Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education

A CAISE Inquiry Group Report

July 2009

About CAISE

The Center for Advancement of Informal Science Education (CAISE) works to strengthen and connect the informal science education community by catalyzing conversation and collaboration across the entire field—including film and broadcast media, science centers and museums, zoos and aquariums, botanical gardens and nature centers, digital media and gaming, science journalism, and youth, community, and after-school programs. CAISE focuses on improving practice, documenting evidence of impact, and communicating the contributions of informal science education.

Founded in 2007 with support from the National Science Foundation (NSF), CAISE is a partnership among the Association of Science-Technology Centers (ASTC), Oregon State University (OSU), the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE), and the Visitor Studies Association (VSA). Inverness Research Associates serves as evaluator. CAISE is housed at ASTC's Washington, D.C. offices.

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Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education

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Foreword

This report is the result of work over the last year by the CAISE Public Participation in Scientific Research Inquiry Group. We are grateful to all of the members of the group for their contributions and to Rick Bonney of the Cornell Lab of Ornithology for serving as lead author of this report.

CAISE Inquiry Groups help to strengthen and connect the informal science education community by catalyzing conversations across the field around issues and topics of common concern. Drawing in part on results from NSF-funded projects, programs, and products, Inquiry Groups meet together to examine and discuss an issue or set of questions, gather and analyze evidence from practice and research, and synthesize their findings. They document their work with three audiences in mind: the informal science education (ISE) field as a whole, principal investigators (PIs) and prospective PIs of projects funded by NSF's Informal Science Education (ISE) program, and ISE program officers. Inquiry Groups have multiple uses. Their work products are intended to yield practical knowledge that can be put to work, provide evidence of contributions of ISE, and identify areas where more work and investment are needed.

The discussions that began among the members of the Public Participation in Scientific Research Inquiry Group are intended to inform and spark further study, discussion, and reflection among colleagues from across the field. We look forward to continuing the conversation. To find out about online discussions and conference sessions, visit the CAISE web site (www.caise.insci.org) and subscribe to the CAISE Newsletter.

We are grateful to the National Science Foundation for its support of CAISE and the informal science education field.

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Rick Bonney is a Senior Extension Associate and Director of Program Development and Evaluation at the Cornell Lab of Ornithology, where he has worked since 1983. His research focuses on 1) developing projects in which the public actively engages in scientific investigation and environmental conservation and 2) understanding the social and educational impacts of public participation in research. He co-founded the Lab's Citizen Science Program in 1992 and has been Principal Investigator of many of the Lab's Citizen Science Projects. Currently he is Principal Investigator of the Citizen Science Toolkit Project (citizenscience.org) and advises numerous projects throughout North America that are developing exhibits, curricula, interactive websites, and public participation in research programs focused on science.

Heidi Ballard is an Assistant Professor of Environmental Science Education at the University of California, Davis. Her work focuses on examining the process and environmental learning outcomes of participatory research approaches and citizen science efforts for ecological monitoring in conservation and natural resource management contexts. Her recent work includes examining the processes and outcomes of integrating local ecological knowledge with conventional science to improve learning about ecosystems. Previously, she worked with Latino migrant forest workers and with a Native American tribe to develop research and monitoring of non-timber forest products, harvest, and management. She received her Ph.D. in Environmental Science, Policy, and Management from the University of California, Berkeley.

Rebecca Jordan is an Assistant Professor of Environmental Education and Citizen Science in the Department of Ecology, Evolution, and Natural Resources at Rutgers University New Brunswick. As director of the Program in Science Learning, Rebecca is a behavioral biologist who devotes most of her research effort to investigating public learning of science. In particular, she is interested in practices to integrate ecological content knowledge and science reasoning skills into formal and informal science curricula. She received her M.Sc. and Ph.D. in Organismic and Evolutionary Biology at the University of Massachusetts and completed a post-doctoral fellowship at Princeton University and a visiting assistant professorship at Elizabeth City State University in partnership with the University of North Carolina at Chapel Hill.

Ellen McCallie is Deputy Director of the Carnegie Museum of Natural History in Pittsburgh, and is completing a Ph.D. as part of the Center for Informal Learning and Schools (CILS) at King's College London. Ellen's research seeks to facilitate interaction, collaboration, and meaning-making among scientists, publics, evaluators, and ISE professionals. Previously, Ellen served as Director of the Center for Advancement of Informal Science Education (CAISE). Ellen has also worked in various ISE media, including museums, gardens, and science television. She began her career conducting ecological and agricultural research in Brazil and Indonesia.

Tina Phillips is an Extension Associate at the Cornell Lab of Ornithology and Project Leader for NestWatch, NestCams, and CamClickr. She received a B.S. in Biology from the State University of New York at Stony Brook where she conducted research studying animal behavior. For the past decade, she has worked in the Lab of Ornithology's Citizen Science Program using citizen-collected data to study bird breeding biology. She has helped to develop numerous science inquiry curricula, and frequently writes and speaks about the educational and scientific outcomes of citizen science. In addition, she is pursuing a Ph.D. in science education at Cornell University, examining the relationship between citizen science participation and environmental literacy and behavior.

Jennifer Shirk works at the Cornell Lab of Ornithology as the Citizen Science Toolkit Project Leader. She coordinated the 2007 Citizen Science Toolkit Conference, and currently facilitates a website to support and network Public Participation in Research projects (www.citizenscience.org), which was inspired by the needs of conference participants for shared resources and strategies across different programmatic models. Shirk received her M.S. in 2005 from the Cornell Department of Natural Resources for investigating an inquiry-based School-Science Partnership, and is currently a Ph.D. candidate in the same department working to understand the strategies employed by science researchers to find professional success through Public Participation in Research.

Candie C. Wilderman is a Professor of Environmental Sciences at Dickinson College in Carlisle, Pennsylvania and Chair of the Environmental Studies Department. She received an M.A. in geology from Harvard University and a Ph.D. in Geography and Environmental Engineering from Johns Hopkins University. She is Founder and Science Director of ALLARM (Alliance for Aquatic Resource Monitoring), a community-based volunteer stream monitoring network in Pennsylvania, which was founded in 1986 and which provides technical and programmatic mentoring support to watershed groups and communities involved in watershed documentation, protection, and restoration. Her teaching and research interests include operational models for community-based research and education, undergraduate pedagogy, watershed assessment and management, aquatic ecology, and Chesapeake Bay restoration and protection issues.

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We thank the Cornell Lab of Ornithology's Program Development and Evaluation Unit for hosting an Inquiry Group meeting in September 2008 and the Environmental Studies Department of Dickinson College for hosting a second group meeting in January 2009.

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While we have benefited greatly from the support and input of others, the final content of this report, including any errors, is the responsibility of the authors, and does not necessarily reflect the views of the Center for Advancement of Informal Science Education or the National Science Foundation. This material is based upon work supported by the National Science Foundation under grant No. DRL-0638981.

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Executive Summary

Introduction

This report describes how Public Participation in Scientific Research (PPSR), in the context of informal science education (ISE), can provide multiple opportunities to increase public science literacy.

The ISE field is large and continually evolving. In the broadest sense it encompasses the range of science learning opportunities and activities that people experience across their lifespan outside of school. ISE can be delivered via numerous venues including lectures, TV programs, films, exhibits, websites, digital games, and community projects that are experienced or viewed in homes, science centers and museums, zoos and aquariums, botanical gardens and nature centers, and youth, community, and after-school centers.

As the concept of ISE emerged in the 1940s and 50s it was called "Public Understanding of Science" (PUS), and the current ISE program at NSF, which is one of the largest funders of ISE project development in the United States, is a direct descendant of the Public Understanding of Science program created at NSF in 1958 (Lewenstein 1992). Many ISE projects still follow the PUS concept or model, which is premised on the idea that science, scientists, and other experts know and should determine what the public needs to learn. Explain science to the public, the reasoning goes, and both science and scientists will enjoy greater support, which in turn will lead to greater economic prosperity, enhanced quality of life, and world leadership in science and technology. Most PUS activities involve exhibits, lectures, media broadcasts, and public programs through which the public is informed about science and expected to embrace it.

Recent research has suggested several shortcomings in the PUS model, two of which are relevant to this inquiry. First, educational research shows that people have greater motivation to engage and learn if the subject matter is directly relevant to their lives and interests and/or if the learning process is interactive—one in which the learner can directly affect the learning process, content, and/or outcomes of the experience (Falk 2001).

Second, PUS usually focuses on delivery of specific content rather than on helping the public experience and understand the process of research, that is, the way that scientific questions are asked, answered, and debated by the scientific community (Lewenstein and Bonney 2004).

To address these concerns, many ISE programs, projects, and activities developed over the past two decades have aspired to actively involve the public directly in the multifaceted and iterative processes of scientific investigation. Such efforts include citizen science, volunteer monitoring, and participatory action research. Projects that fall into these categories allow participants to learn both science content and process while experiencing the fun and excitement of research.

In response to a request by the National Science Foundation, the Center for Advancement of Informal Science Education (CAISE) established an Inquiry Group to

- identify and describe the range of ISE projects and activities in which the public is involved in one or more of the various stages of research
- describe models for public participation in scientific research

- understand and describe the educational impacts of PPSR projects
- make recommendations for conceptualizing and developing future ISE activities that will enhance public participation in scientific research.

We hope that this report will serve as a starting point for discussion about the value and potential for PPSR projects as a form of informal science education. While we have attempted to capture current thinking in this area, we realize that the conversation is just beginning.

Models for Public Participation in Scientific Research

Scientific investigations include many processes, steps, or activities in which the public can be involved. These include:

- Choosing or defining questions for study
- Gathering information and resources
- Developing explanations (hypotheses) about possible answers to questions
- Designing data collection methodologies (both experimental and observational)
- Collecting data
- Analyzing data
- Interpreting data and drawing conclusions
- Disseminating conclusions
- Discussing results and asking new questions

From an educational perspective, PPSR models differ chiefly by involving the public in these steps to varying degrees and by altering the amount of control that participants have over the different steps. For this report we have divided PPSR projects into three major categories:

1) **Contributory projects**, which are generally designed by scientists and for which members of the public primarily contribute data
2) **Collaborative projects**, which are generally designed by scientists and for which members of the public contribute data but also may help to refine project design, analyze data, or disseminate findings
3) **Co-created projects**, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process.

Impacts of Public Participation in Scientific Research

To investigate the educational impacts of PPSR we reviewed ten projects including examples of each model type—five Contributory, three Collaborative, and two Co-created. To standardize our methods of analysis for each selected project, we developed a rubric based on the evaluation framework described in *Evaluating Impacts of Informal Science Education Projects* (Friedman 2008). Our rubric describes potential impacts in the general categories of developing understanding and knowledge, enhancing engagement or interest, improving skills, changing attitudes, and changing behavior.

Next, for each project that we reviewed, we examined project descriptions and published reports to identify goals, objectives, and potential indicators for each impact category. Finally we determined measured outcomes (which were rare for most studies) and inferred outcomes (outcomes that seem to be happening but which are based on anecdote or perception as opposed to qualitative or quantitative evaluation).

In most cases, using this rubric to assess project impact was challenging because few if any of the projects that we reviewed used anything like it in their original or ongoing evaluations. However, we believe that our rubric represents an important step in bringing cohesion to the emerging PPSR field. It can be used not only as a guide to project assessment, but also as a tool for project planning and development.

Awareness, knowledge, and/or understanding

All PPSR projects seem to contribute to awareness, knowledge, and/or understanding of key scientific concepts related to the study at hand. This conceptual understanding ranges from purely scientific information to environmental issues and regulations. Participants in many PPSR projects also gain knowledge of the process of science. Indeed, this is one area where PPSR projects have the potential to yield major impacts, particularly Collaborative and Co-created projects, which engage participants in project design and data interpretation to a significant degree. Participants in most of the Collaborative and Co-created projects also seem to have gained knowledge of community structure and environmental regulation.

Engagement or interest

Increasing public engagement in scientific activities is an area at which PPSR projects excel. Participants who take part in a project's full range of activities are deeply engaged in conducting science. Indeed, enlisting people into PPSR projects is probably one of the most expedient methods for informal science educators to engage people in science in a fun and meaningful way. PPSR projects provide opportunities for people to develop interest and engagement by either trying something new or by expanding previously existing interests. The different PPSR models allow varied levels and types of engagement so that individuals with varying levels of expertise can develop a new interest or take deeper steps in their practice or engagement.

Skills

PPSR projects are excellent for developing science-related skills. Participants in most projects increase their ability to identify organisms, to use measurement instruments, to collect field data following specific protocols, and to sample consistently over time. Thousands of individuals have submitted data on nesting birds, the distribution and abundance of monarch butterflies, patterns of water quality, and the distribution and abundance of invasive plants. Furthermore, these data have been of sufficient quality to allow scientific analyses and to be published in peer-reviewed scientific publications. Participants in data analysis workshops gain additional skills in reading and interpreting graphs, drawing conclusions from evidence, and raising new questions as a basis for new study designs. Participants in Collaborative and Co-created projects also increase their ability to identify and distinguish habitats, to identify and select study sites, to weigh the pros and cons of various research design and data collection methods, and to communicate their results to the public.

Attitudes and behaviors

Few instances where PPSR project participation has affected attitudes toward science have been documented. Nevertheless, individuals who learn to function as scientists, or at least to understand how scientists work, could be expected to increase their already positive attitudes toward science. We do see evidence that Co-created projects that are initiated to meet specific community needs can draw concerned citizens into the scientific process who might not otherwise be involved in science-related activities. In addition, participation in PPSR projects can change behaviors. First of all, the projects cause people to take part in scientific research, which is a huge behavior change for many! Participation also can lead to other types of behavior change such as improving habitat for wildlife or noticing invasive species in the environment. And some PPSR participants become more engaged in community politics and more confident about asking for a place at the table in making decisions about community planning.

Opportunities for the Field

We suggest that projects focusing on PPSR represent an emerging field of informal science education that is ripe for further development, and we urge developers of ISE programs to consider four PPSR approaches in their work.

Creating new PPSR projects

Although hundreds of PPSR projects are now under way, both large and small, room for new projects exists in three areas:

1) Projects designed to study new scientific questions
2) Projects designed to engage new audiences
3) Projects designed to test new or enhanced PPSR models.

Many new projects could be created that will appeal to the increasing numbers of amateur naturalists and stargazers who are interested in lending their brains to science. Developers should be aware, though, that coming up with questions that are appropriate for PPSR is not a simple task, especially if the project desires to reach a wide audience.

And from an educational perspective, developing projects to answer new scientific questions may not be the most strategic approach for the ISE field unless new projects strive to enhance existing PPSR strategies or reach truly new audiences. But to reach new audiences, significant research into motivations for members of the public to understand and participate in research will be needed. Also required is research into the ways in which individuals perceive themselves or can develop identities as scientists, potential scientists, and critical thinkers. We suggest that new projects, especially if they desire to engage diverse audiences, test Collaborative and Co-created approaches to PPSR.

Enhancing PPSR projects already underway

We believe there is tremendous potential to enhance projects that are already underway. In particular, we suggest that many projects could be expanded to involve more individuals in more aspects of science inquiry. For instance, Contributory projects can be expanded into Collaborative models, at least for some project participants. At the same time, Collaborative and Co-created projects can learn many lessons from successful Contributory projects. For example, water quality monitoring projects could work together to design and develop regional and national databases that would allow participants to compare data and findings across larger regions or over long spans of time.

Add PPSR to other types of ISE projects

Examination of the NSF portfolio shows that relatively few full-fledged PPSR projects have been funded to date, although several have started in the last few years. More common in the portfolio are PPSR "add-ons," that is, citizen science projects that are associated with other projects such as films or exhibitions. We suggest that more closely integrating PPSR efforts into other types of ISE projects would represent strategic investment by the field. ISE projects seeking to deepen their impact through inclusion of PPSR techniques should consider partnering with PPSR projects already under way.

Enhancing research and evaluation surrounding models of PPSR and their impacts

Many questions remain to be answered about the potential for PPSR projects to contribute significantly to the ISE field. These include questions about personal and extrinsic motivators, altruistic intentions, and the notion that projects may be tiered or might serve as gateways for other projects to embrace participants who join projects for different reasons. Questions also remain about the learning implications of various types of PPSR projects. What is the nature of questions that enable participants to not only collect data but also to reflect on their experiences? Do participants, or potential participants, prefer to become involved with questions that deal with basic science, that resolve issues, that are simply fun, or all of the above? To what extent do participants gain from projects because they help to shape them? Yet other questions relate to the overall impacts of PPSR participation, including participation in areas of inquiry that have not been well studied such as modeling, data visualization, and data dissemination. Finally, we need to better understand the behavioral impacts of PPSR, which could push the boundaries of what we currently define as learning in the realm of science, including learning that affects participants' lives in a very broad sense.

Part 1: Introduction

Members of the public participate in scientific research in many ways and for many reasons. Some people conduct personal research to answer their own questions. However, most individuals who are involved in scientific research work as part of an organized group or project. Research groups involving the public can be as small as a few people gathering data on the quality of a local stream or as large as several thousand people participating in a national bird count.

At the core of most projects is a scientific question or environmental issue that is best addressed by analyzing large amounts of data that are collected across a wide area, or over a long period of time, or both. For example, understanding how water quality changes across a watershed, or how the timing of plant reproduction is affected by a warming climate, requires many individuals to work in concert, collecting and contributing information sufficient to understand the issue.

Public participation in scientific research is not a new concept. Lighthouse keepers began collecting data about bird strikes as long ago as 1880. A group of amateurs started the Astronomical Society of the Pacific in 1889; the National Weather Service Cooperative Observer Program began in 1890; and the National Audubon Society started its annual Christmas Bird Count in 1900 (Droege 2007). Throughout the 1900s, individuals across North America participated in projects to monitor water quality, document the distribution of breeding birds, and scour the night skies for new stars and even galaxies.

The interest of Science, Technology, Engineering, and Math (STEM) educators in public research projects is fairly recent, however, and corresponds roughly with publication of the Benchmarks for Scientific Literacy (AAAS 1993) and the National Science Education Standards (National Research Council 1996). These publications espoused the idea that the public, in addition to knowing science facts, should also understand the process by which scientific investigations are conducted. As a result, the 1990s saw the emergence of several projects seeking to enlist the public in authentic scientific research.

At the National Science Foundation, the concept of developing public understanding of science through public participation in scientific research seems to have begun with the 1992 award for a project called “Public Participation in Ornithology” (DRL-9155700). Developed by the Cornell Lab of Ornithology (CLO), the project launched three “National Science Experiments,” parts of which continue today (Bonney 2007). In each of these experiments the public gathered and submitted data to answer a specific question following a protocol developed by CLO staff. In addition, each project supplied participants with “Research Kits” containing educational support material such as identification guides, recorded bird sounds, and background reading explaining the reasons for the projects and describing the scientific method. One newspaper reporter, writing about CLO’s Seed Preference Test, called the project a “Trojan Horse approach to education.”

In 1995 Rick Bonney coined the term “Citizen Science” to refer to CLO’s growing number of scientist-driven public research projects (Bonney 1996). (At the time, he was unaware of the use of the term by Irwin [1995] to refer to citizen engagement in science policy.) The name took hold, and by 2001 had made its way into NSF’s Informal Science Education[1] program solicitation. Today, hundreds of citizen science projects, a number of which have been sponsored by NSF, are under way across the country. Project descriptions for many of them can be found at the website www.citizenscience.org.

[1] A note on terminology: To differentiate when we are referring to the National Science Foundation Informal Science Education Program as opposed to the field of informal science education, we have adopted the following convention: The “NSF ISE Program” is used to refer to the former, while “ISE” and “the ISE field” are used for the latter.

Citizen science is not the only model for public involvement in research, however. Other models include volunteer monitoring, community science, and participatory action research (Cornwall and Jewkes 1995, Wilderman et al. 2004, Lawrence 2006, Cooper et al. 2007, Ely 2008). Often these models provide participants with a more comprehensive exposure to scientific methodology than do the projects typically operated by science institutions. For example, in most participatory action research, participants help to ask the research question, design the study, and interpret results in addition to collecting data. The various models and terms often blur, however, and defining each one precisely is challenging.

Nevertheless, elucidating the basic models for public participation in scientific research (PPSR) and understanding how the models differ is an important first step in describing the emerging PPSR field and assessing and anticipating the learning impacts of the entire spectrum of PPSR projects.

Part 2: Models for Public Participation in Scientific Research

Scientific investigations include many processes, steps, or activities in which the public can be involved. From an educational perspective, PPSR models differ chiefly by involving the public in various steps to varying degrees and by altering the amount of control that participants have over the different steps.[2] For this report we have divided PPSR projects into three major categories:

1) Contributory projects, which are generally designed by scientists and for which members of the public primarily contribute data

2) Collaborative projects, which are generally designed by scientists and for which members of the public contribute data but also may help to refine project design, analyze data, or disseminate findings

3) Co-created projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process.

The basic models of PPSR are shown in Table 1.

Table 1. Models for Public Participation in Scientific Research

Step in Scientific Process	Steps included in Contributory Projects	Steps included in Collaborative Projects	Steps included in Co-created Projects
Choose or define question(s) for study			X
Gather information and resources			X
Develop explanations (hypotheses)			X
Design data collection methodologies		(X)	X
Collect samples and/or record data	X	X	X
Analyze samples		X	X
Analyze data	(X)	X	X
Interpret data and draw conclusions		(X)	X
Disseminate conclusions/ translate results into action	(X)	(X)	X
Discuss results and ask new questions			X

X = public included in step; (X) = public sometimes included in step

2 The authors are not implying that all scientific research includes all of these steps or that there is a defined "order" to scientific investigation. Rather, we articulate these steps to outline a range of common research activities in which members of the public might participate.

Contributory PPSR Project Model

Contributory projects are researcher-driven data-collection projects. Scientists ask questions for which answers require the accumulation of large amounts of data collected over wide geographic areas and/or over long spans of time, and members of the public collect relevant data following protocols predetermined by the scientists. Most projects labeled “citizen science” fall into this model (Bonney 1996, Krasny and Bonney 2005, Bonney 2007). In some projects the public is encouraged to analyze data, typically using online data visualization tools, but seldom are project participants expected to present results of analyses in such a way that they contribute to the research process. Participants do not determine any of the steps in Contributory projects. An example of a Contributory project is CLO’s Project FeederWatch, for which participants count the kinds and numbers of birds that visit backyard feeders during winter and report their data on carefully designed data forms. Researchers at CLO then analyze the data to understand and report trends in winter bird populations.

Collaborative PPSR Project Model

In Collaborative projects, as in Contributory projects, scientists ask research questions, and members of the public collect data to help answer those questions. However, project participants are actively involved in multiple research activities, including analyzing samples, interpreting data and drawing conclusions, and presenting results to other members of the public and/or to scientists and community decision makers. Participants also may help to design and refine data collection protocols. Many volunteer monitoring projects fall into this category (Whitelaw et al. 2003). Examples include some of the more complex water quality monitoring projects, for which participants work under the guidance of scientists to gather water samples, examine their content, perform basic data analyses, and present their findings to local government agencies.

Co-created PPSR Project Model

In Co-created projects, members of the public come up with a question or issue, often a community concern such as point-source pollution, and then work with scientists to answer the question and suggest solutions. Participants are encouraged to take part in all stages of the research process, from defining the question to disseminating conclusions and asking new questions, and if any part of the project does not work well, scientists and public participants work together to modify it for increased effectiveness. Thus, public participants exert significant control over Co-created projects. Many projects in this category have been labeled “community science” or “participatory action research” (Cornwall and Jewkes 1995, Wilderman et al. 2004, Fernandez-Gimenez et al. 2008). Examples include some public health or environmental restoration initiatives.

As methods of informal science education, particularly for helping the public learn about the process of scientific investigation, each model has strengths and weaknesses. To better understand the characteristics of each model and to learn how PPSR projects can be developed or redesigned to yield the greatest possible learning impacts, we have examined a variety of projects of each model type.

Note that in our attempt to develop models of PPSR we have deliberately excluded public engagement in science (PES) activities that involve members of the public in understanding and influencing public policy as opposed to participating directly in research. PES projects exist worldwide and include citizen juries, consensus conferences, and science shops (Rowe and Frewer 2005). Some educators might consider PPSR to be one form of PES. This idea is discussed further in the CAISE report *Many Experts, Many Audiences* (McCallie et al. 2009).

Part 3. Methodology for Meta-analysis of PPSR Projects

For our meta-analysis we reviewed ten PPSR projects including examples of each model type—five Contributory, three Collaborative, and two Co-Created. Our original plan was to create a purposive sample by examining an array of PPSR projects of all types, determining which had been most extensively evaluated, and then selecting ten projects for which we could extract project impacts from final evaluation reports or other project publications. We quickly discovered, however, that few PPSR projects have been evaluated comprehensively, especially those that we have categorized as Collaborative or Co-Created. In many cases, evaluations simply have not been conducted. In addition, many PPSR projects were started with an emphasis on scientific or community problem-solving goals as opposed to educational goals. In other words, we are layering educational models over projects that were developed not so much to help people learn about science as to address scientific or community needs. In the end we created a convenience sample including most of the USA-based PPSR projects that we could locate—either from the NSF ISE portfolio, from the list of projects available at www.citizenscience.org, or by reference from colleagues-- that included measured and reported outcomes or for which we felt that we could infer outcomes from available information. (We excluded from analysis most projects developed by the Cornell Lab of Ornithology to avoid oversampling; these are included in the Appendix of this report, which lists projects funded by the NSF ISE Program through June 2009.)

To standardize our methods of analysis for each selected project, we developed a rubric based on the evaluation framework described in *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman 2008). We decided to use the Framework for three reasons. First, its categories were developed by leading evaluators in the ISE field. Second, all ISE projects funded by NSF are now expected to use the Framework to guide their evaluations, so we seized the opportunity to assess its utility in guiding our meta-analysis. Third, we hoped that the rubric would be a first step toward developing an organized methodology for comparing outcomes across a variety of PPSR projects, not just for this report but for the growing PPSR field in general.

Our rubric is shown in Table 2. We took the impact categories shown in bold directly from Friedman: Developing understanding and knowledge, enhancing engagement or interest, improving skills, changing attitudes, and changing behavior. We also included a sixth category, "other," which dealt primarily with social and community impact. Next, for each of the major categories we developed subcategories by reviewing goals and learning objectives for individual PPSR projects. Additional subcategories emerged as our analyses were completed, because we discovered that we had not anticipated all impact types.

For each project that we reviewed, we examined project descriptions and reports to identify goals, objectives, and potential indicators for each impact category. For example, a stated goal might be increased awareness of biodiversity, and a potential indicator might be changes in awareness based on scores on a pre- post-test assessment. Next we determined measured outcomes (which were rare for most studies) and inferred outcomes (outcomes that seem to be happening but which are based on anecdote or perception as opposed to qualitative or quantitative evaluation). In some cases we contacted project staff for additional information. The final reviews were validated across the inquiry group by consensus dialogues.

In most cases, using this rubric to assess project impact was challenging because few if any of the projects used anything like it in their original or ongoing evaluations. However, we believe that our rubric represents an important step in bringing cohesion to the emerging PPSR field. It can be used not only as a guide to project assessment, but also as a tool for project planning and development.

Table 2. Assessment Rubric for Describing Impacts of Public Participation in Scientific Research Projects				
Impact category	Stated goal	Potential indicators	Measured outcomes	Inferred outcomes
Awareness, knowledge, and/or understanding (of) [1]				
Content (Concepts)				
Process				
Nature of science				
Careers				
Community				
Engagement or interest (in) [2]				
Content (Concepts)				
Process				
Community				
Careers				
Skills [3]				
Asking questions				
Study design				
Data collection				
Data analysis				
Data interpretation				
Discuss results				
Disseminate results				
Using technology				
Writing				
Community				

Attitudes [4]				
Toward science				
Toward content				
Toward people				
About activities				
Toward species				
About careers				
About theories				
About community				
Behaviors [5]				
Time engaged				
Time outdoors				
Lifestyle changes				
Within community				
Community involvement				
Citizen action				
Responsible environmental behavior				
New participation				
Other [6]				
Social capital				
Community capacity				
Economic impact				

Impact Categories

[1] Measurable demonstration of assessment of, change in, or exercise of awareness, knowledge, understanding of a particular scientific topic, concept, phenomena, theory, or careers central to the project.

Evidence for participant awareness can be observed through direct assessments, self-reports, or self-reflection.

[2] Measurable demonstration of assessment of, change in, or exercise of engagement/interest in a particular scientific topic, concept, phenomena, theory, or careers central to the project.

Indicators of engagement and interest may include length of commitment to, or depth of involvement with, a project or choices to further pursue content knowledge or related activities beyond a project's scope.

[3] Measurable demonstration of the development and/or reinforcement of skills, either entirely new ones or the reinforcement, even practice, of developing skills. These tend to be procedural aspects of knowing, as opposed to the more declarative aspects of knowledge impacts. Although they can sometimes manifest as engagement, typically observed skills include a level of depth and skill such as engaging in scientific inquiry skills (observing, classifying, exploring, questioning, predicting, or experimenting), as well as developing/practicing very specific skills related to the use of scientific instruments and devices (e.g. using microscopes or telescopes successfully).

Indicators of skill development could include a demonstrated degree of proficiency (such as the ability to identify species) or adoption and employment of a science-related skill (for example, prediction, argumentation, or synthesis).

[4] Measurable demonstration of assessment of, change in, or exercise of attitude toward a particular scientific topic, concept, phenomena, theory, or careers central to the project or one's capabilities relative to these areas. Although similar to awareness/interest/engagement, attitudes refer to changes in relatively stable, more intractable constructs such as empathy for animals and their habitats, appreciation for the role of scientists in society or attitudes toward stem cell research

Some standardized metrics for evaluating attitudes are available, but many rely on participant self-reports. In the context of PPSR, outcomes may include changing participants' attitudes about the role of science in their lives or communities, or improving attitudes about particular species, resources, or partnering organizations.

[5] Measurable demonstration of assessment of, change in, or exercise of behavior related to a STEM topic. These types of impacts are particularly relevant to projects that are environmental in nature or have some kind of a health science focus since action is a desired outcome.

Evidence of behavior change might include participants' self-reported intentions, and longitudinal tracking to determine whether such behavior change has occurred.

[6] Other

The NSF framework allows for measuring outcomes that do not fit well into the other five categories. We chose to look for evidence that projects affected participants' views of their communities, both socially and economically, and/or participants' interactions with other people and scientific institutions.

Part 4. Public Participation in Scientific Research Sample Project Descriptions

Contributory Projects

The Birdhouse Network

The Birdhouse Network (TBN), developed and operated by the Cornell Lab of Ornithology (CLO) with funding from the National Science Foundation, operated from 1996 until it was absorbed into NestWatch in 2007 (www.nestwatch.org). For TBN, participants placed nest boxes in their yards or neighborhoods and then collected data about the birds that bred in them during spring and summer. The data were submitted to CLO where scientists interpreted the information to develop a better understanding of temporal and geographic variations in the reproductive strategies of cavity-nesting birds throughout the United States and Canada. The project also aimed to enhance volunteer appreciation and understanding of the biology and ecology of breeding birds along with an understanding of the process by which scientific research is conducted.

Seeing young birds up close brought joy and discovery to participants in The Birdhouse Network. *Photo courtesy The Birdhouse Network*

During the project's 10-year run, approximately 5,000 participants monitored 75,000 nests in 49 states and seven Canadian provinces. Typical participants were older, well educated, retired females. Participants were encouraged to monitor nest boxes once or twice per week during the breeding season. Some observed just one or two boxes per week, while others monitored several dozen or even hundreds of boxes. The average number of boxes monitored was 22.

This project included a comprehensive website housing all project materials—instructions, data forms, and resource guides. Project staff also communicated with participants via a semiannual printed newsletter called "Inside the Birdhouse," email updates throughout the year, individual emails and phone calls, two email discussion listservs, and Birdscope, CLO's quarterly newsletter. Participants learned how to conduct the project on their own either by reading through a printed Research Kit (in the early years of the project) or by reading the directions online (later in the project when the Internet had become widely established as an easy means of communication).

Participants in TBN conducted repeat visits to nest boxes, recording individual nest locations, site characteristics, species using the box, and number of eggs and young in the nest. They also recorded important dates such as estimated first egg date, hatch date, and fledge date for each nest. After 2001 all data were entered online, where the information could be viewed and edited throughout the year. While participants did not have access to the raw data, they could visualize data through a variety of "canned" data queries. (Participants in newer CLO projects, such as eBird and NestWatch, have access to raw data.) Some participants provided suggestions to project staff—for example, interesting questions for scientists to study or new data collection methods—but this was neither required nor expected. In one "substudy," which focused on blowfly parasitism, participants collected and submitted complete nests to a partnering researcher (federal permits needed to be obtained to allow this activity).

To date, scientists have used TBN data to examine various breeding parameters and have published results in 11 peer-reviewed scientific journals.

Evaluation of TBN included a mix of qualitative and quantitative research methods. In 1997, participants were sent a pre-test survey before receiving educational materials and a post-test survey at the end of the field season. These surveys attempted to measure changes in science content knowledge (in this case, biology of breeding birds), science inquiry knowledge, and attitudes toward science and the environment. Comparisons of pre- and post-project surveys showed that TBN participants significantly increased their knowledge of bird biology (Brossard et al. 2005).

To determine whether participants had increased their knowledge of science process as a result of participating in TBN, evaluators gathered self-reports via a close-ended question followed by an open-ended question to assess the self-report responses. In general, participants did not seem to increase their science process knowledge, and three factors could have contributed to this finding. First, most participants probably joined TBN to learn about cavity-nesting birds as opposed to the process of science. Second, the Research Kits contained little information explicitly aimed at describing or explaining the process of science and showing participants how their activities fit into that process. Third, the project procedures did not ask participants to reflect on the scientific process (Brossard et al. 2005). However, interviews with project staff show that some participants did ask original questions and that some of these questions were refined and developed into new TBN studies. Also, some participants set up their own experiments and shared results with email discussion groups and CLO scientists—at least a dozen participant-initiated studies are currently presented on TBN's website (now located at www.nestinginfo.org). These results suggest that Contributory PPSR projects have the potential to incorporate multiple facets of scientific inquiry.

To assess participant attitudes toward science, the evaluators used a modified version of an existing standardized instrument—the Attitude Toward Organized Science Scale (ATOSS) (National Science Board 1996). Results showed little to no change as a result of TBN participation. To assess changes in environmental attitudes, evaluators used a version of the New Environmental Paradigm (Dunlap and Van Liere 1978), which revealed no evidence that project participation led to a less anthropocentric worldview of nature. The fact that TBN participants entered the project with very positive attitudes toward science and the environment compared with the "average public" could have yielded these findings (Brossard et al. 2005).

For considering potential behavior changes among participants, anecdotal evidence is available from email correspondence and online discussion groups, examination of products produced by TBN participants, and participant interviews (Phillips et al. 2006). This information shows that some participants increased "pro-bird" behaviors such as erecting nest boxes, providing water sources, planting native plants, designating yards as "wildlife sanctuaries," and disseminating information to other community members.

Spotting the Weedy Invasives

Spotting the Weedy Invasives, operated by Rutgers University and the New York/New Jersey Trail Conference and sponsored by the United States Department of Agriculture, engages hikers in identifying and mapping invasive plants along 160 km of trails in the New York/New Jersey Highlands (www.trails.rutgers.edu). The project began in 2006 with four researcher-defined goals:

1) Generate a long-term dataset about the distribution and abundance of key invasive plant species

2) Help participants learn about the ecology of invasive plants

3) Help participants understand how project data will be used to draw conclusions about the establishment and spread of weedy invasive plants

4) Encourage participants to take personal action toward reduction or eradication of invasive plants.

Each year the project attracts from 30 to 40 participants, most of whom are members of the NY/NJ Trail conference. About half of participants are men and half women; the average age is mid 50s; and about 85% of participants are currently employed.

Volunteers for Spotting the Weedy Invasives attend training sessions before they begin to collect data. *Photo courtesy Spotting the Weedy Invasives*

Participants spend at least 30 hours in the field each year. At the beginning of each season they attend a one-day training session at which they learn how to recognize the target species and collect required data. Additional training material is available online. After training, pairs of volunteers are assigned to hike a two-mile stretch of trail, stopping every 0.3 km to record the presence and relative density (low, medium, or high) of a selected suite of invasive plant species (averaging about 12 species depending on the year). Data validation efforts include

1) volunteers submitting a plant clipping of the first plant spotting

2) all volunteers walking a common trail for which invasive plant distribution is known

3) 25–50% (depending on the year) of data collected being validated by an external expert.

While participation in this project is limited primarily to the collection of data, during the training session participants also practice the development of explanations. They hear about how conclusions are drawn, and they are offered the opportunity to help disseminate conclusions about the study to local groups and/or land managers.

Project staff have investigated several aspects of project impact via written questionnaires developed by project staff and administered at three points during the project:

1) After the initial training session;

2) After a debriefing session held immediately following data collection; and

3) Six months after the data collection period.

Note that of the results discussed below, 1) and 2) are the sources of pre-test data and 3) is the source of posttest data. Most participants filled out questionnaires during the initial training and the debriefing sessions, while 35% returned the 6-month follow-up survey. All data were self-reported information (project director, personal communication).

All individuals indicated that they enjoyed project participation and felt they had gained knowledge about invasive plants. They also enjoyed the notion of doing something positive for science. Nearly three-quarters of respondents reported that they significantly increased their content knowledge, and pre- and posttest comparisons showed a 20% increase in the number of individuals who were able to provide correct responses to questions probing general background information about invasive plants.

Participants who completed pretests generally had a sense that science can be uncertain and that conclusions are tentative. They tended to rank highly the extent to which evidence should be visible, thus underappreciating the role of inference in drawing conclusions. Slightly over half of respondents articulated the necessity of controlling variables during an experimental process. However, fewer than one-third were able to adequately tease causation apart from correlation. Understanding of these issues did not measurably change between pre- and post-project participation, but views of science did change for some individuals. Nine of the 33 respondents stated that they possessed a greater understanding of the scientific process. Their responses varied in terms of sophistication—some held the notion that science is a way of reasoning, while others saw science only as experimentation and observation, most often through trial and error. Two individuals stated that science equates to a content area such as biology or physics. Variation in these responses did not correspond to professional background.

With respect to general environmental literacy as defined by the North American Association for Environmental Education (2000), individuals came to the project greatly concerned about the environment, and their concern did not change measurably following participation. However, respondents perceived their environmental knowledge to be only moderate (both pre- and post-participation), indicating that concern about environmental issues is not necessarily matched by the perception of knowledge about those issues. Civic awareness, as defined by awareness of the ways in which environmental problems are solved, was moderate pre-participation and increased slightly after participation. Participation did not affect locus of control (i.e., sense of empowerment resting within the individual versus beyond individual control).

Some slight changes in behavior were noted among respondents. When participants began the project, 78% said that they considered invasive plants when making plant purchases, and 30% viewed invasive plants and other environmental issues as influential in their voting decisions. Although the latter measure did not change, the proportion of people considering invasive plants while making purchases increased to 86% at project completion. In addition, 39% stated they had begun to take notice of invasive plants in the environment, and 43% reported that they talked to others about invasive plants. Planting habits were changed by 9% of respondents, and 6% went on to seek other volunteering opportunities. Common explanations for individuals who did not take action included time constraints and a sense of futility given the scale of the problem.

ALLARM Acid Rain Monitoring Project

The Alliance for Aquatic Resources Monitoring (ALLARM) Acid Rain Project (www.dickinson.edu/allarm) operated throughout the state of Pennsylvania from 1984 through 2005. It was started as a data-gathering and informal science education project by Candie Wilderman, Professor of Environmental Science at Dickinson College in Carlisle, in response to an observation by Pennsylvania state legislator John Broujos that, although Pennsylvania receives the most acidic deposition of any state in the nation, Pennsylvania citizens are mostly unaware of the problem. For this project, trained participants made weekly visits to a stream of their choice where they tested the water for pH and alkalinity.

The project had many researcher-defined goals. Scientifically, the project aimed to document patterns of response to acid deposition in Pennsylvania streams. In the area of education, the project aimed to help participants gain knowledge of the extent and impact of acid deposition on streams and to develop awareness of the variability in aquatic systems and the challenges involved in characterizing them. In the realm of conservation, the project desired to help participants first build a strong sense of place by visiting a single site on a weekly basis and then to build a sense of stewardship for that place. Finally, the project aimed to empower participants with first-hand knowledge of the responses of streams to acid rain so that they could, if they chose, participate in community efforts to find solutions.

Each year the project involved about 150 adult participants with the following audience composition: 75% male; 72% college educated; 63% small town/rural, 30% suburban, 7% urban; and 38% retired.

ALLARM acid rain monitoring volunteers follow set protocols to test water pH. *Photo courtesy ALLARM*

As in most water quality monitoring projects, this one required volunteers to demonstrate their competency in collecting and analyzing samples before participating. They began the project by attending one or two training workshops at which they learned how to analyze water for pH and alkalinity and to choose study sites. After the workshop they sent in a split sample for Quality Control/Quality Assurance (QC/QA) testing. (In this procedure, the volunteer splits a sample into two, measures his/her half, then sends the other half to a lab for testing and comparison to the volunteer's results.) Individuals who passed this assessment chose a stream site or sites, usually near their home and complying with site-selection criteria; visited their site(s) once per week; tested the stream for pH and alkalinity using a field kit developed by ALLARM; and filled out a data form. Participants averaged about two hours of effort each week and needed to pass QC/QA once per year to continue to contribute data. Although individuals networked with other participants if they chose to attend additional training workshops, they worked independently for the bulk of the project.

Project data were managed and analyzed by ALLARM staff but were available to the public through the Pennsylvania Spatial Data Analysis website, the ALLARM website, and the Pennsylvania Keystone Monitoring Database. Participants received annual reports including analyses of the patterns found at their stream site(s) within the larger context of all sites sampled. Participants also had opportunities to attend presentations on the science and policy of acidic deposition presented by ALLARM staff on a roughly bi-monthly basis. ALLARM staff also disseminated results through scientific papers, conference presentations, legislative testimony, newsletters, and articles (for example, Wilderman and Schott 1991; Wilderman and Vorhees 1999; ALLARM 1986–2009).

While we have characterized the basic design of this project as contributory, the project did include the opportunity for participants to go beyond data collection if desired. For example, participants often gathered local information on their stream sites to help explain detected water quality patterns. Also, many participants chose to disseminate project conclusions via newspaper editorials, contact with local and state officials, and contact with angler and conservation clubs, even though ALLARM offered no training or formal support for participants to engage in these activities.

Finally, some participants discussed project results and asked new questions at training workshops or at presentations on the science and policy of acid deposition. In fact, because so many participants began asking questions that went beyond the single issue of acid deposition, ALLARM expanded its focus to include a wider range of water quality issues, changed its name from Alliance for Acid Rain Monitoring to Alliance for Aquatic Resources Monitoring, and broadened its project design from Contributory to a Co-created model (Wilderman et al. 2003). So, although the "final" step in the scientific process was not a formal step in the operational process of the original project, the discussing of results and the asking of new questions happened to such an extent that the project itself was significantly expanded to address a broader range of community-based issues.

The ALLARM Acid Rain Project received informal evaluation by project staff. Assessments included feedback through interviews, discussions at workshops, participant surveys, workshop evaluations, quality control passage rates, and examination of participant-created products emerging from the project.

ALLARM staff noted numerous project impacts. Many participants wrote increasingly sophisticated comments on data forms, indicating that they were gaining knowledge of many concepts about acid deposition and stream quality. By participating in the QA/QC, participants gained an appreciation of the importance of validation in the scientific process. And some participants clearly increased their understanding of the concepts of variability and sampling intensity and used this knowledge to describe the acid deposition problem through letters to the editor, discussions with government representatives, and presentations at community events.

Participants were deeply engaged with this project. About 90% of those who started monitoring stayed with the project for the required one-year period and about 20% stayed from 2–5 years. Also, about 5% of volunteers were observed to take direct action as a result of their monitoring. Some participants reported feeling isolated in the project, and although training workshops helped to develop a sense of community, individuals who attended workshops did not seem to engage in continued networking.

Participants clearly developed skills in data collection. About 95% of all volunteers eventually passed QC/QA tests and went on to collect weekly data. However, the project did not seem to help participants develop other skills. For instance while volunteers generally understood the criteria for site location and were able to choose suitable study sites, they had little understanding of the overall statewide study design. There was also a great deal of variability in the level of understanding of the data among volunteers, and few volunteers took it upon themselves to independently disseminate the analyses that ALLARM presented to them. However, project staff occasionally received copies of letters written and anecdotal information on conversations and presentations given by participants.

Overall attitudes toward science did not seem to shift as a result of project participation. Most participants felt that they learned a particular skill to help them contribute to the work of scientists, but that their role was that of technician. However, participants consistently reported enjoying workshops and monitoring activities. Most had the sense that the activities were making a useful contribution to the scientific database, largely because they trusted the scientists involved.

While project staff had no knowledge of direct citizen action resulting from the project, volunteer interest in expanding the project beyond the issue of acid deposition into broader environmental monitoring ultimately led to the expansion of ALLARM into new watershed-based projects. Some of the acid rain volunteers participated in the broader program of watershed monitoring when it was created.

Monarch Larva Monitoring Project

The Monarch Larva Monitoring Project (MLMP) was begun by researchers at the University of Minnesota in 1997 to involve citizens in collecting data to help explain the distribution and abundance patterns of monarch butterflies during the breeding season in North America and to inform monarch conservation (www.mlmp.org). Sponsored by the National Science Foundation from 2002 through 2005, MLMP seeks not only to gather important data but also to provide citizens with hands-on experience in scientific research, thereby enhancing their appreciation and understanding of monarchs, monarch habitat, and the scientific process in general.

The audience comprises all ages and demographics. About half of participants, including teachers, naturalists, and parents, report that they monitor monarchs with three to five children each. While the project has not collected detailed data on the total number of participants—only one volunteer records data for each site—participants have now monitored 956 field sites in 28 U.S. states and 3 Canadian provinces, so the total number of participants is likely in the thousands.

Participants learn project procedures either by reading directions online or, if they live near a participating nature center, by attending an in-person training session at which they learn about monarch biology, practice monitoring and data-entry protocols, and receive all needed materials.

Once trained, volunteers choose and describe their own monitoring sites, which include backyard gardens, abandoned fields, pastures, and restored prairies located throughout the monarch's breeding range (mainly the eastern half of the United States and southeastern Canada, although some volunteers monitor a western population in coastal California). The only requirement is that the sites contain milkweed (*Asclepias spp.*), the monarch's larval host plant.

A volunteer monitors monarch butterfly populations in Duluth, Minnesota. *Photo courtesy MLMP*

Once their sites are chosen, participants conduct weekly surveys of monarchs and milkweeds. They randomly choose as many plants as possible to census (typically from 50 to 500), then record the number of milkweeds examined and the numbers of eggs and larvae observed, identifying larvae to a specific instar (monarchs go through five larval instars). They enter their data into an online database, which they can modify throughout the season. At the end of the season they send project managers hard copies of their data sheets, which are used to spot-check the online data and then archived. Summaries of the data are made available online and through an annual newsletter. Raw data from individual sites can be downloaded from the website, and other data are made available upon request. Many people, including both participants and non-participants, request raw data for informational, scientific, and educational purposes. No data analysis tools are provided, however.

Optional data-collection activities include assessing milkweed quality, measuring rates of parasitism by parasitoid wasps and flies, and collecting weather data. The assessment of milkweed quality involves comparing plants occupied by monarchs to random plants by measuring the same characteristics of each (height, reproductive status, age, herbivore damage, and the presence or absence of invertebrates). Participants who engage in the parasitism study collect monarch eggs or larvae (mainly fourth or fifth instars), rear the caterpillars indoors, record whether they survive to adulthood and, if they do not, record what causes their death.

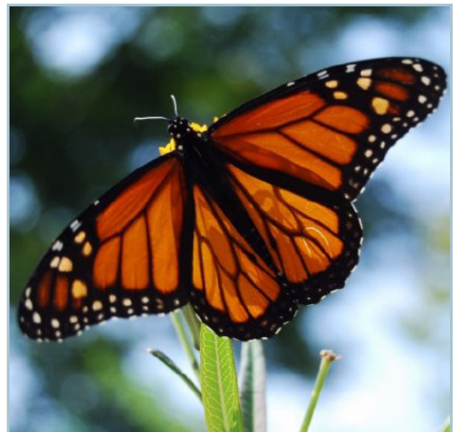
MLMP staff have collected numerous comments that show the importance and significance of the project for its participants. For example, a high school student from Minnesota stated, "It is amazing to me that when people all over the country take a little time every week, and even more in some cases, to count butterfly eggs, the end result is a network of data that can help us decipher where the butterflies go and when and how … This is real life proof that when everybody works together, things can be done." And another student stated, "MLMP has given me the opportunity to learn how a truly massive research project functions, but has also let me understand how important every piece of data is, no matter how small, when needed to reach a conclusion." Still another student states, "The MLMP has helped me become a better scientist in so many ways. Most importantly, it gave me a large interest in science. It encouraged me to ask questions such as why and how and to find these answers through experimenting."

MLMP also has been assessed through an evaluation that focused on understanding the impacts of the project on children who were being mentored by an adult participant (Kountoupes and Oberhauser 2008). The most commonly noted outcome, ascertained through detailed interviews with MLMP participants, is learning and understanding about real scientific research. Adults perceived that children felt like real scientists and were proud of their contributions.

Interview data also highlighted the importance of the social aspects of the program. The shared experience allowed children to meet new friends with like interests while enjoying time together in the outdoors. One interviewee described the experience for her group of children as "science bonding."

Another emphasized a need for alternatives to sports-centered recreation, describing childrens' thirst for learning about nature.

Although this project has focused primarily on data collection, many participants, especially teachers and naturalists, have chosen to engage youth participants in a variety of related science-process activities of their own design, including defining new questions for study, developing hypotheses, designing data-collection methodologies, interpreting data and drawing conclusions, and disseminating results. Not surprisingly, adults who engage youth in these activities report the strongest learning gains. For this reason, the MLMP is expanding the program by supporting volunteers who use their MLMP experiences to conduct independent investigations. In one case, an independent investigation instigated by a volunteer led to a paper co-authored by three volunteers and published in the peer-reviewed literature (Oberhauser et al. 2007). Other projects are highlighted in the annual newsletter, and project coordinators correspond frequently with volunteers who are conducting their own studies.



Monarch butterfly. *Photo by Christine Ruffo*

Community Collaborative Rain, Hail, & Snow Network

CoCoRaHS (the Community Collaborative Rain, Hail, and Snow Network) is a community-based network of volunteers of all ages and backgrounds working together to measure and map precipitation (rain, hail, and snow) (www.cocorahs.org). Begun at the Colorado Climate Center at Colorado State University in 1998, CoCoRaHS is now sponsored by the National Oceanic and Atmospheric Administration (NOAA) and a variety of other organizations. Anyone interested in watching and reporting weather conditions is invited to participate, and more than 12,000 observers are currently contributing observations from 39 states.

Goals of CoCoRaHS include providing large quantities of high-quality precipitation data for a variety of users while encouraging citizens to have fun participating in meteorological science and heightening their awareness about weather. From 2003 to 2006 the project was supported by the National Science Foundation to help the organization provide enrichment activities in water and weather resources.

Using a simple rain gauge, CoCoRaHS volunteers take measurements of precipitation from as many locations as possible each time a rain, hail, or snowstorm crosses their area. They record their reports on the project website where the data are organized, displayed, and analyzed by a variety of individuals and organizations including the National Weather Service, hydrologists, emergency managers, city utilities, farmers, and even insurance adjustors. Training is provided either online via downloadable slide shows or, in some states, at local training sessions. Feedback to volunteers is provided primarily through a bi-monthly newsletter that can be received by email or downloaded as desired.

At the end of the grant period, project staff had received approximately 7,000 volunteer applications, and nearly 4,900 participants, located primarily in the Midwest, collected data at some point during the project. Most of those who applied were adults in the age range from 55 to 80 years old, with a secondary peak of applicants, representing families with school-aged children, of parents in their 30s and 40s. Approximately 60% of registrants were male and about 40% female.

The duration of participation varied widely. Some participated sporadically or for a short period of time, while others participated thoroughly and continuously after first getting started. Some reported every day, while others reported only during storms. Those who signed up but did not participate offered a wide range of reasons ranging from expense of rain gauges to lack of time for attending training or collecting data.

Participants in CoCoRaHS measure amounts of rain, hail, and snow. *Photo by Henry Reges, CoCoRaHS*

Project staff found that the most effective training, especially for beginners new to data collection, was face-to-face workshops. Individuals who attended group training sessions were more likely to participate and to participate longer. However, providing personal training for all participants is difficult for large-scale projects, and the project staff feel that successfully growing the project will depend largely on increasing training options.

Evaluation of this project included participant inventory and tracking, precipitation data compilation (providing information on the duration and spatial distribution as well as data quality provided by CoCoRaHS volunteers), participant surveys, and focused interviews with a randomly selected group of several dozen participants (CoCoRaHS 2007).

Project staff identified several project activities during which learning could take place, including siting and installing rain gauges, measuring and reporting precipitation, examining self-collected data over time, and reading results from newsletters. However, little information about learning seems to have been collected for project evaluation. The only information available from the final project is the statement "from surveys and interviews, most participants are able to define specific learning that they have identified. In many cases, the learning is simply an increased awareness of the surrounding environment and how it is affected by precipitation. The most common learning is that precipitation is much more variable than most people realized."

Collaborative Projects

Salal Harvest Sustainability Study

The Salal Harvest Sustainability Study, sponsored by the Community Forestry and Environmental Research Partnership through a researcher (Heidi Ballard) at UC Berkeley and the Northwest Research and Harvester Association (NRHA), ran from 2001 through 2004. The project took place on Washington's Olympic Peninsula and involved harvesters of salal (*Gaultheria shallon*) in research to determine the effects of harvest intensity on the plant's growth and biological and commercial production. Salal is an evergreen shrub harvested as a non-timber forest product (NTFP) for use as greenery in the floral industry. The increasing harvest rate in recent years is causing concern about the impacts on habitat by some public land managers.

Specific goals of the study were to determine effects of different harvest intensities to inform management of the plant and improve harvesting practices; to involve and potentially empower salal harvesters in research affecting their livelihoods; and to provide harvesters with forestry and technical job skills that could help them gain employment in forest management. Approximately 35 salal harvesters took part in the project, about 10 of whom participated during all four years. Most were undocumented Latinos between the ages of 20 and 40 who were learning English. A few were Asians or Caucasians. All participants depended at least part time on harvesting salal for their livelihood; for most it was a full-time job.

The project began with the researcher training the 10 harvesters onsite, either individually or in small groups of three to four participants. They learned about site selection, methods design, data collection, and interpretation of results. Then, over the course of the year, each participant spent about 40 hours working on site assessments, research design, and data collection. During the second and third years harvesters spent about 20 hours per year collecting data. Also during the third year, all 10 participants, along with about 25 additional harvesters, attended a workshop to learn how to interpret graphs and draw conclusions from evidence and observations. During the fourth year each participant spent about three hours discussing and disseminating project results. The project scientist compiled the data and kept in touch with participants either in person during the field season (May–November) or by phone.

Participants in the Salal Harvest Sustainability study depend on salal for their livelihood. *Photo by Heidi Ballard*

This project is considered collaborative because, while the project scientist had the final say on defining the research questions and developing study hypotheses, participants played a key role in each. Despite their relatively short time living and working in the forests of the Olympic Peninsula (12 years or less), the harvesters had developed local ecological knowledge that often surpassed that of forest professionals, including knowledge about ways in which understory plants respond to timber management practices such as thinning, and understanding of which overstory conditions help commercial-quality salal to grow best. They also knew the various harvest practices, and helped design the project to test the two practices most often used. They chose research locations that reflected the variety of environmental conditions in the area, such as differing elevations and forest stand types. The researcher and harvesters collaborated to design response variables in the plant's growth which would detect and measure specific impacts due to harvesting, including percentage of leaves damaged by insects or fungi and stem density of harvestable new shoots, variables not found in the literature. Harvesters collected all types of project data and applied all harvest treatments, calibrating treatments across individuals and sites.

After treatment, the researcher took responsibility for analyzing the information. However, the harvesters played a key role in interpreting the data at a large workshop facilitated by the researcher and leaders of the NRHA, during which harvesters interpreted graphs of harvest yield results. They analyzed why some results differed from their hypotheses, why sites responded differently to the same harvest treatments, and how results could be used for management recommendations. Conclusions were summarized by the researcher and disseminated to the local public, private land managers, Washington State University Cooperative Extension, and the NRHA.

Impacts of this project were assessed in two ways. First, the researcher used semi-structured interviews to collect ethnographic data and information about participants' knowledge of local ecology throughout the course of the project. In addition, an outside evaluator interviewed seven participants during the final year of the study to determine what they had learned during the project, what they thought the researcher learned from them, and their recommendations for other scientists who would like to work with similar participants in the future (Ballard and Huntsinger 2006; Ballard 2008; Collins et al. 2008).

Based on information collected during the interviews, harvesters appeared to develop awareness and understanding of science concepts, such as understanding of plant associations, ecological relationships, and forest succession. In addition, in their discussions of experimental design, data collection, and results interpretation, harvesters demonstrated substantial awareness of how science is conducted. While three harvesters expressed frustration with the tedious detail of the scientific process and felt it a waste of time, four others expressed interest in working with other scientists again, especially to study the effects of fertilizer on commercial production and how white pine blister rust could be treated using pruning methods for commercial use of the pine boughs. Both of these studies were pursued in collaboration with Washington State University Extension scientists during following years, providing evidence that these types of programs can generate novel research questions. Two harvesters inquired about USDA Forest Service Technician jobs, reflecting a desire to move toward a job requiring higher skill, although they did not apply owing to their legal status.

The project also increased the ability of participants to collect field data, to record and observe consistently, and to use measurement instruments. Participants in the results interpretation workshop also gained skills in reading and interpreting graphs, drawing conclusions from evidence, and explaining how the results compared to their own observations in the forest.

Some harvesters expressed increased concern for the environment, for the health of the forest, and for the sustainability of the resource. Several expressed a new awareness of how their harvesting practices affected the health of the forest, although they stated that economic pressures to harvest would heavily outweigh environmental concern.

Importantly, harvesters who participated in the research project demonstrated an increase in involvement in the NRHA and in the harvester community as a whole. Harvesting is an isolating livelihood, especially for illegal workers, so any group participation vastly increases social capital. Project participation also led to increased harvester credibility and improved relationships between harvesters and forest managers. Rather than being perceived either as invisible or as a nuisance, forest managers began to see harvesters as holders of important ecological knowledge and skills and started to view their contributions as valuable (Ballard 2008).

Community Health Effects of Industrial Hog Operations

Community Health Effects of Industrial Hog Operations (CHEIHO) was a project conducted by a partnership between the Concerned Citizens of Tillery (CCT) and academic researchers at the University of North Carolina, Chapel Hill (UNC-Chapel Hill) School of Public Health from 2003–2005. The CCT is an active community organization located in a rural and predominately African-American town in North Carolina. CHEIHO was an epidemiological study of the acute human health effects of pollution caused by industrial hog operations located near residences (www.cira-unc.org/collabs). Because high-density swine production often occurs in communities comprising low-income residents and/or people of color, the project focused on issues of environmental justice as well as public health. In earlier research projects that quantified the disproportionate location of industrial hog farms in poor communities, community members participated in evaluating data quality through their knowledge of local hog operations, making decisions about how to define study populations, choosing and defining variables for analysis, and interpreting results. Hence, the CHEIHO project built on other PPSR environmental health research projects that the CCT and the university have conducted since 1998 (Farquhar and Wing 2003, Wing et al. 2008).

The goals and study questions for this and the other projects of the CCT-UNC-Chapel Hill partnership originated in the exposed communities. Specific goals of the CHEIHO project were to integrate ethnographic and epidemiological research on acute exposures and their relationships to both health-related outcomes and quality-of-life concerns; to provide environmental health education to community members; and to promote community participation in environmental and social justice movements. Data were collected from September 2003 through September 2005 in 16 rural communities in eastern North Carolina. The study included 104 volunteers, primarily African Americans, who were non-smokers over the age of 18 living within 1.5 miles of at least one industrial hog operation. Sixteen of these participants recorded data from air pollution monitoring equipment once per week in each community for two weeks. The remaining 88 participants collected self-administered health data twice each day for 14 days. All participants underwent a three-hour training session at which they practiced filling out a data collection diary and built rapport with each other and the project research team. Each volunteer also participated in six hours of interviews.

The scientific team included a core of three community leaders affiliated with CCT as well as three university researchers. These core participants conceived of the research question based on problems they experienced in their community, designed the study, conducted the training sessions, provided data-quality check visits to volunteers once during their two-week data-collection sessions, helped to analyze the data, and facilitated numerous community meetings. The core team also published project data in public health journals, and CCT used the research results to lobby for change in land use policies in the region.

Goals and questions for the Community Health Effects of Industrial Hog Operations project originated in the affected community. *Photo by Gary R. Grant*

The research questions included: What was the frequency, magnitude, and duration of swine odors experienced by project volunteers? What were the levels of several airborne toxins in the area around hog operations, how were they related to odors experienced, and how were pollution levels related to acute health effects experienced by residents (such as lung function, blood pressure, mood, stress, and quality of life)? How were the cultural and social contexts of rural life related to experiences of environmental exposures and quality of life?

The 88 participants who were involved primarily in data collection recorded observations about hog odor outside their residence at predetermined times; recorded whether they experienced any irritation of the eyes, nose, throat, or had any physical health symptoms; took their own blood pressure; collected a sample of saliva; and blew into a lung function monitor. All these participants also discussed summaries of the data analysis during community meetings. Finally, the core research team and many of the additional participants were involved in disseminating project conclusions by presenting at community meetings in surrounding areas.

Information about the impacts of this project on land use policy, environmental justice research, and community health education have been reported in Wing et al. (2008). These authors did not, however, formally measure specific knowledge about science content or process. However, project personnel believe that training in the data collection procedure resulted in a significant increase in awareness, knowledge, and understanding of human health and air quality issues as well as in understanding of data collection methodologies including making careful observations, looking for patterns in data, and being consistent in data collection. They also note that "participants gained confidence and a greater sense of legitimacy by seeing their experiences and views embedded in a scientific process in which they participated." This research involved members of the public who felt marginalized and placed the experiences of these individuals in the context of a scientific study, empowering communities through connections with professional research.

Participants in this project also made new connections with neighbors and organizations, increasing social capital. Wing et al. (2008) report that participation in research broadened some participants' perspectives on community involvement and environmental injustice and awakened awareness about the potential for change. For example, during the qualitative interview following the quantitative data collection, one participant stated "I never thought about it [the concentration of hog houses] …The day after we did the class [CHEIHO training], I rode around and counted how many hog houses. I counted 22. I never knew there were that many hog houses …[or] how in the world they got here."

While the CHEIHO project did not specifically measure science education impacts, community education about environmental health was an explicit goal and was documented during the project (Wing et al. 2008). An additional goal was to build the organizing and communication skills of community members to take action in local, regional, and state arenas to address the environmental health and injustice problems in their community. In this light, the authors state that evidence of their education goals being met can be found in the community action that led to policy change and improved health. For example, the work of the Concerned Citizens of Tillery and UNC Chapel Hill researchers has resulted in an ordinance regulating the corporate hog industry.

Invasive Plant Atlas of New England

The Invasive Plant Atlas of New England (IPANE), initially funded by the U.S. Department of Agriculture, is another project that seeks to engage volunteers in identifying and mapping invasive plants (www.ipane.org). The project was begun in 2001 to develop a widespread early detection system. Since that time, project organizers developed educational goals that called for increasing content knowledge and science process skills among participants. These goals include not only the understanding of the effects of invasive plant species on native ecosystems but also an understanding of how invasive species data are collected. The project also aims to engage participants in management actions through partnerships with management organizations.

So far the project has trained 900 individuals, all adults, and now includes approximately 500 active volunteers. Participants are recruited through flyers and project partners, including the University of Connecticut, the Silvio O. Conte Refuge of the U.S. Fish & Wildlife Service, and the New England Wildflower Society.

Participants begin by taking part in a one-day training session at which they learn how to identify and collect data on invasive plants and how to select sample sites, both terrestrial and aquatic, based on habitat characteristics. After training, participants designate plots—the number is up to each participant—within their chosen sites. They visit each plot once, spending approximately 30 minutes and collecting data on the distribution of invasive species as well as species abundance, percent cover, and mode of reproduction. Observations are supported by photos or samples and all data are entered online.

Participants in the Invasive Plant Atlas of New England monitor the occurrence of non-native species such as this Japanese Barberry. *Photo courtesy IPANE*

Supplemental training materials are available online, and advanced training sessions dealing with specific species also are available. Project data are used and interpreted primarily by project scientists but are available to the public via the project website. In addition, participants are welcome to share their ideas or concerns about data collection with the project partners. So far the data have been used to inform state legislation on invasive species. For example, in Massachusetts, IPANE worked with the Massachusetts Invasive Plant Evaluation Project (MIPEG) to develop the Massachusetts Prohibited Plant List.

We consider IPANE to be a Collaborative project for three reasons. First, participants select their own study sites (although this also occurs in many contributory projects). They are given a set of criteria and then use this information to select sites they deem worthy of study. Second, project organizers encourage individuals to become involved with curriculum and management projects as evidenced by links to those programs at the IPANE web portal (project organizers acknowledge that these linkages are still at an early stage in development). Third, and most important, participants are encouraged to disseminate the data they collect, and project organizers work to link interested individuals to partner organizations such as the Connecticut Invasive Plants Council, Connecticut Invasive Plant Working Group, the Northeastern National Parks Invasive Evaluation Project, MIPEG, and the New England Invasive Plant Group (NIPGro).

Because the original goal of this project was primarily scientific, impact assessment has focused on the number of records collected across the region. To date, 11,596 field records have been submitted on 5,389 field forms. Clearly the project has developed an early-detection invasive-plant network from which participants and scientists can benefit.

While this project has not been extensively evaluated from an educational perspective, a questionnaire focusing on assessing participants' perceptions of the project has been developed and disseminated by project staff. The questions focus on specific aspects of the plants to be studied and the nature of the ecological interactions within relevant plant communities. Questions were also asked about the helpfulness of different aspects of training sessions: Species identification, methodology and data forms, and online data entry. In addition, data and website use were assessed. The questions were mostly multiple choice although several yes or no questions were followed with "if not, why" which required a write-in answer.

The results helped project organizers to make decisions about updating the training schedule and program. Suggestions were solicited at the end of the questionnaire for additional workshop ideas. However, staffing limitations appear to hinder organized assessment of learning, and the survey is not administered regularly. In terms of desired learning outcomes, based on the nature of the questions, the project seems to focus on increasing awareness, engagement, skills, and attitudes. The training seems to focus on helping participants understand the process of how the project data need to be collected. As the partnerships develop, project organizers intend to further articulate learning goals and outcomes.

Co-created Projects

Shermans Creek Conservation Association

Shermans Creek Conservation Association (SCCA), a group of residents of the Shermans Creek Watershed in south-central Pennsylvania, conducts several monitoring projects under the guidance and mentorship of ALLARM. SCCA also conducts local educational outreach and collaborates with local and state officials to implement sound land use practices (www.shermanscreek.org). Begun in 1998, SCCA receives a variety of grants from organizations such as the Pennsylvania Department of Environmental Protection and the League of Women Voters Water Resources Education Network.

Shermans Creek Watershed covers approximately 250 square miles of Perry County. The audience for SCCA's activities consists mostly of local residents, who live in small towns and surrounding agricultural areas. ALLARM supports SCCA not by setting its goals and activities but by helping the group reach the goals that its members have agreed upon. ALLARM provides training, technical support, QA/QC, and programmatic and grant-writing assistance.

The goals of SCCA are several. Scientifically the project aims to monitor the health of Shermans Creek Watershed to target critical areas for protection or mitigation and to inform management decisions. The project also seeks to help all watershed residents become aware of the watershed's importance to their quality of life and to instill in residents a desire for its protection. In addition, SCCA hopes to empower community members to meaningfully participate in making decisions about how the watershed is managed.

At the heart of the project is long-term monitoring. When the project began, its overall objectives were to collect at least five years of baseline data on the status of Shermans Creek and its tributaries, to disseminate those data, and to restore and/or mitigate areas that were identified as needing action. These activities have been realized: About five core organizers and 14 additional volunteers have collected extensive water quality data from stream sites throughout the watershed from 2001 to the present. In fact, these individuals have been engaged in virtually every step of the scientific process. They have gathered background information and, as part of a six-month study-design process, have helped to choose questions for study. They have been trained by ALLARM staff to collect and analyze samples and then, every month for at least one year, each volunteer has used field kits to analyze streamwater pH, alkalinity, nitrates, dissolved oxygen, and temperature. Volunteers also have conducted seasonal visual assessments of instream, bank, and riparian zone conditions. And at least once per year volunteers have sampled macroinvertebrates, which they have identified to the level of order.

Members of the Shermans Creek Conservation Association monitor the health of the watershed to target critical areas for protection. *Photo courtesy ALLARM*

After three years of monitoring had occurred throughout the watershed, ALLARM conducted two data analysis workshops. Leaders used guided discovery to help participants interpret project data, draw conclusions, and identify areas of concern. Through this activity participants learned how scientists evaluate evidence and what constitutes sufficient evidence for drawing conclusions. They also learned about the challenges involved in understanding seasonal and spatial variability. ALLARM used the volunteers' analyses to compile an extensive report that presented their project findings and made recommendations for future action. SCCA disseminated the report to residents and municipal offices throughout the watershed (Wilderman 2005).

Many SCCA volunteers took significant action based on the study results. Actions included visiting every municipal office in the watershed to network; developing a watershed conservation plan; helping a local borough develop a source water protection plan after a contamination event; and petitioning the state for an upgrade of the stream to exceptional value, which would require the state to bestow such status on a warm water fishery for the first time in history. (A decision on this request is still pending.)

In addition to monitoring, SCCA also conducts numerous educational activities including monthly meetings, stream cleanups, and "kid days." These programs involve approximately 100 residents each year. SCCA was also involved in a full-year educational project with the local high school in which multiple courses used the watershed for the focus of their activities, and students conducted projects that they presented at the end of the year at a "Town Meeting." Finally, the SCCA newsletter goes to all watershed households two times per year. Participants contribute significant time to this project. About five community leaders each contribute about 50 hours per year in project organization, while about 15 other volunteers each contribute about 40 hours per year in monitoring.

Because participants in SCCA's monitoring effort have been involved in each step of the scientific process, they have developed a remarkable degree of understanding about scientific methodology along with excellent data collection skills. By participating in study design workshops, participants have been able to see their own questions be translated into research projects, and they have learned what kinds of questions can be answered through scientific investigation and what kinds of questions are better answered by other means. Study design workshops also have increased participants' awareness of the need to clearly articulate the intended use of data before data-collection methods are chosen. While ALLARM played a major role in the initial study design, SCCA volunteers have subsequently redesigned the study using their knowledge of fundamental concepts and techniques, indicating significant growth in their understanding of the scientific process (Wilderman 2005).

SCCA volunteers also have learned to analyze and find stories in their data. This activity, along with knowledge of local conditions, has allowed volunteers to play a significant role in shaping project reports, targeting critical areas for protection and mitigation, and disseminating this information.

Of course, not all volunteers have been equally impacted by project participation. ALLARM staff feel that those who have attended the data analysis workshops seem to have learned the most. Many of these participants initially felt that the science underpinning the project lay in field sampling and data analysis, but have grown to understand that the "real" science lies in study design and the ways in which evidence is evaluated to draw conclusions. Participants who have chosen to restrict their activities to field sampling and analysis have not learned this valuable lesson.

The majority of volunteers have fulfilled their commitment of attending one training workshop, monitoring one stream each month over one full year, and participating in the QC/QA program. Recruitment of volunteers for new activities, such as the rivers conservation plan and the petition to upgrade the stream, has been reasonably successful. All volunteers have consistently reported enjoying workshops and monitoring activities, and most have made an effort to be involved in new workshops as they move through the scientific process of monitoring and data analysis. Most also have expressed the sense that project activities are making a useful contribution to knowledge about the watershed and have reported an increased sense of community involvement (SCCA president, Linda Sieber, personal communication, SCCA semi-annual newsletters).

Reclam the Bay

Reclam the Bay (RTB) seeks to engage community volunteers in maintaining clean water and restoring shellfish to Barnegat Bay, New Jersey (www.reclamthebay.com). The project began in 2005 as an educational effort of the New Jersey Ocean County Cooperative Extension office. In 2006 participants took ownership of the project, designated a 501(c)3, and began raising their own funds. The project involves approximately 50 volunteers across a range of ages. To date, these individuals have contributed more than 4,700 hours of project time. Some individuals participate occasionally while others spend several hours per month in project activities.

Participants in Reclam the Bay are helping to restore shellfish to Barnegat Bay, New Jersey.
Image courtesy Reclam the Bay

Volunteers begin by participating in a 24-hour training course in which they learn about the biology, ecology, and rearing of shellfish. After completing the course and receiving a certificate, participants find suitable rearing locations and build upwellers to rear young shellfish. When sufficiently grown, the animals are collected and released into the bay where they grow to legal size and can be harvested. Participants collect data regarding the rearing system as well as information on water quality and biotic data such as growth rate. Scientists use the data for publication, while volunteers use it to influence decisions about how the bay is managed. In 2008, 1.4 million clams were planted in two estuaries and plans are in place for a third estuary.

We consider RTB to be co-created because participants are deeply engaged in all aspects of the project. For starters, both scientists and participants choose questions for study. In 2009, participants will investigate why the growth rates of larval shellfish vary. Participants who wish to gather background information are encouraged to do so and share the information with scientists. Both volunteers and scientists develop hypotheses—while the scientists are seen as experts, both groups work together to share ideas. And although data-collection methodologies were initially designed by project scientists, some project volunteers have now created new systems for rearing young shellfish.

Project scientists guide the data analysis process, but participants are involved and help to interpret data and draw conclusions. Participants and scientists also work together to spread awareness of project results and to educate the public about the consequences of shellfish filtering on water quality. Participants hold several sessions during the year. Finally, participants and scientists work together to develop future questions.

Assessment of project impact has been limited owing to a paucity of resources. Pre- and post-project testing of participants using surveys developed by project staff has shown gains in content knowledge (project director, personal communication). In addition, many volunteers are highly engaged, not only in rearing shellfish but also in leading educational programming. Project participants have started a fundraising foundation that has raised $40,000. They also have developed a popular tourism and educational program titled “The Clam Trail” that has raised over $50,000.

The project also has led to partnerships for disseminating information on bay stewardship. Six national and state organizations have been included along with two elementary schools and a high school. Volunteers have reached 4,600 individuals through 91 community-based presentations, and they provide information to a popular radio personality in an effort to further involve the community.

Project coordinators feel that measuring impact by assessing community involvement is cost effective, and that successful community involvement reflects the successful nature of the project’s educational programming.

The following tables summarize the sample projects, goals, and outcomes.

Table 3. Contributory Models of PPSR: Sample Project Goals and Outcomes

Project: Background	ISE Goals	Training	Measures/Outcomes
The Birdhouse Network: Participants across the US and Canada monitored nest boxes to collect data on breeding birds.	Participant appreciation and understanding of breeding bird biology; participant science process knowledge.	Procedural training to ensure accurate data collection and appropriate monitoring was provided through online or print Research Kits.	Pre/post tests revealed increases in content knowledge and potential for further science process learning, and qualitative data suggest some positive changes in environmental behavior.
Spotting the Weedy Invasives: Volunteers in the New York/New Jersey Highlands surveyed invasive plants along hiking trails.	Participant knowledge of plant ecology; understanding of data usage; participant action to control invasive plants.	A one-day course and online materials covered mainly protocols, with some attention to science process skills and community outreach.	A series of three questionnaires showed self-reports of content knowledge gains, but were inconclusive regarding process knowledge gains. Slight changes in behavior were reported.
ALLARM Acid Rain Monitoring Project: Participants across Pennsylvania tested stream water pH and alkalinity.	Participant knowledge and awareness of aquatic systems and health; participant empowerment and stewardship.	Participants attend 1-2 training sessions which explained data collection protocols and tested proficiencies.	Interviews, surveys, observations, and documentation of participation revealed deep project commitment, solid data collection skills, and limited gains in process knowledge. Some stewardship action was noted.
Monarch Larva Monitoring Project: Volunteers across North America survey milkweed patches for monarch eggs and larvae.	Participant appreciation and understanding of monarch biology; participant knowledge of science processes.	Protocol training materials are online, with limited in-person training sessions offered regionally.	Mixed-methods research showed adults who mentored youth in independent investigations reported strongest learning gains and noted youth awareness of science processes.
Community Collaborative Rain, Hail, and Snow Network: Participants across North America monitor amounts of rain, hail, and snow that fall in their home area.	Participant awareness of weather trends; participation in and enjoyment of meterological science	In-person training in some areas; elsewhere online materials explain procedures for data collection and reporting.	Participant demographics, surveys, and select interviews suggest that participation varies widely and that great potential exists for advancing learning outcomes.

Table 4. Collaborative Models of PPSR: Sample Project Goals and Outcomes

Project: Background	ISE Goals	Training	Measures/Outcomes
Salal Harvest Sustainability Study: Salal harvesters on Washington's Olympic Peninsula researched effects of harvesting intensity.	Involve and empower harvesters in relevant research; provide harvesters with technical job skills; improve resource management and harvesting practices.	Onsite, small group training in research design, data collection, and data interpretation. An additional workshop for all participants covered interpreting graphs and drawing conclusions.	Semi-structured interviews by researcher, paired with outside evaluation, revealed knowledge gains of scientific concepts and processes. Harvester skill set increased, as did credibility with agency personnel.
Invasive Plant Atlas of New England: Volunteers in New England survey plots for invasive plants.	Participant science content knowledge and process skills; participant understanding of data collection methodologies; participation in management actions.	Initial one-day training session supplemented with online resources and advanced workshop opportunities.	Questionnaires revealed that participants perceived learning goals and opportunities. Training focus could be enhanced to capitalize on these potentials.
Community Health Effects of Industrial Hog Operations: Residents of Tillery, North Carolina, participated in an epidemiological study of residences near large-scale hog farms.	Participant and community environmental health education; community participation in environmental and social justice movements.	Small group of community members on the research team worked closely with researchers to provide training to a larger group of community members in monitoring air quality and conducting self-administered health tests.	Co-authored publications by community members and researchers noted increases for participants in awareness, knowledge, and understanding of health and air quality issues, and an appreciation of data collection concerns. Participant confidence, social capital, and empowerment also improved.

Table 5. Co-created Models of PPSR: Sample Project Goals and Outcomes

Project: Background	ISE Goals	Training	Measures/Outcomes
Reclam the Bay: Volunteers monitor and manage habitat for rearing shellfish in Barnegat Bay, New Jersey.	Participants and project directors state goals for: participant and community awareness and knowledge of water quality and shellfish ecology; participant action to improve water quality through shellfish restoration.	Intensive training course covers shellfish biology, ecology, and rearing practices.	Pre-post tests show gains in content knowledge. Project evolution demonstrates participant commitment to habitat management goals as well as community stewardship and education.
Sherman's Creek Conservation Association: Participating residents of the Sherman's Creek Watershed in Pennsylvania direct the agenda of a water quality monitoring initiative.	Participants articulate project goals for: monitoring and managing the watershed; raising community awareness of watershed health and importance; community empowerment for informed decision making.	A regional resource organization provides workshops for goal setting, data collection techniques, and data analysis, for drawing conclusions. Not all participants attended all workshops.	Through intensive interaction with participants, researchers documented that individuals who were deeply involved in the full research process increased understanding of, and skills in, scientific processes, particularly in refining questions and interpreting data.

Part 5. Impacts of Public Participation in Scientific Research

Awareness, knowledge, and/or understanding

All PPSR projects seem to contribute to awareness, knowledge, and/or understanding of key scientific concepts related to the study at hand. This conceptual understanding ranges from purely scientific information to environmental issues and regulations. Participants in The Birdhouse Network learned facts about bird biology; those in Spotting the Weedy Invasives learned about the ecology of invasive plants; participants in the ALLARM acid rain study learned about acid deposition; and those in Reclam the Bay learned about the habitat needs of shellfish. Gains in content knowledge are among the easiest to measure with project-specific surveys and questionnaires, and are typical for most types of informal science education projects and programs.

But participants in many PPSR projects also gain knowledge of the process of science. Indeed, this is one area where PPSR projects have the potential to yield major impacts, particularly Collaborative and Co-created projects, which engage participants in project design and data interpretation to a significant degree. For example, participants in the salal harvest study, Reclam the Bay, and the Shermans Creek Watershed study increased their understanding of the process of science to the point where they revised study methods and conducted essentially independent research. And participants in CHEIHO learned science processes even though many had never been exposed to science before.

Even participants in Contributory projects report increased science inquiry skills. One-third of participants in Spotting the Weedy Invasives stated that their understanding of science process had increased. The Monarch Larvae Monitoring Project newsletter describes volunteers who came up with research questions of their own, including “Are some sites better monarch homes?” “Does spotted knapweed affect milkweed patch quality?” And “Are deer good for monarchs?” These participants would not have asked these questions had they not been part of the project. Some participants in The Birdhouse Network used the project database to ask and answer their own bird study questions or designed their own projects. And some ALLARM acid rain project participants increased their understanding of the concepts of variability and sampling intensity and used this knowledge to describe the acid deposition problem through letters to the editor, discussions with government representatives, and presentations at community events.

Participants in most of the Collaborative and Co-created projects, including IPANE, SCCA, the salal harvester project, and CHEIHO also seem to have gained knowledge of community structure and environmental regulation. Salal harvesters learned that belonging to an organization allowed them to communicate more effectively with forest managers than if they worked alone. CHEIHO participants learned about the laws that could help them stop more hog farms from being located in their communities. Members of the Shermans Creek Conservation Association learned that most land use planning decisions in Pennsylvania are made at the local level, so they took a copy of their report to every municipality to ensure that their voices would be heard at the table. In addition, when their analyses indicated that they were studying a high-quality stream, they used their data to petition the state to upgrade the stream’s classification and provide it with better protection. These actions indicate that SCCA members gained knowledge of community dynamics and environmental regulation.

Engagement or interest

Increasing public engagement in scientific activities is an area at which PPSR projects excel. Participants who take part in a project’s full range of activities are deeply engaged in conducting science, although they may not always realize this fact. The fact that information collected by citizen scientists have yielded some of the largest databases available about the distributions and abundances of plants and animals on our planet showcases the level of engagement of volunteers in gathering information to further the cause of science and environmental management. Indeed, enlisting people into PPSR projects is probably one of the most expedient methods for informal science educators to engage people in science in a fun and meaningful way.

PPSR projects provide opportunities for people to develop interest and engagement by either trying something new or by expanding previously existing interests. For example, when a bird watcher begins to report her bird sightings or an angler helps to monitor the quality of a favorite fishing stream, PPSR helps individuals see that their interests can connect to science, and that learning science can enhance their enjoyment of their interests. The different PPSR models allow varied levels and types of engagement so that individuals with varying levels of expertise can either develop a new interest or take deeper steps in their practice or engagement. The fact that PPSR projects are often long-lived and frequently cross large geographic boundaries provides opportunities for continuity over time and for people to participate, take breaks, and then return.

Indeed, many participants in PPSR projects return year after year. Individual participants in The Birdhouse Network, ALLARM's acid rain and watershed projects, IPANE, and Reclam the Bay have gathered data for many years. Many project directors report a small cadre of participants who engage at particularly intense levels and, in certain cases, take a leadership role in the project. While outcomes of this intense level of participation vary, a notable example is that of participants in Reclam the Bay, who raised nearly $100,000 and took project information to thousands of individuals in their community. Some CHEIHO participants took their data to state regulatory agencies to revise land use laws around hog farm development, and participants in IPANE took their data to members of management agencies, who used the information while creating lists of threatened and endangered species.

Some PPSR projects also help to build community. Large-scale Contributory projects such as The Birdhouse Network tend to position themselves around virtual communities, while Collaborative or Co-created projects with face-to-face interactions are effective at building "real-world" communities.

Skills

PPSR projects are excellent for developing science-related skills. Participants in most projects increase their ability to identify organisms, to use measurement instruments, to collect field data following specific protocols, and to sample consistently over time. For example, 95% of individuals who started the ALLARM Acid rain project passed the quality assurance test, and in Spotting the Weedy Invasives, volunteers were able to correctly indentify 90% of common invasives, with variance in participant accuracy measured as similar to that of professionals (project director, personal communication). Thousands of individuals have submitted data on nesting birds, the distribution and abundance of monarch butterflies, patterns of water quality, and the distribution and abundance of invasive plants. Furthermore, these data have been of sufficient quality to allow scientific analyses and to be published in peer-reviewed scientific publications (see www.citizenscience.org for a growing list).

Participants in data analysis workshops gain skills in reading and interpreting graphs, drawing conclusions from evidence, and raising additional questions as a basis for new study designs. In the ALLARM data interpretation workshops, volunteers learned basic concepts of causes, effects, and interactions of water pollutants through a self-discovery exercise with a virtual watershed in preparation for informed interpretation of their own data. Participants in Collaborative and Co-created projects also increased their ability to identify and distinguish habitats, to identify and select study sites, to weigh the pros and cons of various research design and data collection methods, and to communicate their results to the public.

However, helping participants learn the skills that take them beyond data collection and into study design, data analysis, and data interpretation is not an easy task. Typically it requires a significant degree of individualized attention. For example, volunteers do not always agree about the most important concerns to be addressed, so the study design process often becomes focused on developing consensus on priorities. Also, volunteers usually need help in focusing their concerns on questions that can be answered within an appropriate time frame and with available resources. Once established, however, questions that volunteers have raised themselves provide a high level of motivation for project participation.

Helping volunteers learn to analyze and interpret data is also time consuming, and “short cuts” do not generally work. For example, ALLARM has used a training model where scientists present completed project reports to participants and explain how their data were analyzed and the significance of their findings. In these cases, the volunteers invariably claim that they do not understand the patterns well enough to disseminate them or to discuss the results with others. On the other hand, when ALLARM staff train volunteers to find stories in the data themselves, the volunteers are eager and able to disseminate results.

Attitudes

Few instances where PPSR project participation has affected attitudes toward science have been documented. Only one of the projects that we investigated, The Birdhouse Network, formally attempted to measure attitude change, with no change demonstrated. This may not be surprising, as we know that participants in many PPSR projects are already interested in science. Nevertheless, individuals who learn to function as scientists, or at least to understand how scientists work, could be expected to increase their already positive attitudes toward science. For example, parents stated that their children felt like scientists after participating in the MLMP.

We do see evidence that Co-created projects that are initiated to meet specific community needs can draw concerned citizens into the scientific process who might not otherwise be involved in science-related activities. This was particularly true for the salal harvester project and CHEIHO. Such participants are likely to experience significant changes in their attitudes toward science, although whether such change will take place, and whether change will be positive or negative, remains to be studied.

Indeed, many participants probably learn that scientific investigation can be tedious. But even individuals who decide that they do not want to become scientists may become better consumers of science as both their understanding and attitudes change.

Behaviors

Although behavior change is often considered to be the “Holy Grail” among project impacts, it is the least studied and understood owing to the challenges of determining causal relationships in varied learning environments. However, anecdotal evidence does suggest that participation in PPSR projects can change behaviors. First of all, the projects cause people to take part in scientific research, which is a huge behavior change for many! Participation also can lead to other types of behavior change. For example, participants in TBN showed increased “pro-bird” behaviors such as improving their habitat for wildlife. Some participants in Spotting the Weedy Invasives said that they had begun to take environmental concerns into account when purchasing plants, and 40% said that they had begun to notice invasives in the environment. Members of the ALLARM acid rain project were so desirous of increasing their water quality monitoring activities that the organization broadened its focus and changed its name. And harvesters who participated in the salal research project demonstrated an increase in involvement in the NRHA and in the harvester community as a whole. In the SCCA project, volunteers became more engaged in community politics, and more confident about asking for a place at the table in decision making about future land use for the watershed.

Part 6. Opportunities for the ISE Field

Many types of informal science education programs and projects are valuable for increasing public understanding of science content and concepts. Many types of projects also can help to change attitudes and behaviors related to science and the environment (National Research Council 2009). Projects that directly involve members of the public in scientific research seem particularly suitable for increasing participants' understanding of science process, creating deep engagement in science, and developing multiple scientific skills including observation, study design, sampling, data collection, data analysis, and drawing conclusions from evidence. PPSR projects may also be valuable in changing behaviors and attitudes toward science, but indicators that can measure such impact will need to be developed to draw decisive conclusions with respect to these impacts.

We suggest that projects focusing on Public Participation in Scientific Research represent an emerging field of informal science education that is ripe for further development. We urge developers of ISE programs to consider PPSR approaches in their work. This could involve

1) creating new PPSR projects
2) enhancing PPSR projects already underway
3) adding PPSR elements to other types of ISE programs, such as exhibitions
4) enhancing research and evaluation of PPSR including best practices for developing different models and understanding their impacts on participants, researchers, and communities.

Creating new PPSR projects

Although hundreds of PPSR projects are now under way, both large and small, room for new projects exists in three areas:

1) Projects designed to study new scientific questions
2) Projects designed to engage new audiences
3) Projects designed to test new or enhanced PPSR models.

The natural world is full of questions whose answers truly require a PPSR approach. The number of published scientific papers based on citizen-collected data is increasing each year (see www.citizenscience.org). Many more projects could be created that will appeal to the increasing numbers of amateur naturalists and stargazers who are interested in lending their brains to science. Developers should be aware, though, that coming up with questions that are appropriate for PPSR is not a simple task, especially if the project desires to reach a wide audience. Projects for which data collection relies on basic skills, such as counting a few species of birds at feeders or determining the pH of a water sample, are generally more appropriate than projects that require high levels of skill, at least for projects that follow the Contributory model. Also, projects that are based on popular hobbies like watching birds generally draw more participants than projects that are not (Bonney et al. in press).

From an educational perspective, however, developing projects to answer new scientific questions may not be the most strategic approach for the ISE field unless new projects strive to enhance existing PPSR strategies or reach truly new audiences. Most of the projects studied for this report, especially those labeled Contributory, seem to reach audiences already knowledgeable about science and the environment. While such audiences can always learn more—especially advanced science skills—the case studies that focus on Collaborative and Co-created models have shown that non-typical audiences can be reached with topics and approaches that speak to specific personal and/or community needs and interests.

To reach new audiences, however, significant research into motivations for members of the public to understand and participate in research will be needed. Also required is research into the ways in which individuals perceive themselves or can develop identities as scientists, potential scientists, and critical thinkers. To date, very little front-end evaluation has been carried out to assess community desire, interest, or perceived relevance of PPSR, especially for contributory projects. In fact, we are aware of only two studies, both NSF-funded planning grants, that have investigated perceptions of science and PPSR possibilities for audiences who are not traditionally involved in ISE programming: (Garibay, 2004; Garibay, 2009). Both of these studies have revealed that new audiences (in these cases, Latinos) will be most interested in projects that are highly relevant to pressing needs and issues for a community. Further, the number of individuals who will be involved in such projects may not be high, at least not at first. This fact is evident in examining Co-created projects, which in most cases do result from community-identified needs, and which can reach diverse audiences at least in small numbers.

We suggest that new projects test Collaborative and Co-created approaches to PPSR. One idea that seems worthy of further examination is the approach taken by Reclam the Bay, the Salal Harvest Sustainability project, and CHEIHO of working with a "core" of community members who collaborate closely with scientists as part of a research team and participate to a high degree, and a secondary level of participation by a larger number of community members who primarily contribute to data collection and possibly study design. This model of "peripheral participation," developed by Lave and Wenger (1991), has been widely used to move people from peripheral to core participation in a variety of efforts. For projects that wish to use a Co-created approach, key factors are building trust and mutual respect between scientists and participants, having an ethical commitment to protect participants from harmful consequences of participating in research, and creating transparency in the entire decision-making process at every step of the research project.

Enhancing PPSR projects already underway

Our case studies suggest that projects which involve members of the public in the largest number of steps or categories of research, those that we have categorized as Collaborative or Co-created, yield the greatest impacts in terms of understanding science process, developing skills of scientific investigation, and changing participants' behaviors toward science and/or the environment. Indeed, it stands to reason that people who have participated intensively in a research or monitoring project will be that much better consumers of science, will be more active in decision making around science and the environment in their communities, and will change their behavior toward the scientific problem being investigated more substantially, than individuals who are involved peripherally in a project. Therefore, we believe there is tremendous potential to enhance projects that are already under way on several fronts. In particular, we suggest that many projects could be expanded to involve more individuals in more aspects of science inquiry.

For instance, Contributory projects can be expanded into Collaborative models, at least for some project participants. One idea is to involve participants in the study design process. In the case of SCCA, participants dealt with the study design process more easily after the initial study design was completed. They increased their confidence and direction, and were able to mark their progress in a systematic manner. They also were encouraged to understand the iterative nature of designing a study, informed by feedback from monitoring activities in the field. However, helping individuals understand how research and scientific data are used and applied to policy and management must be deliberative and facilitated. Learners must not only be exposed to ideas, they must understand how experts think about those ideas.

Indeed, informal science educators are recommending that the science behind ISE projects be both explicit and reflective (Akindehin 1988; Crawford et al. 2005), allowing learners the opportunity to reflect upon and refine ideas, and to practice and make mistakes. Further, given that experts have a hierarchically organized scheme by which they reason about scientific problems (Bransford et al.

1999), participants need to be exposed to educational experiences that not only teach about particular concepts but also about ways to think about and practice these concepts. More research and testing will be required to learn how to provide such opportunities for large audiences, that is, to bring data analysis and interpretation, hypothesis testing, and discussion of results to projects that have started with a contributory design. As MLMP already has started to do, participants could see videos or online tutorials that help them develop questions and projects of their own that would take their data collection activities further and deeper. Other ideas include holding regional training workshops where participants can learn skills of data interpretation and analysis, making data more available and providing tools for simple visualization and analysis, or providing the opportunity for participants to develop their own questions and contribute their findings to participant blogs or online newsletters as occurred in TBN.

At the same time, Collaborative and Co-created projects—in many cases, projects that have been started more to meet community needs than for educational reasons—can learn many lessons from successful Contributory projects. For example, water quality monitoring projects could enhance educational support materials to help participants learn more about aquatic organisms, such as online videos or identification keys. Such projects also could work together to design and develop regional and national databases that would allow participants to compare data and findings across larger regions or over long spans of time. Such studies could prove particularly valuable for studying large-scale issues such as the effects of global warming on water quality. They also would help participants place their research in a global context.

Our suggestion that the ISE field take a hard look at enhancing projects that are already underway does not preclude an important role for organizations or institutions that have not previously been involved in PPSR efforts. On the contrary, we believe that it increases such opportunities and encourages the development of new partnerships. Almost any institution could find an existing project, such as NestWatch, MLMP, a water quality monitoring project, or any of the other dozens of projects listed at the Citizen Science Central website (www.citizenscience.org) and adapt or modify it for local or regional use, for example, by adding workshops to take participants as deeply as possible into all science process activities surrounding that project. This approach would be one of the easiest and most effective methods of adding Collaborative or Co-created approaches to projects that already provide significant infrastructure for PPSR. In other words, it would leverage previous work and allow the testing of new approaches to expose existing participants to more advanced scientific concepts and skills and tailor existing projects to new audiences.

Another idea for engaging new audiences is to employ the newest in Web 2.0 technologies to existing projects. If a major goal of ISE is to engage younger audiences, then projects must be relevant and current for such audiences. As an initial first step, projects should provide alternate avenues to reach new audiences by building online social presence through FaceBook, Twitter, MySpace, and a slew of other social networking sites. Creating an online presence, however, does not necessarily equate to creating an online community. More research on best practices for online learning and community building should be pursued and broadly disseminated.

Adding PPSR to other types of ISE projects

Examination of the NSF portfolio shows that relatively few full-fledged PPSR projects have been funded to date, although several have started in the last few years. More common in the portfolio are PPSR "add-ons," that is, citizen science projects that are associated with other projects such as films or exhibits. We suggest that more closely integrating PPSR efforts into other types of ISE projects would represent strategic investment by the field. However, we suspect that many project developers will underestimate the amount of funding and effort that is required to develop a PPSR project, and we predict that many "side projects" will not yield demonstrable impacts unless they build on PPSR projects and networks that already exist.

Again, we suggest that ISE projects seeking to deepen their impact through inclusion of PPSR techniques consider partnering with pre-existing PPSR projects. Indeed, such partnerships would benefit both programs. For example, a traveling exhibition about monarch butterflies could be used to increase interest and participation in the MLMP, while the PPSR project would provide a meaningful, long-term, immersion experience for visitors who become interested in monarchs and want to take their interest further.

Enhancing research and evaluation surrounding models of PPSR and their impacts

Many questions remain to be answered about the potential for PPSR projects to contribute significantly to the ISE field. An important question is what motivates participants to participate in PPSR projects, which raises a number of additional questions about personal and extrinsic motivators, altruistic intentions, and the notion that projects may be tiered or serve as gateways for other projects to embrace participants who join projects for different reasons.

Many questions also remain about the learning implications of various types of PPSR projects. What is the nature of questions that enable participants to not only collect data but also to reflect on their experiences? Do participants, or potential participants, prefer to become involved with questions that deal with basic science, that resolve issues, that are simply fun, or all of the above? To what extent do participants gain from projects because they help to shape them?

Other questions relate to the overall impacts of PPSR participation, including participation in areas of inquiry that have not been well studied such as modeling, data visualization, and data dissemination. Also important to understand are the behavioral impacts of PPSR. Does participating in a national bird count cause consumers to purchase shade grown coffee? Does spending time collecting water samples lead to reduced water consumption activities? Indeed, understanding the impacts of PPSR could push the boundaries of what we currently define as learning in the realm of science, including learning that affects participants' lives in a very broad sense.

Equally important is examining the learning impacts for scientists involved in PPSR efforts. What are they learning in terms of science knowledge, science process, and attitudes about science? This type of research has not been done at all as far as we can determine.

Part 7. Conclusions

Public Participation in Scientific Research projects, especially those labeled as citizen science, are growing in numbers every day. A quick Google search will yield hundreds of projects under way across North America and beyond, each one hungry for volunteers. Considering the potential for such projects to contribute high-quality data for scientific monitoring and research, and to help participants develop a greater understanding of science—both content and process—the PPSR "movement" seems well justified.

At the same time, the process of studying and understanding the best ways to develop, implement, and evaluate PPSR projects is just beginning. Based on a review of a handful of projects representing a range of PPSR models, we have suggested several ideas for PPSR project development and many areas in which we believe that the field can grow as a discipline. We believe that, if project developers try some of the ideas suggested here, the field will expand in new and compelling directions. Many opportunities exist for continued study of the PPSR concept, including additional project reviews that might uncover more robust conclusions about project impacts, and which could suggest additional avenues for project development. In particular, we urge continued research into project designs that will harness the strengths of each PPSR model, merging model elements to yield the greatest learning impacts.

We also believe that the field must do a far better job of articulating learning goals and desired outcomes than most PPSR projects have done so far. In addition, the field must develop more effective and comprehensive methods of impact evaluation. At a June 2007 workshop, "Developing a Citizen Science Toolkit," funded by the National Science Foundation and held at the Cornell Lab of Ornithology, more than 50 individuals gathered to compare notes on developing "best practices" for citizen science project development. Tools and tips were offered for essentially every area except project evaluation. Many participants noted that evaluation is the most challenging and least understood step in the process of project development, which is one reason why the meta-analysis that we conducted for this report yielded so few robust evaluation reports.

We conclude that developing, validating, and disseminating evaluation strategies would significantly enhance the impact of PPSR projects and the ISE field as a whole. Such strategies and tools are needed to guide project development. They also would provide ISE professionals with methods for measuring baseline scientific and environmental literacy and for documenting changes in literacy that could be attributable to PPSR project participation. We urge the field to begin developing, testing, and employing more robust evaluation methods and to make a major effort to share project results, both positive and otherwise, to help the PPSR field continue to grow and mature. We hope that the rubric provided in this report will help to move this effort forward.

Appendix

Public Participation in Research Projects funded by the National Science Foundation since 2000

Informal Science Education Program

Although hundreds if not thousands of citizen science and related PPSR projects are under way today, relatively few have been funded by the Informal Science Education (ISE) program at the National Science Foundation (NSF). Most of the projects that have been funded by the ISE program and which are fully operational have been developed by the Cornell Lab of Ornithology (CLO). We selected one NSF-funded CLO project, The Birdhouse Network, for review in this report. The only non-CLO PPSR projects that have been funded by ISE and which are "completed"—as far as we can determine—are the Monarch Larva Monitoring Project developed by the University of Minnesota and CoCoRaHS, The Community Collaborative Rain, Hail, and Snow Network developed at Colorado State University. Both of these projects also are reviewed in this report.

Three additional projects have been funded recently by the ISE program and their development is now underway. These are Citizen Science Laboratory at Hacienda la Esperanza, developed by the Conservation Trust of Puerto Rico; Have You Spotted Me? Learning Lessons by Looking for Ladybugs, developed by the Department of Entomology at Cornell University; and Communicating Climate Change, a network of citizen science projects being organized through the Association of Science-Technology Centers.

In addition, one recently funded exhibition project includes a citizen science component: Seasons of Change: Signs of Climate Change in New England and North Carolina, which is under development by Brown University.

We provide here a brief overview of ISE-funded PPSR projects.

Public Participation in Ornithology: An Introduction to Environmental Research (DRL-9155700). Cornell Lab of Ornithology: 1992–1996.

This project launched the Citizen Science Program at the Cornell Lab of Ornithology. It funded the development of Project PigeonWatch (ongoing; www.birds.cornell.edu/pigeonwatch) and Project Tanager (now Birds in Forested Landscapes; www.birds.cornell.edu/bfl); major enhancements to Project FeederWatch (ongoing; www.birds.cornell.edu/pfw); and a national Seed Preference Test. PigeonWatch involves city dwellers in counting the kinds and numbers of different color types of pigeons throughout the United States; Birds in Forested Landscapes allows birders to help study the habitat requirements of many species of North American birds; and Project FeederWatch is a fall/winter count of the kinds and numbers of birds that visit backyard feeders in the United States and Canada.

The Cornell Nest Box Network (DRL-9627280). Cornell Lab of Ornithology: 1996–2001.

The Cornell Nest Box Network was renamed The Birdhouse Network (TBN) and is fully described in the sample projects section of this report. TBN was absorbed into NestWatch in 2007 (see below).

Parents Involved/Pigeons Everywhere (DRL-9802248/0926149). Cornell Lab of Ornithology: 1998–2004.

This Parental Involvement grant developed major enhancements to Project PigeonWatch (www.birds.cornell.edu/pigeonwatch) though collaborations with a network of science museums, science centers, and nature centers.

Citizen Science Online (DRL-0087760). Cornell Lab of Ornithology: 2001–2006.

This project funded the development of two ongoing projects: the Great Backyard Bird Count (www.birdsource.org/gbbc) and eBird (www.eBird.org). The Great Backyard Bird Count is a one-weekend count of backyard birds that takes place throughout North American each February, and eBird allows birders to report any bird they see, any time, any place throughout most of the western hemisphere. Both projects are cosponsored by the National Audubon Society.

Monarch Butterfly Larval Monitoring: A Nationwide Citizen Science Initiative (DRL-0104600). University of Minnesota: 2001–2006.

This project, now called the Monarch Larva Monitoring Project (www.mlmp.org), is growing every year and is fully described in the sample project section of this report.

Birds in the Hood (DRL-0125633). Cornell Lab of Ornithology: 2002–2007.

This award funded development of Urban Bird Studies, essentially a simplified version of eBird appropriate for urban audiences. The project evolved into the current Celebrate Urban Birds! (www.birds.cornell.edu/celebration).

Bringing CoCoRaHS to the Central Great Plains: an Informal Science Education Project for Rural Communities (DRL-0229723). Colorado State University: 2003–2006.

The Community Collaborative Rain, Hail, and Snow Study involves participants in collecting precipitation data across the country and is fully described in the sample projects section of this report.

Citizen Science Laboratory at Hacienda La Esperanza Reserve (DRL-0327374). Conservation Trust of Puerto Rico: 2007–current.

The Conservation Trust of Puerto Rico, in collaboration with the Interdisciplinary Center for Coastal Studies, New York Botanical Garden, Puerto Rico Youth at Risk, Boy Scouts, and the Cornell Lab of Ornithology is developing a comprehensive citizen science program for involving the public in researching archeology and human impacts on local ecosystems; conservation and restoration of wetlands; seed dispersal by bats and birds; ecology of coastal land crabs; flowering and fruiting patterns of local flora; and shoreline and costal processes at one of the Trust's premier reserves.

Project NestWatch (DRL-0540185). Cornell Lab of Ornithology/Smithsonian Migratory Bird Center: 2006–current.

NestWatch involves participants in collecting data about bird breeding biology across North America. It also involves a virtual citizen science project, called Camclickr, for which participants gather data from online images provided by a series of NestCams located in several different states (www.nestwatch.org). The former Birdhouse Network, described in the sample project section of this report, was absorbed into NestWatch in 2007.

Seasons of Change: Signs of Climate Change in New England and North Carolina (DRL-0714744). Brown University: 2007-current.

Seasons of Change will be a traveling exhibition highlighting how regional iconic "harbingers" are related to climate change—for example, the impacts of a changing climate on the maple syrup industry in New England and shifts in bird migration patterns in North Carolina. The project will include a citizen science program for installations that can provide outdoor venues.

Have You Spotted Me? Learning Lessons by Looking for Ladybugs (DRL-0741738). Cornell University Department of Entomology: 2008–current.

Now called the Lost Ladybug Project (www.ladybug.org), this project involves rural children across the continent in searching for endangered and threatened species of ladybugs. Participants submit data in the form of digital photos.

Communicating Climate Change (DRL-0813135). Association of Science-Technology Centers: 2008–current.

The Association of Science-Technology Centers (ASTC), in collaboration with the Yale Project on Climate Change and the Cornell Lab of Ornithology, is developing a network of science centers that are using citizen science as a means of helping visitors understand local impacts of climate change (http://astc.org/iglo/c3). The project is beginning with 12 science centers spanning the United States from the east coast to Hawaii. Additional partners include the University Corporation for Atmospheric Research, the American Geophysical Union, and NOAA.

Other NSF programs

A small amount of work in PPSR has been conducted with funding provided by NSF programs outside of ISE. Providing a complete list is beyond the scope of this report. Three examples, however, include:

Community Dynamics of an Emergent Pathogen: Intrinsic vs Extrinsic Mechanisms (Emerging Frontiers 0622705). Cornell University: 2006–current.

This project explores the effects on disease dynamics of multiple hosts that differ in competence and transmission routes. Some of the data for this research come from a citizen science project run by the Cornell Lab of Ornithology called the House Finch Disease Survey (www.birds.cornell.edu/hofi).

CI-Team Implementation Project: Using the GODM Cyberinfrastructure to Involve Citizen Scientists in Moving from Data Isolation to Data Integration (Office of Cyberinfrastructure 0632613). Colorado State University: 2006–present.

The aim of this project is to empower citizen scientists to use an existing cyberinfrastructure to digitally collect, input, integrate, and analyze data on the distribution of non-native plants and animals.

Citizen Science and Sea Turtle Conservation: Critical Perspectives from Social Studies of Science (Science, Technology, and Society 0724608). Duke University: 2007–current.

This research, a collaboration between Duke University, Nicholas School of Environment and Earth Sciences, and the North Carolina Wildlife Resources Commission (NCWRC), examines the relationship between volunteers collecting data for the North Carolina Sea Turtle Project and the scientific establishment to which they contribute their information.

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