Cultivating connection: Incorporating meaningful citizen science into Cape Cod National Seashore's estuarine research and monitoring programs

By Brett Amy Thelen and Rachel K. Thiet

LONG BEFORE BIODIVERSITY BECAME A MAINSTAY OF the conservation lexicon, amateur naturalists were trekking through the field, observing and recording the occurrence and distribution of species. Today, volunteer participation in ecological research is hailed as a pillar of effective community-based environmental management. This "citizen science" integrates environmental education with conservation biology, and can thus inform ecological management while fostering public awareness of critical environmental issues.

Even with the additional effort required to train and supervise volunteers, citizen science programs can save considerable expense and time in the field (Darwall and Dulvy 1996; Newman et al. 2003), allowing for the expansion of existing research programs (Darwall and Dulvy 1996; Fore et al. 2001). Furthermore, participating in citizen science programs may strengthen volunteer commitment to conservation (Evans et al. 2005). Miles et al. (1998) found that volunteers in ecological restoration initiatives developed a "hands-on, healing relationship" with the natural world. This relationship can spur further environmental action: 4.5% of the volunteers participating in a U.K. mammal survey subsequently switched to conservation-oriented careers, while some 30% joined conservation groups (Newman et al. 2003). Because of this potential for inspiring community involvement in environmental issues, participatory science has been identified as one of the most urgently needed environmental education initiatives for cultivating successful community-based environmental management (Evans and Birchenough 2001; Danielsen et al. 2005).

Despite the benefits of citizen science, some scientists have expressed concern about the validity of volunteer-generated data. Indeed, certain projects are not appropriate for volunteer involvement: complex research methods (Newman et al. 2003) and projects that require long hours of arduous or repetitive work (Darwall and Dulvy 1996; Newman et al. 2003) and taxonomic identification to the species level (Penrose and Call 1995; Darwall and Dulvy 1996; Fore et al. 2001) may not be suitable for volunteers. Without proper training in research and monitoring protocols, volunteers are also more likely to introduce bias into their data (Eaton et al. 2002; Danielsen et al. 2005).

When designed with these limitations in mind, however, citizen science initiatives can make important contributions to science and management. Numerous studies have demonstrated that volunteers can successfully perform basic data collection tasks when given a half day or more of practical field training (Darwall and Dulvy 1996; Graham et al. 1996; Evans et al. 2000; Fore et al. 2001; Foster-Smith and Evans 2003). In fact, Fore et al. (2001) found no difference between freshwater macroinvertebrate samples collected by trained volunteers and control samples collected by professional scientists. Because much of the fieldwork needed for ecological monitoring is labor-intensive but technically straightforward (Foster-Smith and Evans 2003), volunteer monitoring projects carry considerable scientific potential.

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Today many organizations engage citizens in ecological research and monitoring through participatory science programs (Penrose and Call 1995; Eaton et al. 2002), but the success of these programs varies according to their unique ecological, social, and organizational settings. For instance, whereas a local organization might find volunteer monitoring useful for informing small-scale water quality management decisions, a national park might determine that the same monitoring protocol does not meet its need for data that can withstand scientific scrutiny in a peer-reviewed journal or court of law (Penrose and Call 1995). In order, then, to engage more communities in valid, valuable ecological monitoring, it is first necessary to evaluate pilot citizen science projects across a variety of ecosystems and organizations (Foster-Smith and Evans 2003).

"Citizen science" integrates environmental education with conservation biology, and can thus inform ecological management while fostering public awareness of critical environmental issues.

As a prototype park for the National Park Service (NPS) Inventory and Monitoring Program, Cape Cod National Seashore (Massachusetts) already takes a lead in the development of monitoring protocols for Atlantic and Gulf coastal ecosystems. This role also provides an opportunity for the national seashore to serve as a model for integrating citizen science into ecosystem monitoring efforts. Cape Cod scientists have identified a need for baseline information about benthic mollusk populations in restoring estuaries; because mollusks are relatively easy to sample and are culturally and commercially important in coastal New England, national seashore managers also support volunteer involvement in mollusk monitoring.

The objectives of this study were to determine (1) whether volunteers can collect reliable, reproducible data on mollusk populations for use in Cape Cod National Seashore's estuarine monitoring and management programs, and (2) whether such citizen science projects increase participant support for estuarine restoration on Cape Cod.

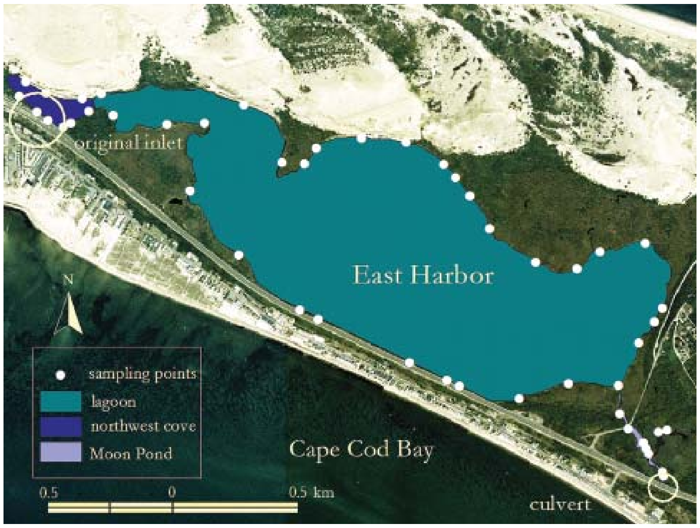

Figure 1. Mollusk sampling locations at East Harbor, Cape Cod National Seashore. Benthic mollusk sampling was conducted from 10 July to 26 August 2005 in three regions of East Harbor that vary markedly in salinity and distance to Cape Cod Bay: Moon Pond (creek), the central lagoon, and the northwest cove.

IMAGE COURTESY OF MASSGIS

Methods

Study site

East Harbor is a 719-acre (291 ha) coastal lagoon and salt marsh that originally functioned as an estuary, connected to Cape Cod Bay by an inlet at its western end (fig. 1). In 1868 it was completely isolated from the bay by the construction of a solid-fill causeway for trains and automobiles (Portnoy et al. 2005). After this construction, salinity throughout East Harbor decreased to near-freshwater conditions, the waters became highly eutrophic (i.e., nutrient-enriched) with large blooms of nitrogen-fixing cyanobacteria, and fish and invertebrate numbers declined precipitously. In December 2001 a massive fish kill prompted an experimental opening of the culvert that connects the system to Cape Cod Bay (Portnoy et al. 2005; fig. 1).

The culvert was permanently opened in November 2002, and salinity throughout the lagoon has increased dramatically since then. By September 2004, at least 15 species of estuarine fish, crustaceans, and invertebrates had also recolonized East Harbor (Portnoy et al. 2005).

Volunteer recruitment and training

Fourteen volunteers were recruited from a local AmeriCorps program and by publicizing the project in local newspapers. They spent approximately 285 total volunteer-hours doing supervised fieldwork, with eight volunteers contributing more than one field day to the project. Sixty-three percent (five) of these active volunteers were year-round residents of lower Cape Cod; 50% (four) were affiliated with AmeriCorps–Cape Cod or Cape Cod National Seashore; 88% (seven) were between the ages of 18 and 34; and 88% (seven) had an undergraduate degree.

Prior to data collection, all volunteers participated in three hours of field training, which included a one-hour introduction to estuarine restoration and hands-on practice of mollusk sampling (described below). All volunteers received the same training, and volunteer fieldwork was supervised by the first author, an independent researcher under permit to the park, at all times.

To determine whether participating in this project increased volunteers' support for estuarine restoration on Cape Cod, we administered written pre- and post-program questionnaires to all regular participants. Questionnaires contained a combination of open-ended questions and Likert scale responses, in which volunteers used a five-point scale to record their agreement with 15 statements about conservation, restoration, and citizen science (Thomson and Hoffman 2003; table 1).

Mollusk sampling

To evaluate the validity of volunteer-generated data, we enlisted the support of two professional researchers with extensive shellfish experience on lower Cape Cod: Kurt Schlimme, former deputy shellfish constable for the town of Wellfleet, Massachusetts, and Krista Lee, physical scientist for Cape Cod National Seashore. Benthic mollusk sampling was conducted from 10 July to 26 August 2005 in three regions of East Harbor that vary markedly

Figure 2. Northern quahogs (*Mercenaria mercenaria*) were one of several culturally and commercially important mollusk species detected by volunteers in the restored East Harbor estuary, Cape Cod National Seashore.

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Table 1. Selected questions from the written pre- and post-program questionnaire used to measure shifts in volunteer attitudes toward estuarine restoration after participating in this citizen science project

Please rate the extent to which you agree or disagree with each of the following statements (1 = Strongly Disagree, 2 = Disagree Somewhat, 3 = No Opinion, 4 = Agree Somewhat, 5 = Strongly Agree)
I am familiar with Cape Cod National Seashore's estuarine restoration program.
I am concerned about the effects of estuarine restoration on freshwater plant species.
I am concerned about the effects of estuarine restoration on freshwater animal species.
Estuarine restoration benefits people in coastal communities.
Estuarine restoration should be a top priority at Cape Cod National Seashore.
Open-ended questions: please write your answer below
What have you learned about *ecological restoration* as a result of participating in this citizen science project?[a]
What have you learned about *wetlands ecology* as a result of participating in this project?[a]
What worked well in this project?[a]
What did *not* work well in this project?[a]
What recommendations do you have for improving the citizen science experience at Cape Cod National Seashore?[a]

Note: The pre-program survey also contained questions about participant demographics. For a full list of the questions in the citizen science questionnaire see the Web edition of this article at http://www.nature.nps.gov/ParkScience/index.cfm?ArticleID=236.

[a]Included only in the post-program survey.

in salinity and distance to Cape Cod Bay: Moon Pond (creek), the central lagoon, and the northwest cove (fig. 1). Fifty sampling points (10 in Moon Pond [creek], 30 in the central lagoon, and 10 in the northwest cove) were systematically selected to ensure that sampling was evenly distributed throughout each region. At each point, mollusk species richness and density were sampled using a combination of one 3.9-inch (10 cm) diameter benthic core and digging within a 4.84-ft^2 (0.45 m^2) quadrat (Dethier and Schoch 2005). Sediment from benthic cores and quadrats was wet-sieved through 0.08-inch (2 mm) and 0.25-in (0.64 cm) mesh, respectively; all mollusks retained on the sieves were counted live and identified to genus or species (figs. 2 and 3). Data obtained from both methods were extrapolated up to individuals 10.76 ft^{-2} (1 m^{-2}), a common way to express mollusk density (Hunt et al. 2003; Poulton et al. 2004).

Volunteers and professional researchers sampled each point within one week of each other, using the same protocol and field equipment. To account for potential differences in mollusk diversity and abundance due to disturbance during sampling, each point was divided into two immediately adjacent quadrats, one for volunteer sampling and the other for sampling by our professional researchers.

Data analysis

To assess the validity of volunteer-generated data, we compared volunteer with professional data for species richness and the density of the four most abundant mollusk species. All data were non-normally distributed because of high variability in species

Figure 3. Researchers sampled mollusk species using a combination of benthic cores and digging within 4.84-ft^2 (0.45 m^2) quadrats. Sediment from cores and quadrats was wet-sieved through 0.08-inch (2 mm) and 0.25-inch (0.64 cm) mesh, respectively; all mollusks retained on the sieves were counted live and identified to genus or species.

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richness and density among sample plots, and data transformation did not improve normality. Thus, we used nonparametric Wilcoxon rank-sum tests (Zar 1999) to compare volunteer-generated data with the data collected by professional researchers.

Statistical analysis of volunteer responses to the written questionnaires was precluded by the low number of program participants; we summarize qualitative trends below.

Results

Volunteer vs. professional data quality

For species richness and density of the four most abundant mollusk species, we found no significant differences between data collected by citizen science volunteers and data collected by professional researchers, both across East Harbor as a whole and in each region individually (Wilcoxon rank-sum tests, $p \leq 0.05$; table 2, figs. 4 and 5). Citizen scientists detected 14 mollusk species throughout East Harbor while professional researchers detected 15; volunteers and professionals detected 13 species in common (table 2).

Volunteers and professionals found roughly equivalent densities for the four most abundant mollusk species; however, densities quantified using benthic cores were highly variable, both among sample plots within each region of East Harbor and between observer groups (fig. 5).

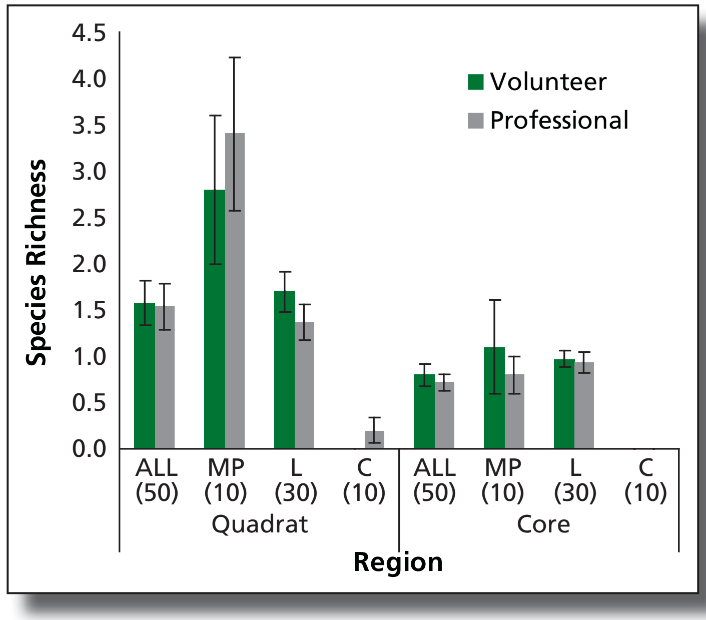
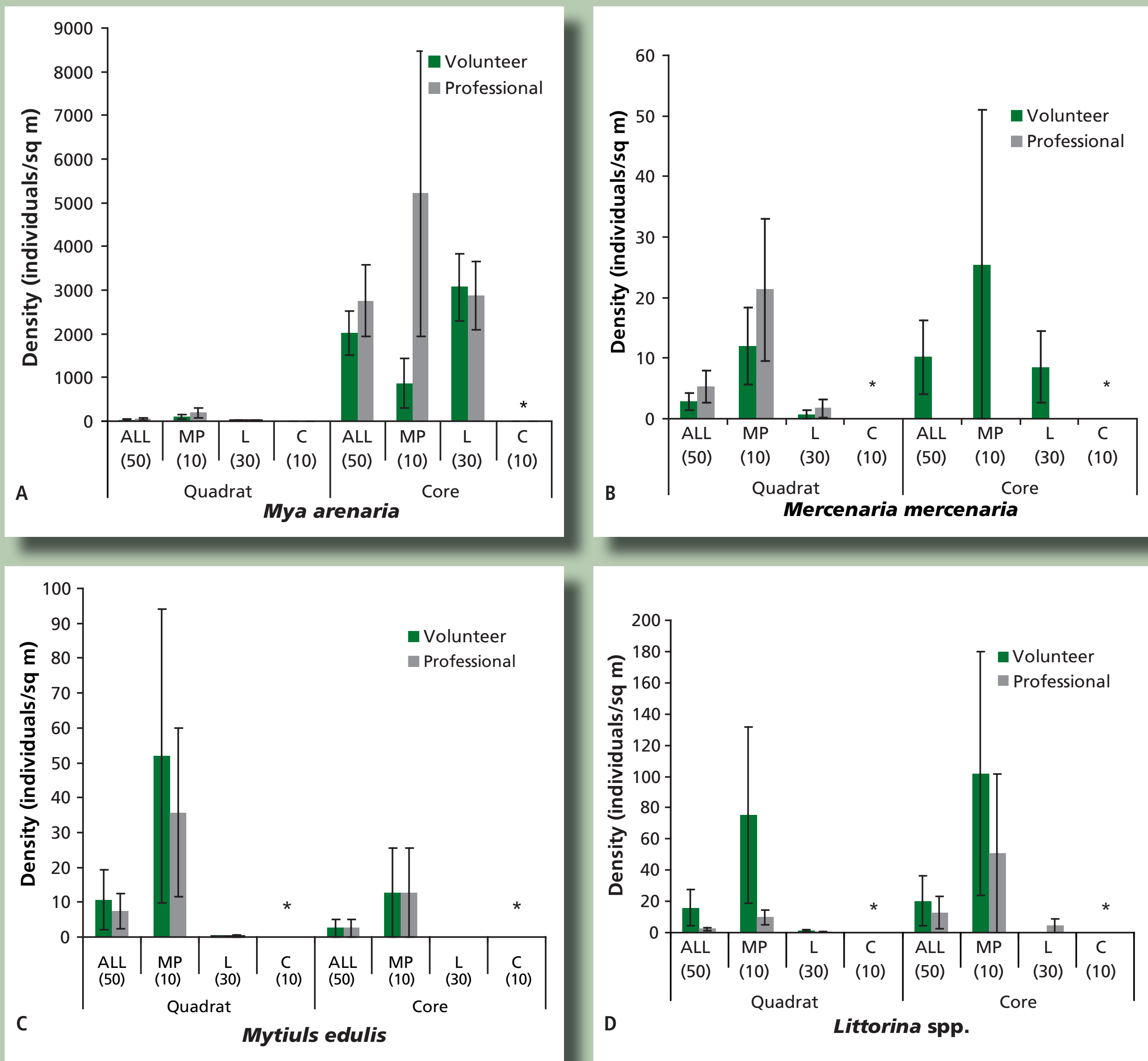


Figure 4. Mean mollusk species richness (± SE) at East Harbor, Cape Cod National Seashore, by observer, region, and sampling method. ALL = East Harbor as a whole, MP = Moon Pond (creek), L = central lagoon, C = northwest cove. Number in parentheses denotes sample size.

Table 2. Mollusk species detected at East Harbor, Cape Cod National Seashore, by volunteers and professional researchers, 2005

		Detected by	
Common name	**Scientific name**	**volunteers**	**professionals**
Softshell clam	*Mya arenaria*	X	X
Periwinkle	*Littorina* spp.	X	X
Blue mussel	*Mytilus edulis*	X	X
Northern quahog	*Mercenaria mercenaria*	X	X
Dwarf surfclam	*Mulinia lateralis*	X	X
Amethyst gemclam	*Gemma gemma*	X	X
Jingle	*Anomia* spp.		X
Ribbed mussel	*Geukensia demissa*	X	X
Northern moonsnail	*Euspira heros*	X	X
Common razor clam	*Ensis directus*	X	X
False angelwing	*Petricola pholadiformis*	X	X
Bubble snail	Order Cephalaspidea	X	X
Atlantic surfclam	*Spisula solidissima*		X
Baltic macoma	*Macoma balthica*	X	X
Stout tagelus	*Tagelus plebeius*	X	X
Atlantic dogwinkle	*Nucella lapillus*	X	

Note: Species are listed in order of abundance. Eastern oysters (*Crassostrea virginica*) were also observed anecdotally by both volunteers and professionals, but were not found in any sample plots.



Figures 5a–d. Mean density (± SE) of the four most abundant mollusk species at East Harbor, Cape Cod National Seashore, by observer, region, and sampling method. ALL = East Harbor as a whole, MP = Moon Pond (creek), L = central lagoon, C = northwest cove. Number in parentheses denotes sample size. Asterisks denote regions and sampling methods for which no mollusks were detected. The magnitude of variability illustrated here appears greater than it actually was in the field because we extrapolated data to individuals 10.76 ft^{-2} (1 m^{-2}).

Participant attitudes toward estuarine restoration

Qualitative comparison of pre-and post-participation questionnaires revealed several trends. Forty-five percent of all participant responses to the survey questions were the same in both pre- and post-program surveys. However, after participating in this project, 50% (four of eight) of active volunteers reported increased familiarity with Cape Cod National Seashore's estuarine restoration program, increased agreement with the idea that estuarine restoration benefits people in coastal communities, increased support for continued restoration efforts, and decreased concern about the effects of estuarine restoration on freshwater plant and animal species in impacted areas. One participant summarized her experience by saying, "We all learned from each other, it wasn't too difficult for a layperson, and it gave me a much deeper sense of connection to the landscape, which was exactly my goal."

In response to our open-ended request for recommendations for improving the citizen science experience at Cape Cod National Seashore, 50% (four of eight) of active volunteers specifically requested more opportunities for participating in ecological research and monitoring on Cape Cod. Furthermore, the field sampling itself was highlighted as a valuable educational experience: no volunteers reported learning more from the training than from the fieldwork, but 38% (three of eight) of respondents reported learning more from the fieldwork than from the training.

Discussion

This study is a first approximation of the efficacy of engaging volunteers in monitoring culturally and ecologically important natural communities at Cape Cod National Seashore. Mollusk data collected by citizen scientists were comparable to those collected by professional researchers, thus demonstrating that supervised volunteers are capable of collecting reliable data on mollusk populations for use in monitoring and restoring estuaries at Cape Cod National Seashore. These findings are promising, given that the national seashore prioritizes estuarine restoration and is managing restoration work at the four largest tidally restricted estuaries on Cape Cod (Portnoy et al. 2003).

Density data collected using benthic cores showed high variability among sample plots within each region of East Harbor, and between observer groups. Both instances of high variability may be due to the naturally patchy, sparse distribution of mollusks in the field (Hunt et al. 2003; Commito et al. 2006). When coupled with the small number of plots sampled, this variability may have reduced our statistical power to detect significant differences between professional- and volunteer-generated data. Future researchers should minimize these potential problems by sampling more intensively.

It is also important to note that, though we encouraged volunteer autonomy in the field, the first author consistently assisted with fieldwork and regularly answered volunteer questions about methodology and species identification, and two volunteers expressed uncertainty about their ability to sample successfully without supervision. In fact, other studies suggest that sustained personal communication with scientists and hands-on field training are essential to the success of citizen science projects. Evans et al. (2005) found that face-to-face contact between scientists and volunteers was vital to one avian citizen science program near Washington, D.C., and volunteers in a U.K. mammal survey were unable to perform monitoring tasks without field training, even after receiving written instructions (Newman et al. 2003). Indeed, more than half of the volunteers participating in our study identified thorough, informative training as one of the project's key strengths.

The chief of natural resources at Cape Cod National Seashore estimates that overseeing the recruitment, training, and supervision of volunteers for this one-year study achieved no significant cost savings over using regular NPS staff. However, citizen science initiatives can be cost-effective over time, especially if volunteers make long-term commitments to ecological monitoring (Darwall and Dulvy 1996; Newman et al. 2003), or if one professional researcher or park manager supervises multiple volunteer projects. Participatory science programs may be particularly well suited for national parks with Research Learning Centers, which were designed as "places where science and education come together to preserve and protect areas of national significance" (National Park Service 2005). Some parks may be interested in establishing unsupervised citizen science projects; in these cases, further research is needed to determine whether high-quality data can be generated by unsupervised volunteers.

Our pre- and post-program surveys reflect an additional benefit of citizen science: increased support for estuarine restoration. We did not record a sea change in attitudes toward restoration among our participants, largely because they were highly supportive of ecological restoration from the start. However, our volunteers expressed strong interest in preserving estuarine restoration as a management priority at Cape Cod National Seashore and in expansion of citizen science opportunities on lower Cape Cod. By talking with neighbors, friends, and family, these citizen scientists may become effective ambassadors for restoration, recruiting additional volunteers and expanding the project's impact within the greater community (Evans et al. 2005). Such public support is vital for parks like Cape Cod National Seashore, which operate within a mosaic of privately owned land and regularly encounter local resistance to restoration efforts.

Conclusion

Volunteer involvement in ecological monitoring has been shown to facilitate swift, meaningful conservation actions within local communities, both through direct action and by fostering community-wide conservation dialogue (Danielsen et al. 2005). At the same time, research by professional scientists is more likely to influence environmental policy at the state and federal levels. By pairing reliable, locally relevant data collection with the NPS information infrastructure, citizen science partnerships between national parks and local communities carry great potential for enhancing estuarine restoration, both locally and nationally.

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