Top Down or Bottom Up?
ALLARM's Experience with Two Operational Models for Community Science

Candie C. Wilderman[1], Alissa Barron[2], and Lauren Imgrund[1]

[1] Alliance for Aquatic Resource Monitoring (ALLARM), Department of Environmental Studies, P.O. Box 1773, Dickinson College, Carlisle, PA 17013
[2] NOAA Coral Reef Conservation Program, 1305 East-West Highway, Rm. 10203, Silver Spring, MD 20910

Biographical Sketch of Authors
Candie C. Wilderman is a Professor of Environmental Sciences at Dickinson College in Carlisle, PA. She earned a B.S. in Geology from Tufts University, an M.A. in Geology from Harvard University and a Ph.D. in Geography and Environmental Engineering from Johns Hopkins University. She is also Founder and Science Director of ALLARM (Alliance for Aquatic Resource Monitoring), a community-based volunteer stream monitoring network in Pennsylvania, founded in 1986 and staffed by Dickinson College faculty and students. Her teaching and research interests include: operational models for community-based research, watershed assessment and management, aquatic ecology, and Chesapeake Bay restoration and protection issues.

Alissa Barron served as the first Assistant Director of ALLARM (The Alliance for Aquatic Resource Monitoring) from 2001-2003. She directed ALLARM's involvement in a statewide network of watershed service providers, providing capacity-building technical assistance to watershed organizations and coordinating a statewide quality control program for water chemistry. Alissa currently serves as the Outreach and Education Coordinator of the National Oceanic and Atmospheric Administration's Coral Reef Conservation Program. She holds a B.A. in Environmental Studies from Brown University.

Lauren Imgrund is the Director of The Alliance for Aquatic Resource Monitoring (ALLARM) at Dickinson College. She is responsible for leadership of the ALLARM program including overseeing the operation, managing the budget, fundraising, training, and supervising the staff. She develops and executes technical assistance to watershed organizations and represents ALLARM on state and non-profit advisory panels. Lauren has worked in the conservation field for 15 years and has a B.S. in Environmental Science from Juniata College, Huntingdon, PA.

Abstract
Most operational options for community science in the US can be categorized along a multi-dimensional continuum of community involvement -- from community-based participatory research or "science by the people" to the "community workers model", where the role of volunteers may be limited to sample collection for a scientific institution or agency. The Alliance for Aquatic Resource Monitoring (ALLARM), a project of the Environmental Studies Department at Dickinson College in Carlisle, PA, partners with Pennsylvania communities and individuals who are working to protect and restore watersheds. For the first ten years of the program, ALLARM enlisted hundreds of volunteers across the state of Pennsylvania in research on the effects of acid deposition on Pennsylvania waterways. In 1996, our focus shifted to work cooperatively with volunteer stream monitoring groups to identify watershed issues specific to each community and to provide training for volunteers to address these issues. ALLARM's

experience of evolving from a single-issue, “top-down” program to a multi-issue, “bottom up” program has given us some special insights into the strengths and challenges of the different models.

Attributes of the two models that we have used will be examined in terms of: 1) differences in the nature and scope of the issues addressed, 2) the required investment by the service provider to meet the mentoring needs of the community to achieve the goals of the project, and 3) the outcomes of the projects in terms of the interest and engagement in the project, community-building, ownership and understanding of data, and empowerment of community members.

Since the late 19^{th} century, when the US Weather Bureau began to train community people to collect data at volunteer weather stations, community science in the United States has assumed a number of different operational models, all which of depend on essential partnerships between the citizenry and professional scientists (Sclove et al. 1998, Raloff 1998, Park et al. 1993). The Alliance for Aquatic Resource Monitoring (ALLARM), a community science project of the Environmental Studies Department at Dickinson College, Carlisle, PA, has provided technical and programmatic support to Pennsylvania communities and individuals who are working to protect and restore watersheds since its founding in 1986. The roles in which ALLARM has engaged citizen-scientists have varied over the past 18 years (Wilderman et al. 2003). The following article will focus on the range of operational models adopted by community science projects in the U.S., using the experience of ALLARM to examine two of these models in terms of: 1) the relationships between the community and the service providers, and 2) the outcomes.

Staffed by two full-time professionals, a part-time science director, and about a dozen Dickinson College students each semester, ALLARM's original mission was to enlist volunteers in the study of the effects of acid deposition on Pennsylvania waterways. For the first ten years of the program, ALLARM worked with hundreds of volunteers across the state to compile the largest, most comprehensive database on the pH and alkalinity of Pennsylvania streams. In 1996, our focus shifted to work with locally-based groups to help them to develop and implement watershed-based water quality monitoring programs. Towards this end we created a Technical Support Center which includes our Community Aquatic Research Laboratory. Today ALLARM works cooperatively with volunteer stream monitoring groups to identify watershed issues specific to each community and to provide training for volunteers to address these issues. Our mission is two-fold: first, to empower communities and individuals with scientific knowledge so they can participate meaningfully in decision-making processes, in advocacy, and in action to protect and restore our natural resources, and second, to provide Dickinson College students with opportunities to use their classroom experiences to directly benefit communities, thereby enhancing the quality and relevance of undergraduate science education (Wilderman 2003).

OPERATIONAL MODELS FOR COMMUNITY SCIENCE

Communities have a wide variety of reasons for becoming involved in the investigation of their natural world through scientific research. The ways in which they become involved are largely dependent on the nature of the relationship that they establish with the professional scientists with whom they work. In Pennsylvania, these professional partners are often called "service providers," which is defined as a group of professionals who provide needed technical and programmatic support for community projects. The operational options for these projects can be arranged roughly along continua of increasing levels of community "control." To determine the extent of community control, five questions can be asked, thus producing five separate but parallel continua:

- Who defines the problem?
- Who designs the study?
- Who collects the samples?
- Who analyzes the samples?
- Who interprets the data?

Not all of these questions will be relevant to every community science project, but they work quite well for many. All models may have value and different models may be more appropriate for different scientific issues and community concerns. The value of asking these questions lies in understanding where a partnership sits on the continuum of increasing community involvement and control.

One common model for community/service-provider partnerships can be called the "community workers model." In this model, professional scientists define the problem, design the study, identify the goals and methods, and do the analysis and interpretation. The professional scientists train community volunteers to serve as workers who collect locally-based data. Examples of this type of citizen science include some research projects by the Cornell Laboratory of Ornithology, such as the study of the infestation of blue bird nests by Protocalliphora (blowflies), where the volunteers collect abandoned nests and send them to the research laboratory for evaluation (Whitworth 2002). Another example is the Maryland Department of Natural Resources' Stream Waders Volunteer Monitoring Program, where citizens are trained to collect macroinvertebrates at sites designated by the Department. The samples are then sent to professionals at the Department for identification and enumeration, and the data are analyzed and interpreted by the professional biologists in the Department (Maryland Department of Natural Resources 2002).

A second model involves research scientists addressing a concern defined by the community. In this "consulting" model, the community sets the research agenda, but the professionals actually design the study and collect, analyze and interpret the data. The "science shops" in Europe typically operate in this manner, where professional scientists provide research support to community groups, "in the form of equitable partnerships between the social 'client' and the researchers, and in response to concerns expressed by civil society" (Gnaiger and Martin 2001). This has also been called "science for the people" (Sclove 1997).

A third model is a variant of the community workers model. The scientific community establishes the agenda and study design; community workers collect the samples, but in this case, they are also trained to analyze the samples. The scientists do the data analysis and interpretation based on the volunteers' test results. One example of this "community workers model 2" is the network of weather monitoring stations established by the National Weather Bureau; 97% of the 11,800 weather stations are volunteer-based (Lee 1994). The ALLARM acid rain project described below is also an example of this model, as are most projects involving bird counts designed and managed by the National Audubon Society and the Cornell Laboratory of Ornithology.

A fourth model involves maximum community control and participation. In what has been called "community-based, participatory research," the professionals provide training and technical support to the community so that they may perform their own research on issues of their own concern. Put more simply, this is "science by the people" (Sclove 1997). Community members identify the concerns and are then trained to design the study, collect the data, analyze and interpret the results, and the turn the data into action. When ALLARM's focus expanded from the single-issue acid rain project to include a more holistic watershed-based approach in 1996, our work through the Technical Support Center came to embody this fourth model.

The table below summarizes the four operational models described above.

	Who defines the problem?	Who designs the study?	Who collects the samples?	Who analyzes the samples?	Who interprets the data?
Community Workers #1	Professionals	Professionals	Community	Professionals	Professionals
Consulting Model	Community	Professionals	Professionals	Professionals	Professionals
Community Workers #2	Professionals	Professionals	Community	Community	Professionals
Community-based Participatory Research	Community	Community	Community	Community	Community

ALLARM's Acid Rain Project: Community Workers Model 2

ALLARM (originally called the Alliance for Acid Rain Monitoring) grew out of a concern by a local state representative that the public was inadequately informed about the impacts of acid deposition in the state. In his effort to introduce an Acid Deposition Control Bill in Pennsylvania, he suggested to a group of scientists that a program be started where volunteers monitor streams and observe the impact of acid rain. Intrigued by the potential public educational value of such a hands-on project -- and hopeful that applying academic work to help solve human problems might motivate students -- the Environmental Studies Department agreed to start such a group on an experimental basis (Wilderman 1999). In this example the agenda was set by a state representative and the academic institution, but not by the participants in the project. Each participant chooses a stream site to monitor and analyzes the water for pH and alkalinity on a weekly basis. Results are reported to ALLARM. The data management, analysis and interpretation are performed by ALLARM and returned to volunteers in the form of written reports. Field kits and quality control/quality assurance programs were developed by ALLARM staff members, who also train volunteers.

Analysis of the ALLARM pH and alkalinity database has indicated that the problem of acid deposition has been underestimated in Pennsylvania and that many more streams than previously identified are impacted by acidic episodes over the course of a year. Faculty and students have presented these results at professional conferences and as published abstracts (Wilderman and Reusse 1991, Wilderman et al. 1999). Data have also been used by state agencies to revise fish stocking practices and to target streams for possible inclusion on the state impaired streams list. Citizens used the data to craft testimony at state senate hearings in support of an acid deposition control act and to lobby for acid deposition control in the 1990 amendments to the federal Clean Air Act. A new project, comparing stream data taken prior to the implementation of the Clean Air Act amendments to new data taken after implementation, is currently being designed by Dickinson faculty and students to assess the actual effectiveness of the reduction of precursors.

ALLARM's Aquatic Resources Projects: Community-based, Participatory Science

As a result of citizen requests, ALLARM expanded its program to provide technical support to assist watershed associations in addressing environmental concerns beyond the single issue of acidification of water resources. This new focus moved the ALLARM project into the model of community-based, participatory science ("science by the people"), a model with the highest level of community participation and control. In our watershed projects, volunteers define the problems, design the studies, collect and analyze the samples, and interpret the data – all in partnership with professional scientists.

As the scope of our projects has widened, and as we have shifted to a model of increased community control, we have significantly increased the scope of our training and mentoring programs. We expanded our field methods training to include additional chemical parameters, biological indicators, hydrological indicators, as well as riparian zone and instream habitat assessments. Even more critically, we have added intensive training in the first and last steps of the assessment process: the study design and the data analysis and interpretation. These additional training workshops have been developed in partnership with other professionals at River Network, Stroud Water Research Center, the Delaware Riverkeeper Network, and the Pennsylvania Department of Environmental Protection.

During our watershed-specific study design trainings, we require that the groups define their goals, including how they will use the data. This leads them to sound choices about methods, sampling density, and sample locations. For example, group members learn that the level of sophistication of the methods used must be determined by the expected end use of the data and budgetary constraints. As we train volunteers in data management and data interpretation, we guide them through simple statistical analysis. And finally, we train them to effectively present the data as it reflects on the questions they are addressing.

If our partner groups decide to take action, ALLARM works with them to use the data to plan and implement watershed action plans. Recent uses of data include: developing grant proposals for restoration projects; developing watershed fact sheets for local residents and government officials; working with farmers and other landowners to implement "best management practices" for livestock, crop, and forestry operations; developing conservation easement programs; upgrading stream protection due to high quality water; removing dams; and implementing stream and riparian zone restoration projects. ALLARM has also worked with groups on cooperative fundraising for these action plans. These activities include writing joint grant proposals, reviewing the group's proposals, and providing advice on budgeting and equipment purchases.

ALLARM also provides laboratory support to our partner groups. Students working in our Community Aquatic Research Laboratory perform split sample analysis for quality control for each volunteer, evaluate various types of chemical monitoring equipment to provide sound suggestions to volunteers on appropriate equipment for their needs, and conduct analysis for additional parameters (such as metals and bacteria) that cannot be measured by field kits.

In 2000, as the state of Pennsylvania recognized the value of partnerships between community volunteers and professional scientists, ALLARM became involved in the formation of the Consortium for Scientific Assistance to Watersheds (C-SAW). C-SAW is an assembly of service providers who provide customized technical support for local watershed groups; the program is funded by the PA Department of Environmental Protection's Growing Greener Grant Program. This partnership of service providers has increased ALLARM's capacity to work with community organizations, using the model of community-based, participatory science.

WHAT HAVE WE LEARNED BY WORKING WITH THE TWO MODELS OF COMMUNITY SCIENCE?

Choice of a model to use in a participatory research project should take into account the goals of the project and the needs of the community. In working with both a community-workers model (acid deposition project) and a model of community-based participatory research (watershed projects), we have encountered different challenges and experienced different benefits. In addition, there is a distinct difference in the nature and scope of the issues being addressed in each of the two projects. The watershed projects consider broader issues, but each focuses on a local, geographically distinct area. The acid rain project considers a narrow issue on a statewide basis. In addition, the overall goals of the two projects differ. The goals of the acid rain project are documentation and awareness, whereas the goals of the watershed projects also include action and building capacity in the community for sustaining the ability to collect and utilize knowledge.

In the following discussion we will briefly contrast: 1) the mentoring needs of the community to achieve the goals of the project, and 2) the outcomes of each of the two models used, as we have experienced.

Required investment by service providers: how do the mentoring needs of participants in the two models differ?

Volunteer recruitment and retention:

- In the acid deposition project, where the volunteers are dispersed throughout the state, ALLARM is responsible for volunteer recruitment and retention. Although this helps to streamline our operations because there is no need to transfer these skills to volunteers, we have found it harder to find interested individuals in communities where we have not already developed relationships. In addition, we need to expend more effort in retention, since volunteers are not part of a residential community, and are only connected through this project.

- In watershed projects the group is responsible for volunteer recruitment and retention. Since the group has local connections and may have a strong existing volunteer base, recruitment may not require much effort on the part of the professional partner. However the group may need support to develop skills in managing volunteers and to spend time defining and breaking up tasks to facilitate and coordinate the involvement of many volunteers.

Goal setting and study design:

- In the acid rain project, the study design and goals are established by ALLARM. Our challenge is to describe the project in a meaningful way so that volunteers will contribute their time and effort.

- In the watershed projects, goal setting and study design is one of the most time-consuming and challenging steps for both the community and the service provider. A watershed group must reach a consensus on a single study design with a set of goals and priorities. This process may involve a good deal of conflict and may result in the alienation of some stakeholders. This requires skill on the part of the service provider in negotiating that fine line between facilitation and control. If there are existing tensions within the community where power relationships have been established for many years, the service providers may need to invest a great deal of effort to determine who it is that they are "serving." In our experience of developing study designs with over 10 watershed groups to date, this process of reaching a consensus on the study design takes an average of 4-6 months, and requires a great deal of commitment and effort on the part of all parties involved.

Technical training and support

- In the acid deposition project, fewer indicators are measured and so less training and less protocol development is required. However, since volunteers are scattered throughout the state, more effort must be expended to bring workshops to all areas of the state. Individuals are responsible for sending their own samples to the laboratory and may not always do so in a timely or correct way. Also, there are no fellow group members with which to consult about questions or problems.

- In the watershed projects, there are a wide variety of biological, chemical, and physical indicators that are assessed. Therefore, more laboratory support is needed for a wide range of activities, and more protocols need to be developed, requiring the dedication of more resources. Partnering among service providers (such as in the C-SAW program, described above) is one effective way to address this high demand for expertise. Also, there is a strong need for translation skills on the part of the service providers, to assure that community participants have the necessary technical information.

  On the other hand, in the watershed projects it is more cost-effective to train people who are from the same watershed because more people can be trained at one time. There is more peer support during training, because watershed groups are small and more interwoven than individual volunteers. It is also more also cost-effective for groups to send samples to the laboratory from a central location, and more likely that they will do so using the prescribed protocols.

Data analysis and interpretation

- In the acid rain projects, ALLARM does all of the data analysis and interpretation, which is then shared with the volunteers in the form of individualized and collective graphs, tables, and reports. Although we often get feedback from volunteers, there is no formalized protocol for assessing the impact of this analysis on their thinking or action.

- Although we have provided data analysis and interpretation reports for some of our earlier watershed partners, it is our strong conviction that volunteers need to have a major role in the process of analysis and interpretation for two reasons: 1) to fully understand and "own" the results of their own work, and 2) to inform the interpretation with the local knowledge that they possess. One of the most challenging steps in the watershed assessment projects is teaching volunteers how to convert data to information. For that reason, we are developing and implementing a series of data analysis and interpretation workshops, which are challenging and have been met thus far with mixed success.

Action planning and implementation

- In the acid rain project, most of the data use has involved dissemination of the results to the scientific community by faculty and students, and to the political arena by individual volunteers, who have initiated and followed through on the action themselves, either at the local level or in support of state or federal legislative efforts. Because volunteers are not part of a single community, planning for action and use of the results is decentralized.

- In the watershed projects, action planning is more formal. In fact, volunteers are required to articulate how they plan to use the data in the early stages of the study design, since the methods must match the end use. Although the results of the study may modify the group's thinking on data use, original intentions are often a good place to start. One of the central roles for the professional scientists is to help volunteers make a case to others that the data they have collected are scientifically valid. We also may provide facilitation in decision-making, and training in effective presentation of the results. We may review and comment on documents they produce. Action options are many, and as service providers, our job is to listen carefully to the will of the community and to help facilitate whatever action they decide to take.

How do the outcomes of the two models differ?

If the outcomes of community science projects are measured by the number of pages produced or the efficiency of producing results, the acid rain operational model proves superior. Because the service provider retains control of the study design, protocols, data analysis, and interpretation, the scientific community often sees this partnership as more scientifically rigorous. This model is extremely effective in collecting large amounts of data from diffuse geographic areas efficiently and effectively.

If the outcomes of community science projects are measured in terms of building capacity in communities for collecting knowledge and collectively implementing action to address common concerns, then the watershed project operational model proves superior. Although the process of knowledge-gathering may take longer with this model, and the results may have less precision and accuracy, outcomes associated with social change in the community (which are more difficult to assess quantitatively) are clearly evident. In many cases, the acquisition of the scientific knowledge may be the means, rather the end, in community-based participatory research projects.

The following table summarizes and contrasts the outcomes of the two operational models in terms of 1) the interest and engagement in the project, 2) the ownership and understanding of the data, 3) the building of community capacity, and 4) the empowerment to act.

TOPIC	SUBTOPIC	COMMUNITY WORKERS MODEL #2 (ACID RAIN PROJECT)	COMMUNITY-BASED PARTICIPATORY RESEARCH MODEL (WATERSHED PROJECTS)
INTEREST AND ENGAGEMENT IN PROJECT	Investment in study design and data analysis process	Less investment in the study design leaves volunteers often unclear about the purpose of the project.	Higher investment in study design translates into higher level of commitment, understanding and service; some may get discouraged and quit.
	Effect of group support	Volunteers often feel isolated, which translates into volunteer retention problems.	Support from group members help motivate and provide peer mentoring. It also can provide substitute labor for times when volunteers need to be elsewhere.
	Perspective of volunteers towards value of project	Volunteers are more likely to trust the scientific validity of a project controlled by professionals.	The amount of trust that the volunteers place in the project may vary quite a bit.
COMMUNITY BUILDING	Sense of common goals	Volunteers commit to already established goals and do not go through a consensus-building process.	The process of reaching consensus on goals and objectives builds a strong sense of commitment and community unity. Some members may become alienated in the process.
	Connection to group	Volunteers may not know each other; need newsletters and workshops to bring folks together.	Volunteers have a strong sense of belonging to the group and get to know each other quite well.
	Future involvement in community issues	Individuals may develop an increased sense of stewardship and build a strong relationship to place, which may motivate them to get involved with other issues.	Watershed members are likely to get involved in other community issues as their sense of unity and empowerment grows. Community is more likely to be able to sustain its efforts at gathering knowledge, after the relationship with the service provider is over.
OWNERSHIP AND UNDERSTANDING OF DATA	Level of understanding	Volunteers do not feel it is critical for them to understand the details of the data analysis, but are content to make a contribution to the database.	Involvement in study design, data analysis, interpretation, and action plans leads to better understanding and "ownership" of the data.
	Use of data	Most volunteers will not feel comfortable using the data in advocacy, although some may seek additional support to do so.	Volunteers who have interpreted the data themselves have a stronger understanding of its implications, and can use the data to participate more meaningfully in advocacy and decision making.
EMPOWERMENT	Building a sense of empowerment in lay persons	Volunteers in this project develop an intimate knowledge of a single place, and may develop a strong sense of stewardship through this knowledge.	The experience of finding patterns in data through their own research helps groups better evaluate environmental threats and interpret other data by professional scientists. This knowledge is power, and possessing it levels the playing field in the decision-making process.

CONCLUSIONS

Community science requires partnerships between the general community and those with scientific expertise ("service providers"). Most operational options for these partnerships in the US can be categorized along a complex, multi-dimensional continuum, from community-based participatory research or "science by the people," involving maximum community control, to what we call the "community workers model," where the role of volunteers may be limited to sample collection. ALLARM's experience of evolving from a single-issue, "top-down" program (community workers model – acid rain project) to a multi-issue, "bottom up" program (community-based participatory research model – watershed projects) has given us some special insights into the strengths and challenges of two of these models.

Both models are powerful ways to gather knowledge for the documentation of environmental impact; both models build an awareness and sense of stewardship among their participants. If the major goal is to gather scientific knowledge for use by the scientific community, then the acid rain model is most suitable. However, there is a trade-off between efficiency and democracy. If the major goal of the project is to shift the power and control of decision-making into the hands of community members and to build community capacity to continue gathering knowledge for action in a sustainable manner (after the partnership with the service provider is over), then the watershed projects operational model is more appropriate. However, as the amount of community control increases, the need for programmatic and technical support from the service providers increases dramatically. There are significant challenges to obtaining funding and other appropriate awards for scientists who wish to engage in this type of participatory research.

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