Society and Natural Resources, 17:817–839, 2004

ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920490493837

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Volunteer Macroinvertebrate Monitoring in the United States: Resource Mobilization and Comparative State Structures

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Emergence of local citizen monitoring groups has provided a structure for public participation in environmental issues but little is known about how these groups are achieving their goals. We examine a subset of citizen monitoring groups in the United States that conduct volunteer macroinvertebrate monitoring (VMM) as a tool for investigating stream health. Through a survey of VMM groups throughout the United States and interviews with state leaders, we found that VMM groups vary in size and character, and utilize a variety of means to achieve their goals. The majority of VMM groups rely on in-kind support from state and regional programs. Overall, these groups are more interested in conducting VMM to foster public awareness, rather than bringing about structural or legislative change. Based on resource mobilization theory, we illustrate that the opportunity structures at the state level significantly impact the character and success of U.S. VMM groups.

Keywords citizen science, grass-roots environmental management, opportunity structures, resource mobilization, stream monitoring, volunteer macroinvertebrate monitoring, water quality monitoring

Throughout the United States, citizens have been organizing to take action on behalf of ecosystems in their local area. Many of these groups work in concert with local and state governments to track environmental changes and promote environmental stewardship among residents in their area. Monitoring natural systems through data collection on various ecological parameters (e.g., water chemistry, vegetation composition, diversity of bird species) has become an increasingly popular vehicle for citizen groups to take action in local watersheds. One popular tool, volunteer macroinvertebrate monitoring (VMM), gives citizens the opportunity to collect data that track changes in the biotic community of a stream, providing them with a better understanding of the

Received 4 March 2003; accepted 10 May 2004.
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impacts of land use on watershed health. VMM can, in turn, produce valuable data for state and local governments. While participation in VMM is believed to enhance environmental awareness, little has been written about how VMM groups are organized, the role of centralized support, or the overall outcomes of VMM efforts.

In recent years government programs have been increasingly supportive of local watershed groups, providing services and funding for a variety of different activities including VMM (U.S. EPA 1996). States can choose to support local monitoring efforts directly, through the creation of a centralized monitoring program, or they can support them indirectly by providing resources such as funding, access to the expertise of professionals, and creating opportunities for networking. In this article we explore the ways in which citizens are using VMM throughout the nation by examining the goals, methods, and reported outcomes of their programs. In addition, we examine the role of state-supported programs in creating opportunities and supplying resources for citizen monitoring groups.

Citizen Data Collection and The Emergence of Local Social Movement Organizations

Citizen environmental monitoring groups dot the landscape. Ranging from small neighborhood groups or school clubs to large watershed associations, these groups hope to protect and improve natural resources in their local areas. The mission of these groups can be relatively specific, such as a Michigan watershed association that hopes to stop dredging in a local stream, or broad, such as a Maryland group that hopes to improve the environmental quality of their watershed by mobilizing volunteers for advocacy, restoration, and education. Unlike citizen groups who have formed to address issues of hazardous substances (Couch and Kroll-Smith 1991), most of these groups are concerned with ecological degradation rather than human health risks.

Social movement literature, founded on resource mobilization theory and new social movement theory, offers a framework to examine the mechanisms through which local citizen groups accomplish their goals. Current scholars use the strengths of both resources mobilization (RM) theory and new social movement (NSM) theory to address research questions appropriate for the post-2000 social movements (Morris 2002; Canel 1997; Morris and McClurg Mueller 1992). Social movements arise when people come together to challenge the existing norms. NSM theorists provide insights into the broad context of why a social movement is emerging. Succinctly summarized by Canel (1997), NSM's focus is civic society and the tensions that create an arena for cultural redefinition of ideology, an individual's "agency" within society, and new legitimacy. In contrast, RM theorists provide greater insights into how a social movement evolves from a broad civic discourse to the micro-level instrumental actions of organization building and the process of relationship construction with the political and state structures.

Within this article we focus on the micro level, laying a foundation for increased understanding of resources, organizational development, political opportunities, and networking in citizen monitoring groups using VMM. The task of analyzing the cultural framing and redefinition of social roles is best left to a later study that incorporates richer qualitative data for understanding meaning construction than a national survey can provide.

Resource mobilization theorists postulate that rational strategies are paramount to realizing the mission of individual groups, referred to as social movement organizations (SMOs) (Gamson 1990). McCarthy and Wolfson (1996) describe three

strategies through which SMOs can succeed in fulfilling their mission: (1) *public education* involves bringing awareness or consciousness to a wider audience; (2) *direct service* changes the conditions that they find unacceptable; and (3) *structural change* makes an effort to change the legal or authoritative structures.

According to RM theorists, to succeed in changing mainstream society, social movement organizations (SMOs) must secure resources from both inside and outside their organizations (Morris 2002; Jenkins 1983; McCarthy and Zald 1977). These resources can include not only financial or material capital (e.g., money, space, equipment), but also human capital (e.g., knowledge, volunteer effort) and social capital (e.g., networking potential, organizational resilience) (Jenkins 1983; McCarthy and Wolfson 1996). Political opportunity structures, or the degree of openness of a state or political system to the goals of a social movement, are critical in defining the success of a social movement organization (Eisinger 1973). More recent theorists have expanded this definition to include the political creation of structural opportunities that provide resources to an organization (Tarrow 1994; Canel 1997).

The value of social movement theory is tested in the context of a range of social change experiences from revolutionary or political movements to environmental or lifestyle movements. Much has been written about the environmental movement as a large-scale social movement (e.g., Dunlap and Mertig 1992; Lofland 1996). While grievances regarding human use of the environment were present many decades prior to the 1960s, during the 1960s environmental sentiment in the United States grew to movement proportions. As a result of the larger environmental movement, a myriad of SMOs, such as the Environmental Defense Fund, were formed to actively bring about legislative change (Dunlap and Mertig 1992; Lofland 1996). In the United States, this first wave of environmental SMOs was followed by a period of more localized action during the 1980s and 1990s in which groups focused on local community action and/or environmental justice.

Today the environmental movement includes a large number of citizen groups, some of which identify themselves as watershed groups. Weber (2000) describes a subset of this movement as those participating in grass-roots ecosystem management (GREM) by emphasizing the human relationship with geographic place. As part of what is identified as a "watershed approach" to natural resource management, federal and state funds and technical support became available to local groups, spurring wide-ranging growth in the community-based environmental protection movement (U.S. EPA 1996). Unlike the social movements of the 1960s, some scholars have proposed that the growth of localized groups in the 1980s and 1990s can be linked in part to the willingness of state and federal agencies to provide political opportunity structures for these SMOs by devolving financial and political resources to them (Leach and Pelkey 2001). This step toward empowering citizens to take ownership in resource management is typified in a statement by former commissioner of the U.S. Environmental Protection Agency (EPA), Carol Browner, who believed the best model for natural resource management was when "people work[ed] together to protect public health and the environment, community by community, watershed by watershed" (U.S. EPA 1996).

Citizen Monitoring as a Tool for Social Movement Organizations

One strategy of local environmental organizations is to gather information on the quality of natural resources in their area. During the 1990s there was tremendous growth in volunteer monitoring (Lathrop and Markowitz 1995; U.S. EPA 1998). To

create healthier watersheds, many citizen groups were drawn to stream monitoring because it provided opportunities for hands-on learning, thus expanding their knowledge of local ecosystems.

Volunteer macroinvertebrate monitoring (VMM), which involves collecting and identifying larval insects from stream bottoms, not only provides volunteers a glimpse into the underwater ecosystem but can produce quantitative data that serve as an indicator of stream quality and lead to a better understanding of the impact of human actions on aquatic life.

Because there are no studies that analyze the use of VMM at a national level, we begin by presenting data that characterize citizen monitoring groups that have chosen to use VMM. Grounded in resource mobilization theory, we explore how opportunity structures impact citizen monitoring groups under different models of state-level support. For the nation as a whole, and for each of three models for state support, we ask: (1) What are the basic characteristics of citizen monitoring groups using VMM and what are their overall goals? (2) Why have groups chosen to use VMM? (3) What kind of resources are they expending to conduct VMM? (4) What are citizen groups' perceptions of the "on-the-ground" outcomes of VMM?

Methods

Data collection took place in two stages. First, through interviews with state-level leaders and a web search, we sought to (a) understand the motivations and strategies of volunteer monitoring service providers, (b) document the diversity of state-level approaches to VMM, and (c) generate a list of goals and outcomes that could be used to develop a survey instrument for volunteer groups. Second, we administered a questionnaire to volunteer monitoring groups in the United States in an effort to (a) collect baseline data on the state of VMM throughout the country and (b) understand the impact of a range of state-level VMM programs.

Interviews with National and State Level Leaders

To understand the leadership perspective and design an effective questionnaire for VMM groups, we began by identifying volunteer monitoring service providers or leaders responsible for creating and maintaining volunteer macroinvertebrate monitoring programs at the national and state level. We identified key contacts from the U.S. EPA volunteer monitoring directory (U.S. EPA 1998), the 2000 National Volunteer Monitoring conference participant list (U.S. EPA 2001), and a web search. We conducted 20- to 40-minute telephone interviews with 16 state leaders located in 12 states. Interview topics included structure and makeup of VMM program(s), concerns that have led volunteers to be involved, VMM protocols, VMM data use in their state, and VMM successes and failures. Interviews were taped and analyzed for emerging themes.

National Survey of Volunteer Monitoring Groups

A questionnaire was designed using a uni-mode approach, making it possible to conduct the survey through e-mail ($n = 127$), U.S. mail ($n = 10$), or over the telephone ($n = 1$)(Dillman 2000; Schaefer and Dillman 1998). Responses from leader interviews were used to design a 38-question survey instrument that reflected the range of goals, protocols, and outcomes experienced by VMM groups, including demographic information, overall group goals, reason for using VMM, stream sampling protocols, outcomes, and group structure.

Our survey population consisted of all self-identified citizen groups (more than two people) in the United States that were actively conducting volunteer macroinvertebrate monitoring by the summer of 2002. School classes that conduct VMM as part of their regular curriculum were not included in the population. To get a cross section of the country, and ensure a robust sample, we randomly selected 50% of the states in each of the 9 U.S. Census Bureau regions. For each of 25 selected states, we created a list of VMM groups using three sources:

- Public lists of VMM groups obtained through state and regional service providers.
- Web sites found through Internet searches on "volunteer stream monitoring, *state*" and "volunteer macroinvertebrate monitoring, *state*" using Google.
- Self identified macroinvertebrate monitors registered in the U.S. EPA 5th edition of the *Volunteer Monitoring Directory* (U.S. EPA 1998).

For each of the organizations we attempted to identify either the VMM coordinator or the overall leader. If possible, we collected e-mail addresses, phone numbers, and addresses for each contact person. Because we hoped to learn from groups who had experienced all components of the VMM process, we eliminated groups that had been active for less than one year.

Using the tailored design method (Dillman 2000) we contacted each group up to five times. After one initial contact via e-mail or telephone, surveys were sent via e-mail (as attachment or embedded text) or U.S. mail. Survey format was identical whether it was sent via e-mail or U.S. mail. Because the survey was designed as a unimode survey, all groups were offered the opportunity to take the survey over the telephone. In the end, we interviewed only one group over the telephone.

We identified 366 groups in 18 of 24 states.[1] Of these, 86 groups responded that they were no longer active in VMM, or that their group had been active less than 1 year; 24 groups were unreachable because e-mails were returned and/or phone numbers did not yield a positive affirmation that the individual was still located at that number. Of the 258 remaining surveys, 138 were returned, for a response rate of 55.49%. We calculated a modified response rate of 70.2% by making the conservative assumption that some nonresponders were no longer active.[2]

Analysis

Mean survey results were calculated for the entire sample, and then for each of three categories based on data that identified state service provider models (Table 1). A Kruskal–Wallis test for nonparametric data was utilized to compare mean scores in each of the state model groups.

Results

In the following sections we analyze the state of volunteer macroinvertebrate monitoring (VMM), first from the perspective of state and national organizers, then from the perspective of individual VMM groups. We begin each section by examining VMM overall, and then compare VMM under each of three models of state-level assistance.

Defining Categories of State Level Support

Is state-level support influencing the success of VMM groups? In this study we sought to identify a range of approaches to VMM at the state level. Through

TABLE 1 Questions Used to Place States into Groups that Categorize Level of Centralized Support for VMM; "No" Answers are Highlighted Gray (Group 0 = No VMM; Group 1 = Limited Support; Group 2 = Networked; Group 3 = Centralized)

State	1) Are there adult volunteers who have been doing VMM for more than a year?	2) Are there organized resources available to volunteer groups in the state? (financial support/training for those who ask/strong regional networks?)	3a) Are the same protocols used statewide?	3b) Is there a statewide database that has the potential to include majority of VMM data?	3c) Are the majority of volunteers trained a through statewide program?	Group
Alaska	y	y	n	n	n	2
Arkansas	y	y	y	n	y	3
Colorado	n	n	n	n	n	0
Connecticut	y	y	y	y	y	3
Delaware	y	y	y	y	y	3
Kansas	y	n	n	n	n	1
Kentucky	y	y	y	y	y	3
Louisiana	n	n	n	n	n	0
Maryland	y	y	n	n	n	2

Massachusetts	y	y	n	n	n	2
Michigan	y	y	n	n	n	2
Missouri	y	y	n	y	y	3
Nevada	n	n	n	n	n	0
New Jersey	y	n	n	n	n	1
New Mexico	n	n	n	n	n	0
North Carolina	y	n	n	n	n	1
Pennsylvania	y	y	n	n	n	2
South Dakota	n	n	n	n	n	0
Tennessee	y	n	n	n	n	1
Utah	n	n	n	n	n	0
Vermont	y	n	n	n	n	1
Virginia	y	y	y	y	y	3
Washington	y	y	n	n	n	2
West Virginia	y	y	y	y	y	3
Wisconsin	y	y	n	n	n	2

interviews with state leaders and through web searches we derived answers to a series of questions that helped us group each state into one of four general models corresponding to differing kinds of state support of VMM programs (Table 1). If there were no groups (question 1), the state was considered to be in group "zero" (no active VMM), and was not included in our questionnaire. If there were adult volunteers who had been involved for more than a year (question 1), but no regional or centralized support or resources available (question 2), the state was considered to be in group 1 (limited support). In limited support states, groups were primarily self-motivated, drawing on the literature, web sites, and services of centralized programs. VMM data were not used at the state level, and agency representatives were not hired to support VMM programs. When resources at the state level were allocated to help VMM groups, it was extremely informal. In a third category, if there were some resources (question 2), but the state rated a "no" for two out of three categories in question 3, it was placed in group 2 (networked). In networked states, agencies were financially supportive and sometimes directly involved in VMM, but programs were administered at a regional or local level. Lastly, if a group answered "yes" to two of three categories in question 3, it was considered to be in group 3 (centralized). In centralized states, strong statewide programs provided funding, training, and data management. These services were provided either through direct administration by state agencies, such as in Missouri, or, in the case of Delaware, through delegation of VMM programming to a nongovernmental organization (NGO). Both centralized and networked states recognized VMM as an important activity, and had devoted state resources to help it succeed.

Leadership Perspective on VMM

Across the board, state and national leaders reported in their interviews that volunteers were extremely enthusiastic about VMM. A majority of leaders identified the value of VMM as a tool for building awareness of water-quality issues. Leaders also mentioned that VMM groups were able to enhance their relationships with local government. While they recognized the challenges of producing useful data through VMM, they believed that being involved in VMM makes people more aware and gives them confidence to voice their concerns.

Many leaders also commented that volunteer data could make a valuable contribution to state and local databases. Organized databases existed at the state level in half the states interviewed. In each of these states, leaders reported that VMM programs influenced decision making about natural resources. Among other things, leaders reported that VMM influenced how agencies spent their time; that VMM data helped determine where restoration should occur; that it increased the number of sites sampled and provided valuable baseline data; and that they used VMM data in their 305(b) reports to Congress. As one agency leader reported, "Volunteers really increase the manpower for screening natural resources."

While many were enthusiastic about the potential of VMM, they understood its limitations. For example, a Department of Environmental Protection (DEP) employee from Pennsylvania reported that while the agency was willing to use volunteer data that conforms to a predetermined standard, it recognized that the majority of groups were not interested in meeting the state's quality assurance standards. The DEP, when asked, is willing to provide support for groups that are collecting data for local interest, but does not use local data unless they conform to central standards. Other states were less positive about the potential for

VMM data. Leaders from three states indicated that while they recognized the value of VMM as a tool for educating citizens about water quality, they were not able to use volunteer data because of their questionable quality. In Louisiana, for example, the state had attempted to implement a volunteer monitoring program but found that "when compared to professional results, the volunteers were not getting it right."

While all but one interviewee believed that VMM data have the potential to inform professionals about stream quality, they realized the challenges inherent in collecting quality data. When asked to relay a tangible success story about how VMM data had promoted a change in the status quo, interviewees replied with general examples about how the existence of VMM groups influenced society. Several cited examples of how volunteers were able to identify pollution sources, but were not specific about how VMM data were impacting their capacity for action. In Virginia, for example, the program coordinator for Virginia Save Our Streams spoke of a volunteer group that was able to identify the source of a fish kill by walking upstream from one of its sampling sites and finding the site of a manure spill. While this investigation was the direct result of monitoring, it did not rely on the more complex tasks of collecting and identifying macroinvertebrates, but merely on noting the absence of a previously present macroinvertebrate community.

In summary, while state and local service providers were confident VMM has the potential to be a valuable source of knowledge, there were very few stated examples of volunteer groups taking action as a result of data generated through VMM. State service providers recognized the value of promoting education and awareness, yet were challenged to integrate the data into a larger knowledge base that could be used to enhance and protect natural resources.

Extent of VMM in the United States

Overall, VMM groups had between 2 and 7000 members, with an average of 268 (Table 2). For many groups VMM was only one in several programs. The number of individuals actually engaged in VMM (stream monitors) ranged from 1 to 100, with an average of 30 (Table 2). The groups surveyed had been conducting VMM from between 1 and 12 years, with an average of 4.12 years. Only 34.4% of the groups surveyed had been active in VMM for <3 years. Stream monitoring groups in centralized states were significantly smaller than groups in networked or limited support states, while the number of individuals monitoring streams was not significantly different among state models (Table 2). The ratio of stream monitors to overall members in the organization or group was significantly higher in centralized states than in states with limited support (Table 2). These results suggest that more groups are forming expressly for the purpose of monitoring in centralized states, whereas monitoring is part of a larger organizational mission in states that lack a centralized program. Groups in centralized states have existed for an average of 5.03 years, significantly longer than groups in networked states, which have existed for an average of 3.54 years (Table 2).

Goals of Groups Using VMM

We asked recipients to assess four possible group goals. The list was designed to represent different strategies for achieving SMO success (McCarthy and Wolfson

TABLE 2 Volunteer Macroinvertebrate Monitoring (VMM) Group Demographics, 2002

Demographics	Average for all groups	Limited support	Networked	Centralized	*p*-Value (Kruskall–Wallis)
Average number of members in organization	267.9 ($n = 127$)	616.50 (a) ($n = 12$)	335.62 (a) ($n = 71$)	72.87 (b) ($n = 46$)	.0004
Average number of stream monitors	30.33 ($n = 129$)	28.25 ($n = 12$)	34.42 ($n = 72$)	24.43 ($n = 47$)	0.0628
Ratio of stream monitors to members	0.41 ($n = 124$)	0.20 (a) ($n = 11$)	0.39 (a, b) ($n = 70$)	0.50 (b) ($n = 45$)	.0084
Years group has done VMM	4.12 ($n = 131$)	4.55 (a, b) ($n = 11$)	3.54 (a) ($n = 76$)	5.03 (b) ($n = 44$)	.0093

Note. Significantly different averages at $p = .05$ are signified by different letters; shared letters indicate categories are not significantly different from one another.

1996). Three of four goals were identified as having an average rank of "somewhat important." Public education was the most important of these, identified as "high priority" by nearly three-fourths of the volunteer groups. Conversely, only one-third of volunteer groups identified enforcement as high priority, while improving legislation appeared to be the lowest priority, with one-fifth of the responders considering it "not a goal" (Table 3). There was no significant difference in average scores among different state models.

Next we asked them to consider the reasons for choosing VMM as a technique for reaching their goals. Similar to the overall goals (Table 3), VMM groups were less interested in regulatory, court related, or planning decisions than they were in awareness and education (Table 4). They were optimistic about the potential for VMM and ranked many possible objectives as "high priority." The majority of groups ranked "education," "awareness," and "collecting baseline information on stream health" to be very important goals, whereas less than 30% indicated that "using their data in local planning decisions," "using their data in court," or "influencing policy" were "high priority." There was no significant difference among the average scores with respect to the state models.

Sites Visited and Resources Used for VMM

In an effort to understand the nature of VMM groups as social movement organizations, we asked respondents about the resources their groups had invested in VMM. We were interested in financial, human, and social capital expended by the group, as well as the in-kind support they received from other organizations or service providers.

With respect to financial capital, in 2001, 43% of the groups using VMM had an organizational budget of less than $5000, 33% had an organizational budget of $5000 to $50,000, and 24% had a budget of over $50,000. The budget for VMM ranged from zero (in 32%) to over $1000 per site (in 5%). The average spending per site per year was $211 (Table 5). There was a significant difference ($p = .003$) in average costs per site between VMM groups in centralized versus networked states (Table 5). In addition, the value of VMM equipment that is owned and controlled by the group is significantly lower in centralized than in networked states ($p = .006$) (Table 5).

With regard to human capital, VMM groups report having an average of 30.33 stream monitors per group (Table 2), which corresponds to an average of 2.8 volunteers per site monitored, and an average of 11.6 hours per volunteer each year (Table 5). This corresponds to an average of 32.55 person hours per site. When comparing human resources expended for VMM under different state models, volunteers in limited support states spent somewhat less time than groups in networked or centralized states ($p = .0419$; Table 5). In addition, the number of training hours required for group leaders was significantly higher in centralized and networked states than in states with limited support ($p = .0108$; Table 5). These data illustrate a positive relationship between state level investment in VMM, and human capital generated at the group level.

One important type of financial and human capital reported was the in-kind support received from service providers or other organizations. For each of nine VMM tasks, we asked respondents to state if it was done independently or with the aid of a service provider. Volunteer groups reported to be self-sufficient with respect to site identification (72%), organism collection (81%) and identification (70%), and

TABLE 3 Group Goals for Volunteer Macroinvertebrate Monitoring Groups, 2002, on a Scale of 0–4 with 0 = "Not a Goal" and 4 = "High Priority"

Goal category	Goals: Our strategy is ... ($n = 135$)	Average score	No response	"High priority"		"Not a goal"	
				Frequency	%	Frequency	%
Education	To protect water quality through educating the public to change their actions.	3.52	0	99	73	2	1
Structural change	To protect water quality through improved legislation.	1.96	3	25	19	27	20
Structural change	To actively promote enforcement of ordinances that will protect water quality.	2.51	1	41	31	17	13
Direct service	To directly restore natural systems in the area.	2.99	1	68	51	10	7

TABLE 4 Reasons for Using Volunteer Macroinvertebrate Monitoring, 2002, on a Scale of 0–4 with 0 = "Not a Reason" 4 = "High Priority"

Why did you choose VMM? Because VMM . . . ($n = 137$)	Average score	No response	"High priority"		"Not a reason"	
			Frequency	%	Frequency	%
Education						
• Provides an educational experience	3.52	0	101	74	1	1
• Increases awareness	3.69	1	103	76	2	1
• Gives us baseline information on stream health	3.68	1	105	77	2	1
Structural change						
• Identifies priority problems that can alert professionals	3.33	1	84	62	4	3
• Gives us data that can add stream to 303(d) listing	2.15	2	34	25	29	21
• Gives us data that can be used in court	0.99	4	8	6	65	49
• Gives us data that can be used in local planning decisions	2.46	1	39	29	13	10
• Gives us power to influence policies	2.58	2	39	29	11	8
Direct service						
• Helps set priorities for restoration	2.69	1	45	33	10	7

TABLE 5 Resources Allocated for Volunteer Macroinvertebrate Monitoring (VMM), 2002

	Average for all groups	Average for limited support states	Average for networked states	Average for centralized states	*p* Value
2001 Budget of VMM	4040.64 ($n = 109$)	2715.714 (a) ($n = 8$)	5832.62 (a) ($n = 67$)	875.29 (b) ($n = 34$)	.011
Number of sites, 2001	13.31 ($n = 132$)	10.909 ($n = 11$)	13.276 ($n = 76$)	13.956 ($n = 45$)	.082
Value of VMM equipment ($)	5450.59 ($n = 135$)	5665.39 (a, b) ($n = 11$)	7592.92 (a) ($n = 77$)	2363.24 (b) ($n = 47$)	.006
2001 $ per site	211.71 ($n = 107$)	103.71 (a, b) ($n = 8$)	301.81 (a) ($n = 66$)	59.04 (b) ($n = 33$)	.003
Number of hours for averge volunteer, 2001	11.624 ($n = 121$)	5.625 (a) ($n = 12$)	12.970 (b) ($n = 67$)	11.190 (a, b) (n = 42)	.042
Number of training hours required for team leaders, 2001	9.36 ($n = 114$)	3.300 (a) ($n = 10$)	8.7344 (b) ($n = 64$)	11.887 (b) ($n = 40$)	.011

Note. Significantly different averages at $p = .05$ are signified by different letters; shared letters indicate categories are not significantly different from one another.

data management (57%). In contrast, fewer groups were independent in monitoring design (37%), protocol selection (29%), and data analysis (38%).

In addition we asked respondents whether their group had received in-kind support in a variety of other categories (Table 6). VMM groups appear to be well supported through in-kind contributions. While there is no significant difference among state-level models in the total combined in-kind score (a composite of all the support a group has received), volunteer groups in limited support, networked, and centralized states may be utilizing different types of support (Table 6). Fewer volunteer groups in limited support states get help with training, data management, or data promotion than in centralized states; however, groups in limited support states appear to have proportionally more equipment loaned to them.

Data Collection, Management, and Use

From a resource mobilization perspective, we expect that groups engage in VMM because it helps them meet their goals. Since VMM involves an evaluation of a local stream, one important benefit is an increase in knowledge, which relies on the collection of quality data. We investigated data quality by asking respondents about their data collection, management, and analysis methods. We also asked them to quantify how, and if, their data were made public.

In summary we found that while >50% of groups had a specific plan regarding how to collect quality data, many did not use methods sanctioned by professional resource managers. For example, professionals agree that to select a representative sample of the benthic community, volunteers should sort a random subsample of organisms (Plafkin et al. 1989; Karr and Chu 1999). Only 34% of groups sort a random subset of organisms. To determine subtle differences in stream quality, professionals rely on identifying organisms to family or species level using a microscope. While 76% of groups do identification to family, only 46% use a microscope.

Creating a well-structured data management system can be challenging. Fifty-seven percent of groups use an external data management system, whereas only 38% have their own data management system. (Some groups may use both). Of the groups in centralized states, 78% use an outside data management system, in contrast with 50% in networked states and 17% in limited support states.

After the effort of collecting and managing data, how are groups actually using their data? While 74% of groups responded that they send their data to a larger organization that publishes it, more than 50% publish it themselves, either exclusively or in addition to sending it off to a larger organization. While less than half of the groups have their own data management system, 54% publish the data in an annual report or newsletter, indicating that some groups are using the data management system provided by an outside entity to give them results that they use in their own publications. Ninety-two percent of groups in limited support states responded that they gathered data that primarily informed their group, in contrast with 53% of groups from centralized states.

In summary, there is a range of different approaches to data collection, management, and use. While many volunteer groups are making an effort to collect data that can be used in professional resource management databases, many are not using all of the steps required for quality data. For VMM data to be considered professional quality, each group's approach will need to be considered on a case-by-case basis. While there are a fair number of groups producing "usable" data, VMM

TABLE 6 Types of In-kind Support Received from Service Providers, 2002

Type of in-kind support ($n = 137$)	Frequency (for all groups)	Percent receiving support	Percent limited support ($n = 12$)	Percent networked ($n = 77$)	Percent centralized ($n = 48$)
Site visits	89	65	42	68	67
Training	111	81	58	82	85
Data management	93	68	33	69	75
Promotion	87	64	50	71	54
Help with grant writing	44	32	33	32	31
Equipment donated	73	53	42	45	69
Equipment loaned	61	45	58	47	38

TABLE 7 Action Outcomes for Volunteer Macroinvertebrate Monitoring Groups, 2002

During 2000 and 2001, number of times your data have ...	Average for all groups	Average for limited support states	Average for networked states	Average for centralized states	*p* Value
Been used in an official report	1.7826 ($n=115$)	0.50 (a) ($n=10$)	1.75 (b) ($n=64$)	2.14 (b) ($n=41$)	.0208
Been used by a local unit of government when considering land use planning	0.4823 ($n=106$)	0.222 ($n=9$)	0.614 ($n=57$)	0.3000 ($n=40$)	.3030
Been summarized by a newspaper	1.00 ($n=116$)	1.200 ($n=10$)	1.1167 ($n=60$)	0.7907 ($n=43$)	.4210
Illustrated a specific trend that motivated further investigation	0.7091 ($n=110$)	0.3000 ($n=10$)	0.8070 ($n=.57$)	0.6744 ($n=43$)	.3869
Been shared at a public hearing	0.9107 ($n=112$)	0.6364 ($n=11$)	1.1186 ($n=59$)	0.6905 ($n=42$)	.0992
Been shared at an event	3.1351 ($n=111$)	1.100 (a) ($n=10$)	3.678 (b) ($n=59$)	2.8571 (a, b) ($n=42$)	.019

Note. Significantly different averages at $p=0.05$ are signified by different letters; shared letters indicate categories are not significantly different from one another.

TABLE 8 Outcomes of Volunteer Macroinvertebrate Monitoring on a Scale of 0–4 with 0 = "Not an Outcome" and 4 = Very Important Outcome

Outcomes ($n = 134$)	Average score	No response	"Very important"		"Not an outcome"	
			Frequency	%	Frequency	%
Education						
• Volunteers understand the relative health of streams better now	3.59	1	93	70	1	1
• Our volunteers are more aware and engaged in promoting water quality since we started	2.99	0	60	45	8	6
• Being out there has caused us to recognize things	3.84	2	76	58	5	4
• Our volunteers are more aware and engaged in promoting water quality since we started	2.99	0	60	45	8	6
Structural change						
• Local government uses VMM data for land use decisions	1.67	11	16	13	31	25
• VMM data are used to create the 303(d) list	1.20	9	13	0.10	63	0.50
• Our VMM data have influenced policies	1.54	7	10	0.08	37	0.29
• As a result of VMM data political changes have been enacted	0.75	9	3	0.02	68	0.54
• Our VMM data have given us a voice in development	1.33	5	7	0.05	50	0.39

• Our VMM data have been used in public debates	1.04	8	9	0.07	64	0.51
Direct service						
• As a result of VMM resources have been allocated for restoration	1.50	6	16	0.13	50	0.39
• Streams have improved through sharing VMM data	0.96	6	3	0.02	62	0.48
• Streams have improved because we started VMM	0.99	5	5	0.04	58	0.45
• We stopped a potential threat due to VMM	0.98	7	13	0.10	70	0.55
Social capital						
• Being involved in VMM has given us access to a network of professionals	2.89	2	53	0.40	5	0.04
• We have become part of network because we started VMM	2.55	2	50	0.38	22	0.17
• We have become acquainted with other volunteer groups as a result of VMM	2.62	3	48	0.37	14	0.11
Human capital						
• VMM data have helped us in voicing our concerns	2.25	4	37	0.28	27	0.21
• Our VMM data are used in research	1.54	6	22	0.17	48	0.38
Financial capital						
• Our VMM data have helped us receive financial support	1.52	6	18	0.14	47	0.37

across the country has not yet established the credibility necessary to ensure confidence on the part of natural resource professionals.

Outcomes and Actions

Lastly, we were interested in learning how the effort expended to do VMM was impacting group action. Overall, groups reported that participating in VMM motivated them to make a positive change in the resource an average of 1.9 times in the history of their programs. In 2000 and 2001, VMM groups were producing an average of 0.89 official reports a year, sharing their data at public events an average of 1.57 times a year, and had their data summarized in a newspaper an average of once every 2 years (Table 7). VMM groups report that their data were only used in local land use planning approximately once in 4 years.

Volunteer groups in centralized or networked states produced significantly more official reports than groups in limited support states ($p = .02$). There were also significantly more events reported in networked than in limited support states ($p = 0.02$) (Table 7). These results illustrate that at least for those two parameters, state-level support of VMM does indeed lead to greater action.

As reflected in the section on group goals, when asked to rate outcomes on a Likert scale, volunteers were consistently more likely to rate education and awareness as "very important" than outcomes relating to structural change or direct service (Table 8). When asked to respond to "streams have improved because we started VMM," only 4% of respondents answered that this closely represented their experience, while 45% reported that this was not an outcome they had experienced. Only 8% of groups reported that the statement "our VMM data have influenced policies" closely represented their experience, while 29% reported that this was not an outcome. Volunteers recognized VMM as a tool more useful in building social capital, or an enhanced network, rather than human capital in the form of increased knowledge about stream systems (Table 8).

Discussion

In this study we focus on how VMM has been used as a tool for people to investigate the interaction between human land use and stream quality. Using resource mobilization theory as our basis, we illustrate that groups are indeed forming to promote healthy watersheds, and that they seek to do this through the utilization of volunteer macroinvertebrate monitoring. We provide a window into the workings of citizen monitoring groups, illustrating that there are a variety of groups who secure public resources by using VMM, and are thus embedded in a complex relationship with state and regional governments. By contrasting groups formed under different models of state support, we shed light on the relationship between government and citizen action, and contribute to the understanding of how these partnerships are shaping the current environmental movement.

Little work has been done to characterize the goals and outcomes of groups who utilize one of the most popular citizen monitoring tools in the nation, VMM. While there are diverse groups using VMM, this study illustrates that the most popular goal is to promote education and awareness of local water resources, rather than to work for structural change such as changing the legislative climate, or instituting new zoning regulations. These goals correlate closely with stated outcomes. More often groups report their greatest success to be furthering public education and network building rather than having had a direct impact on the resource. Unlike social

movement organizations of the 1960s and 1970s that worked to actively change governmental policy (Dunlap and Mertig 1992), these place-based groups are working closely with, rather than in opposition to, state and regional government. By conducting VMM, a partnership between government entities and social movement organizations is more the rule than the exception.

While mobilizing the necessary resources is only one component of creating a successful movement (Canel 1997), resource mobilization (RM) theory can help us understand the conditions under which social movement organizations become effective change agents. It postulates that the availability of opportunity structures, as well as a group's ability to secure outside resources, influences the degree to which the group can succeed in reaching its goals (McCarthy and Zald 1977; Tarrow 1994). Through both formal and informal support structures, citizen organizations are using VMM as a tool to garner the financial, human, and social capital necessary to promote their organizational agendas. Most groups rely on significant in-kind assistance from outside sources (state, regional, or local government entities) to help them with tasks such as protocol identification, training, and data management.

In a recent article about the watershed movement in the western United States, David Getches (2002) postulated that government involvement is necessary to maintain the energy and focus of watershed groups. By comparing groups in limited support states to groups in networked or centralized states, we can conclude there is a relationship between the outcomes of VMM and the availability of state-level support structures. Fewer groups are choosing to do VMM when support is hard to secure. For example, in Vermont, where there is no state infrastructure to accept citizen data, and almost no funding for VMM at the state level, many of the groups we initially contacted had abandoned their programs in the last few years. When groups do utilize VMM in limited support states, it tends to be one of many activities supported by a larger organization. Volunteers devote significantly less time to VMM activities, and likewise are significantly less likely to share their data than groups in centralized or networked states.

How a state chooses to support VMM is another important factor shaping the character of VMM groups. In centralized states, where it is most often a state agency administering a largescale VMM program, the average group size is significantly smaller, and the ratio of stream monitors to total members is significantly larger than in networked or limited support states. While this study did not directly address the question of whether VMM enhances identity formation, we can hypothesize that while groups may receive more resources in centralized states, the high level of government involvement may compromise the ability of a group to take ownership of the process, or may allow the formation of groups without an otherwise well developed identity.

In networked states, local citizen groups may have to work harder to gain access to resources available at the state level. For this reason, groups tend to be larger and spend more money per site than groups in centralized states. Pennsylvania and Michigan, for example, are highly supportive of VMM, but choose to provide support though a grants program rather than direct programming for VMM. To receive funding and support, citizen groups have to articulate a vision for why and how they intend to utilize VMM. If they receive funds, they can then purchase their own equipment, and create their own sampling protocols. In this study, we illustrate that VMM has increased the potential for citizen groups to build networks, and has provided a point of entry for state and regional government to partner with locally

based citizen organizations, leading to the formation of what Weber (2000) calls grass-roots ecosystem management organizations. Willkenson (1991) explores the nature of networks within society and postulates that "weak ties" (formal or transitory contacts among relative strangers) link locally cohesive groups together and can be critical to creating powerful communities. Within the environmental movement, VMM provides opportunities for citizen groups to come in contact with both service providers and other citizen groups, effectively enhancing the weak ties that can serve as the glue for a larger environmental movement. Leaders reported on the contagious enthusiasm that is generated by coming together for VMM. This enthusiasm provides openness for social learning and identity formation described by new social movement theorists as a necessary component of successful movements (Canel 1997).

While VMM holds great promise as a tool for an environmental movement, tension exists between the goals of government service providers and citizen organizers. Our study illustrates that while the groups stressed education as their primary objective, national and state leaders are focused on producing data through VMM. Burchfield (2002) argues that science rarely directly informs policy and suggests that we view it as an "art" rather than a process of discovering the truth. Our study confirms that in the case of VMM few groups perceive that their data has led to concrete policy change, but rather that it has increased public education and helped them form networks. While Burchfield's message may indeed be true, if we value the emerging networks we should be conscious of how data is viewed by the array of actors involved. Ultimately, the creation of a new identity for the environmental movement may be challenged if it takes place within a network that is built on unclear expectations about data accuracy. Our study illustrates that while the majority of groups may be implementing quality assurance measures, many of their protocols fall short of what professionals view as necessary for producing "useable" data. If, as Canel (1997) describes, the complex relationship between government policy and citizen identity is at the root of social change, it may be critical for program organizers to pay attention to the tension between citizen objectives and the needs of state agencies. Further investigation into the nature of these tensions is needed to clarify where expectations could be modified and potential pitfalls avoided.

Notes

1. In 1 of the 25 initial states chosen, group contact information was not available. We choose to eliminate the state from our data set.

2. We calculated a revised estimate of the number of surveys sent by assuming that the percentage of nonactive nonrespondners in each state was equal to the percentage of responders who replied that they were inactive: $\mathrm{Rn} = n - (n \times \mathrm{pna})$ where Rn is revised number sent, n is number of surveys sent, and pna is percentage of responders that were not active.

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