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Civil society research and Marcellus Shale natural gas development: results of a survey of volunteer water monitoring organizations

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Abstract This paper reports the results of a survey of civil society organizations that are monitoring surface water for impacts of Marcellus Shale development in Pennsylvania and New York. We argue that enlisting volunteers to conduct independent monitoring is one way that civil society organizations are addressing knowledge gaps and the "undone science" of surface water quality impacts related to gas extraction. The survey, part of an ongoing 2-year study, examines these organizations' objectives, monitoring practices, and financial, technical, and institutional support networks. We find that water monitoring organizations typically operate in networks of two main types: *centralized networks*, with one main "hub" organization connecting many chapter groups or teams, and *decentralized networks*, consisting primarily of independent watershed associations and capacity building organizations. We also find that there are two main orientations among water monitoring groups. Roughly, half are *advocacy-oriented*, gathering data in order to improve regulation, support litigation, and change industry behavior. We characterize the other half as *knowledge-oriented*, gathering data in order to protect natural resources through education and awareness. Our analysis finds that many monitoring programs function relatively independently of government and university oversight supported instead by a number of capacity building organizations in the field. We argue that this reflects neoliberal tendencies toward increased public responsibility for environmental science. We also find that new participants in the field of water monitoring, mainly large environmental NGOs integral to the operations of centralized networks, are shifting monitoring programs towards more advocacy-oriented objectives. We believe this shift may impact how civil society water monitoring efforts interact with regulatory bodies, such as by taking normative positions and using volunteer-collected data to advocate for policy change.

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Introduction

In the past several years, energy companies have pursued sources of natural gas in the USA that were previously considered too difficult to access, including the Marcellus Shale, a geological formation located in the northeastern USA. Significant public concerns have focused on the degradation of surface water quality due to the potential impacts of hydraulic fracturing or "fracking," a step in the gas production process that injects three to five million gallons of fluid, consisting of water, sand, and chemical additives into a gas well to stimulate production. There are multiple pathways for surface water pollution associated with development of the Marcellus Shale, including spills of chemicals, frack fluid, or flowback (waste water from fracking operations) at the drilling site, accidents involving trucks hauling chemicals or frack fluid, and increased runoff due to road development, well pad construction, and pipeline construction (Soeder and Kappel 2009).

In response to public concerns about the environmental impacts of Marcellus Shale gas development, there are a growing number of efforts to gather data about watershed quality and to monitor pollution levels in surface water. Several federal, regional, state, and municipal government agencies monitor surface water quality. However, shrinking budgets in regulatory agencies, combined with the difficulty

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of keeping pace with the rapidly developing shale gas boom, have created challenges to creating and maintaining robust regulatory infrastructures for surface water monitoring. In this context, community-based water monitoring groups have emerged as important producers of data about surface water quality. At least 22 Pennsylvania organizations—working in hundreds of watersheds—are monitoring surface water with the aim of identifying impacts of shale gas development.

This study examines the role of nonprofit organizations, such as capacity building organizations and environmental advocacy groups, in providing scientific expertise and taking on leadership roles with community-based water monitoring efforts. Previous research suggests that alliances with university researchers have been the predominant source of credibility for community-based efforts to gather scientific knowledge about the environment and public health (Savan et al. 2003; Brown 2007). University-based experts can provide guidance on research design and data analysis. However, some research suggests that nonprofit organizations are playing an increasingly independent role in the conduct of scientific research. Hess (2009) finds that civil society research—"research funded by nonprofit organizations linked to social movements"—often addresses topics that are not addressed by university-based scientific research efforts. Our study suggests the important role of both universities and nonprofit environmental organizations in developing water monitoring protocols and diffusing them through volunteer trainings. However, while universities still play a key role in supporting volunteer water monitoring, nonprofit organizations have a large presence, and this has had an impact on the objectives and practices of water monitoring groups.

Civil society water monitoring

While the threat of Marcellus Shale gas development has sparked new interest in watershed monitoring across Pennsylvania, many of these new efforts are being initiated by civil society organizations operating in a political–economic climate in which scientific knowledge is increasingly being generated by nongovernmental and nonacademic entities. Enlisting volunteers and gathering independent resources to conduct water monitoring is one way that organizations supporting civil society research address the problem of "undone science" or "areas of research that are left unfunded, incomplete, or generally ignored but that social movements or civil society organizations often identify as worthy of more research" (Frickel et al. 2010: 444). Hess (2009) argues that there are three common ways by which civil society organizations contend with the issue of undone science. These include (a) bringing issues of concern to the attention of political leaders, (b) appealing directly to expertise of research scientists, primarily through partnerships with universities, and (c) identifying knowledge gaps and sponsoring independent research to fill those gaps.

Changing relationships in how civil society groups engage public institutions versus universities and versus producing their own capacity for science can be attributed to shifts in recent decades that have changed who supports applied environmental science. Lave (2012) argues that the growing prominence of "extramural" environmental science (research done by nonprofessionals) is a consequence of neoliberal transformations in the domain of environmental governance in the 1980s. Geographer Noel Castree (2010) points out that ideas consistent with neoliberalism were present in the US Environmental Movement. Just as the "environmental decade" of the 1970s was reaching its end, neoliberal policy ideas gained ascendance in public institutions tasked with basic scientific research. Castree notes, "since the mid-1980s, many neoliberal values and principles have steadily made their way into the domain of environmental policy" (Castree 2010: 6). In the 1990s, scientific research at academic institutions was similarly transformed by increasing pressure to commercial their resources, develop closer relationships with industrial partners, and share the costs of research with private funders (Kleinman and Vallas 2001). Lave argues that this "tyranny of relevance" in academia has had the effect of prioritizing research with commercial potential at the expense of other forms of applied science (Lave 2012).

Indeed, Finewood and Stroup (2012) note the prominence of neoliberal discourse in public debates about water quality in Pennsylvania's debates on natural gas drilling. Proponents of natural gas development employ economic frameworks to position water quality as but one component for consideration in assessing the costs/benefits of natural gas development in the region. Meanwhile, those who oppose the gas industry situate water quality in noneconomic terms—as critical to maintaining healthy communities, the long-term conservation of local ecosystems, and protecting one's quality of life.

The turn to extramural environmental science, including civil society water monitoring, to counter a perceived lack of attention to science for "public good" has mixed consequences. On one hand, neoliberal environmentalism opens the door to "a new wave of appropriation of labor and knowledge" by scientists of participating citizens (Lave 2012: 28). Increasingly, academic scientists recognize the value of "citizen science"—the use of volunteers to gather data in a wide variety of fields. Therefore, university researchers frequently support volunteers not only out of a sense of public duty but also out of necessity, as they search for low-cost alternatives to data collection, such as with the Audubon Christmas Bird Count (Cohn 2008) or by parsing massive amounts of information in the SETI@home search for extraterrestrial life (Anderson et al. 2002). On the other hand, Lave notes that citizen-based environmental science groups "have been able to establish serious scientific credibility in startling upsets of the traditional construction of scientific legitimacy" and are increasingly "accorded a place at the table in many regulatory decisions" (Lave 2012: 28).

The research on civil society environmental monitoring suggests that these projects can have had multiple positive outcomes. They have been shown to make differences in drawing regulatory attention and sometimes improving industry accountability (Frickel and Vincent 2007; Overdevest and Mayer 2008; Ottinger 2009). O'Rourke and Macey (2003) show that the rise of community-based (air quality) monitoring programs in California and in Louisiana corresponded with significant drops in industrial accidents and toxic chemical releases. Countering skepticism about citizen science credibility, Pfeffer and Wagenet (2007) cite numerous studies demonstrating the relative accuracy of biological sampling by trained volunteers when compared to control groups of professional scientists.

Secondary benefits are also noted in these programs, such as increases in public awareness of environmental issues and broader community engagement in local governance (Stedman et al. 2009; Brasier et al. 2011). Overdevest and Mayer (2008) suggest that community-based environmental monitoring projects often emerge where residents feel they have been denied access to valuable knowledge about environmental threats. Their study demonstrates that civil society groups that use monitoring as part of their "tactical repertoire" are subsequently "altering the balance of power between activists, state regulators, and private firms based on their ability to contest official accounts of environmental quality" (Overdevest and Mayer 2008: 1497). Nevertheless, many smaller water monitoring programs also shy away from direct engagements with regulatory agencies instead choosing to focus on public awareness campaigns and broader goals of environmental stewardship (Nerbomme and Nelson 2004).

In the case of surface water monitoring, the relationship between civil society groups, universities, and the state is complex. Many grassroots water monitoring programs began in the late 1960s, as lake and river associations formed around the country to address issues related to declining water quality (Lee 1994). Following the Clean Water Act in 1972, which required states to implement surface water quality assessment programs, community-based monitoring programs were seen as one way to enlist the public in developing water resource management strategies informed by local needs (Lee 1994). Civil society water monitoring gradually gained national footing as state and federal agencies recognized the value this provided to environmental protection programs.

In Pennsylvania, state support for watershed associations was crucial. A 2005 study of Pennsylvania watershed associations—regional nonprofit organizations dedicated to protecting a particular water body—found that 40 % of surveyed groups were established during a particularly robust period of state government support when more than $1.2 billion was allocated through the Department of Environmental Protection (DEP) Growing Greener grants beginning in 1999 (Stedman et al. 2009). While not all of these watershed associations developed monitoring programs, a 2002 report presented by the DEP's Citizens' Volunteer Monitoring Program (CVMP) lists 138 organizations of all types actively monitoring throughout the state. The report described the DEP's purpose in supporting these civil society water monitoring programs: public education, baseline data collection, and watershed assessment—but interestingly not for official regulatory purposes (Wilson 2002).

However, shrinking resources are creating many challenges to continued support for water monitoring efforts. Some estimates show the Pennsylvania DEP general fund has been reduced by nearly 30 % from 2002 to 2011 (Pennsylvania Environmental Digest 2011). In 2009, DEP canceled its funding for the CVMP, which provided training, equipment, and administrative support to more than 11,000 volunteers throughout the state (Wilson 2002; PALMS 2010). Meanwhile, the number of sites permitted for Marcellus Shale gas drilling has grown to nearly 10,000 in Pennsylvania between the years 2007 and 2012 (Kelso 2012), making the need for water monitoring even more pronounced. To meet this need, civil society monitoring groups must seek funding and support from sources other than the state government.

When considering the implications of declining state support for water monitoring efforts in Pennsylvania, we reflect upon previous studies of how civil society monitoring programs find support. Often, the success of civil society monitoring efforts continues to depend on provision from academic scientists and institutions. Floress et al. (2011) demonstrate that Midwestern watershed conservation groups connected with universities and municipal governments are more likely to receive funding and complete their objectives. Savan et al. (2003) show that access to university resources can improve community-based monitoring programs by offering access to laboratories and environmental experts to solve data quality issues and flesh out stricter study designs. University researchers can also be important sources of support and credibility for community-based environmental monitoring efforts; however, civil society organizations, particularly large and well-funded environmental organizations, have also emerged as important contributors to environmental science. In a national study of research produced by environmental organizations, Hess (2009: 321) concluded:

> Some civil society organizations can marshal the expertise needed to produce scientific reviews, generate new and surprising research findings, produce research that has credibility among policymakers and the media and, in some cases, even challenge the fundamental assumptions and research agendas of a research field.

Hess (2009) did not address whether civil society organizations were working with volunteers to gather environmental data at the local scale. However, given the growing recognition among academic researchers of the value of citizen science, it would not be surprising to see nonacademic organizations adopting similar scientific research practices. Indeed, our research indicates that several large environmental advocacy organizations are using volunteers to collect water quality data to use in large-scale research and policy advocacy efforts. Could civil society organizations, therefore, provide resources to community-based environmental monitoring groups in ways previously seen in partnerships with government institutions and academic researchers? This study provides some preliminary answers to this question and suggests hypotheses to be examined in future research.

Survey methods

In January 2012, a survey was mailed to watershed associations and volunteer-based civil society monitoring groups identified as likely to be engaged in water monitoring or other watershed protection work in New York State and Pennsylvania. The aim was to survey the entire population of civil society organizations potentially engaged in water monitoring in the two states. The mailing list was populated by compiling contacts from a variety of publicly available databases as well as a snowball sampling method that involved interviews with numerous key players in the water monitoring field. Databases included the EPA's "National Directory of Volunteer Monitoring Programs" and Pennsylvania's DEP "Statewide Directory of Citizen's Volunteer Monitoring Programs" (EPA 2013; PA DEP 2013). We also obtained lists of water monitoring projects published by the National Audubon Society, the Pennsylvania Council of Trout Unlimited, and Pennsylvania's Water Resources Education Network among others. [1] Within the survey itself, we asked respondents to identify other water monitoring organizations with whom they were in contact. Several additional mailings of the survey were sent as we learned of organizations not on our initial list. We contacted survey recipients repeatedly through letters, emails, postcards, and telephone calls in order to obtain a high response rate (Table 1).

We identified 24 organizations that are specifically monitoring the impacts of Marcellus Shale development or gathering baseline data for that purpose. Of these, only two were in New York. This paper, therefore, focuses primarily on Pennsylvania.[2] In addition to data collected through the survey, participant observation of training sessions was conducted with four of the organizations. Field notes from these events provide another source of data for our analysis of their water monitoring programs and how they are supported.

The science of civil society water monitoring

The 2002 DEP CVMP report describes the field of Pennsylvania volunteer monitoring at that time: of the 138 organizations actively monitoring in the state, each claimed an average 20 members and a median budget of under $3,000. Only 25 % of these groups used quality assurance and quality control (QA/QC) protocols, and collected data was mainly used by the volunteer organization or conveyed to a local government agency. In some ways, our survey suggests that little has changed in the civil society water monitoring community in the last decade. However, new environmental threats have prompted numerous watershed associations and advocacy organizations to begin monitoring surface water quality or to shift the purpose of legacy monitoring programs in ways that differ from the state of the field a decade ago.

Capacity building organizations such as the Alliance for Aquatic Resource Monitoring (ALLARM) based at Dickinson College in Carlisle PA and Nature Abounds, which support efforts in the Allegheny Mountains, have developed monitoring programs for community-based monitoring in consultation with representatives at state agencies (ALLARM 2012). Capacity building organizations are working with small watershed associations, as well as large environmental advocacy organizations to help train volunteers, design monitoring studies, choose sampling sites, and identify funding sources.

Civil society water monitoring programs specific to Marcellus Shale impacts appear to focus on a common set of parameters different from the past. For example, whereas in the 2002 CVMP report, visual inspection, total dissolved solids (TDS), and conductivity all ranked low in the list of common indicators (33, 23, and 10 % of groups, respectively); they are now of highest priority for Marcellus Shale water monitoring. It is clear, both from the surveys and in our observations of volunteer training sessions, that a general consensus focuses on indicators associated with the chemical signatures of flowback water. Survey data shows that 90 % of groups monitoring impacts of Marcellus Shale development measure some combination of conductivity, TDS, pH, and water temperature. Other indicators commonly monitored

[1] No comprehensive information source on these groups existed at the time of the study beyond partial lists, which in many cases were also outdated or no longer supported. For example, author correspondence with the EPA in September 2011 confirmed their directory is not actively managed internally and relies on self-reporting of monitoring groups.

[2] In order to protect the privacy of participating groups, only a subset of civil society organizations are mentioned by name herein. Privacy preferences were determined during the survey process.

Table 1 Survey response rate

Surveys sent	No. of respondents	Groups monitoring (any monitoring)	Groups monitoring (Marcellus monitoring)[a]
219	188 (85.8 % response)	76 (40.4 % of respondents)	24 (31.6 % of all monitoring)[b]

[a] Only groups conducting water monitoring specific to Marcellus Shale are considered for analysis

[b] Of 24 eligible groups, 22 are located in PA and two are located in NY

include total hardness, alkalinity, and dissolved oxygen. A smaller proportion of groups (25 %) also periodically sampled for the presence of specific metals and chemicals such as nitrates, sulfates, phosphates, and iron. The consensus around relevant parameters suggests that organizations are sharing information and ideas with one another, an observation that is supported by our interviews and informal conversations with representatives of various water monitoring groups.

Numerous monitoring organizations monitor for environmental impacts beyond what may be associated with a release of flowback water. For example, 8 % of respondents monitor "visual indicators" like roadway runoff and stream embankment erosion. Visual monitoring is primarily done by inspection and written into field notes. Seventy-five percent of respondents also report monitoring biological indicators, such as in periodically sampling for benthic macroinvertebrates. None of the reporting civil society monitoring organizations collect data-related episodic weather events such as cumulative rainfall, but observation in training sessions reveal they are attuned to how such weather events may impact surface water sampling.

Time and funding constraints affect the choice of parameters to monitor and the tools in use. Conductivity and TDS, for example, can be measured using a single handheld electronic meter, such as the LaMotte Tracer PockeTester, which can be purchased for about $100. ALLARM teaches volunteers to use the PockeTester as part of a 6-hour program that also includes lessons for identifying sampling sites and adhering to proper quality controls (field notes, volunteer training session, Central Pennsylvania, May 20, 2012). Groups that monitor for other indicators, such as total hardness and dissolved oxygen, require extensive chemistry kits. However, these kits can cost upwards of an additional $100, as well as a more comprehensive (multiday) training program (field notes, volunteer training session, Central New York, March 10, 2012).

Based on a series of interviews with representatives at state environmental management agencies, we discovered a frequently expressed concern that volunteer-collected data could not be used in litigation nor could it be used to definitively confirm pollution events. Pfeffer and Wagenet (2007) and Savan et al. (2003) note an important factor determining whether or not data from civil society monitoring efforts will be treated seriously by regulatory agencies is the extent to which volunteers adhere to quality control standards outlined by certified expert bodies. Two thirds of survey respondents report following some kind of QA/QC procedures; however, QA/QC appears limited to chemical monitoring data (as opposed to visual or biological monitoring). Most common methods reported are the regular calibration of monitoring equipment and by conducting duplicate field measurements. About half of those doing QA/QC also send "split samples" to a laboratory to check the accuracy of their field calculations. These partners are a mix of privately contracted laboratories and services provided by local universities. In sum, less than one third of all monitoring organizations participate in QA/QC measures in partnership with a partnering laboratory.

When asked how organizations report their data, more than half (55 %) publish their findings on a public website, blog, or other accessible online format. Other common ways of sharing data are through private exchanges with other groups (50 %) or by way of password-protected databases (20 %). Twenty percent of organizations we found share no data at all. The most common cited reason for this was simply because no pollution event had yet to be detected by their volunteers, such as a possible spike in conductivity or TDS.[3] Besides making data available to the public, our survey also revealed that only a third of organizations reported having data sharing agreements with municipal, state, or federal agencies.

These findings suggest that many of the monitoring efforts in the field may face credibility disputes in the future if their data is used to contest a pollution event. Although further research is required on this point, it is possible that skepticism about the quality of volunteer-collected data has discouraged some civil society organizations from viewing their efforts as serving a regulatory role, and thus, limits the extent to which they pursue standardized monitoring protocols, follow QA/QC procedures, and share their data in regulatory contexts. However, it is worth noting that the majority of monitoring programs that adhere to laboratory-tested QA/QC do so as a result of relationships established by capacity building organizations—those nonprofit groups specializing in training and supporting community-based monitoring programs—and are more likely to utilize advanced databases for storing their results as well. Capacity building organizations have also been essential in directing groups to select indicators compatible

[3] For example, the ALLARM protocol (2012) guide volunteers to note "very high concentrations of the indicator and signature chemicals in flowback water [TDS average of 10,000 mg/L] in comparison to water quality criteria in PA [TDS averages of 500 mg/L]."

with programs operated by government agencies like the Susquehanna River Basin Commission that collects data on water temperature, pH, conductivity, dissolved oxygen, and turbidity (SRBC 2009).

The field of civil society water monitoring

Survey results reveal that water monitoring organizations typically work in networks of two main types: *centralized networks*, with one main "hub" organization connecting many chapter groups, and *decentralized networks*, with multiple organizations collaborating or sharing resources but without a central hub. We also find that there are two main orientations among water monitoring groups: *advocacy-oriented*, gathering data in order to improve regulation, support litigation, and change industry behavior, and *knowledge-oriented*, gathering data in order to protect natural resources through education and awareness. These variations are important for understanding the role that capacity building organizations and large environmental advocacy organizations play in shaping the state of the field of civil society research related to Marcellus Shale water monitoring.

Many organizations monitoring the impacts of Marcellus Shale development are doing so as a direct response to gas development in their watersheds. More than half of respondents reported Marcellus Shale drilling in their region as moderately or highly active and another third anticipated drilling in the near future. The majority (19 of 24) of organizations now monitoring for Marcellus Shale water quality impacts have been in existence for a decade or more engaged in prior environmental advocacy, conservation, or water quality stewardship efforts. However, our survey revealed that more than half (13 of 24) of these organizations began their water monitoring programs only within the last 3 years, roughly corresponding to the rise of Marcellus Shale development in their regions.[4]

Organizational objectives

Objectives of water monitoring projects vary. We asked respondents to identify their groups' objectives from a list ("check all that apply"). All 24 groups reported that they aim either to increase public knowledge or contribute to scientific knowledge, and nearly all groups (90 %) pursue environmental health objectives such as "protect biodiversity" and "prevent pollution." However, less than half (42 %) of respondents selected one or more of the following objectives: "improve regulation of the natural gas industry," "change industry behavior," or "support litigation." In most cases, an organization that selected one of these three objectives selected the other two as well. We refer to these as the advocacy-oriented water monitoring groups (Table 2). Most (7 out of 10) of the advocacy-oriented water monitoring groups also corresponded with those we found above to have formal data reporting agreements with local, state, or federal agencies.

We refer to organizations that did not select any advocacy-oriented objectives as knowledge-oriented water monitoring groups to denote their emphasis on generating and sharing knowledge, as opposed to having overt political or legal agendas. As one possible illustration of how this division can impact monitoring practices when asked what would occur if a potential pollution event was detected, most (8 out of 14) knowledge-oriented groups stated they would contact a local conservation district or state agency. However, knowledge-oriented groups were found to have established few formal reporting agreements with regulatory agencies. Organizations with this kind of reporting relationship often refer to their volunteers as "first responders" or "eyes and ears on the ground" but do not see "improving regulation" or "changing industry behavior" as a component of their monitoring objectives.

Centralized monitoring networks

Our survey of organizations furthermore suggests that monitoring programs consolidate resources and develop partnerships in two distinct ways. Some create a centralized system for gathering water quality data, with one "hub" organization in the center of multiple local groups that are monitoring particular watersheds. We refer to the organizational structures established by these hubs and their local branches as centralized networks (Table 2). Centralized water monitoring networks are led by large, well-established environmental advocacy organizations, as well as regional organizations that train and coordinate multiple teams of volunteers. We received 12 surveys from organizations that operate within a centralized network. Six of these organizations serve as "hubs" that reported on behalf of their affiliated chapters; the remaining six are chapter groups of their respective networks. The hubs are the Pennsylvania Senior Environmental Corps (PaSEC), the Pennsylvania Council of Trout Unlimited (PATU), Mountain Watershed Association, the Delaware Riverkeeper Network, Community Science Institute, and Creek Connections. Centralized monitoring efforts tend to cover a large terrain. Some focus on specific watersheds with an

[4] Numerous additional monitoring groups have formed only in the last 12 months and are currently beginning field collections. Many of these emerging groups, such the Sierra Club's Atlantic Chapter Water Sentinels program, are located in New York State where, at the time of this paper, a moratorium remains in place against hydraulic fracturing. The newest groups were not included in the survey, but will be the subject of follow-up research.

Table 2 Organizational orientations versus objectives

	Decentralized monitoring networks	Centralized monitoring networks
Advocacy-oriented objectives	Four total (K-C Stream Team) (Loyalhanna W.A.)	Seven total (Trout Unlimited) (Mountain W.A.)
Knowledge-oriented objectives	Eight total (Chartiers Creek W.A.) (Baylor Lake)	Five total (PA Senior Env. Corps) (Creek Connections)

average of 20 monitoring sites, but three networks manage statewide programs with over 100 monitoring sites.

One "hub" organization, the PATU, was established in 1963 to protect and restore watersheds for coldwater fisheries. PATU serves as the umbrella for 50 local chapters and 12,000 members across the state. Many of these chapters began water monitoring in the last 2 years as part of their Coldwater Conservation Corps, a program organized in partnership with ALLARM. In addition to managing local stewardship programs, PATU also assists national Trout Unlimited's "Marcellus Shale Project" in advocating "to promote sound management policies" with federal, state, and local partners (Trout Unlimited 2013).

By comparison, the PaSEC exemplifies a more traditional monitoring program now managed through a centralized network. Prior to loss of state funding in 2007, PaSEC facilitated volunteer monitoring, primarily for acid mine drainage, with seniors aged 55 and older across more than 18 counties in Pennsylvania (Nature Abounds 2013). Nature Abounds, a capacity building organization established in 2008 to encourage environmental education and stewardship, took stewardship of the PaSEC under a 2010 grant agreement with the EPA and the PA DEP Growing Greener Grant Program (Nature Abounds 2013). Nature Abounds now acts as a hub-supporting PaSEC chapters by arranging for training, technical support, and in recruiting additional volunteers to conduct Marcellus Shale monitoring.

Funding for hub organizations in centralized networks comes from a range of established sources, including the Colcom Foundation, PA DEP Growing Greener Grants, the Western Pennsylvania Conservancy, as well as county conservation districts and are subsequently dispersed to subgroups within their network. Reported budgets for water monitoring range from $10,000 to more than $50,000, and nearly all hub organizations have paid staff to manage their programs.

Seven of the twelve organizations in centralized networks are identified as advocacy-oriented, indicating that improving regulation, supporting litigation, and/or changing industry behavior are among the primary aims of their water monitoring program. Among the six "hub" organizations identified, five of these indicate advocacy-oriented aims. These are mainly long-standing organizations, with considerable experience in environmental politics. This suggests that several relatively large environmental advocacy organizations are playing an important role in facilitating centralized volunteer water monitoring programs with distinct advocacy objectives.

Decentralized monitoring networks

In contrast to the centralized networks, many of the efforts to monitor the impacts of Marcellus Shale development are being carried out by relatively independent groups that focus on particular watersheds or streams without the support of an umbrella organization. We characterize these programs as operating in decentralized networks. Decentralized networks are largely volunteer-based and draw upon scattered financial, technical, and logistical resources to support their water monitoring programs. Some decentralized monitoring organizations have large operating budgets associated with unrelated long-term conservation efforts. However, budgets for Marcellus Shale water monitoring are small—typically under $5,000—and only three surveyed organizations have part-time or full-time staff. Decentralized monitoring organizations tend to monitor far fewer sites than those in centralized networks, with an average of 20 sites. One group, the Baylor Lake Volunteer Testers for example, monitors a single lake. One third of groups in decentralized networks receive assistance from a nearby university such as St. Francis University, Lock Haven University, and Waynesburgh University, and half of decentralized organizations receive some form of logistical support from a local government agency. Most monitoring programs supported by watershed associations were found to exist in decentralized networks.

Chartiers Creek Watershed Association (ChCWA) in Washington County, Pennsylvania, is representative of many of the smaller, less connected organizations in our survey. ChCWA supports 17 volunteers conducting Marcellus Shale water monitoring within the upper Chartiers Creek Watershed. Limited funding and technical support is supplied by private donations and from the Washington County Watershed Alliance, a local capacity building organization that received Growing Greener funds to establish ChCWA in 1999. Initial training was conducted by ALLARM, a capacity building program based at Dickinson College, but subsequent training is done in-house by pairing newcomers with more experienced members.

In some cases, several decentralized organizations actively collaborate to carry out water monitoring. One example is the Laurel Highlands Marcellus Shale Monitoring Project, an alliance formed between the Loyalhanna Watershed Association, Mountain Watershed Association, the Conemaugh Valley Conservancy, and four other local watershed groups. The effort began in 2011 to purchase and place data loggers near Marcellus Shale gas wells throughout the 1,887 square mile Kiski-Conemaugh and Youghiogheny watersheds (LWA 2012). Partnerships like the Laurel Highlands Project suggest that a diverse group of organizations can come together within decentralized networks to share resources. For example, in addition to participating in the data logger collaboration, the Kiski-Conemaugh Stream Team, a program of the Conemaugh Valley Conservancy, monitors additional water quality indicators throughout their watershed (Conemaugh Valley Conservancy 2011). Mountain Watershed Association—also a hub of their own distinct monitoring network—contributes expertise to the partnership by advocating for watershed protection efforts in the state, writing policy briefs, and engaging regulatory agencies (field notes, regional watershed conference, Central Pennsylvania, May 20, 2013).

Conclusion

In this study, we used the case of volunteer monitoring of the watershed impacts of Marcellus Shale natural gas development in order to examine the role of civil society organizations responding to public concerns about water quality impacts in a climate increasingly dominated by neoliberal discourse. Consistent with previous studies of citizen science, we found that many monitoring programs continue to depend not only upon university resources—particularly the volunteer training programs and monitoring protocols offered by ALLARM at Dickinson College—but also from partnerships developed with many other regional colleges offering laboratory and data management expertise. We also found that numerous smaller water monitoring programs, especially those managed by watershed associations, continue to depend upon government agencies for technical support and funding in more traditional monitoring arrangements.

Our findings suggest that many civil society monitoring programs are developing close relationships with nonprofit capacity building organizations—although sometimes based in universities—that specialize in offering training, research tools, and other related support to their volunteers. In building these relationships, we believe the prominence of hub organizations and centralized networks is significant. Hub organizations create tight partnerships between monitoring groups and capacity building organizations and are adept at bringing resources into their network. Hub organizations also take leadership roles in selecting research priorities and the overall objectives of their monitoring programs. This is noteworthy because it poses an alternative to the style of expertise and problem selection provided by academic scientists and regulatory officials who have historically guided community-based water monitoring efforts. This alternative relationship may also reflect a shift away from citizen science models that use volunteers as free labor towards more participatory processes of public engagements in scientific research.

How do these differences affect the practices of the community-based water monitoring groups that have historically relied on either university scientists or government agencies for support?, and what lessons might be drawn from this case study to better understand community-based responses to gas development elsewhere? While civil society organizations in the Marcellus Shale may be adopting research practices similar to efforts supported by government institutions and university scientists, there are notable differences and potential drawbacks. Hess (2009) notes that environmental advocacy organizations are less likely than university scientists to publish in peer-reviewed journals or to engage broader scientific questions. Consistent with Lave's (2012) "tyranny of relevance," the work of civil society organizations is often designed to address immediate issues. Nevertheless, while in some respects, this may be viewed as detrimental to addressing long-term scientific issues; the acute attention of civil society research on water quality may also be more likely to serve the needs of communities concerned about rapidly occurring environmental degradations.

The presence of advocacy-oriented objectives among nearly half of water monitoring groups, particularly in centralized networks driven by hub organizations, is also meaningful. Environmental advocacy organizations have knowledge and capacity to guide water monitoring groups through the process of obtaining a wide range of resources, as well as in mobilizing citizens to participate in broader coalitions. Advocacy-oriented hub organizations are also more likely to be large environmental NGOs with long-standing political or legal objectives. Unlike university scientists, they are willing to take normative positions and use volunteer-collected data to advocate for policy change. If, as Lave (2012) suggests, citizen science groups are increasingly "accorded a place at the table" in regulatory decision-making, then the advocacy aims present in these water monitoring programs may have interesting outcomes. In the context of broader debated about the environmental impacts of shale gas development, the combination of citizen science research to address immediate issues along with guided policy engagements may have positive impacts on future regulatory actions around water quality management.

Enlisting volunteers to conduct water monitoring independent of government and university oversight is one way that civil society organizations are addressing knowledge gaps and the "undone science" of surface water quality impacts related to Marcellus Shale development. However, changing relationships between who supports monitoring and towards what purpose raises many additional questions: if data collected by volunteers is managed centrally, will it be used differently and have different effects than data collected and maintained by dispersed organizations? Do coalitions of decentralized organizations enable a more effective use of limited resources? Will convergences of monitoring protocols and quality assurance practices increase credibility of volunteer monitoring data for regulatory use? Additional research will continue to investigate the objectives, access to resources, and monitoring practices present within the Marcellus Shale civil society water monitoring community in their efforts to conduct independent research to fill knowledge gaps. We also hope to better understand how the growing prevalence of organizations with advocacy aims is impacting civil society engagements with policymaking. We hope this work will shed light on the relative merits of different civil society monitoring arrangements present in the Marcellus Shale, as well as to assist communities affected by natural gas development elsewhere in determining appropriate responses.

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