considered to be direct "users" of the monitoring data collected by CCS programs. One representative commented on the case of a specific CCS program and the changes they made to some of their data practices. They shared:

"Specific changes to protocols in the case of [CCS program] ... I know there have been changes made to both the kind of data form and also particularly the reporting format that's provided to state managers to better meet their needs ... also many conversations about [data type] ... how that gets reported and how it's described."

## 4 Discussion

Our findings shed new light on our questions about how California's MPAs have influenced or shaped CCS programs, and what lessons have been learned that could help better plan and utilize CCS in MPA monitoring moving forward. Based on the perceptions of CCS program leaders, California MPAs have not only allowed CCS programs to continue their activities and contributions, but in many cases increase or expand them. This is reflected in survey responses, which all, regardless of State support, indicated either no changes or increases related to people, data, programmatic elements, and funding. Further, there appears to have been a broad-based increase in CCS capacity in response to MPAs, regardless of direct funding from the State. This suggests a valuable positive feedback loop between conservation policy and management and CCS, where CCS not only contributes to conservation policy and management (McKinley et al, 2017) in terms of the capacity that MPA partners can leverage in future years, but MPAs also foster CCS capacities

The structural diversity of CCS programs, and our mixed methods approach, allowed us to dig into the nuances of conservation policy impacts on CCS. The programs we examined varied in their scope of inquiry, model and approach to data collection, geographic range of sites, frequency of participant monitoring, level of training required, communication and engagement level with participants, funding structure and eligibility, among other factors. While this study does not include an exhaustive analysis of the ways in which all marine and coastal CCS programs active along the California coast have been impacted or shaped by the MLPA and implementation of the MPA Network, it provides a snapshot of an array of impacts from multiple perspectives of those directly involved in MPA planning and decision-making in addition to implementers and facilitators of participatory monitoring activities and programs.

## 4.1 The role of funding

We found evidence for cascading impacts of the MLPA on CCS programs along with strengthening ties and partnerships between CCS programs and MPA leadership as California's MPA Network has been established and implemented. While State funding was recognized by many as an important factor in expanding CCS capacity, reach, and data contributions, it was not seen as requisite for CCS programs to be successful in contributing to various monitoring conservation goals of the MLPA and MPA program. As noted above, some programs were able to leverage MPAs in service of fundraising efforts focused on federal or other sources outside of the State's MPA monitoring program.

That said, it has been documented that sustained funding is an important factor for the long-term success and overall effectiveness of MPA networks. Gleason et al. (2010) noted that adequate resources such as monetary funds in addition to adequate staffing are essential factors to successful MPA-planning process and beyond. The leveraging dynamic described above may be beneficial to the State; however it may not be a reliable long-term strategy on its own. We argue that the State has a responsibility to monitor and aid the financial vitality of key partners to the MPA Program, especially CCS programs, in order to bolster and sustain the monitoring capacity and effectiveness that these programs provide.

One MPA Leader explicitly commented on bureaucratic barriers to many CCS programs being eligible to apply for and/or receive State funding due to their 501(c)(3) status, which the State does not recognize as an eligible fiscal sponsor. It would behoove the State to make greater efforts to either make changes to funding mechanisms or create assistance pathways for organizations to meet funding eligibility requirements. Perhaps establishing memoranda of understanding (MOUs) with partner CCS programs would not only expand funding opportunities, but also deepen relationships and trust among and between MPA leaders and CCS programs and their participants. This notion aligns with the recommendation given by Fox et al. (2013) that establishing MOUs within the MLPA Program provides and expands opportunities for successful MPA planning and implementation at the nexus of scientific integrity, funding, partnership, and public engagement.

Beyond MOUs, the establishment of a formalized fiscal sponsorship model could be another solution to addressing funding eligibility barriers faced by CCS programs. Under this approach, state-recognized nonprofit organizations could serve as intermediaries, providing administrative and financial oversight to enable CCS programs to access public and private funding streams that would otherwise be out of reach due to their informal organizational status. A pilot implementation of this model could be explored with existing initiatives such as the Grunion Greeters program. Despite the program's significant contributions to species management and public engagement, its limited institutional structure presents a barrier to sustainable funding. By partnering with established nonprofits through fiscal sponsorship agreements, such programs could receive funding while maintaining operational autonomy. This model has proven successful in the field of environmental education via organizations like Earth Island Institute, which supports emerging initiatives by providing administrative infrastructure under a shared legal umbrella. Adapting these models to the CCS sphere could increase financial stability, promote innovation, and provide sustainability for a diversity of impactful programs.

The suggestions above are motivated by the reality that, aside from the actual amount of funding available, CCS programs can also benefit from clear communications about funding timelines, availability, and the various technical and administrative expectations that come with funding. Some of the insights from our interviews point to evolving relationships between CCS programs and MPA partners. This evolution may be positive in some cases, could also lead to misunderstandings and uncertainties for programs seeking funds in what feels like a constantly shifting landscape.

contributing to MPA monitoring to tap into other sources of funding, and to recruit and retain participants. In other words, the establishment and ongoing implementation of MPAs offered CCS programs a compelling new narrative about their work, which was useful with multiple audiences. In turn, MPA leaders are still able to coordinate with any CCS programs collecting data relevant to the broad scope of monitoring, regardless of any more formalized relationship tied to funding, although this was one area where some felt more work was needed.

In regions around the globe with limited financial and institutional resources, such as small island nations and coastal developing states, the integration of CCS into MPA networks presents a promising, cost-effective strategy for enhancing both ecological monitoring and community engagement. Rather than relying solely on professional scientific teams, which may be prohibitively expensive or logistically challenging to maintain, these regions can leverage community-based participation to expand the spatial and temporal reach of data collection. For example, platforms such as iNaturalist offer scalable digital tools for public reporting and species identification. Similar successes have been documented globally: in Australia, the CoralWatch program enables recreational divers, tourists, and local communities to contribute valuable data on coral health at minimal cost (Schläppy et al., 2017). These models demonstrate how CCS can not only supplement traditional monitoring efforts but also foster stewardship and local ownership of conservation initiatives—an especially critical consideration in resource-limited regions.

Even without a financial link between MPA leaders and CCS programs there is potential for strong collaborations and partnerships that promote overall success and attainment of goals for both MPAs and CCS. As described by Kelly et al. (2019), the establishment and fostering of relationships between MPA leaders and CCS programs via social license, which the authors describe as being akin to social acceptance and support entrenched in trust, has the potential for positive implications for marine conservation and management at large through a finding of common ground among diverse groups of marine stakeholders. They go on to stress that establishing social license and meaningful partnerships is not just a "one-off," but rather a "continuous process of repeated interaction and positive engagement" (p. 7). Through deep and sustained partnerships between MPA leaders and CCS programs there becomes greater potential for the benefits of not only both audiences but overall positive conservation impacts as well as benefits to a diverse network of MPA stakeholders.

## 4.2 State funding not required for CCS and MPAs to mutually benefit

California's MPAs represented a value proposition, even for those CCS programs that did not benefit from direct MPA-related monetary support. Many that did not receive funding from the State reported similar impacts and degrees of positive impact. These non-State-funded CCS programs explicitly used their role in

## 4.3 Challenges for CCS programs in implementation

Importantly, our results revealed not only benefits of the MPA program for CCS programs, even outside of direct funding, but we also heard a variety of anecdotes about challenges that can hinder their effectiveness and potential impacts. Chief among these is funding instability, which threatens program sustainability, limits

staffing and logistics capacity, and hinders the ability to scale or innovate. Several program coordinators noted the consistent challenge of identifying and securing sources of funding with MPA Watch sharing they are "constantly looking for funding." This financial instability not only reduces the reach of CCS efforts but could also compromise their long-term scientific rigor and contributions to monitoring and other data-related outputs over time. This suggests that, to the extent that MPA partners remain focused on CCS as an important part of implementation, they should consider more than just the overall level of monetary support. Managers should carefully consider the particular needs of CCS, rather than lumping it in with more traditional, professionalized forms of monitoring.

CCS programs also contend with ongoing challenges in volunteer management and retention broadly (West and Pateman, 2016; Robinson et al., 2021) and certainly in the context of MPAs. High turnover requires programs to repeatedly "rebuild" their volunteer bases. Programs like BeachCOMBERS also highlighted the difficulty of "balancing new and experienced volunteers." These dynamics are further compounded by systemic equity and accessibility issues. Barriers related to time, training, and financial resources often exclude low-income or underrepresented communities, creating what Beach Watch described as a volunteer pool that is "kind of a monoculture." LiMPETS noted "gatekeeping exists on who can join," and the Crystal Cove Conservancy emphasized "barriers for low-income communities." The challenges of recruiting and retaining volunteers are an ongoing reality for many CCS programs (West and Pateman, 2016; Fischer et al., 2021), as are the more specific challenges of broadening participation and increasing diversity, equity, and inclusion (Pandya, 2012; Soleri et al., 2016; Harwell et al., 2022). They have particular relevance in the context of MPA implementation, given the increasing prominence of environmental justice and DEI goals that MPA partners are advancing. The recommendations resulting from the MPA decadal management review call out these goals, and specifically point to CCS as an area where progress could be made (see recommendation 6a in CDFW 2022).

We also found that communication gaps between CCS programs and MPA managers, and between programs and their volunteers, additionally present a significant and often overlooked challenge for CCS programs. These gaps can weaken volunteer engagement and long-term impact, with many programs citing the lack of feedback loops or structured mechanisms to keep volunteers informed and engaged. For instance, MARINe SSWD noted there is "no structured way to update volunteers." Without consistent feedback, volunteers may not fully understand how their data contributes to MPA monitoring and broader scientific impacts. Grunion Greeters reported that their program receives "limited feedback from MPA leaders," and MPA Watch emphasized that "communication with volunteers is the responsibility of individual organizations," highlighting a fragmented system that places the burden of engagement on local coordinators without systemic support. These findings are consistent with Golumbic et al.

(2019), who found that of the several CCS cases they studied, the most successful included a substantive focus on strong communications with volunteers that empowered and motivated retention. Further, gaps in communications not only affect volunteer retention but also threaten the long-term credibility and transparency of CCS as a tool for collaborative governance in marine conservation. Establishing more consistent, centralized, and reciprocal communication pathways could enhance volunteer satisfaction, build trust, and strengthen the link between community monitoring and adaptive management.

Taken together, and in light of the overall expansion and leveraging dynamics we observed with MPA-related CCS, these challenges all represent opportunities for MPA partners to build on success, and improve the institutionalization of mutually beneficial relationships.

## 4.4 Forces driving impacts beyond funding

Our study used predetermined impact type categories, and specifically looked at funding as a potential driver of positive impacts. In the coding process, we also looked for other kinds of impacts discussed by CCS program leaders and MPA leaders. This revealed broad changes (past, present, or future) that some had witnessed or were aware of that were very relevant to CCS, but not linked explicitly to an impact for a specific program, and points to a possible explanation for the across-the-board positive impacts we observed, regardless of funding. Numerous study participants cited the role of the MPA Collaborative Network, a nonprofit organization of 14 collaboratives active along the California coast with a mission to empower diverse communities to engage in marine protected area stewardship for a healthy ocean, in bridging the divide between members of coastal communities (including CCS program participants) and the regulatory agencies and entities that were charged with rolling out the MPA Network and Program. The MPA Collaborative Network was referenced by both CCS program leaders and MPA leaders as a key partner organization that has played a pivotal role in taking action to advance the goals and work of MPAs in a variety of ways as part of MPA implementation, especially in terms of increased public awareness and participation. For example:

"The MPA Collaborative Network was a very important addition to the [MPA Statewide Leadership Team Working Group] so that we have this top-down from government down to locals and then also locals leading and informing this team." -MPA Leader

"A lot of [CCS programs] have a voice. They're not on the leadership team but they're a part of the MPA Collaborative Network and their information is conveyed to the leadership team. So I would say they have a voice … and so moving forward there could be more use and connection with them." -MPA Leader

"I think that putting people in a situation where they're actively doing something rather than just saying something makes a

difference. In the MPA Collaborative Network, for example, what a lot of people in the collaboratives are worried about is [other] people taking animals out of the intertidal zone during low tides, or fishing across the boundaries or doing things they shouldn't be doing. So rather than 'don't do this, don't do this, don't do this,' which is totally understandable, it's nice to also say 'and here are some positive things that you could do that will help the environment and help people who are trying to manage the environment." -CCS Program Leader

The integral role connecting individuals and groups with specific interests in the protection and management of marine and coastal areas throughout California, largely orchestrated by the MPA Collaborative Network, has long been identified as a key element to the planning and implementation of the statewide MPA program. As described by Sayce et al. (2013), a key step in the public participation process of MLPA implementation was to establish networks of "key communicators" in regions throughout the state in order to create connections between marine constituent groups and MPA planners and leaders. Today, the MPA Collaborative Network maintains the role of being a key partner and connector between MPA leaders and a diverse set of regionally-organized collaboratives that bring together representatives from communities, Tribes, and various organizations representing different marine stakeholder and user groups including many CCS programs. Our results suggest that this effort has had a positive impact such as institutional capacity-building efforts, spanning multiple scales of governance and geography, could be just as important as direct funding to individual CCS programs.

## 4.5 Considerations for supporting and integrating CCS in MPA networks

To support the application of this study's findings across diverse geographic and institutional contexts, we present a practical framework designed to guide MPA managers, CCS program leaders, policymakers, and funders in exploring how CCS can be effectively integrated into MPA monitoring. This framework draws from lessons learned in California, where the implementation of a statewide MPA network catalyzed a variety of both direct and indirect impacts on CCS programs. Organized around five key dimensions (program context and capacity, partnerships, funding, broader impacts, and iterative learning) and summarized in Figure 3, the framework emphasizes adaptive, inclusive approaches. It can serve as a flexible tool for both emerging and established MPA initiatives aiming to leverage CCS as a powerful means of advancing conservation, fostering community ownership, and building resilient monitoring systems.

### 4.5.1 Assess program context and capacity

- Evaluate program diversity and variation: Understand the specific characteristics of existing or potential CCS programs, including scope of inquiry, data collection methods, geographic coverage, training needs, engagement strategies, and governance structures.
- Identify enabling conditions: Determine whether local environmental, institutional, and social conditions are conducive to the integration of CCS into MPA monitoring. Consider existing community interest, trust in regulatory institutions, and logistical infrastructure.
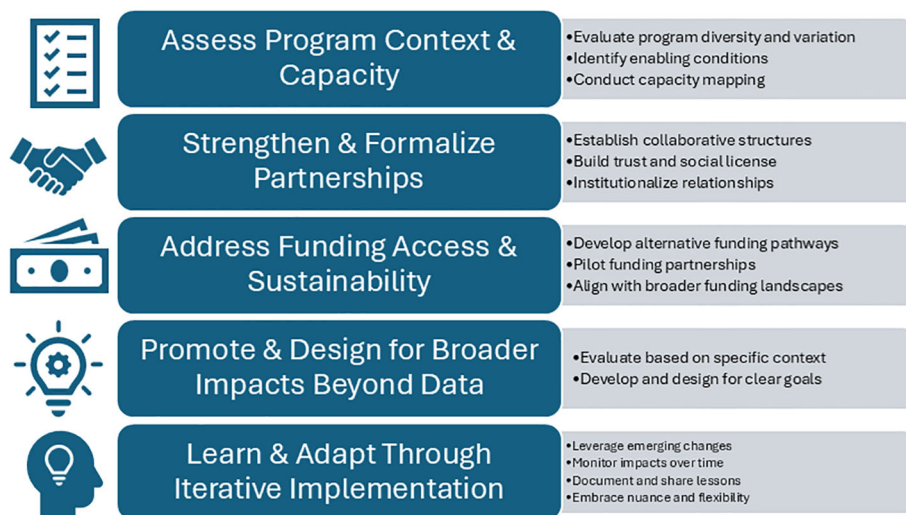


**FIGURE 3**
Overview of the key elements of the framework for effectively integrating CCS programs in MPA implementation.

- Conduct capacity mapping: Assess existing CCS and MPA program capacities (including human, financial, and technological) to identify strengths and gaps that influence their ability to collaborate.

### 4.5.2 Strengthen and formalize partnerships

- Establish collaborative structures: Facilitate ongoing coordination between MPA leaders and CCS program representatives through advisory groups, working groups, or regionally organized collaborative models like California's MPA Collaborative Network.
- Build trust and social license: Engage stakeholders early and consistently, acknowledging past conflicts or alienation and emphasizing co-creation and mutual benefit.
- Institutionalize relationships: Explore mechanisms such as MOUs to deepen cooperation and formalize partnerships without necessarily relying on financial linkages.

### 4.5.3 Address funding access and sustainability

- Develop alternative funding pathways: Promote innovative models like fiscal sponsorships through which established nonprofits serve as intermediaries to help smaller or informal CCS programs access public and private funds.
- Pilot funding partnerships: Start with targeted initiatives to test scalable funding solutions, particularly in regions where CCS programs are active but lack formal recognition.
- Align with broader funding landscapes: Encourage CCS programs to align their goals with overlapping policy priorities (such as biodiversity monitoring, climate resilience, and science education) to diversify their funding base.

### 4.5.4 Promote and design for broader impacts beyond data

- Evaluate based on specific context: CCS investments should not necessarily be evaluated on the same narrow basis as traditional professional monitoring.
- Develop and design for clear goals: Managers should be clear about their goals for CCS such as education, stewardship, and policy engagement, and design initiatives accordingly.

### 4.5.5 Learn and adapt through iterative implementation

- Leverage emerging changes: The value and role of MPAs in CCS programming can evolve; for example some programs saw that MPA-related narratives used for volunteer recruitment began to grow stale.
- Monitor impacts over time: Use surveys, interviews, or participatory evaluation to continually assess how CCS programs are evolving in response to MPAs or other conservation interventions.

- Document and share lessons: Create platforms such as regional workshops or peer learning exchanges for sharing lessons learned across regions and contexts.
- Embrace nuance and flexibility: Recognize that the impacts of MPA policies on CCS programs will vary by region and by program. Avoid one-size-fits-all models and instead emphasize adaptive learning and context-sensitive design.

## 5 Conclusion

Our study of exploring and understanding how the past 10+ years of the implementation of California's MPA Network have shaped community and citizen science along the coast has revealed different kinds of impacts on a diverse network of CCS programs. Overall, CCS program leaders consistently reported no decreases in program-related elements, with many noting increases in participant engagement, data quality, program capacity, and funding opportunities. Notably, programs initiated alongside MPAs tended to report more favorable outcomes compared to pre-existing initiatives, suggesting a beneficial synergy between MPA implementation and CCS activities that were designed specifically around MPAs.

The qualitative insights gathered from interviews with both MPA leaders and CCS program leaders added depth to these findings, illustrating the nuanced ways in which MPAs have enhanced participant engagement, refined data practices, and fostered stronger partnerships and funding avenues. Conversely, MPA leaders provided high-level perspectives on the evolving role of CCS, emphasizing the importance of collaboration and data alignment.

Beyond their role in providing data for MPA monitoring, CCS programs generate a wide range of broader social and ecological benefits. Programs such as Snapshot Cal Coast have demonstrated how citizen science can serve as a platform for environmental education, advocacy, and public engagement. By involving residents, and particularly youth and underrepresented groups, in hands-on biodiversity assessments, CCS initiatives promote environmental literacy and cultivate a sense of stewardship that can extend well beyond the boundaries of designated MPAs. For example, the LiMPETS program has led to sustained involvement of school groups and educators in coastal science, influencing local conservation discourse and inspiring future generations of scientists and advocates.

CCS programs can also help to mitigate some of the initial tensions and stakeholder alienation that often accompany MPA implementation. While the establishment of MPAs can sometimes trigger conflict, especially in regions where resource users feel excluded from decision-making, CCS offers a means to rebuild trust by creating inclusive spaces for participation and dialogue. In doing so, CCS fosters more equitable conservation outcomes and reinforces the legitimacy of marine management efforts in the eyes of local communities. Ultimately, these programs demonstrate that the value of citizen science extends well beyond data collection, contributing to more resilient social-ecological systems and durable conservation solutions.

While many studies have focused on how CCS can be useful for conservation, this study has examined evolving CCS capacity in relation to a conservation policy. This lens provides valuable nuance for practitioners grappling with the reality that collaboration across scales is an essential for the implementation of ambitious conservation policies. Our findings suggest that investment in CCS can take many forms beyond funding. Indeed, simply acknowledging CCS as an important contributor lends a degree of legitimacy that can benefit CCS programs, as they seek resources and recruit participants. Future research should explore the long-term sustainability of these impacts and identify strategies to address any gaps in understanding between MPA leaders and CCS programs. By expanding opportunities for CCS programs to be involved in and contribute to MPA monitoring, in addition to fostering ongoing dialogue and collaboration, stakeholders can enhance the strength and effectiveness of not only public engagement in MPA monitoring but progress towards successfully achieving the goals of California's Marine Life Protection Act.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving humans were approved by UC Davis Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

TH: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. RM: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing –

review & editing. HB: Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

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## Conflict of interest

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

## Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

## Publisher's note

## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2025.1548864/full#supplementary-material

## References

Aceves-Bueno, E., Adeleye, A. S., Bradley, D., Tyler Brandt, W., Callery, P., Feraud, M., et al. (2015). Citizen science as an approach for overcoming insufficient monitoring and inadequate stakeholder buy-in in adaptive management: criteria and evidence. *Ecosystems* 18, 493–506. doi: 10.1007/s10021-015-9842-4

Ballard, H. L., Harris, E. M., and Dixon, C. G. H. (2018). "Science identity and agency in community and citizen science: evidence & Potential," in *Commissioned paper for the Committee on Designing Citizen Science to Support Science Learning*. Available at: https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_189606.pdf. (Accessed October 10, 2023).

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., et al. (2014). Next steps for citizen science. *Science* 343, 1436–1437. doi: 10.1126/science.1251554

Braun, V., Clarke, V., Terry, G., and Hayfield, N. (2019). "Thematic analysis," in *Handbook of research methods in health and social sciences*. Ed. P. Liamputtong (Singapore: Springer), 843–860. doi: 10.1007/978-981-10-5251-4_103

California Department of Fisheries and Wildlife (2022). *California's marine protected area network decadal management review*. Available online at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=209209&inline. (Accessed March 12, 2023).

Cigliano, J. A., and Ballard, H. L. (2017). "The promise of and the need for citizen science for coastal and marine conservation," in *Citizen science for coastal and marine conservation*. Eds. J. A. Cigliano and H. L. Ballard London., 3–16. doi: 10.4324/9781315638966

Cigliano, J. A., Meyer, R., Ballard, H. L., Freitag, A., Phillips, T. B., and Wasser, A. (2015). Making marine and coastal citizen science matter. *Ocean Coastal Manage.* 115, 77–87. doi: 10.1016/j.ocecoaman.2015.06.012

Creswell, J. W. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches. 4th Edition* (Thousand Oaks, California: Sage).

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika* 16, 297–324. doi: 10.1007/BF02310555

Fischer, H., Cho, H., and Storksdieck, M. (2021). Going beyond hooked participants: The nibble-and-drop framework for classifying citizen science participation. *Citizen Sci. Theory Pract.* 6, 10. doi: 10.5334/cstp.350

Fox, E., Miller-Henson, M., Ugoretz, J., Weber, M., Gleason, M., Kirlin, J., et al. (2013). Enabling conditions to support marine protected area network planning: California's Marine Life Protection Act Initiative as a case study. *Ocean Coastal Manage.* 74, 14–23. doi: 10.1016/j.ocecoaman.2012.07.005

Freitag, A., Meyer, R., and Whiteman, L. (2016). Strategies employed by citizen science programs to increase the credibility of their data. *Citizen Science: Theory Pract.* 1, 2. doi: 10.5334/cstp.6

Garcia-Soto, C., Seys, J. J. C., Zielinski, O., Busch, J. A., Luna, S. I., Baez, J. C., et al. (2021). Marine citizen science: current state in europe and new technological developments. *Front. Marine Sci.* 8. doi: 10.3389/fmars.2021.621472

Gleason, M., McCreary, S., Miller-Henson, M., Ugoretz, J., Fox, E., Merrifield, M., et al. (2010). Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. *Ocean Coastal Manage.* 53, 52–68. doi: 10.1016/j.ocecoaman.2009.12.001

Golumbic, Y. N., Baram-Tsabari, A., and Koichu, B. (2019). Engagement and communication features of scientifically successful citizen science projects. *Environ. Communication* 14, 465–480. doi: 10.1080/17524032.2019.1687101

Harwell, T. A., Low, R., Mattheis, A., Riedinger, K., and Fischer, H. (2022). Is citizen science queering science? An exploration of the personal dimensions of engaging LGBTQ+ citizen science volunteers. *Int. J. Sci. Education Part B* 13, 116–130. doi: 10.1080/21548455.2022.2137706

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., and Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen-science programs: citizen-scientist knowledge gain. *Conserv. Biol.* 25, 1148–1154. doi: 10.1111/j.1523-1739.2011.01745.x

Kelly, R., Fleming, A., and Pecl, G. T. (2019). Citizen science and social licence: Improving perceptions and connecting marine user groups. *Ocean Coastal Manage.* 178, 104855. doi: 10.1016/j.ocecoaman.2019.104855

Kirlin, J., Caldwell, M., Gleason, M., Weber, M., Ugoretz, J., Fox, E., et al. (2013). California's Marine Life Protection Act Initiative: Supporting implementation of legislation establishing a statewide network of marine protected areas. *Ocean Coastal Manage.* 74, 3–13. doi: 10.1016/j.ocecoaman.2012.08.015

McKinley, D. C., Briggs, R. D., and Bartuska, A. M. (2012). When peer-reviewed publications are not enough! Delivering science for natural resource management. *For. Policy Economics* 21, 1–11. doi: 10.1016/j.forpol.2012.03.007

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

Meyer, R., Korabik, A., Harwell, T., Petersen, N., and Ballard, H. (2022). *Examining the role of community and citizen science in marine protected area implementation* (Davis, California: eScholarship). doi: 10.58076/C6RP4M

Newman, G., Chandler, M., Clyde, M., McGreavy, B., Haklay, M., Ballard, H., et al. (2017). Leveraging the power of place in citizen science for effective conservation decision making. *Biol. Conserv.* 208, 55–64. doi: 10.1016/j.biocon.2016.07.019

Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment*, 10(6), 314–317. doi: 10.1890/120007

Robinson, J. A., Kocman, D., Speyer, O., and Gerasopoulos, E. (2021). Meeting volunteer expectations — a review of volunteer motivations in citizen science and best practices for their retention through implementation of functional features in CS tools. *J. Environ. Plann. Manage.* 64, 2089–2113. doi: 10.1080/09640568.2020.1853507

Sayce, K., Shuman, C., Connor, D., Reisewitz, A., Pope, E., Miller-Henson, M., et al. (2013). Beyond traditional stakeholder engagement: Public participation roles in California's statewide marine protected area planning process. *Ocean Coastal Manage.* 74, 57–66. doi: 10.1016/j.ocecoaman.2012.06.012

Schläppy, M.-L., Loder, J., Salmond, J., Lea, A., Dean, A. J., and Roelfsema, C. M. (2017). Making waves: marine citizen science for impact. *Front. Marine Sci.* 4. doi: 10.3389/fmars.2017.00146

Soleri, D., Long, J. W., Ramirez-Andreotta, M. D., Eitemiller, R., and Pandya, R. (2016). Finding pathways to more equitabl e and meaningful public-scientist partnerships. *Citizen Science: Theory Pract.* 1, 9. doi: 10.5334/cstp.46

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E., et al. (2015). Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biol. Conserv.* 181, 236–244. doi: 10.1016/j.biocon.2014.10.021

West, S., and Pateman, R. (2016). Recruiting and retaining participants in citizen science: What can be learned from the volunteering literature? *Citizen Sci. Theory Pract.* 1, 15. doi: 10.5334/cstp.8