CITIZEN SCIENCE:
THEORY AND PRACTICE

LAVA-Lobos: Raising Environmental Awareness through Community Science in the Galápagos Islands

RESEARCH PAPER

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ABSTRACT

Community science involves scientists and community members co-creating and co-executing scientific research. Given their deep engagement of non-scientists, these projects have great potential to improve their participants' scientific knowledge and pro-environmental attitudes, as well as to collect first-order data on issues of local and scientific concern. To investigate this potential, we implemented a community science project to monitor an endemic species of sea lion in the Galápagos Islands and empirically assessed its impacts on the community scientists (local high-school students). We discovered that our community scientists increased their understanding of the nature of science, knowledge of sea lion biology, and intrinsic motivations for conservation as a result of their participation. These results provide empirical evidence that community science initiatives can be effective tools for helping community members to increase both their scientific knowledge and their environmental awareness.

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INTRODUCTION

Environmental conservation is an issue of pressing global concern. This area is ripe for a community-based approach to conservation, one that deeply engages with community members on pressing environmental issues while simultaneously collecting data on these issues in order to expand our scientific knowledge. For our project, we implemented such a community-based approach in the Galápagos Islands, a place where the impact of human development contrasts sharply with the natural world. These islands are famous from Charles Darwin's writings in *The Voyage of the Beagle* and for their role in inspiring his thinking about evolutionary processes. The Galápagos are home to a large array of endemic species that are found nowhere else in the world. These islands are also biologically fragile, since even small changes in local climatic conditions can have massive effects on local populations of plants and nonhumans animals (Snell et al. 2002).

The Galápagos Islands were designated UNESCO's first World Heritage site in 1978. Today, 97% of the land mass and 100% of the ocean are protected as part of the Galápagos National Park and Marine Reserve. The remaining 3% of the land is reserved for use by humans, and about 35,000 people call Galápagos their home. Perhaps surprisingly to those of us from the global north, these Galapagueños (for the most part) remain disconnected from the historical and scientific importance of their islands. Because the National Park is so highly protected, visitors can enter the Park only in the company of a professionally trained Naturalist Guide, who can supervise a maximum of only 16 people. These constraints, while designed to protect the fragile ecosystem of the Galápagos, puts access to the Park well out of reach of the average Galapagueño family (Brewington 2013). And yet, it is the choices of the people who live on these islands that will in large part determine if the unique flora and fauna for which these islands are famous will continue to survive and thrive. That is, Galapagueños are being asked to be stewards of a place that they are largely prevented from visiting.

Our work in the Galápagos Islands uses partnership between academic researchers and community members to begin to address this disconnect. This project can not only help to raise environmental awareness in this underserved community, but also can provide a model for how to engage in such projects in other areas of the world that are vulnerable to climate change.

COMMUNITY SCIENCE

Citizen science, or the involvement of non-professional scientists in scientific inquiry (Irwin, 1995), can take many forms. These range from projects in which non-professional scientists contribute primarily by collecting data for professional scientists to projects in which non-professional scientists choose their own research questions and conceptualize entire frameworks for investigation, with varying amounts of input from professionals (Bonney, Ballard et al. 2009; Kullenberg and Kasparowski 2016).

Some of the most well-known citizen science projects ask citizens to provide a professional research team with additional observations that would be difficult or time-consuming to obtain, such as ornithologists obtaining data from volunteers conducting bird counts (Bhattacharjee 2005). Such projects typically involve their participants only in the data-collection phase of the research, and typically communication is only one way: Citizen scientists provide observations to the researchers, but usually have very little input into the questions that are being investigated or into how their data are used. There is a distinction between this work, which is sometimes called scientific authority-driven citizen science (Ottinger 2017b), and more bottom-up projects addressing pollution and other health hazards (e.g., Allen 2018), or public health issues (community-based participatory research) (Hacker 2017). Such projects are often lay led, allowing their participants to have more control over the investigation. We focus here on an approach included in this more participatory category, community science, emphasizing the fact that the community is involved in the scientific work much more holistically than is typical of many citizen science projects (see Bonney et al. 2016; Irwin 1995; Shirk et al. 2012). Ideally, projects are co-created amongst non-scientist community members and professional scientists, where both are involved in the project at every stage (see examples in Fischer et al. 2021; Hinojosa et al. 2021; Nuessle et al. 2020).

Because of this deeper and more intimate involvement of community members in the scientific process, we believe that projects using a community science model will likely have a greater impact on participants than projects with shallower engagement, and can provide a good model for increasing environmental awareness and action in communities like Galápagos, where this concern is desperately needed. Involving community members in the co-creation, execution, and communication of a conservation biology project can be particularly effective in promoting pro-environmental attitudes and ongoing conservation actions (Chan et al. 2016; Mordock and Krasny 2001). For our project, we were especially interested in the connection between community science and science education: Can a community science research project bolster its participants' understanding of first-order scientific issues as well as their motivations toward conservation?

Prior work has asked versions of this question (for example see Kieslinger et al. 2018; Schaefer et al. 2021). One goal of many citizen science projects, accurate data collection, has been tested by many researchers by comparing the data that citizen scientists collect to data that professionals collect (e.g., Aceves-Bueno et al. 2017; Nuessle et al. 2020). Additionally, many projects foreground educational and policy-oriented goals, such as increasing participants' scientific literacy, changing participants' attitudes toward scientific issues, and bringing participants' concerns to the foreground in civic decision-making contexts (Turrini et al. 2018). With respect to the topic of the current investigation, it has been argued that various forms of citizen science can indeed encourage participants to learn more about the natural world or to positively shift their attitudes toward conservation (see Crall et al. 2013; Fortmann 2008; Jørgensen and Jørgensen 2021).

The effectiveness of citizen science and community science with respect to learning goals is an important field of study (Roche et al. 2020). For example, Ballard and Belsky (2010) report on a kind of community science project for harvesters of the Salal plant in the American northwest, where harvesters who had little formal science education participated in a project to study the relationship between harvesting intensity and yields in subsequent seasons. These researchers found that the harvesters increased their ecological literacy by engaging in the project. Similarly, youth who participated in citizen science and community science projects in California developed environmental science knowledge, identity, and agency with environmental science and conducting stewardship activities (Ballard et al. 2017).

Other studies have been more pessimistic. For example, Toomey and Domroese (2013) were interested in testing whether participation in a citizen science study in New York City could change attitudes about environmental stewardship. They found that participants' attitudes did become more pro-environmental, but these changed attitudes didn't necessarily make the participants more likely to get involved in advocacy (see also Kimura and Kinchy 2016). However, the projects in this study followed a more traditional approach to citizen science, in which the participants were primarily involved only in collecting data. On the whole, then, we see the extant literature as giving reasons for optimism that community science projects can both generate primary scientific data and help participants build their own knowledge about and engagement with science. One of our primary goals with this project was to test this hypothesis.

Many (perhaps most) citizen science or community science efforts rely on volunteers, who are intrinsically motivated to participate (see review in West and Pateman 2016). These individuals thus tend to already be highly engaged with science or conservation, meaning that any effects of their participation in a community science project are likely to be minimal; they are volunteering precisely because they are already interested in nature and are concerned about it (see West et al. 2021). Our approach to partnering with local communities in the Galapagos, in contrast, partnered with a local high school and worked with a group of their students. Specifically, our community scientists were all of the students who were enrolled in the International Baccalaureate (IB) program at the school. Although these students had to display a high level of academic achievement to enter the IB program, they did not have to show any particular interest or aptitude in biology or conservation, so they were not necessarily already interested in the issues that we were investigating. We believe that this makes for a more rigorous test of the potential of participatory science to improve environmental attitudes, since our participants did not self-select to engage in our project. Working within the context of a school program also allowed us to rely on teachers and other staff for accountability and continuity of support when our own staff could not be in the field. In addition to assisting with the development of the research project and conducting the research, these students were also responsible for choosing how to communicate the results of this project to their community.

Our choice to work with students also reflects past research showing that children and youth may be particularly receptive to pro-environmental messages (Chawla and Derr 2012; Evans et al. 2018). Targeting young people may thus be an especially effective strategy for community science projects that aim to increase pro-environmental attitudes. In addition, because the community science approach involves engaging with issues that the community itself identifies as important, we started our process by assessing community needs, using a semi-structured interview with adults in public areas of town that began with broad questions (e.g., "In your opinion, what (if any) changes would you like to see made in Puerto Baquerizo Moreno?") and then focused on narrower topics (e.g., "Have you noticed that tourism affects the animals on the islands?"). We also used a snowball sampling process, beginning with our project co-director (third author) who is a resident of San Cristóbal. Through these methods, we obtained a sample of 24 residents (17 male, 7 female). Although we did not conduct any formal analyses of these interviews, we note that a high percentage (46%) of the individuals we interviewed mentioned education as a major issue in their community. The same percentage mentioned conservation-related needs. These responses further encouraged us to engage with students in this community science project.

LAVA-LOBOS

Our project involves working with a local community to identify an issue of interest, to develop and refine the project, to execute it, and to have a role in determining how the knowledge gained in the project should be used. In our work in the Galápagos, we call this approach LAVA: *Laboratorio para Apreciar la Vida y el Ambiente* (Laboratory for the Appreciation of Life and the Environment). This particular implementation of this approach is called LAVA-Lobos, because it focuses on sea lions, locally called *lobos marinos*.

To be more specific, our project studies the social structure and behavior of Galápagos Sea Lions (*Zalophus wollebaeki*), an endemic species of sea lion. According to the IUCN Red List, the world's most comprehensive inventory of species' conservation statuses, the population declined 60–65% from 1978 to 2001, reaching a low point of 14,000–16,000 individuals in 2001 (Alava and Salazar 2006). Since then, populations throughout the Galápagos have stabilized, but the species remains vulnerable. Primary threats to the sea lions are anthropogenic disturbances, climatic variations produced by the El Niño cycle, and increases in average sea surface and air temperature due to global climate change (Denkinger et al. 2015; Riofrío-Lazo et al. 2017).

To protect and monitor the sea lions, the Galápagos National Park launched a management plan in 2012, which introduced a standardized procedure for taking censuses of sea lions and suggested strategies to reduce human impacts. While our choice of topic reflects scientific interests and the priorities of the Galápagos National Park, more importantly, this topic was selected based on conversations with community members, who shared their observations of increasing tensions between sea lions and humans. Boating, dog walking, fireworks, pollution, and direct harassment have all been responsible for sea lion injuries and deaths. Indirectly, humans seem to be changing sea lion behavior, making them simultaneously more aggressive and also more likely to occupy human spaces such as park benches and boats. At the same time, sea lions are considered the symbol of the town that is our study site (Puerto Baquerizo Moreno), and Galapagueños are aware that endemic animals like sea lions are an important driver of tourism, which is a major sector of the Galápagos Islands' economy. Finally, local wisdom follows science in understanding that the health of the sea lions is an indicator of the health of the marine environment. Given that many Galapagueños make their living by fishing, when the sea lions are not thriving, trouble awaits.

The LAVA-Lobos project thus has two main goals: to work with the community of Puerto Baquerizo Moreno to study human/sea lion interactions and to measure the impact of participating in this project on the community scientists (high school students). With respect to the first goal, a set of findings about sea lion behavior has been published (Walsh et al. 2020), providing strong evidence that data collected in this kind of community science project can genuinely contribute to the body of scientific knowledge. Here, we focus on the second goal, reporting findings about our work with the community scientists, specifically regarding improving students' scientific understanding of sea lions as well as their attitudes towards conservation.

METHODS

PARTICIPANTS

We recruited 33 participants (18 female), who were juniors and seniors in a local high school (UAE San Cristóbal) and who were enrolled in an International Baccalaureate (IB) program. We implemented this project over the course of three years, reaching 10 students in 2017, 17 in 2018, and 6 in 2019. These numbers represent the entire IB class for each year; students participated in our project as part of their educational experience. As the students were minors, we obtained consent for their participation from their parents (protocol approved by the IRB at an Ecuadorian university, Universidad de San Francisco de Quito, with a reliance agreement from our US-based universities). Students provided verbal assent before beginning work on our project.

MATERIALS AND PROCEDURES: SEA LION PROJECT

The project is based in the town of Puerto Baquerizo Moreno on the island of San Cristóbal in the Galápagos, the easternmost inhabited island in the archipelago. Approximately 8,000 people (nearly 25% of the entire human population of the Galápagos) live in this waterfront town. We identified four target beaches that sea lions frequently use as haul-out sites for sleeping and nursing their pups.[1] These beaches varied in their level of human disturbance, allowing us to draw comparisons between these locations to quantify the effects of human presence on sea lion behavior and social structure.

With respect to the protocol for studying the sea lions, citizen science projects (including community science projects) depend in large part on having a straightforward, easy-to-execute protocol, allowing non-scientists to conduct the research with little training (Bonney, Cooper et al. 2009). The Cornell Laboratory of Ornithology has developed a set of best practices for constructing such protocols, including an emphasis on developing materials that promote learning, which we aimed to follow in the development of our project. To that end, we first consulted with the biologists on our research team to design an initial version of a protocol that would allow us to measure the impact of human presence on sea lions and to chart other aspects of the sea lions' behavior. Other members of our research group piloted this initial protocol in December 2016, with the help of undergraduate students from our universities and local Naturalist Guides. Based on feedback from these pilots, we made adjustments and constructed training materials before launching the project with our first cohort in June 2017.

Briefly, the protocol first involved recording the age class (pup, juvenile, adult, or unknown) and sex (male, female, or unknown) of each sea lion on a beach, the number of people on the beach (not counting the research team), and the observation start time. Then, students conducted an approach assay on each sea lion, which involved walking slowly toward each sea lion from 6 meters away until 2 meters away, the legal limit of approach to any nonhuman animal in the Galápagos. Students recorded the reaction of the sea lion from 0 (least reactive) to 5 (most reactive). Students additionally noted how the sea lions were grouped together and recorded all instances of the following behaviors for 15 minutes: nursing, calling, growling, barking, and challenging. These observations and behavioral assays were performed on each beach once or twice per week for a seven-month period (corresponding to two school semesters). This helped to enhance the scientific merits of this project, since having such detailed observations over such a long period of time can highlight seasonal changes in the sea lions' behavior.

In order to train our community participants to conduct this protocol with a high degree of fidelity, four undergraduate research assistants (occasionally assisted by a graduate student) lived in Puerto Baquerizo Moreno during June and July in each of the three years of the project. They were responsible for working with the Galapagueño high schoolers twice per week to teach them to execute the protocol, to identify sea lions' age and sex, to conduct the approach assay, and to distinguish among different sounds that sea lions make. As part of these lessons, the undergraduate research assistants also taught about basic sea lion natural history and about the process of science (e.g., the importance of consistency in data collection, the ongoing nature of scientific research).

Over the course of the three years of the project, on the basis of feedback from our student community scientists and our undergraduate training teams, we made some changes to the protocol, for example, to refine the age classes for easier categorization by the students.

The scientific findings, briefly, were that sea lions on more disturbed beaches were less reactive (i.e., scored lower on the approach assay) than sea lions on less disturbed beaches. In addition, aggressive behaviors (e.g., growling) directed towards humans were less common on beaches where the sea lions grouped more closely together, but aggressive behaviors directed toward other sea lions were more common on such beaches (for more details, see Walsh et al. 2020).

MATERIALS AND PROCEDURES: EDUCATIONAL RESEARCH WITH COMMUNITY SCIENTISTS

As noted above, a primary goal of this project was to assess its impact on our community scientists, specifically focusing on whether these students gained knowledge or shifted attitudes as a result of their participation (following the framework suggested by Kieslinger et al. 2018). Our primary assessments were quantitative and measured three main topics: knowledge of the nature of science, knowledge about sea lions, and attitudes toward conservation. All pre-test and post-test instruments for each of the three years of the project are available on the Open Science Framework (https://osf.io/v369q/).

To measure participants' knowledge of the nature of science, we conceptualized science as a set of domain-general skills and practices, following prior work in philosophy of science (e.g., Godfrey-Smith 2003) and science education (e.g., Lederman 2007). We primarily took a quantitative approach to measuring this construct, adapting closed-ended questions from other work on this topic (Lombrozo et al. 2008; Slater et al. 2019; Weisberg et al. 2021); all complete assessments are available on OSF (https://osf.io/v369q/). Additionally, at all time points, an open-ended question asked students to define the word "science" (based on the Views of Nature of Science questionnaire, Lederman et al. 2002; see also Weisberg and Sobel 2022).

To measure sea lion knowledge, we constructed a series of multiple-choice questions based on aspects of sea lion natural history that we taught to the students or that were measured in the protocol. Our analyses here focus on seven questions that were asked at both pre- and post-test across all three years of the project; these are highlighted in the documents available on OSF (https://osf.io/v369q/).

To measure attitudes about conservation, we used two existing instruments, the New Ecological Paradigm Scale, or NEPS (Dunlap et al. 2000), and the Motivation for Environmental Action scale, or MEA (Cornell Laboratory of Ornithology 2014). The NEPS presents 15 statements with which participants agree or disagree on a 5-point scale. Seven of these statements reflect agreement with the dominant social paradigm, in which humans are apart from and superior to nature and in which environmental crises are not particularly urgent. The other eight statements reflect agreement with the new ecological paradigm, in which the environment is in danger and humans must learn co-exist with nature. Participants received two scores from this measure, averaging together their responses to each subscale, which reflected their level of agreement with each paradigm.

The MEA asked participants to think about some of the things that they do to protect sea lions and to agree or disagree with 14 statements about why they do these things on a scale of 1 (strongly disagree) to 5 (strongly agree). Half of the items reflect extrinsic motivations, and the other half of the items reflect intrinsic motivations. Participants received an average score for each subscale. The scores for extrinsic motivation were then subtracted from the scores for intrinsic motivations to obtain a view of the extent to which participants' motivations for helping sea lions were primarily intrinsic (positive scores) or extrinsic (negative scores).

In addition to these three main quantitative measures, we asked a variety of open-ended questions throughout the three years of the program to gain a better sense of their knowledge and attitudes. For example, at pre-test, we asked how students view the conflicts between humans and sea lions and what they hope to learn from their participation in this community science project. At post-test, we asked them to tell us something surprising that they learned about sea lions and what they would do differently if they were to do this project over again.

All participants responded to all of these quantitative and qualitative measures at two time points: before training began (May or June) and at the completion of the project, which coincided with the end of the Ecuadorian school year (December or January). The assessments were conducted in Spanish and students' responses were translated by members of our research team.

RESULTS

All raw data on all measures from the pre-tests and post-tests of the three years of the project, as well as our analysis script, are available on OSF (https://osf.io/v369q/).

QUANTITATIVE MEASURES

See Table 1 for descriptive statistics across the three years of the project for the quantitative assessments.

Nature of science

With respect to students' knowledge of the nature of science, we first examined their answer to a multiple-choice question asking about the difference between a theory and an opinion (2017) or the difference between a theory and a hypothesis (2018 and 2019). We found that 27 participants out of our 33 (81.8%) answered this question correctly at pre-test and 24 participants out of our 33 (72.7%) answered this question correctly at post-test. Although this was not a statistically significant difference ($\chi^2(1) = 0.78$, $p = .38$, Cohen's d = 0.31), it is important to note that participants are generally answering this question correctly.

Similarly, we asked students a multiple-choice question about the nature of scientific knowledge, specifically whether it can be modified as new information challenges prevailing theories. All participants answered this question correctly at both pre-test and post-test in 2017 ($n = 10$) and in 2018 ($n = 17$), so we chose not to include it in 2019. However, this again indicates that these students do understand important facets of how science is practiced.

Finally, we asked students their level of agreement with a series of statements about the nature of science on a 5-point scale. We coded their responses so that higher numbers would reflect greater agreement with the scientific consensus and constructed an average for each participant at pre- and post-test. At pre-test, participants scored an average of 3.42 (SD = 0.67); at post-test, they scored an average of 3.86 (SD = 0.61). This was a statistically significant increase, as measured by a paired t-test ($t(32) = -3.30$, $p = .002$, Cohen's d = 1.17). This indicates that participating in this project did indeed

ASSESSMENT	2017 (n = 10)		2018 (n = 17)		2019 (n = 6)		TOTAL (n = 33)	
	PRE-TEST	POST-TEST	PRE-TEST	POST-TEST	PRE-TEST	POST-TEST	PRE-TEST	POST-TEST
Nature of Science Scale (5 points)	3.00 (0.24)	3.68 (0.24)	3.82 (0.68)	4.08 (0.55)	3.00 (0.47)	3.56 (0.98)	3.42 (0.67)	3.86 (0.61)
Sea Lion Knowledge Test (percent correct)	61.67% (12.82%)	80.00% (12.05%)	53.79% (14.75%)	63.59% (15.68%)	66.67% (17.30%)	71.43% (12.78%)	58.51% (15.14%)	70.0% (15.58%)
New Ecological Paradigm Scale – Dominant Paradigm Subscale (5 points)	2.58 (0.52)	2.26 (0.55)	2.97 (0.57)	2.77 (0.51)	3.21 (0.45)	2.50 (0.47)	2.89 (0.57)	2.56 (0.55)
New Ecological Paradigm Scale – New Paradigm Subscale (5 points)	4.08 (0.22)	4.11 (0.37)	4.04 (0.38)	4.03 (0.44)	2.06 (0.74)	4.02 (0.66)	3.69 (0.88)	4.06 (0.45)
Motivation for Environmental Action (difference score)	1.30 (0.29)	1.73 (0.71)	1.27 (0.82)	1.84 (0.72)	–1.64 (0.84)	1.74 (1.00)	0.75 (1.34)	1.79 (0.75)

Table 1 Participants' average performance on the quantitative assessments, across years.

Note: Standard deviations are in parentheses.

improve these students' understanding of aspects of the practice of science.

Sea lion knowledge

There were seven questions about sea lion natural history and National Park regulations that were asked consistently at pre-test and post-test across all three years of the project. We found that participants answered 58.51% of these questions correctly at pre-test (SD = 15.14%) and answered 70.00% of these questions correctly at post-test (SD = 15.58%). This was a statistically significant improvement, paired $t(32) = -3.57$, $p = .001$, Cohen's d = 1.26.

Attitudes toward conservation

For the NEPS, as noted above, each participant received two scores: one reflecting their agreement with the dominant ecological paradigm and one reflecting their agreement with the new ecological paradigm (5-point scale). We found that agreement with the dominant social paradigm significantly decreased from pre-test to post-test (pre-test mean = 2.89, SD = 0.57; post-test mean = 2.56, SD = 0.55; paired $t(32) = 3.22$, $p = .003$, Cohen's d = 1.14), while agreement with the new ecological paradigm increased from pre-test to post-test (pre-test mean = 3.69, SD = 0.88; post-test mean = 4.06, SD = 0.45; paired $t(32) = -2.12$, $p = .04$, Cohen's d = 0.75). These results indicate that students' views about nature shifted to become more pro-environmental as a result of their participation.

For the MEA, participants' scores were positive at both time points, indicating that their motivations to engage in actions to help sea lions were generally intrinsic (pre-test mean = 0.75, SD = 1.34; post-test mean = 1.79, SD = 0.75). Nevertheless, there was a statistically significant increase in scores between pre- and post-test, indicating that participants' motivations became increasingly dominated by intrinsic factors over the course of this project (paired $t(32) = -4.07$, $p < .001$, Cohen's d = 1.44).

QUALITATIVE MEASURES

To analyze the open-ended questions, we used a directed content analysis approach (as implemented in Walls 2012; see also Hsieh and Shannon 2005). This approach utilizes existing theory to help define the initial coding categories, which are then refined through further examination of the responses.

For the question asking the students to define the word "science" ($n = 31$ responses at both pre- and post-test), we relied on prior work on children's responses to this question (Walls 2012; Weisberg and Sobel 2022) to select two initial coding categories. First, we first looked for themes of students describing science as a *type of learning* (e.g., "Experimentation to arrive at a deeper understanding of something."), which tended to be expressed using words like "learn", "understand", "discover", and "study". We found this theme in 48% of the responses at pre-test and in 32% of the responses at post-test. Second, we looked for references to science as an *active process* (e.g., "It is to study something, come up with a hypothesis, and at the end get results."), which prior work has suggested is associated with a more mature conception of the nature of science (Weisberg et al. 2021; Weisberg and Sobel 2022). This theme appeared in 48% of the responses at pre-test and in 42% of the responses at post-test. In addition to these themes drawn from existing theory, we found that more than half of the responses at pre-test (52%) and almost half of the responses at post-test (48%) talked about science as encompassing everything (e.g., "For me the word science is a study around everything. It is not just about nature but about everything we do or have around us.").

When we asked students to identify or describe conflicts between sea lions and humans ($n = 33$ responses, question asked at pre-test only), they tended to mention ways in which humans, either locals or tourists, affected the sea lions, for example by getting too close to them or by throwing sand or stones (e.g., "I think that it could be that the community is disturbing the peaceful life of the sea lions by throwing things at them and provoking them to react aggressively"). This theme occurred in 76% of responses. However, they also mentioned ways in which the sea lions caused trouble for humans, primarily by stealing fish or bait from fishing boats (e.g., "It can be that they eat the bait or disturb ships. The sea lions don't let them [fishermen] do their work"), or by crowding the beaches and making them smell bad (e.g., "There is a large quantity of sea lions on the seafront and they get it dirty and make it smell bad and because of this it is not very pleasant to be with the sea lions"). This theme occurred in 67% of responses. Many students' responses (42%) were coded into both categories, indicating that they recognized that these conflicts are not one-sided (e.g., "To have feeling and respect their habitat – this is already their home and we have our space and they also have theirs").

At post-test ($n = 31$ responses, question asked at post-test only), students said that they were surprised by some of the things they were able to observe about sea lions that they had never seen before, such as witnessing the birth of a pup or learning that sea lions could be identified by their unique flipper patterns. In their reflections on the project itself and what they would do differently ($n = 30$ responses, question asked at post-test only), many identified logistical issues like scheduling time to be on the beach or feeling bored by performing the protocol over and over again.

DISCUSSION

One of the main ideas behind the concept of community science is to produce scientifically sound data on a question of mutual interest to the scientific community and to a local community, while simultaneously engaging community members in all aspects of the research process. The LAVA-Lobos project met many – although not all – of these goals.

The main goal of this paper is to empirically assess whether our community scientists' participation in science improved their knowledge and attitudes regarding sea lions and fostered beneficial views of conservation. We found the students who participated in this project increased their understanding of the nature of science, their knowledge about sea lion natural history, their pro-environmental attitudes, and their reported motivations to help the sea lions. These results strongly indicate that community science projects can serve multiple roles, educating participants about the natural world as well as improving their views of nature. This conclusion aligns with findings from other work on community science, which has similarly found that individuals' participation in these kinds of projects can improve understanding both of the topic under study and of the practice of science itself (Ballard et al. 2017; Fischer et al., 2021; Nuessle et al., 2020). It also aligns with past theoretical work on the evaluation of citizen science projects (e.g., Kieslinger et al., 2018; Schaefer et al., 2021) in its focus on using multiple types of evaluation to test whether aspects of the project met our primary educational goals as well as our goals for increased personal and social engagement with science.

LIMITATIONS AND FUTURE DIRECTIONS

Regarding the extent to which this project was truly community science, we acknowledge there were limits to students' participation in the entire scientific process. We chose to have the data entered, analyzed, and interpreted by our research team, as is common in many community science projects (Stevens et al. 2014), because students were not familiar enough with the concept of data entry or with the tools in the time we had. Similarly, although we made changes to the data collection protocol based on students' feedback over the years, they also lacked the expertise to fully assist in the development of this protocol.

That said, the students took the lead on communicating our results to their community, via a video message (in 2017) and theatrical productions that they presented at school events and at the waterfront (in 2018 and 2019). Over the course of the project, we also incorporated more varied ways to communicate about their efforts to other members of their community, such as "ride-alongs," in which students brought family members or friends to the beach to demonstrate the protocol. It is clear from these efforts that these students were highly engaged in the project and felt ownership over the data that they had collected, even if they were not personally involved in analyzing these data; future research could more explicitly measure this relationship. Future work should also assess the impacts of the project on the broader community, as these students' involvement in this project may have spillover effects on their families' or friends' attitudes toward sea lion conservation.

Regarding our survey methods, although we did find statistically significant increases in knowledge from pre- to post-test, the average score on our sea lion knowledge test was only 70% at post-test, which is lower than expected given that they had spent 7 months observing them. This could be because the questions on our assessment were not a good fit to the work they had been doing on the protocol. Future iterations of this project could include more questions about students' conceptions of the practice of science or adopt a more qualitative approach to more fully measure how participants' ideas about this topic may have shifted over the course of the project (e.g., Hinojosa et al., 2021; Lederman et al., 2002).

Crucially, our measures of pro-environmental action ask participants to self-report their attitudes but do not measure any actual behavior, and it is well known that there is a gap between reported attitudes and behavior (Kollmuss and Agyeman 2002; Steg and Vlek 2009; Toomey and Domroese 2013); therefore, we cannot make direct claims about changes in behavior based on our findings. Future iterations of this project should aim to determine whether the changes in reported attitudes that we identified actually translate into action. Focusing the assessments on students' perceptions of human/sea lion interactions could provide additional nuance to students' changes in attitudes.

Finally, our community scientists participated in this project twice a week for seven months, representing a considerable commitment of time. While we found positive impacts of this project on the students' knowledge and attitudes, we cannot yet determine whether similar impacts would occur for projects with shorter timescales or with less intense training. We also note that our sample size here was rather small and included only students in a school program, limiting the breadth of the conclusions we can draw. Future iterations of this project should aim to reach larger and more diverse groups of individuals and should focus particularly on the question of whether academic credit or other extrinsic motivations are necessary for our effects to occur. Inclusion of a control group and of interim assessments could also help to tease out the answers to those questions.

APPLICATIONS

Based on our work on this project, we offer some general principles for other research groups to keep in mind when adopting a community science approach (see also Bonney, Ballard et al. 2009; Fischer et al. 2021; Hacker 2017):

- When choosing a question to investigate, it is vital to take into account the needs of the community in which the research will be conducted. For our project, we interviewed community members about issues of concern to them and then chose one of those issues where we felt that a scientific study could have an impact. Other projects have taken more bottom-up approaches, where community members approach scientists (e.g., Ottinger 2017a). Still others have approached a community with an initial study idea and worked collaboratively to refine and implement it for mutual benefit (e.g., Hinojosa et al. 2021).
- When reaching out to community partners to develop and conduct the research project, there are often tradeoffs to navigate between accessing a broad cross-section of the community as opposed to recruiting volunteers, as noted above and as frequently discussed in the literature on citizen science and community science (e.g., Blake et al. 2020; Ellis and Waterton 2004; Fischer et al. 2021; Goodwin 1998). In our case, we considered how the community scientists will maintain their motivation and enthusiasm over the entire course of the project; different motivations may govern participants' decisions to begin participating than their decisions to continue participating (West and Pateman 2016). Although we ensured continued participation in our project by working through a school program, developing a project that explicitly includes opportunities to build intrinsic motivation could be even more effective at ensuring long-term attitude change (see Falk 2001; Lepper and Henderlong 2000; West et al. 2021).
- When developing protocols and educational support materials, it is important to keep in mind both the existing level of expertise of the community scientists and the overall goals of the project. In our case, we carefully developed our data collection protocol to work well with our community scientists, but did not give the same consideration to the data entry or analysis protocol. If a goal is to involve community scientists in designing the research project itself and in analyzing and interpreting data, then explicit protocols must be developed for those aspects of their experience as well. Nuessle et al. (2020) suggest different tracks of participation, with some focusing more on data collection and others focusing more on protocol development or data analysis.

CONCLUSION

The sea lion project that we present here can provide a model for developing scientifically meaningful community science initiatives that are connected both to community interests and to conservation goals. In addition, aspects of the community science approach are increasingly being recognized as important parts of global conversations about the equity of science. For example, the effects of climate change will differ depending on local conditions, and these effects will disproportionately impact already-vulnerable communities. Community members have the unique expertise to provide insight into these potential effects and their solutions. Incorporating their knowledge with the scientific research provides a helpful way to move forward with climate-change adaptation efforts (e.g., Sheppard et al. 2011; Shi et al. 2016). Given this, we believe that other communities or research groups should consider adopting similar approaches to constructing partnerships around scientific issues, as our work shows that it can be beneficial both to scientific knowledge and to increasing pro-environmental attitudes.

DATA ACCESSIBILITY STATEMENT

All materials and data related to this project are available on the Open Science Framework (https://osf.io/v369q/).

NOTE

1 We began the project with three beaches in 2017 and added a fourth in 2018.

ETHICS AND CONSENT

This project was approved by the Comité de Ética de Investigación en Seres Humanos (Ethics Committee for Human Research) at the University of San Francisco de Quito, with reliance agreements in place at the University of Pennsylvania and Villanova University. All participants' parents or guardians provided consent for their participation and research was carried out in accordance with the Declaration of Helsinki.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

This project was jointly conceived and developed by all four authors. The first and last author obtained funding. The sea lion observation protocol was developed by the second author and was piloted and implemented by the second and third authors. The first author developed the assessment tools for the community scientists and worked with the third author to collect the human subjects data. The first author analyzed the data and wrote the first draft of the manuscript, which was subsequently edited and agreed upon by the other three authors.

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