# Volunteer Stream Monitoring and Local Participation in Natural Resource Issues

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## *Abstract*

*This research evaluates whether increased learning, local political participation, and more extensive social networks are related to participation in a volunteer stream monitoring project in Wisconsin. We hypothesize that participation in volunteer monitoring increases factual learning among experienced volunteers compared to inexperienced volunteers, that participation also is associated with increased community political participation in community natural resources management, and increased size of personal action networks. We find that participation does not significantly increase factual learning; rather, new volunteers and experienced volunteers were equally knowledgeable about stream-related topics. However, participation does significantly increase the political participation, personal networks, and feelings of community connectedness among volunteers. We consider our findings in light of the possibility of using volunteer monitoring to enhance local social capital and contribute to the adaptive management of water resources.*

***Keywords:*** *adaptive management, stream monitoring, citizen science, learning, civic participation, social capital*

## Introduction

Over the past 20 years, citizen volunteer monitoring programs have become popular in the North America (USEPA 1994). Monitoring programs enlist citizen volunteers, provide training in methods of environmental sampling, and may provide materials and support for citizens to sample environmental quality parameters in their community lakes, streams, and other natural areas. In some programs, monitors report sampling data to state agencies for official uses; however, for many agencies, the projects are intended primarily as citizen education and outreach opportunities (Savan, Morgan and Gore 2003). Sometimes environmental and conservation groups have supported monitoring programs to provide citizen surveillance of state environmental regulations — such as observers who monitor for Clean Water Act violations on industrial timber harvests in the southern U.S. (see Dogwood Alliance 2003). At other times, groups support volunteer data collection to help contribute to national data sets on trends in species habitat or abundance — such as Audubon bird counts.

Today, there is a great deal of volunteer monitoring occurring in streams, riparian areas, and lakes (Grossman-Garber et al. 1997). Since 1978, 26 state cooperative extension offices have sponsored volunteer water and stream programs, 12 states have formal interactions with existing private groups (CSREES 2001), and it has been estimated that 8,500 volunteers monitor rivers, streams, lakes, ponds, wells, wetlands, and estuaries in Cooperative Education sponsored or co-sponsored programs across the U.S. Most volunteers monitor rivers and streams, with 5,000 volunteers at over 1,800 sites. Over 2,600 volunteers monitor 860 lake and pond sites. An estimated 700 volunteers monitor U.S. marine and estuary environments (Grossman-Garber et al. 1997).

Volunteer monitoring programs can increase the amount of information about the ecological condition of the resource, support data sharing for community education, provide networks for volunteers and schools, and help to provide information for local civic conservation action (Fore, Paulson and O'Laughlin 2001). These programs, depending on how they are organized, may have the potential to contribute significant environmental and civic capacity to local communities and possibly higher levels of government (Metzenbaum 2002). There currently is an effort to build a comprehensive support system for community volunteer monitoring programs across the nation to coordinate efforts and share learning experiences in the area of water monitoring (CSREES 2001).

While local community monitoring may provide opportunities to improve community environmental and civic capacity, little research has been done on the potential mechanisms of capacity building. In this project, we evaluate the learning and capacity building of volunteer monitoring by reporting the results of a quasi-experimental design study. We surveyed volunteer stream monitors who are or plan to participate in one of 21 local Water Action Volunteer monitoring programs, a program sponsored by the University of Wisconsin Cooperative Extension office and the Wisconsin Department of Natural Resources. We evaluate the effects of program experience on learning, political participation, and community water-issue related networking among experienced and inexperienced volunteers. The results suggest that volunteer monitoring programs do have measurable impacts.

This paper proceeds by reviewing the literature in two key areas: social capital and adaptive management. This literature provides a conceptual framework for evaluating whether water quality monitoring provides a mechanism for learning and participation. We describe the case study site, hypotheses, research instruments, design, and analysis. Finally, we present results and consider them in light of what they tell us about volunteer monitoring.

## Building Social Capital for Environment

Social capital refers to the strength, density, and intensity of connections among social actors, which is thought to be associated with increased capacity for collective action (Lesser 2002; Lin 2001; Putnam 2000; Verba, Schlozeman and Brady 1995). A community with high social capital is one in which members know each other, share common experiences, and form common bonds. Repeated dealings among local community members who have and share information builds bonds of familiarity and reciprocity, which may make coordinated action easier over time.

Research has shown that actors in actor groups with high social capital — i.e., high connectedness and embeddedness in networks — outperform others in a number of domains of social life. Actors with high social capital do better as entrepreneurs (Davidsson and Honig 2003), recover from drug treatment more successfully (Cheung and Cheung 2003), and participate more in the community problem solving (Bowles and Gintis 2002; Teorell 2003).

Due to the collective nature of the benefits, social capital has been called an important public good which communities should develop to better address local social problems (Bowles and Gintis 2002; Lesser 2002; Putnam 2000). Building social capital might be particularly desirable to address problems — such as local environmental problems — which have proven to be difficult for other common methods of social coordination such as markets and hierarchies (Bowles and Gintis 2002; Ostrom 1990). By increasing the capacity of local community members to monitor, communicate, and share information about local environmental quality, communities with programs which generate social capital might spur collective action to help address environmental social problems.

## Monitoring, Learning, and Civic Participation as Mechanisms of Adaptive Management

Adaptive management is a conceptual approach to resource management originally advanced by natural scientists such as C.S. Holling (1978), and Carl Walters (1986) in the late 1980s and early 1990s. More recently, the social and political dimensions have been developed by Lee (1993; and for a recent review on the implications of adopting an adaptive management approach for environmental law and governance, see Karkkainen 2003).

The core notion of adaptive management is that ecological systems are highly complex and dynamic — too complex to be adequately managed with static or fixed approaches to resource management (Jiggins and Roling 2000). Rather adaptive management suggests natural resource management institutions — states, agencies, federal laws, and presumably firms — would do better to develop the capacity to flexibly adjust management objectives to changing knowledge and conditions based on ongoing biological, ecological, and social feedback. In other words, complexity requires governance mechanisms that constantly bring new information for consideration into the management field.

The main methods of adaptive management include monitoring the effects of human intervention, revision of policy and management plans in the light of new learning, and, consequently, increasingly local or place-based management. Monitoring is seen as a way to track the constantly changing conditions of the resource and provide feedback to resource managers about the adequacy of their policy experiments (assumptions). Rich monitoring contributes the knowledge needed to revise policies and understand changing conditions. By increasing feedback, resource issues may be addressed with adequate consideration of the efficacy of assumptions given local conditions.

Unlike traditional technical or scientific approaches to resource management, adaptive management recognizes that value tradeoffs in environmental management are intrinsic — e.g., there are typically social winners and losers in resource decisions (Lee 1993). As such, adaptive management approaches generally make provisions for public participation and debate over changing policy as an integral part of decision-making.

One approach to increasing community and public partnership in adaptive management encourages citizens to help “take measures” or help to monitor environmental management (Lee 1993). By involving members of the public in taking measures, citizens can presumably understand the condition and status of resources, form opinions, educate their neighbors, increase the local understanding, help motivate political support for new policies — or devise protests over those policies — and they may generate partnerships among groups and individuals to provide the institutional basis for alternative ways of addressing problems in the resource basin, i.e., collective action.

While learning within adaptive management is conceptualized as practical learning — e.g., learning-by-monitoring and participatory learning — adaptive management theorists take little notice of the broader learning literature in educational and cognitive science. The literature generally distinguishes between levels of or proficiency in learning (Bloom 1956). These levels can be useful additional heuristics for thinking about what kind of learning volunteer monitors might be expected to achieve. Bloom, for instance, identifies six levels of learning from facts-based learning, to comprehension, application, analysis, synthesis, and evaluation. Proficiency usually advances from simple mastery of facts to higher functionalities, e.g., understanding the implications of facts, the ability to apply facts to new situations, to relate components to the whole, to combine components to form a new whole, and to choose criteria to develop alternatives.

Dreyfus and Dreyfus (2000) similarly distinguish between hierarchical stages of skill acquisition. First, facts acquisition is where learners process information and make decisions based on externally derived rules or heuristics that are taught or instructed. The second stage derives from more contextually-based knowledge acquisition and understanding. Learners make decisions based on a combination of general rules *and* context-specific experience. In the third stage, learners are able to sort through a hierarchical selection of context-informed strategies built from past experience to choose a course of action, given the situation. In the fourth stage, “proficiency,” experience is extensive enough so that what appears to be a non-reflective “intuition,” but which is really refinement of familiarity based on experience, is used to execute tasks. Finally “experts” operate easily on mature and practiced understanding based on experience in many contextual situations and the capacity to use that experience to steer a proper course.

Questions about which level of learning and skill acquisition adaptive management might aspire to, particularly with respect to citizen collaboration and science, are rarely posed within the adaptive management literature. Here, we only measure and assess the lowest level of learning identified by Bloom and Dreyfus and Dreyfus: facts-based learning. However, future research should attempt to address the additional substantive and applied questions about learning derived from the cognitive and educational science literature.

In our study, we consider the operation of a volunteer stream monitoring program — not currently associated with an adaptive management approach — to evaluate several important hypotheses in the social capital and adaptive management literatures. Namely, we evaluate whether the volunteer monitoring programs we study operate as mechanisms that increase community networking, learning, and social capital — or the networks of individuals in the community who know one another, and understand and participate in local stream management issues. The hypotheses we derive from the adaptive management literature suggest that volunteers will have higher levels of facts-based learning from monitoring and training experience. From the social capital literature, we evaluate whether volunteer stream monitoring is associated with increased networking, participation, and personal efficacy in resource related management issues.

## Water Action Volunteers in Wisconsin

The Water Action Volunteer (WAV) program was created in 1996 as a pilot program modeled after the successful and widespread lake monitoring program in Wisconsin. It was created in a joint effort between two state agencies and the main stated goal of the program is to educate citizens about their local natural water resources and to provide an opportunity for them to become involved in basic stewardship of their streams. The program has expanded since its inception and now includes approximately 21 monitoring groups in nine river basins across the State of Wisconsin. WAV is similar to the stream monitoring programs that exist in 26 other states in its goals and methods. Individual groups engage in stream monitoring on a seasonal to monthly basis, and data collected on physical, biological, and chemical parameters in the monitored streams are collated in a program-wide database made available to the public online. While monitoring has been a major focus of WAV groups, at this time, the data collected are not used to evaluate streams or guide management activities by regulatory agencies.

## Methods

### The Samples

Two groups of WAV volunteers were included in this study. The treatment group, *experienced volunteers*, was a census of all Water Action Volunteers who had participated in WAV training and monitoring for at least one season as listed in the volunteer directory updated in February 2003. There were 155 volunteers in this group. The control group, *inexperienced volunteers*, was selected as people who had signed up to become new WAV members for the spring 2003 season, but who had not attended any WAV-related activities nor done any monitoring at the time they responded to the survey. There were approximately 105 people in the control group. We assumed that both groups self-selected into the WAV program in the same manner. We assumed that groups would be similar except in exposure to training and experience in the WAV program. Empirical tests of these assumptions are provided in the paper.

### Research Design

We use a non-equivalent groups, quasi-experimental design (Trochim 2000; Campbell and Stanley 1966). This quasi-experimental design is vulnerable to selection threats that might derive from the non-randomized assignment of subjects to groups (i.e., non-equivalence before treatment). In this case, we test that the methodological hypothesis of non-equivalence by comparing treatment and control on standard socio-demographics, although this in no way eliminates the possibility of selection bias. As will be presented later, the assumption of non-equivalence was rejected. A time-series design estimating effects before and after in the same group or randomized assignment of subjects to treatment and control groups would offer improvements to the reliability of the design (Trochim 2000), however, due to financial and time constraints these approaches were not available in this study.

### The Questionnaire

A questionnaire was developed to collect information on the frequency, duration, and type of volunteer involvement with the stream monitoring program, understanding of basic stream function, the extent to which volunteers participated in resource management-related political activities and the amount of participation in other civic activities. Examples of community activities were contacting a public official or attending a public meeting for a reason not related to natural water resources.

A modified Dillman method was used to distribute the questionnaire (Dillman 1978). It was first mailed to experienced volunteers in March 2003. Two weeks after the initial mailing a reminder postcard was sent to non-responders followed by a second questionnaire one week later. Response rate was 52% for experienced volunteers. A second questionnaire, modified slightly to exclude questions about duration of participation in the volunteer program, was given to the control group of inexperienced volunteers at the beginning of the first training session they attended. Fifty-five percent of the inexperienced volunteers responded to the survey.

The survey was structured in four sections followed by an open-ended question allowing volunteers to comment on the WAV program. Experience in the volunteer program was measured as days and months in the program, number of trainings and meetings attended, number and frequency of sites sampled, and number and type of ecological parameters measured at each site. Knowledge of streams was evaluated using 15 true/false questions about stream functions. The true/false items were drawn from the education materials used to train interviewers; as such they were intended to represent the factual content that the program sought to teach. Second, we presented the items to the program coordinators for expert assessment of content validity. Third, we distributed the questions to a graduate class at a major midwestern research university made up of limnology and social science Ph.D. students to assess comprehension and clarity of wording.

There remains a possibility of low discriminate validity of the instrument. For example, since we evaluated only facts-based knowledge, the true/false questions do not provide a test of whether higher levels of learning (synthesis, analysis, problem solving) might be in evidence. To quantify participation, volunteers were asked the number of times they had participated in a list of activities within the last 12 months. The list of activities was divided into items related to political participation (writing letters to the editor about water, stream or other resource issues, joining an environmental group concerned with water, stream, or other resource issues) and general civic participation (attending school functions or local government meetings). WAV program administrators do not sponsor political activities themselves so that increases in participation after experimental treatment should not be seen as tautological with program participation. Also, measurement of participants' self-assessment of their own level of learning about stream and water quality and subjective sense efficacy in relating this information to other community members was made by asking respondents to rate a series of nine questions on a five-point Likert scale ranging from "strongly disagree" to "strongly agree." Socioeconomic variables measured included gender, age, level of education, type of employment, and household income.

### Data Analysis

The data were analyzed in two ways. We used simple linear regression to estimate the strength of relationships between volunteers' level of learning and participation as a function of amount of time spent in the WAV program. We used comparison of mean statistics using a t-test to determine if participation in the WAV program significantly increased knowledge and water resources political participation. Data were analyzed using Minitab 13.30 (Minitab 2000).

## Results

### Descriptive Results

Table 1 describes the demographic characteristics of treatment (experienced volunteers) and control group (inexperienced volunteers), as well as the general population as a reference group. The assumption that experienced versus inexperienced WAV volunteers are similar except with respect to the treatment variable — stream monitoring — holds. The inexperienced and experienced volunteers were not significantly different on demographic variables (age, gender, education, and income) suggesting that the assumption that they are drawn from the same population is robust. Compared to the general population, both experienced and inexperienced volunteers had more education and higher household incomes than the general U.S. population. These findings compare favorably with previous research that suggests that it is the highly interested, educated and efficacious members of the community that transition from environmental supporters to citizen participants (Greenberg 2000; see also Stern et al. 1999).

Experienced stream monitors sampled streams for an average of 20 months (s.d. 15.16), experienced monitors on average sampled seven times during the year (s.d. 4.42), 34% sampled as individuals, 16% sampled as families. Twenty-one percent of experienced volunteers sampled for greater than 30 months while 11% sampled fewer than nine months. The majority of experienced volunteers report using chemical (94%), biological (93%), and physical (96%) monitoring methods in their sampling. The 11% of inexperienced volunteers who report having participated in another stream monitoring program report monitoring between 2–12 times in the last year.

*Table 1.* Demographic and monitoring participation characteristics of experience (treatment), inexperienced (control) volunteer stream quality monitors in Wisconsin and general U.S. population.

| | **Experienced Volunteers ($\mu$ /s.d.)** | **Inexperienced Volunteers ($\mu$ /s.d.)** | **T-value** | **General US Population ($\mu$)** |
|---|---|---|---|---|
| **Demographic** | | | | |
| Age (years) | 46 (11.6) | 42 (15.3) | 1.82 | 35 |
| Male (%) | 63 (0.49) | 50 (0.50) | -1.53 | 49 |
| Education (college +) | 75 (1.3) | 63 (1.6) | 1.34 | 23 |
| Household Income ($K) | 50-75 | 50-75 | 1.83 | 42 |
| **Participation** | | | | |
| Average months in WAV | 20 (15.2) | --- | | |
| Average months in another program | --- | 0.47 (1.82) | | |
| **Sampling times per year** | 7.3 (4.4) | 0.34 (1.30) | | |
| Individuals | 35% | --- | | |
| Families | 16% | --- | | |
| **Parameters sampled** | | | | |
| Chemical | 94% | --- | | |
| Biological | 93% | --- | | |
| Physical | 95% | --- | | |
| **Self-rating of understanding** (2 = not very well, 3 = somewhat well) | 3.2 (0.48) | 2.3 (0.79) | 7.62* | |
| **Stream quality rating** (2 = not improving, 3 = about the same) | 3.0 (0.79) | 2.8 (1.12) | 1.49 | |

*p < .001

*Hypothesis 1: Volunteer Stream Monitoring Project Increases Understanding of Stream Function.* The null hypothesis is that there is no difference in learning about stream and water resources among experienced and inexperienced monitors. Test results fail to reject the null hypothesis. The mean number of correct answers to true/false questions between groups is not significant at the .05 level (t = .19, df. = 132, p = .850). Experienced volunteers did not possess more factual knowledge about the stream-related topics presented in WAV training materials compared to similar, but untrained and inexperienced, counterparts. Table 2 reports the average correct answers to the true/false questions.

*Hypothesis 2: Volunteer Stream Monitoring Increases Community Participation in Resource-Related Management Issues.* The second hypothesis holds that local monitoring leads to increased community political participation. In our first measure of this hypothesis, we found a significant relationship between WAV experience and actual community political participation. WAV participants were more likely

*Table 2.* Percentage of correct answers to true/false questions by experienced (treatment) and inexperienced (control) volunteer stream quality monitors in Wisconsin.*

| True / False Question | Experienced (%) | Inexperienced (%) |
|---|---|---|
| Snails, sowbugs (isopods) and bloodworms need better water quality than stoneflies, dragonflies and mayflies do. | 91 | 74 |
| Carp can survive in warmer water than brook trout can. | 94 | 86 |
| The major sources of water pollution today in Wisconsin are point sources. | 75 | 68 |
| Reducing phosphorus inputs is often necessary to keep algae growth in check and to keep our streams and rivers healthy. | 90 | 90 |
| Over 97% of water in world is fresh water. | 83 | 84 |
| Silt in stream water can cause stress to trout and other fish. | 96 | 97 |
| Vegetation along the banks of a stream may filter nutrients. | 89 | 95 |
| Excessive algae growth can be a sign of excessive nutrients in the stream. | 91 | 86 |
| The major sources of nitrogen in Wisconsin rivers are natural (non-human caused) sources. | 75 | 68 |
| Turbidity is a measure of water clarity. | 93 | 86 |
| Warm water holds more oxygen that cold water | 81 | 80 |
| Land use can affect stream habitat quality and stream health. | 95 | 98 |
| The number and type of macroinvertebrates living in a stream can indicate how good the water quality is in that stream. | 96 | 95 |
| Polluted runoff flowing over fields, city streets, rooftops, and parking lots is known as nonpoint source pollution. | 90 | 83 |

*None of the relationships in the table are significant at the .05 level

to participate in political action events. The average number of participation events/year of the treatment group was 5.09 compared to 3.86 in the control group (t = 2.14, 117, $p = .034$). A rank ordering of activities participated in most by experienced monitors is in Table 3. The most frequent events engaged in were personal reading or research on water issues; talking with neighbors about water, stream, or other resource issues; attending public meetings to discuss water, stream, or other resource issues; and providing monitoring information to neighbors and friends. Over 50% of experienced volunteers report these activities in the last year.

In a second test, we measured the effect of length of time in the program on types of participation events. The results suggest that length of time in participation is related to probability of political participation (B = .085, t(3.809), $p < .001$).

*Table 3.* Types of political participation events by number and percent of experienced monitors in Wisconsin.

| Types of Political Participation | Participating Respondents Number (%) |
|---|---|
| Engaged in personal reading or research on water issues | 60 (72.2) |
| Talked with neighbors about water, stream or other resource issues | 60 (72.2) |
| Attended a public meeting to discuss water, stream or other resource issues | 51 (62.5) |
| Provided monitoring information about water, stream or other resource issues to neighbors and friends | 45 (54.2) |
| Joined an existing group in your local area concerned with water, stream or other resource issues | 33 (39.8) |
| Sought experts for additional information on water issues | 33 (39.8) |
| Participated in a volunteer stream, river, or lake clean-up day | 29 (34.9) |
| Provided monitoring information about water, stream, or other resource issues to local environmental or civic groups | 25 (30.1) |
| Coordinated a water or stream volunteer activity (other than monitoring) | 22 (26.5) |
| Met, written, or called members of the business community or individual landowners about water, stream or other resource issues | 18 (33.9) |
| Provided monitoring information about water, stream or other resource issues to local officials | 18 (33.9) |
| Formed a group of concerned citizens to discuss/ address water, stream or other resource issues | 9 (10.8) |
| Written a letter to the editor of your local paper about water, stream or other resource issues | 9 (10.8) |

Participation increased with length of time in program. The bivariate model explained just over 15% of the variability ($R^2 = 15.7$).

*Table 4.* OLS regression results: Impacts of length of time in volunteer water monitoring program on participation in political activity types.*

| Variable | OLS Estimate | t-ratio |
|---|---|---|
| Intercept | 3.385 | 6.079** |
| Time (months) | 0.085 | 3.809** |
| $R^2 = .157$ | S.E. = 3.009 | n = 80 |

* cf. Table 3 for list of political activity types. Each respondent was assigned a value based on the number of different *activities* listed in Table 3 in which they participated in the last 12 months.
**$p < .001$

*Hypothesis 3: Volunteer Stream Monitoring Increases Community Networking in Resource-Related Management Issues.* In the first evaluation of this hypothesis, we measured respondents' degree of connectedness to networks as it varied with the duration of time in program. The question read: "I feel connected to people in my community who are interested in stream and water resource issues." The results suggest that the longer in the program, the more connected to others in the community volunteers became (B = .022, t(3.322), $p < .001$). The bivariate model predicts over 12% of the variability in "feeling connected."

*Table 5.* OLS regression results: Impacts of length of time in volunteer water monitoring program on monitors' feelings of community connectedness.*

| **Variable** | **OLS Estimate** | **t-ratio** |
|---|---|---|
| Intercept | 2.684 | 16.469** |
| Time (months) | 0.022 | 3.322** |
| R≤ = .127 | S.E. = 0.871 | n = 78 |

*The question item read: "I feel connected to people in my community who are interested in stream and water resource issues." The item was measured on a 5-point Likert scale.
**$p < .001$

In the second measure of this hypothesis, we asked respondents the following question: "How many people in your local community do you personally know that you believe have a sound understanding of local stream and water resources issues?" The null hypothesis — that there is no relationship between stream quality monitoring and increased size networks — was rejected. Experienced volunteers knew more than twice as many people as their inexperienced counterparts (t = 3.92, df = 110, p = 0.002). Experienced volunteers knew nine community members compared to 3.74 for inexperienced volunteers.

## Discussion

The social capital literature suggests that communities characterized by dense social networks generate greater capacity for better community outcomes, including resiliency, stability, and problem solving. The results here suggest that programs like WAV can be associated with measurable impacts in generating denser networks and more involved citizens. Experienced volunteers were more active than their inexperienced counterparts in resource management-related behaviors, such as talking with and providing information to neighbors about resource issues, engaging in personal reading and research about resource issues, and attending public meetings to discuss issues. Experienced volunteers were also more likely to have denser network ties to other members of the community who shared their interests in natural resources. Networks built through WAV may serve as social mechanisms for increasing political capacity in these communities; and given that the average time in the program was under two years, it is notable that the impacts of the program, especially on increased networks, were apparent at all in this study.

These results suggest that volunteer monitoring programs may have positive effects on developing local capacity in relatively short time frames. The implications for policy include the possibility that encouraging the development of such programs may have positive spillover effects in generating a more engaged and connected citizenry. Given that often today there are substantial public laments and concerns about an ongoing decline in civic culture, these results suggest that some public institutions may *build* social capital rather than relying on its presence a priori (as is indicated by the returns to social capital based on time in the program). This insight has important implications for understanding both where social capital comes from and how to encourage it as a matter of public policy. Still, it should be noted that it appears that only a segment of the population, highly educated and high income, have self-selected and thus tended to individually benefit from these spillovers. Thus, there remain social justice issues over the distribution of these benefits at the individual level of analysis. Future re-search should consider questions about the circumstances and conditions under which a broader range of individuals might participate in such programs.

Secondly, this research was conducted with a view toward the adaptive management literature. This literature suggests that environmental problem complexity, of both social and ecological sources, means that regulatory approaches that favor local monitoring and constant feedback, accompanied by stakeholder participation in these processes, can improve public natural resources management. Feedback from monitoring is held to create an information — or knowledge-rich environment in which rapidly changing conditions can be addressed by local citizens and governments. Increased learning about the status of the resource is held to improve the basis for natural resources decision making (Holling 1978; Lee 1993; Walters 1986).

Here we find that factual learning among volunteers was not increased by monitoring. Our results suggest that the WAV program operates principally to "recruit" already factually educated members of the local public, rather than recruiting unknowledgeable members and teaching them about stream and water resources. However, this research addresses only the first stage of learning as identified by both Bloom (1956) and Dreyfus and Dreyfus (2000): learning about facts. Learning can take more advanced forms. It is possible that at higher levels of discrimination there are learning differences among the experienced volunteers and inexperienced counterparts. We suggest that the adaptive management literature should turn to a deeper consideration of what kinds of knowledge (factual, analytic, synthetic) might be generated, how different levels of learning may differently benefit local communities, and how institutions may be designed to sustain the most desirable public learning experiences in collaboration with citizen volunteer groups. For example, more experienced monitors may have learned beyond the mastery of basic concepts to synthesize aspects of field-based context and knowledge in ways that would be useful to managers. Were this proven true empirically, an alternative institutional model to the WAV model might focus more on providing higher levels of interaction between and among monitors and resource managers to share monitors' and managers' experiences. In terms of future scholarship, these issues raise questions about how learning should be measured and how learning and learning institutions should be encouraged.

## Methodological Limitations and Future Research

We note several caveats. Our results appear to explain relatively small amounts of variance, just over 15% of participation by time in program and 12% of density of social ties. However, it is important to note that our intention is not to model participation or social density per se. Our intention is to model the effects of a given volunteer program on participation and social density. These are complex and multivariate outcomes that depend on many factors across individuals. We evaluate only how the volunteer program may be one contributory factor to the outcomes studied. Viewed in this light and given the arguable substantive importance of increasing political and civic ties and commitments, the programs appear to be a substantively, as well as statistically, significant contributor.

Second, methodologically, a true experimental design would be useful for more precisely isolating experimental effects than is the case with our quasi-experimental design. In the design, we evaluated whether the non-equivalent groups were equivalent on available demographics and confidence was increased because they appeared to be drawn from very similar demographic populations. However, there still may be uncontrolled differences between groups which may affect the results. A pretest-posttest approach with random assignment of subjects to groups in future research would eliminate this bias, but, as is common in applied research such as this, these methods are not always practically available.

## Endnotes

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