POWER AND PERILS OF PARTNERSHIP: A LIFECYCLES APPROACH TO UNDERSTANDING BARRIERS TO DATA USE IN MONTANA VOLUNTEER WATER MONITORING PROGRAMS

by

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DEDICATION

This work is dedicated to my grandfathers. To Dr. Francis Bean. So, few of us survive the academy with such an understanding of love, grace, and the unending mystery we call God. One day I hope to be in your company, but for now, I take comfort knowing these scholastic pursuits have been partially inspired by yours. To Paul Kurjiaka. Always there with a quip, those "Paulisms" have stayed with me and won many a fast friend in the elevator. Thank you for showing me the value of perseverance and that the process of crafting something can be more rewarding than just staring at the results. May I never stop working. Sit finis libri, non finis quarendi.

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ABSTRACT

As socionatural systems become more unpredictable due to increased anthropogenic interference, the need for responsive data-driven governance is apparent. However, there is a repeated assertion that public trust in science and the scientific process is eroding. Public participation in scientific research, or citizen science, is often seen as a pathway to rebuilding public trust in data collection and analysis while also being an effective cost-cutting measure as research funding becomes more and more difficult to secure. I developed case studies of five different volunteer water monitoring programs from across the state of Montana. Each case was primarily constructed from semi-structured interviews with various volunteers, program managers, and decision-makers. These cases explore how trust in volunteer water quality data was generated across stakeholder groups and if, and how, volunteer collected data are used in local governance processes. To explore the relationship between different volunteers, program managers, tributaries, monitoring equipment, and decision-makers, an approach inspired by actor network theory was adopted during the analysis. The five cases all had key parallels in their histories and while each case was distinct, all five seemed to pass through similar phases I describe as a generalized lifecycle. The four key phases of this lifecycle were: 1) an inciting incident, 2) enrollment of allies, 3) re-enrollment of allies, and 4) program evaluation. The second and third phases were key to understanding how data produced by volunteers would eventually be used. When programs enrolled alongside state actors like the Montana Department of Environmental Quality, volunteers and local community members saw decision-making processes as more legitimate, and volunteer water monitoring programs had a direct route to having their data used. However, the process of being enrolled alongside a different monitoring program or state agency created a problem with the salience of volunteer collected data, often making it less reflexive to community needs and less used in local governance processes. In addition, regular re-enrollment with new agencies, partners, and monitoring efforts allowed many programs to secure funding and paths to data use but hampered their ability to produce datasets for long-term trend analysis.

CHAPTER ONE

INTRODUCTION

The rapidly changing climate is putting extreme stress on water use in the American West. Declining snowpack continues to raise concerns and while there may be short-term wet trends in the future, base flow levels in the Upper Colorado River are expected to continue to decline up to 33% by 2080 (Pederson et al., 2011; Miller et al., 2021). While the issue of water quantity is indeed pressing, the changing climate is having a dramatic impact on water quality as well (Michalak, 2016). This quality impact requires continued exploration. It is important to recognize that our current climate and water systems are complex socionatural assemblages, the water system we can observe is a reconfiguration and expression of existing social (anthropogenic) and natural phenomena (Swyngedou, 1999). Water management can be thought of as a socioecological process within this more complex socionatural system (Swyngedou, 1999).

Managing water in this uncertain future will require a large program of water monitoring and analysis, however public support for and broad trust in science and scientific institutions appears to be wavering (Hmielowksi, et al., 2014; Funk et al., 2019; Kinchy, 2020). While there are many causes of this phenomenon, the increased mistrust in science combined with the traditional mistrust of governing agencies in the American west may be contributing to broad mistrust in water managers (Ormerod, et al. 2021). However, the source of this mistrust is likely a result of several private interests applying, “the tobacco strategy” or using fake experts to willfully mislead the public (Oreskes and Conway, 2010).

Co-production of knowledge (Bremer and Meisch, 2017) has been championed both to create salient information to address the climate crisis and to help bridge gaps between traditional research institutions and the end-users of their products. Co-production of knowledge is the process by which those who traditionally hold the power in systems of knowledge production (decision makers and researchers) work with stakeholders to create salient and actionable knowledge (Church et al., In Press). I recognize that co-production is not a "magic bullet" solution that will be appropriate to every possible case and context, but it is a powerful tool for bridging gaps between research institutions, governing agencies, and stakeholders (Church et al., In Press).

One form of co-production of water quality information is volunteer water monitoring programs (VWMP). VWMPs have the potential to meet all the grand promises of co-production: increased trust between stakeholders and decision-makers, development of actionable knowledge, and salient climate-related data (Bremer and Meisch, 2017; Church et al., In Press). In this work, I explore if some of these promises have been realized by a selection VWMPs in the state of Montana.

Outline

After this brief introduction, Chapter 2 contains a literature review focusing on science and technology studies theory, forms of trust, and public participation in scientific research. Chapter 3 discusses the case selection, data collection, and the data analysis process behind this research. The fourth chapter discusses the complex worknets (an uneven relationship between actors doing work on one another to resolve a controversy) surrounding the five studied Montana VWMPs and elucidates how the common lifecycle of these VWMPs creates a path to data use while also revealing the barriers to volunteer collected data use in the state of Montana (Akrich and Latour, 1992; Rydin, 2012). Finally, Chapter 5 reiterates the key lessons learned from this research and includes a discussion of this work's limitations and possible future dimensions for this research.

CHAPTER TWO

LITERATURE REVIEW

Science

What is Science?

Science and technology scholar Naomi Oreskes understands science partially as the process by which experts review claims and attempt to create a consensus on the nature of reality (Oreskes, 2019). It is critical to reaffirm that this science is a human undertaking, and despite what many practitioners believe, cannot produce any ontological truths. Science is often viewed as a small snowball slowly accumulating more and more knowledge as researchers explore the cases that exist at the limits of existing rules and principles, contributing to an avalanche of immutable truths (National Academies of Sciences, Engineering, and Medicine 2019). This scientific imaginary would make an individual researcher a bastion of logic who is inoculated against social pressures. However, the production of scientific knowledge occurs in an explicitly social context, and it can be warped by unethical beliefs or even produce outright incorrect conclusions (Oreskes, 2019). To avoid privileging the researcher as infallible it serves better to think of the scientific process as a series of great leaps and building plateaus of knowledge (Kuhn, 1970; Oreskes, 2019).

Philosopher Thomas Kuhn believed that scientific disciplines operate in several different modes, the most familiar of which is “normal science” (Kuhn, 1970). Normal science is most like the idea of science as the accumulating avalanche, a discipline in this phase will follow a core set of rules and assumptions (Kuhn, 1970). Scientists in the normal mode will use a wide array of methods to answer new questions, all while not trying to shake or disrupt the core assumptions that built their disciplines (Kuhn, 1970). This bundle of core assumptions and beliefs about the nature of reality that links members of a scientific discipline (or the greater scientific project) is called a paradigm (Kuhn, 1970). Unlike the common usage of the term, Kuhn's understanding of the paradigm is not simply a group of trends, but an unshakable epistemological system: going against this paradigm would not make a researcher any more credible and relevant but alien and radical (Kuhn, 1970; Oreskes, 2019). But by observing the history of science we can come to observe that paradigms are not constant. Old ways of thinking are frequently abandoned for new alternatives. If the paradigm is a series of beliefs so well entrenched in the minds of practitioners how can this come to be?

During the process of normal science, researchers often come upon questions that cannot be answered if the assumptions that built their paradigm are true (Kuhn, 1970; Mayo, 1992). The work done solving puzzles near these outlying cases is what advances knowledge the most during normal science (Mayo, 1992). Often, researchers will ignore these outliers until evidence continually builds that the paradigm is not all-encompassing; eventually, a few radical pieces of research will form a new paradigm (Kuhn, 1970). This process is called the paradigm shift and results in a revolutionary science (Kuhn, 1970; Oreskes, 2019). Famous examples of the paradigm shift include Einstein's theory of relativity, the discovery of subatomic particles, and the theory of plate tectonics. Often the paradigm shift is not immediate, and normal and revolutionary science often occurs in tandem (Kuhn, 1970). These dueling groups of researchers continue to publish research across a great paradigm divide until the staunchest defenders of the older paradigm convert or stop publishing (Kuhn, 1970).

In the above description of the structure of scientific revolutions, I did not discuss the "scientific method". This is because there is no observable uniform method for scientific investigation. While the idea of a scientific method evolved from the development of a rational approach to answering questions, no universal set of steps is observed in scientific research today (Oreskes, 2019). Different scientists may use inductive, deductive, or abductive reasoning alongside a variety of research approaches for their investigation even within the same research paradigm (Oreskes, 2019; Mertens, 2012). To answer questions, they may design experiments, utilize predictive models, or infer conclusions solely from observation (Oreskes, 2019). Philosopher Karl Popper believed that instead of a method of rationally answering questions, the method of science was falsification (Kuhn, 1970). Falsification is the idea that scientists test not whether an element of a process or part of a theory is true, but simply that it cannot be proven false (Popper, 1963). If nothing can prove an idea or concept is false, it follows that it is the most likely true explanation. Kuhn noted that this still does not produce objective truth and that many times multiple competing concepts can pass falsification (Kuhn,1970). While falsification is still present in the scientific imaginary today, with several authors suggesting that a return to falsification is necessary across several disciplines, it remains inconsistent with the way modern scientific inquiry is performed (Beven, 2018; Chmielewksi, 2021). Many modern researchers rely heavily on statistics or heuristic models that may not be observable or falsifiable (Oreskes, 2019). The same researchers may even use a range of approaches to address different issues in their field, not just logical falsification (Mertens, 2012).

Latour expands on, and then diverges from, the views of Kuhn in his descriptions of technoscience (Latour, 1987). To Latour, science is a rhetorical process, not an analytical one. Instead of Kuhn's concept of the paradigm as a monolithic unchallenged assumption, Latour notes that science is a chain of unchallenged assumptions or black boxes. The older and more enshrined an individual black box is, the more difficult and costly it is to attempt to un-black box it or challenge how it operates (Rydin, 2012). Latour believes that the study of technoscience should be the study of how black boxes are created, who creates them, who is enrolled in their creation, and how they are challenged. To study technoscience, Latour suggests the researcher adopt his actor network theory approach (Latour, 1987). This approach will be discussed more in the methods section of Chapter Four, but it focuses on exploring the relationship between different actors addressing pressing issues in technoscience and how those actors recruit and enroll other actors to support their conclusions or findings (Latour, 1987; Rydin, 2012).

Returning to the definition of science from the beginning of this section, the unifying force of modern science is an expert consensus system that functions almost as a scientific democracy (Funtowicz and Ravetz, 1994). Scientists have developed complex systems of peer review. Scientists are encouraged to thoroughly show their work and logically demonstrate how they reached their conclusions, while their peers are encouraged to use their expertise on relevant topics to critically review the scientist's claims (Oreskes, 2019). Here, a researcher's expertise is built from years of engaging with relevant work in their field whether it be studying previous research or performing their own (Oreskes, 2019). The process by which expertise is granted is incredibly rigorous. Researchers often need to obtain postgraduate degrees and create a body of work that has been reviewed by individuals considered experts in their field before their expertise is recognized (Oreskes, 2019). While many ecological management decisions are driven by alternative forms of knowledge and expertise, these alternative knowledge sources such as lived experiences are not granted the same privileges as knowledge produced via the scientific expertise system (Cook et al., 2010; Oreskes, 2019). As the production of knowledge becomes more complex, more immediate, and more embroiled in political issues an extended peer network, beyond those with recognized expertise, may need to be put in place (Cook et al., 2010; Ravetz, 1999)

The social verification system of consensus allows scientists to reject claims that do not fit within the current paradigm and correct inaccurate or unethically produced results (Oreskes, 2019). As such, scientifically produced knowledge should always be progressing towards an increasingly accurate approximation of the truth. A criticism of science as expert consensus is that the system that grants expertise upholds hierarchical relationships and is potentially self-reproducing. This self-reproduction may be to the point where it stifles the development of a revolutionary mode of science when one is needed (Oreskes, 2019). In addition, as I noted above, the expertise system excludes a large body of knowledge often used by members of the public and environmental managers to drive their decision-making (Cook et al., 2010; Laves, 2016). Moreover, while the holders of expertise often work rigorously to be granted that status by their peers, the lay public may not be able to see the full system at work, thus leading them to think of scientific disciplines as insular, stagnant, or unrepresentative of their worldviews (Orr, 2004). Ultimately the collaborative process of scientific verification highlights the nature of scientific inquiry as a social system with its own diffusion networks and social learning processes (Funtowicz and Ravetz, 1994). While science is often thought of as pure experimentation, this social context means that even the most rigorous of research is influenced both by data obtained through the scientific process and the opinions of others (Oreskes, 2019). The expert consensus model reaffirms that scientists need to be embedded in social systems to remove or correct egregious information, as opposed to the idea that they must always remain perfectly neutral observers (Oreskes, 2019). This model of understanding science as a collaborative and peer-driven process, especially when it is an attempt to address emerging environmental science issues, is often positioned in opposition to Kuhn's normal mode of science as "post-normal science" (Funtowicz and Ravetz, 1994; Ravetz, 1999).

Trust in Science

Because of the consensus-building system of post-normal science, science may be one of the best methods for approximating the nature of reality that humans have conceived. Again, this stems from encouraging scientists to critically vet the claims of others and to reach an expert consensus (Oreskes, 2019). Currently, the United States is experiencing a crisis of trust in science (Funk et al., 2019; Oreskes, 2019). This crisis has been manufactured by private interests and has been amplified by the misapplication of arguments made by science and technology scholars and other philosophers of science (Kinchy, 2020, Oreskes, 2019). For the past century, private interests have engaged in a multigenerational campaign of disinformation, patterned around a technique called "the tobacco strategy", to disrupt mainstream scientific discourse in the United States to build support for their goals (Oreskes and Conway, 2010). The core of the tobacco strategy is to find advocates within the institution of science for an unpopular scientific opinion, fund these advocates, and have them exploit the consensus-building process generated by normal scientific inquiry to create mistrust for mainstream scientific conclusions amongst laypeople (Oreskes and Conway, 2010). Often the anti-mainstream science advocates supported by the tobacco strategy are not holders of expertise in the field in which they cast doubt but are instead scientists from adjacent fields (Oreskes and Conway, 2010). While the public sees the anti-mainstream advocates as legitimate contributors to open scientific dialogue, the advocates employed as part of the tobacco strategy often are not part of the true consensus-building process (Oreskes and Conway, 2010; Oreskes, 2019). The tobacco strategy was first used to defend private industry against health claims but was then mobilized by American conservative political groups to advance political agendas like continued nuclear armament and fossil fuel exploitation (Oreskes and Conway, 2010). The application of the tobacco strategy to destabilize environmental discourse in the U.S. has contributed to the Pew Research Center observing that only about one-third of the American public believes that environmental researchers are providing fair and accurate information (Oreskes and Conway, 2010; Funk et al., 2019). This is made incredibly visible when considering that consumers of conservative-leaning mass media are significantly more likely to mistrust science as opposed to those who consume other sources of media (Hmielowski et al., 2014).

Public Participation in Scientific Research and Volunteer Water Monitoring

A key mode of scientific inquiry that engages the public is direct Public Participation in Scientific Research (PPSR) (Bonney et al., 2009; Dickinson et al., 2012) Volunteer water monitoring is a form of PPSR that continues to be promoted due to its cost-efficiency, the fact that it engages the public in water discourse, and the assertion that PPSR programs lead to an increase in scientific literacy (Bonney et al., 2009; Fernandez-Gimenez et al., 2008). Recently the buzzword “Citizen Science” has been commonly used to describe all PPSR projects, despite it originally referring to only a small range of PPSR programs that initially excluded volunteer water monitoring and other monitoring projects (Bonney et al., 2009). PPSR projects have been shown to have a range of informal science education benefits such as increasing participants’ knowledge of their specific monitoring area, a slight increase in scientific literacy, and a motivation to take conservation action (Church et al., 2019; Cronje et al., 2011; Stepenuck & Genskow, 2019). The benefits of PPSR programs and volunteer water monitoring programs beyond the individual participant are a key focus of emerging research on the practice (Church, et al. 2019).

There is a repeated assertion that participants in PPSR projects will diffuse some of the information they have learned organically through their social networks (Fernandez-Gimenez et al., 2008; McKinley et al., 2017). This idea may have sprung out of the popular discussions of “barstool science”, the local and informal scientific knowledge spread mostly by hunters and fisherfolk. Paul Robbins noted that “barstool biology” can be used by conservation program managers as a reliable data source (Robbins, 2006). He observed the scientific merit of conversations related to elk hunting across Montana, however, before this work there was little empirical evidence that this activity is occurring with PPSR programs in the state (Robbins, 2006).

Credibility, Legitimacy, Saliency

While trust is understood to play a key role in water governance, in citizen participation trust is often poorly conceptualized by researchers (Voogd et al., 2022). To avoid this pitfall, I will adopt a very specific framework for evaluating trust. While slightly older than other frameworks of trust such as Stern's (2018) trust ecology, Cash et al.'s (2003) Credibility, Legitimacy, and Saliency framework is in line with the ideas of how cultural cognition affects perception and use of information (Kahan et al., 2011). The Credibility, Legitimacy, Saliency framework was also specifically formulated to describe trust generation during knowledge creation processes, and as such it lends itself well to exploring VWMPs (Cash et al., 2003). Instead of simply focusing on the types of trust generated, the Cash et al. (2003) framework focuses on how an individual chooses to trust in a trustee (Cash et al. 2003). The authors propose three sources of trust - Saliency, Legitimacy, and Credibility - and what makes up these sources varies between each trustor (Cash et al., 2003). Credibility in this framework is roughly equivalent to scientific validity; if the information was produced in a way where results can be verified or all parties in a decision-making process agree that there is simply enough evidence, then it should be credible (Cash et al., 2003). Saliency matches with the lay definition of the word; if you are asking someone to trust information that is relevant to their needs, then it is salient (Cash et al., 2003). Legitimacy is if the information was produced with respect for an individual's beliefs, especially if those beliefs clash with the beliefs of those who produced the information (Cash et al., 2003). Legitimacy also implies that everyone who wants or needs to participate in knowledge production has participated (Cash et al., 2003). Here, legitimacy is the key to developing a relationship with the trustor. If someone feels unincluded in the conversation, or if the disagreements between their worldview and the worldview of a trustee are not mediated, they may find scientifically credible and salient information illegitimate (Cash et al., 2003). While volunteer water monitoring is often suggested as a pathway to building legitimacy, the presence of a VWMP on its own may not be enough to create a pathway to legitimacy (Stepenuck and Green, 2015, Ellis and Waterton, 2004).

Engagement in Public Participation in Scientific Research

Several scholars point to engagement as a key factor in determining volunteer water monitoring outcomes beyond the simple generation of data (Kimura and Kinchy, 2019; Philips et al., 2019). Volunteer engagement has historically been measured using the proxy of program structure (Bonney et al., 2009; Stepenuck and Genskow, 2018; Stepenuck and Gesnskow, 2019; Brasier et al., 2017).

A common typology for PPSR project structure was adopted in a 2009 Center for the Advancement of Informal Science Education (CAISE) report (Bonney et al., 2009). The typology divides 14 PPPSR projects by their levels of non-expert participation in the research process. The three categories of PPSR projects are as follows: contributory projects (professionally designed, community members used for data collection), collaborative projects (professional designed, community members involved in multiple steps of the project beyond data collection), and co-created projects (professional and community member designed) (Bonney et al., 2009, Table 1). It is important to note how closely this typology follows Arnstein's ladder of citizen participation (Arnstein, 1969). Both typologies divide public participation into three tiers, each with progressively more and more "citizen" control (Arnstein, 1969; Bonney et al., 2009). This parallel becomes useful because there is often a moral or ethical justification for why programs should want to be situated at the top, citizen control segment, of the ladder (Arnstein, 1969; Quick and Feldman, 2011). Arnstein's ladder is also a more detailed framework with many intermediate steps as opposed to only three designations. As such it becomes more useful when comparing several PPSR programs of similar structure. The table below shows the common PPSR typology and the parallels with Arnstein's ladder.

An expanded version of this typology was used by Stepenuck and Genskow to classify across the United States (Stepenuck and Genskow, 2018). At the time of their survey, most water monitoring program directors characterized the role of volunteers in their programs as being collaborative (Stepenuck and Genskow, 2018). The same survey indicated that programs with more collaborative procedures tended to also have more water policy and governance impacts (Stepenuck and Genskow, 2019). Following these conclusions, we should expect to see programs structured on the high engagement end of this typology to have a more robust diffusion of information process and yield more of the three dimensions of trust (credibility, legitimacy, and saliency) in surrounding communities.

While the typology of program structure is a useful proxy for participant engagement, it does miss meaningful dimensions of non-expert engagement. Researchers have recently begun to expand existing typologies and suggest that an approach that measures outcomes related to participant engagement can take a deeper look at how participants engage with PPSR programs (Philips et al., 2019). Philips et al. (2019) suggest that there are five dimensions of engagement outcomes that can be measured in a PPSR program. While my work does not examine these five

Program Proceess	Choose questions of study or develop hypothesis	Design data collection methedologies	Collect Samples	Analyze Samples	Analyze Data	Interpret Data	Disseminate Findings	Arnstein's Ladder Parallel
Contributory			X		[X]		[X]	Tokenism (Informing)
Collaborative		[X]	X	X	X	[X]	[X]	Tokenism (Consultation)
Co-Created	X	X	X	X	X	X	X	Citizen Power (Partnership)
X - Public or citizens always included in step | [X] - Public or citizens occassionally included in step								

Table 1 - A summary of the common PPSR program typology, adapted from Bonney et al., 2009

dimensions, it is important to note that engagement is a more complex process than simply, “how much do volunteers do.”

The effects of PPSR programs on non-participants or data-driven governance are not necessarily connected to program structure or engagement (Kimura and Kinchy, 2019). Instead, groups that organize around clearly defined causes and goals can have a more significant impact on a key issue or controversy than groups that attempt to work within the structure of normal science which will often be quickly discredited (Kimura and Kinchy, 2019). An excellent example of such discreditation is Japanese media and the Japanese nuclear institution labeling volunteers testing food for trace amounts of radiation after the Fukushima-Daiichi disaster as “radiation brain moms”, even though these groups used top-of-the-line monitoring equipment and followed strict scientific procedures (Kimura and Kinchy, 2019). This is apparent in cases in the U.S where the credibility of volunteers has been called into question when they are involved in water monitoring of areas impacted by hydraulic fracturing (Braiser et al., 2017).

Summary

Public participation in scientific research is often seen as a powerful tool for citizen engagement, science education, and the generation of knowledge (Dickinson et al., 2012). However, if we follow the work of previous authors, it is apparent that there is still a great deal to learn about how the credibility of volunteer-produced data is generated and how if at all volunteers can participate more fully in water governance to produce a more legitimate process (Kimura and Kinchy, 2019; Kosmala et al., 2016). While the credibility of volunteer-collected data is often questioned, I recognize that broadly, volunteer-collected data can be used for scientific analysis or water governance (Kosmala et al., 2016; Muenich et al., 2016). Finally, while I embrace her definition of science, I reject Naomi Oreskes's assertion, that public participation in scientific research is not knowledge production that exists outside of science but is instead inseparable from post-normal science (Oreskes, 2019, Funcowitz and Ravetz, 1994). This is because data generated by volunteers could still be considered part of "normal science" as most VWMPs strive to operate within existing paradigms even if they are working to challenge powerful actors (Kuhn, 1970).

One recurring theme in the following case studies will be the absence of a single absolute authoritative source for information. This provides fertile ground for actor network controversy which will be discussed in Chapter Four (Akrich and Latour, 1992). While there are several statewide data hubs, the creeks, and tributaries most volunteer water monitoring groups observe are often previously unmonitored or have received sporadic monitoring attention. Previous research shows that legitimacy is a key factor in how authoritative sources come to be established, and I will explore how this may be present in the following five cases (Cravens and Ardoin, 2016). The following chapters will explore how the five case study volunteer water monitoring programs in Montana have grown and changed over time, how they built legitimacy and credibility (both in their data and in other sources), and what barriers exist to state agencies, local governments, and citizen groups using volunteer collected data in Montana to drive conservation decision making.

CHAPTER THREE

METHODS AND ANALYSIS

Methods

Case Selection

Data for this research were collected from the summer of 2021 to the spring of 2022. Six volunteer monitoring programs were selected to construct a comparative case study, of these six only five cases were constructed (Yin, 2009). The six programs were identified from all the volunteer water monitoring programs that have a river and stream monitoring component and have ever filed a sampling analysis plan with the Montana Department of Environmental Quality (DEQ) in the state of Montana (N=24). This sampling analysis plan contains quality assurance procedures in addition to data collection procedures for each group, but not necessarily a data use plan. The list of potential programs was generated by combining a list of programs with at least one representative that had attended a training hosted by Montana State University Extension

Program Name	Program Location	Administering Organization
Madison Stream Team	Ennis, MT	Madison Conservation District
Musselshell Salinity Monitoring Program	Roundup, MT	Musselshell Watershed Group
Gallatin Stream Teams	Bozeman, MT	Gallatin Local Water Quality District
Adopt-a-stream	Seeley Lake, MT	Clearwater Resources Council
Sun River Monitoring Program	Great Falls, MT	Sun River Watershed Group

Table 2 - Summary of VWMPs and their affiliations

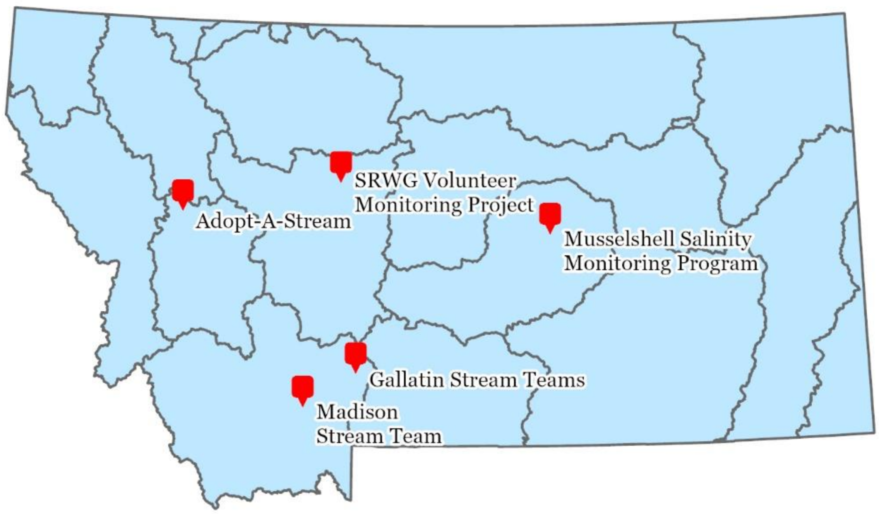

Figure 1 - Map of VWMP locations compared to major MT watersheds

Water Quality (MSUEWQ) with a list of programs tracked by the Montana Watershed Coordination Council (MWCC). The programs were selected purposively to compare programs with varying numbers of volunteers, different program goals and structures, and different levels of engagement with co-primary investigator, Dr. W. Adam Sigler. Programs were also selected to maintain geographic distribution between cases. Program managers were contacted by publicly available email. Successful contact was made with five of the six programs, which then became the cases discussed in this research. The five selected programs used to construct the following case studies and their affiliation are summarized in table 2 above.

Data Collection

The primary method of this research was semi-structured interviews (Patton, 2014). The interview guide was developed to address questions related to how programs were structured, how volunteer collected data were being used (or ignored), and how people communicated their experience with volunteer monitoring programs to others. Three interview guides were created, each designed for a different audience (See Appendix A for complete interview guides). Interview guides were then shared with my master's research committee and Co-PI Dr. Sigler for review. After this expert review, two pilot interviews were done to confirm the format and salience of the guide. After the pilot interviews, the guide was revised and went through another short period of expert review. The second test interview analysis is included in the following chapters.

The first round of semi-structured interviews was conducted with program managers. Program managers were identified from lists of MSUEWQ training participants, MWC program lists, and program websites. They were contacted for an interview via email and interviews were conducted both in person and via videoconference using the Cisco Webex software. After the first round of interviews program managers were encouraged to select key volunteers for further interviews. This snowball sampling method produced n=21 semi-structured interviews (n=12 volunteers, n=9 program managers). These interviews were further supported by n=6 interviews with decision-makers and other important non-participants in the statewide volunteer monitoring network. Interviewees in this category include managers with NorthWestern Energy, a statewide power utility, managers with DEQ, co-primary investigator Dr. Sigler, and an extension staff person. These interviews were conducted to give statewide context to the five programs, but also to see how or if data produced by volunteers were being used to drive state-level decision-making. Interviewees were contacted via email or in person, emails were obtained from State of Montana websites or previous interview participants. This resulted in a total of n=27 semi-structured interviews. All interviews were recorded with the permission of the interviewee. The interview guides and research design were approved by Montana State Universities Institutional Review Board and were found to be exempt from further review (IRB # LB080521-EX). A small majority of the interviewees were male (~65%), the majority of the interviewees were middle-aged or older, and all the interviewees were white or white-passing. Many of the volunteers interviewed possessed degrees in environmental science (or a related field) or advanced degrees in an unrelated field of engineering or science. This is typical of the demographic make-up of participants in PPSR programs overall as observed in other research (Mac Domhnaill et al., 2020). It is important to note that none of the interviewees were members of the underrepresented groups so often excluded from science and policy discussions and who often experience more barriers to participating in PPSR programs (Mac Domhnaill et al. 2020).

Analysis

Each interview was transcribed by a transcription service and then examined line by line for common themes that were then added to a codebook. Interviews were analyzed using the NVivo software (QSR International, 2022). Interviews were coded using a flexible coding process focused on developing substantive codes using an inductive method while also using a pre-developed codebook to identify areas of the interview with theoretical importance (Deterding and Waters, 2018; Beekhuyzen et al., 2010). This coding process produced a mix of strong and weak theoretical approaches that allows the coder to be flexible in their findings while also working within robust theoretical frameworks (Deterding and Waters, 2018; Beekhuyzen et al., 2010). After coding was completed, the codebook was reviewed and revised by an additional researcher.

Interviews were coded deductively for the theories discussed in previous chapters of this thesis like the presence of different forms of trust in the Cash et al. (2003) framework or different elements of knowledge production (see Appendix B for completed codebook). First, interviews were coded for the presence of different components of trust in volunteer collected data and other sources of scientific information. When interviewees discussed trust, it was classified based on whether they discussed saliency, legitimacy, or credibility. When interviewees express mistrust in a source it was coded appropriately for which kind of trust was absent (e.g., insaliency).

Interviews were also coded inductively for how participants discussed their relationship with volunteer collected data. Codes in this section represented themes such as whether volunteer data were being used to drive decision-making if data were being stored in clearinghouses, and how long it took data to be cleaned and processed for future analysis. Another inductive code that emerged during the coding process, was the presence of collaboration between different volunteer monitoring programs and regulatory agencies in groups in Montana. Finally, interviews were coded for different discussions of program histories; this series of inductive codes were heavily referenced in the development of the lifecycles framework used in Chapter Four.

All three groups of inductive codes described above were used to represent the depth and breadth of topics discussed in the semi-structured interviews. As my analysis method pivoted towards an actor network influenced approach, a new series of deductive codes were developed. These codes do not represent the depth and breadth of certain themes but simply areas in the text to return to for holistic actor network analysis. These codes included areas where interviewees listed key actors, areas where they discussed the presence of programs and anti-programs (See Chapter Four), and areas where they discussed black boxes and controversies (See Chapter Four). Deductive codes were also used to highlight different elements of the scientific process such as question generation, research design and procedures, and the role of volunteers in the program. Coding was used to direct future analysis and the quotes used in Chapters Four and Five are representative of the codebook.

CHAPTER FOUR

POWER AND PERILS OF PARTNERSHIP: A LIFECYCLES APPROACH TO UNDERSTANDING BARRIERS TO DATA USE IN MONTANA VOLUNTEER WATER MONITORING PROGRAMS

Introduction

The histories of the five programs selected as case studies for this work all had fascinating parallels. All five cases were mature programs that had operated in some form for about ten years. Over this time the structure of these programs has fluctuated alongside their goals and sources of funding. Initially, I examined how program structure and non-expert participation affects the use of a program's data to drive research or decision-making. During the early interviews for this work, it became apparent that at different periods each program fit into different sections of the Bonney et al. (2009) typology (e.g., contributory, collaborative, co-created). I could take a snapshot of a program at one point in its history and easily classify it as co-created or contributory, but these descriptors never fit a program over its entire lifespan. I found that by pivoting the focus of my analysis onto the histories of the relationships and common stages of the lifecycles of the five cases, a deeper understanding of the way volunteer collected data are used across Montana was elucidated.

Speaking with past and present program directors revealed that the operation of such complex water monitoring programs defies simple characterization. Thus, a holistic approach to analysis was adopted to gain a meaningful understanding of how and if, programs created trust in data or drove decision making. As I proceeded with data analysis it was evident that the flexible structure of the interviews made them suitable for an Actor Network Theory (ANT) inspired analysis. The analysis approach taken for this chapter is heavily inspired by Yvonne Rydin's work exploring relationships between actants in land use planning worknets (2012). Rydin's approach focused on un-black boxing the work of planners and revealing the role of policy as a key non-human actor in planning processes (2012). Here a black box is any component of a complex system where those describing the system take for granted that when inputs enter the box, regular outputs will be produced (Akrich and Latour, 1992). Black boxes are simply taken for granted; they always operate. Black boxes may be pieces of technology like the computer I use to type this sentence or a piece of theory like the assumption that an apple will always return to the earth when dropped from a tree. Simply restated, the black box is the piece of the system that is settled. Like the case of environmental policy relating to commercial development studied by Rydin, studies of environmental policy related to water resources often treat the process of data collection as a black box, assuming that decisions should be (or will be) driven by water data whenever available (2012).

As I began to explore the black boxes surrounding the process of volunteer data collection by following the lifecycles and histories of volunteer monitoring programs, it became clear that three common factors created barriers to the sharing and use of volunteer collected within the worknet: 1) the saliency of water quality data, 2) legislation and agreements creating higher quality requirements than the Clean Water Act, and 3) "data purgatory" or the time it takes for research scientists to valorize (giving data value) data for use in normal science. These barriers are distinct from barriers observed by researchers in other contexts, but these three factors closely parallel the barriers to data sharing observed by Brasier et al. (2017). What makes the barriers to data use in Montana so unique is that they are often a result of the process of collaboration that has been praised in water resource governance (Brasier et al., 2017). In some ways, these barriers are the shadow side of partnership that rides alongside its benefits.

This chapter begins by describing the common program lifecycle of the five cases. Then I break down the worknet and unique histories of each program, paying special attention to how relationships between actors that are results of collaboration in partnership benefit the program. I conclude by analyzing common barriers to data use and tie these barriers to concrete examples found within the five worknets of the five programs studied.

Elements of a Worknet

A worknet is a construct found in some ANT frameworks as opposed to a more traditional network (Latour, 2010). While some, including Latour himself, do not indulge in the use of the term worknet, I will explain later why I find its rhetorical value useful and will primarily use the term throughout this work.

Latour believes networks are heterogenous relationships made up of all human and non-human actors that connect technological and social relationships (Rydin, 2012). Networks are not the object of study but instead a method by which we study actors, the scripts they follow, and the products of their programs (Akrich and Latour, 1992; Rydin, 2012). Relationships within the network are by nature unstable, they do not connect actors in a regular fashion (Rydin, 2012). Latour once described networks as: *"the series of little jolts that allow the inquirer to register around any given substance the vast deployment of its attributes"* (Latour, 2010).

Following this, we must not assume that any two actors in the worknet will be equally connected, and we must not assume that relationships between actors are a constant; the worknet is an evolving piece of the method and will never remain static (Rydin, 2012; Latour, 2010). Some researchers have misinterpreted this approach and center networks as the product to study instead of using the worknet as a method to study relationships between actors (Rydin, 2012). In my method, I adopt two practices to avoid this reinterpretation of the method. First, I am adopting the idea of a worknet, by placing "work" before the "net" we place the relationships between, and work done by, actants ahead of the network as an object of study (Latour, 2010). Finally, while diagrams of a worknet are useful as part of the analysis, none are included here as figures. This is because the reader should not focus on the worknet as a product of the analysis, but rather, on the relationships between actors and their effect on how water monitoring controversies that are present in the worknet are remade into new black boxes (Latour, 1987). The included descriptions should highlight the relationships and complexities of the worknet.

In the worknet, an actor or actant is simply whatever acts (Akrich and Latour, 1992). In the five volunteer water monitoring worknets, actants may be rivers, volunteers, state policy, total maximum daily load documents (TMDLs), and water monitoring equipment. Important to an ANT approach is the relationship between material actors and virtual (social) actors (Latour, 2010, Rydin, 2012). The following pages, will describe what these actors do in their worknets. What you are reading is still a script like the ones present in the worknet and the descriptions of the worknet provided by interviewees (Akrich and Latour, 1992). The work of the actors can be organized into "programs of action" (programs); in this sense, the volunteer water monitoring programs are also programs (Akrich and Latour, 1992). Programs of action are analogous to computer programs in that they are collective instructions that narratively describe an actor's role in a text (Akrich and Latour, 1992). If I instruct you to return to Chapter 2 to read a summary of normal science this would be a program of action that shifted your frame of reference (Akrich and Latour, 1992).

I use the terms "volunteer water monitoring program" and "program" interchangeably. When reading a case, be aware that the program the case centers on is not being viewed as an actor, but as a program of action. Programs of action are opposed by anti-programs, or groups of other actors attempting to achieve a different goal or adopting distinctly different methodologies (Akrich and Latour, 1992). Each of the five cases includes examples of anti-programs that oppose the volunteer water monitoring programs and periods where the volunteer water monitoring program is enrolled to serve another program.

Controversies in a worknet are in many ways the inverse of a black box. Any time actors in a worknet begin to challenge and unpack a previously black boxed set of assumptions they generate controversy (Akrich and Latour, 1992). This thesis is in this sense, also a controversy as I attempt to explore the black box that is often constructed around VWMPs. It is important to note that many things that feel "controversial" are controversies, but not all controversies may be dramatic (Akrich and Latour, 1992; Rydin, 2012).

I present the five cases as five distinct worknets for ease of analysis. Many of these worknets have the same actors and the worknets are intimately related to each other. Water monitoring in Montana is best thought of as a single worknet, but for simplicity, I will show five sections of that greater worknet, each framed around a particular program of action.

Volunteer Water Monitoring Lifecycles

Below are four generalized stages of the life and growth of the worknets of the five cases examined in these studies. While there are parallels to this concept in existing theory, such as the application of panarchy to adaptive social systems (Allen et al., 2014), the lifecycles presented below are based solely on this study's results. I have developed these four phases from my analysis of the five case studies but note that some of the concepts presented within the lifecycles are common to other researchers' understandings (e.g., Prokopy, et al., 2013). In four of the five programs, each phase has been reached. In the Musselshell Salinity Monitoring Program, it appears that only phases one and two have been reached; unlike the other programs, this program appears to be skipping stage three. As will become apparent, phase three may be a phase that many programs pass over.

The phases of the lifecycle do not represent fixed periods. Often programs emerge rapidly after phase one, spend several years in phases two and three, then are jolted by some need to adapt or re-evaluate thrusting them into phase four. Volunteer water monitors also reflect the lifecycle of their program, moving through similar phases throughout their participation.

1. Inciting Incident Phase 1 of the volunteer water monitoring program lifecycle is an event that drives a group of actors together to form the program and begin to set goals. Earlier research has described similar incidents, or "catalyst events", as key moments at the beginning of collaborative management processes (Prokopy et al., 2013). It is no surprise that PPSR programs related to natural resources often begin in response to natural disasters, but inciting incidents may also look like a change in staff members at a local non-profit or conservation district or the success of a similar program in another place. A program may have more than one inciting

incident, especially if it takes several years for the water monitoring program to begin collecting data in earnest.

2. Initial Enrollment of Allies Initial enrollment, phase 2 of the lifecycle, is when the program begins operating and finds its first partners and funding sources. I use the term enrollment because this is the phase where the program is potentially "enrolled" into an existing program to transform its interests and redirect its actors (Callon and Law, 1982). For example, program managers might align themselves with a local utility to help fund monitoring at sites below a dam or they might request funding from a statewide drive to measure dissolved oxygen. In each case, some actant has influenced the research design of the monitoring program to help address that actant's goals. The program has effectively been enrolled into a larger program of action.

The water monitoring program can also stand in opposition to other programs in their region. I use the term "opposition", but instead of clear opposition this often looks much more like two programs operating in parallel. However, opposition is still appropriate as the other programs that are collecting water quality programs become anti-programs.

Simply restated, phase 2 of the program lifecycle is where the actors determine the goals of the monitoring program and the other actors with which they will work. By doing this, the actors developing their program are deciding which other programs they work against or parallel to. This phase is extremely important because it forms the groundwork for how a program may be perceived by outside actors and how their data may be used.

3. Re-enrollment Phase 3 of the program lifecycle is re-enrollment. Securing research funding is one of the most pressing issues facing researchers today (Gauchat, 2015, Bakker et al.,

2010). I observed that funding often did not last long enough for a water monitoring program to operate for more than a few years. Because of this, programs will often re-enroll with new actors throughout their life. Re-enrollment can look like a program becoming part of a new local data collection initiative after the program is already in operation. Re-enrollment often represents a small shift in program goals, monitoring sites, and metrics collected. Partnerships created by re-enrollment are often short-term and benefit the monitoring programs by increasing access to funding and, as I discuss later, providing legitimacy for the volunteer monitors in the eyes of the state. Re-enrolling into a different program also allows existing programs to carve paths to having their data used directly in decision-making. For example, if a city government is extremely interested in nitrate measurements to inform a long-range plan, then switching to collecting that metric gives the existing program a direct influence on local governance.

Re-enrollment can shift the relationship between programs in the worknet. Many programs may find that anti-programs they once opposed or operated parallel to, are now enrolled alongside them. Or the program may find itself enrolled by a former anti-program, thereby completely changing the purpose of the program. Although it can bring many benefits to a program, shifting program objectives related to re-enrollment can be stressful for volunteers. Volunteers may not be able to express the new goals of the program as well as they could of the mission from the original enrollment, especially if they have a long history of participating in the program. Volunteers may also be somewhat unaware of the process of re-enrollment, which is a potential ethical issue. Programs are dependent on volunteers, and generally, the volunteers are willing to contribute to programs because they see them as a local process with minimal influence from outside actors (they often recognize a program’s close ties to research institutions like universities more than relationships to the state). Public trust is often already absent when in it comes to water governance (Voogd et al., 2021, Ormerod et, al, 2021). I found that in these cases, the issues relating to trust in scientists and water managers observed by researchers in other communities were present; one volunteer noted that they even avoided referring to themselves as a scientist during public meetings to avoid being singled out (e.g., Voogd et al., 2021). Again, while clear examples of the erosion of trust due to re-enrollment were not well documented in interviews, it was certainly a concern of volunteers.

Re-enrollment can also be detrimental to the production of long-term background monitoring datasets, which is the stated goal of many programs. This is due to changing monitoring locations and the metrics collected to help accomplish the goals of the larger program in which the volunteers have enrolled. Inconsistent datasets can create difficulties for future researchers who seek to prepare the programs' data and convert it to a standard appropriate for trend analysis. This long process of data cleaning prevents the data from being valorized by the academy and becomes a key barrier to data use that I will explore later.

For many programs, re-enrollment is simply a necessary process as part of their continued survival. It is easy to be critical of re-enrollment as simply "chasing funding" as some interviewees were, but re-enrollment allows programs to be reflexive to the needs of their communities. We might imagine that a perfect program is one that never regularly experiences re-enrollment, but my research suggests many of Montana's monitoring programs fight every year to continue in some form. Re-enrollment has allowed them to continue serving the people of the state, even in such a challenging funding landscape (e.g., Church and Getson, 2019).

Finally, a program can go through re-enrollment several times before reaching a catalyst for phase 4. What separates phase 3 from phase 4 is that a program experiences some structural change during phase 3 but goes through a dramatic metamorphosis after phase 4.

4. Program Evaluation Phase 4 of the lifecycle is the evaluation of the program. This evaluation is more than just re-enrollment. It often is the conclusion of years of data collection leading up to the process of data valorization. The evaluation of a program is often prompted by the introduction of a new program manager or director. However, phase 4 could also be the result of a new inciting incident. This process of returning to the foundation of the program and re-evaluating its current form can result in a program being paused or discontinued. I call this program abandonment and it only occurred in one of the cases. If the program continues to operate, it is in a form that may be recognizable but is distinct from its previous iteration. A program that is re-enrolled (phase 3) is still effectively the same, a program that continues after the evaluation is in the ANT sense a new program of action (phase 2).

For example, after re-enrolling with a city government and completing a two-year campaign to monitor dissolved oxygen, the program manager accepts a new position with their organization and regular operation of the program passes to a new manager. The new manager evaluates the program and decides to continue operating. However, the program is now in flux; effectively having completed its previous goals, the actors require new directions. The new manager decides to scale back the number of monitoring sites in the city and begins a new process of enrollment, this time enrolling with the local university. The program experiences a change in identity that is more complex than simple re-enrollment.

Phase 4 is the potential beginning of a feedback loop. After phase 4 a program can return to phase 2 or discontinue. If leadership changes or the program is evaluated, and the program does not fundamentally change, the program has not progressed onto phase 4. Much like the previous phases, the line between phases 3 and 4 can be blurred and the transition into phase 4 may take several years while the transition out of it appears to be rapid.

<u>Summary</u> Below is a diagram of the generalized lifecycle model for the VWMPs studied as part of this research, that I propose above. There are two aspects of this lifecycle model that are challenging to capture in a generalized graphic. First, the process of re-enrollment may occur any number of times, or it may never occur and be passed over completely. And second, phase 4,

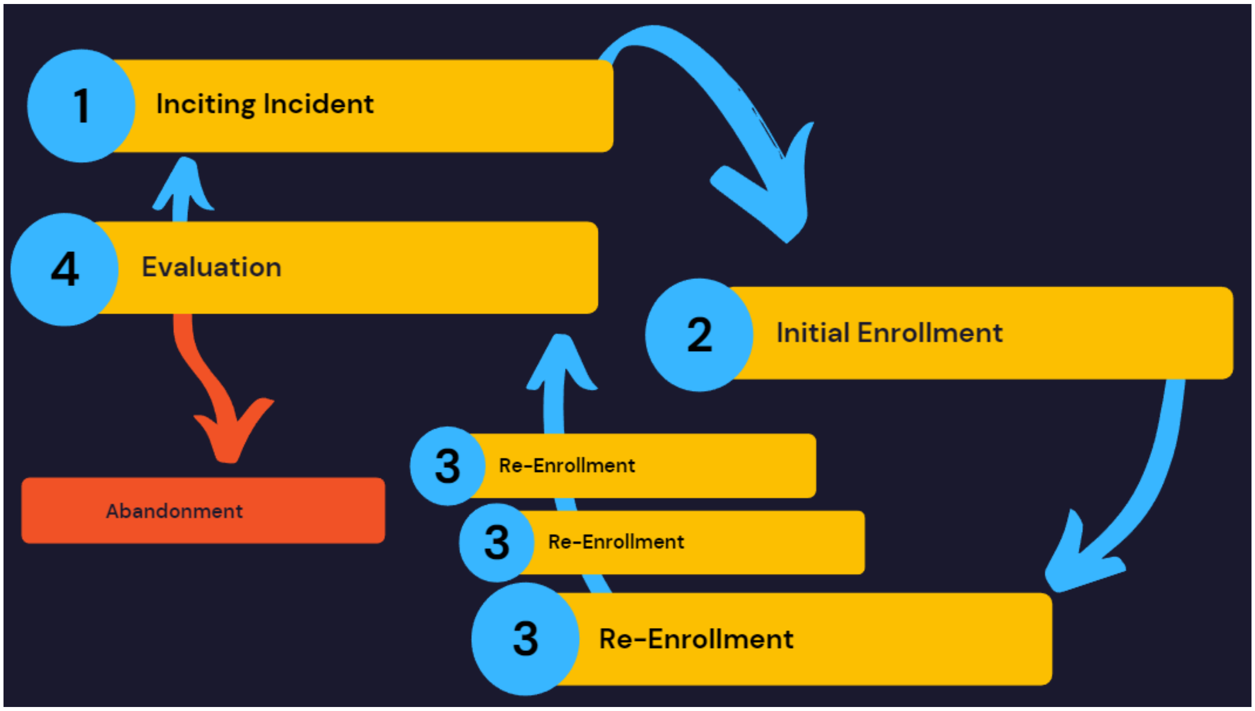

Figure 2 - A generalized form of the four stages of the observed VWMP lifecycle

or program evaluation, can combine with a new inciting incident or replace the need for an inciting incident to begin a new program lifecycle.

Finally, there is one caveat to this entire model. Earlier I drew upon the concept of catalyst events to discuss how inciting incidents drive the creation of VWMPs. I think these incidents are more than just catalyst events, as the transition between any two phases is also marked by events that shake up relationships between actors in their worknets. Perhaps the incidents are better described as the thresholds between regimes identified by panarchy theorists, or the place within a system where there is an opportunity to create change (Allen et al. 2014). In the following case studies, I describe many significant events that are catalysts for organization and community action, however, only catalyst events that create a volunteer water monitoring program are inciting incidents.

Five Water Monitoring Worknets

What follows is a brief description of each of the five cases observed in this research. Each case was incredibly complex and had an expansive worknet; for simplicity's sake, they are presented here in a standardized format. First, I present a table that summarizes the key actors in the case. Then I include a brief background on the case; this background includes a summary of the site-specific details of each case and a summary of the history that led to one program lifecycle. Then I examine one specific program lifecycle in depth (please note that several cases have already completed several program lifecycles and I have chosen only one to describe in depth). Finally, I conclude with a discussion of the current form of the program and its unique impacts on participants.

1. Madison Stream Team

Key Actors	the Madison River, the Madison Conservation District, program managers, Big Sky Watershed Corps members, Dr. W Adam Sigler, the Montana Department of Environmental Quality	
Inciting Incident	Listing of Madison River tributaries as impaired	**"People...were concerned about both the fact that we had impaired waterways as well as the fact that we had not a real strong level of confidence in the way that that designation had been made." - Program Director**
Program Goals	Participation in watershed planning process, challenging impaired status of tributaries	**"I think, contemporarily, it [the goal] would be to provide information on streams of interest for the community but also for the state, in the development of their TMDLs." - Volunteer**
Program Age	~12 Years	
Data Use Victories	Increased legitimacy with DEQ. Successful re-enrollment led to data used for updating TMDL	**"We looked at all the data, including theirs [the Stream Team's] and ours...everything lined up so well...you think about that with landowners sitting in the audience...it's not just us that saw this. There's consensus." - DEQ Employee**
Data Use Barriers	Data often not salient to volunteers, less useful for local governance, long process of data processing for trend analysis.	**"I mean the data we collect isn't really pertinent to what their [the County's] issues are as far as we're interested in water quality and they're interested in water supply." - Volunteer**

Table 3 - Madison Stream Team

Case Background and Earlier Lifecycles The Madison Stream Team is a volunteer water monitoring program operated by the Madison Conservation District since 2010. Over its lifetime it has had three main program managers, but parts of the program have been directed by AmeriCorps members from the Big Sky Watershed Corps Program. The program is based out of Ennis, Montana a large town in Madison County with a population of under 1,000 persons (Cushing Terrel, 2021). Ennis sits alongside the Madison River, a world-renowned trout fishery (Cushing Terrel, 2021. The town’s economy is heavily reliant on fishing-related tourism (Cushing Terrel, 2021).

Phase 1 The inciting incident for the Stream Team was when the community served by the Madison Conservation District (Madison CD) noticed that many of the tributaries in their watershed were being listed as impaired by the Montana Department of Environmental

Quality (DEQ). The program began in community meetings where non-experts worked to decide which of the seventeen impaired tributaries they would investigate. It appears that some of the motivation to begin the program was to preserve the region's reputation as a clean fishery in addition to challenging the outside decisions of DEQ. During this first phase, Dr. Sigler became involved in the program due to his connections with the, at the time, program manager. It was Dr. Sigler's team with Montana State University Extension Water Quality (MSUEWQ) who worked on the stream map of the tributaries that helped spark the public discussion of volunteer water monitoring. While these inciting incidents may not appear to be dramatic catalyst events, without the recognition of the stream status as impaired, no program would have begun in the region.

Phase 2 During phases 1 and 2 of the program's lifecycle, it had a distinctly collaborative structure with goals and monitoring sites being determined by experts working alongside non-experts. However, the focus on tributary monitoring was not simply a result of the impaired listing from DEQ. NorthWestern Energy, a statewide power utility, operates two key power dams on the main stem of the Madison River. In the early days of the program, the actors driving the initial program scripts enrolled with NorthWestern to combine their tributary monitoring with NorthWestern's mainstem program.

> "We kind of knew that the mainstem of the river, like Madison River proper, had a pretty solid sampling strategy. NorthWestern Energy has that mandate for their own sampling …. So we didn't want to step on anybody's toes. It's … one of those situations of like, 'You're doing that? Great. You do that.'" – Madison Stream Team Program Manager

The early worknet centered around the Stream Team – NorthWestern program and was opposed to DEQ's monitoring program. The first training event for volunteers was in 2010 and marked the official beginning of the program. However, this did not last very long as the introduction of a final key actor would lead to a rapid re-enrollment that dramatically increased the program's effect on governance. The introduction of this actor was expected and helped the program achieve one of its initial goals of generating adequate data to determine stream impairment.

Phase 3 Circa 2009, DEQ began the development of an updated Total Maximum Daily Load Document, and Dr. Sigler and the Madison Stream Team leapt to be enrolled in this actor's emergent program. This re-enrollment was centered around the Total Maximum Daily Load (TMDL) and Quality Improvement Plan for the Madison Watershed. TMDLs are standardized technical documents produced by state governments for the federal Environmental Protection Agency (EPA). TMDLs contain information about maximum temperature, turbidity, and sediment in a watershed as well as plans to remediate impaired streams. The Madison Stream Team had originally been organized around challenging or confirming the impaired stream status imposed on some of the Madison's tributaries by the previous TMDL. A call for new partners to help produce the updated TMDL for the watershed was a chance for the Stream Team to address their key concerns. DEQ began working on an updated version of the plan soon after the Stream Team's genesis. The data collected by the Madison CD via the Stream Team would become instrumental in the construction of the updated TMDL. In return, DEQ supported the volunteer monitoring effort, moving funds to the program to perform monitoring that DEQ staff could not.

Phases 1 and 2 were very short in this case and importantly, the actors behind the Stream Team never viewed DEQ as an enemy or opponent. They called into question the credibility of DEQ's decision to list impaired streams due to a lack of data in the region. Partnership with DEQ and enrollment in their program to produce the TMDL was a natural move for the Stream Team. This allowed them access to shape the actor that they had initially questioned. The partnership worked to rebuild the black box the Stream Team had initially challenged, eventually resolving the controversy between the population served by the Conservation District, the tributaries, and DEQ. The Stream Team – DEQ – NorthWestern program that emerged from the partnership allowed the Stream Team to perform robust tributary monitoring for several years. The leadership of the Stream Team program changed three times in the decade leading up to the completion of the TMDL, but the TMDL process prevented a move onto phase four until the most recent program director took the helm. During the TMDL process, data was also used at the local level to help the Madison Conservation District lobby local landowners to conduct remediation projects. The TMDL process was completed in 2020 with the Stream Team's reduced participation in the larger DEQ-NorthWestern-Stream Team program in 2018 after the completion of the draft TMDL.

Phase 4 The completion of the TMDL process, along with the induction of the third program manager, thrust the Stream Team into phase 4 of its lifecycle. Because of their previous enrollment with DEQ, NorthWestern Energy, and Montana State University (via Dr. Sigler), the Stream Team is still well supported with monitoring equipment and professional training for volunteers. However, the program is beginning to suffer an identity crisis; without the driving force of the TMDL, volunteers are unclear about the new directions of the program. It appears that the relationship with Montana State University is growing stronger than the historical relationships with DEQ and NorthWestern Energy. Moreover, the program is reducing its scope, beginning to focus on long-term monitoring of tributaries that could be exposed to development pressures.

Now and Tomorrow Complicating the Steam Team's situation is the encroachment of a new monitoring program into the Madison River watershed. This anti-program also focuses on long-term quality monitoring, but unlike the Stream Team, makes regular use of auto loggers for data collection. Auto logging sensors have been shown to reduce volunteer engagement in a program (Jalbert and Kinchy, 2016). A reduction in engagement like this could impact the legitimacy volunteers feel in the decision-making processes of the Madison watershed, which is one of the key outcomes of enrollment with DEQ. It could also impact the numerous benefits to program volunteers from participating in several steps of the monitoring processes (Church et al., 2019). The program managers and volunteers are now faced with the difficult challenge of potentially re-enrolling with this new auto logger centric program to access funding.

2. Musselshell Salinity Monitoring Program

Key Actors	Geology of the Musselshell Basin, the Musselshell River, program manager and program volunteers, Montana Bureau of Mines and Geology, MSUEWQ staff, broken YSI probe	
Inciting Incident	Flood of 2011	"That's something following ... flooding in 2011, a lot of people had their reservoirs go bad because of high salinity issues. And it is becoming an increasing problem since then." - Program Manager
Program Goals	A better understanding of the water resources of the Musselshell basin and how salinity impacts water resources for producers	"Over the long-term, it'll help them. It'll help ranchers kind of develop their grazing plans, what pastures they're going to use... If the water's no good and they're having to haul water ... they're going to take that into consideration." - Volunteer
Program Age	~11 Years	
Data Use Victories	Created extremely salient data, Trend analysis will be straightforward	"One of the biggest concerns in our area is the salinity of the water... seemed like everybody that came down the road wanted to know what the reading was that day and wanted to know if I could also check some ponds and stuff for them." - Volunteer
Data Use Barriers	Data not commonly used by state agencies	"They [DEQ] put their own monitors out that actually was reading every 30 minutes for, I don't know, a couple of months. So they had their own data but they did compare it with ours." - Program Manager

Table 4 - Musselshell Salinity Monitoring Program case summary

Case Background and Earlier Lifecycles The Musselshell watershed is a roughly Austria-shaped basin in central Montana. Its namesake is the fatmucket mussel, a freshwater mussel native to many parts of central MT (Hoffman and Nowlin, N.D.). The area is extremely rural (less than 10,000 people live in the almost 10,000 sq mile watershed), and while parts of the

Southern Musselshell are not far from Billings (Population of approximately 117 thousand), there are no major cities in this part of the state (Hoffman and Nowlin, N.D., U.S. Census Bureau, 2022). The monitoring program is ostensibly based in Roundup, MT, and Winnett, MT but this fails to capture the extent of the program. The program is operated by the Musselshell Watershed Coalition (MWC), an organization that unites several Conservation Districts and key stakeholders from across the basin. Volunteers in the program monitor the river at several key points in the basin. It may be the program with the most expansive geography described in the included case studies.

<u>Phase 1</u> The Musselshell River itself is a very unpredictable actor in this worknet. It is an unusually saline freshwater river, both due to the region's geology and its history of dryland irrigation (Hoffman and Nowlin, N.D.). In recent years the river has had two extreme flooding events. These events severely changed the run of the river and had the additional effect of adding salts to existing stock ponds. A severe flood in 2011 catalyzed the organization of the current incarnation of the Salinity Monitoring Program. Before the 2011 flood, there was a volunteer monitoring effort, but it was not responsive to community needs.

<u>Phase 2</u> By 2014 the program manager worked with Dr. Sigler to co-create a program with volunteers from across the watershed to produce long-term quality datasets to develop a deeper scientific understanding of the watershed. This early enrollment with MSUEWQ has allowed the program to maintain a consistent mission. Unlike the Madison Stream Team, data are not used as heavily to inform restoration projects. However, the data produced by the Musselshell Salinity Program have proven to be salient enough to local agricultural producers that there are other paths to data use in the region.

The program volunteers represent all walks of life; producers, pastors, scientists, and volunteer firefighters have all been involved in the program. Much of the time the monitors are also involved in other community organizations like conservation or irrigation districts or are local ditch riders. Ditch riders are part-time or volunteer employees of an irrigation district who monitor water use along community irrigation districts. This heavy community involvement in the program transcends political ideology as producers in the region all recognize the existential threat of saline water to their way of life.

The ultra-salience of water quality in this region has led to landowners engaging with volunteers regularly during monitoring periods as one volunteer described:

> "It's usually because I'm dealing with them with the canal work. So, they'll bump in and it's just basically asking is it [salinity] going up? Is it getting up in a dangerous area or is it nice?" – Musselshell Salinity Monitoring Program Volunteer

One interesting set of actors in this specific worknet are the YSI meters and probes used to conduct the monitoring. The equipment used by this program is almost entirely maintained and calibrated by MSUEWQ (this is true of the Madison Stream Team as well). However, multiple interviewees discussed the story of a broken probe. The probe was quickly identified due to its odd readings and sent back to MSUEWQ for replacement and re-calibration. This story, while illuminating a strange actor in the worknet, also demonstrates the close relationship between the salinity monitoring program and MSUEWQ.

<u>Phases 3 and 4</u> The Musselshell Salinity Monitoring Program is unique among the included cases because it has operated without distinct re-enrollment for almost ten years. We may think of this program as a "gold star" program because its core monitoring sites and monitoring goal have remained relatively static.

Final Thoughts Even though several interviews discussed how the Montana Bureau of Mines and Geology is introducing its groundwater salinity monitoring program, no major attempt at re-enrollment with this new program is being made. This has led to a relatively direct attempt for Dr. Sigler and MSUEWQ to review and valorize volunteer collected data and perform long-term trend analysis on the watershed. The weakness evident from this approach is simply the program's overreliance on the partnership of a small group of actors, the loss of which could destroy the program. However, there is no sign of this partnership degrading any time soon.

I believe this program's unique form is only possible because of its initially co-created structure and the incredible buy-in of the actors executing it. There was a strong attitude toward ecological stewardship among landowners in the watershed as one volunteer noted.

> "Two of the ranchers took me on tours of their ranch. They showed me where, every time it rains, the water, they get the most flow, where creeks and coulees are incised and head-cutting, and where there's erosion. They knew. They knew where they had the problems. They knew. They showed me some of the ponds that they cannot even have the cows drink out of because of the salinity level. And they really knew their grass. They knew where they had to have the cows at certain times of the year to keep them out of certain ponds, and just the general water flow and hydrology of their ranches" – Musselshell Salinity Monitoring Volunteer

These attitudes were present in all five programs but were dominant in this program and have persisted even as the program has become more collaborative over time.

3. Gallatin Stream Teams

Key Actors	Program Manager, Gallatin River, Sourdough Creek/Bozeman Creek, Dr. W Adam Sigler, Gallatin County, City of Bozeman	
Inciting Incident	Grant availability/educating an expanding populace	"People... are moving from areas where they don't see this area [Gallatin County] as really having any issues... the task of making people aware of [water quality issues] has just become more daunting. " - Program Manager
Program Goals	Long-term monitoring and trend analysis, education and outreach	"This network program, the main goal of that is long-term trend monitoring, and it's fairly new. And I think that we're still working kind of behind the scenes to ensure that that goal can be met." - Program Manager
Program Age	~14 Years	
Data Use Victories	Many successful lifecycles re-enrollments have led to direct data use in local governance	"I have a lot of heart to hearts with the city, for example, about Bozeman Creek, because there are clear human contaminants from most likely leaking septic in the creek that are then flowing through the city." - Volunteer
Data Use Barriers	Data are insalient to volunteers, potentially insalient to developers, data use hampered by legislation, no trend analysis	"As long as it's good enough for the cow to drink or for it to go to the pivot, a rancher doesn't really care what the quality looks like." - Volunteer

Table 5 - Gallatin Stream Teams case summary

Case Background and Earlier Lifecycles The Gallatin Stream Teams is a program that has completed a full lifecycle several times. The program is centered in Bozeman, MT, and is operated by the Gallatin Local Water Quality District (GLWQD), a non-regulatory county agency, in partnership with the Gallatin Watershed Council. It operates in the same major watershed as the Madison Stream Team, the Upper Missouri Watershed. In many ways, the character of these two programs is extremely distinct despite the similarity of their current form. The Gallatin Stream Teams have historically monitored tributaries of the Gallatin River, especially those like Bozeman/Sourdough Creek which are important to the municipal water supply of the City of Bozeman. These tributaries are in many ways the key actors in this worknet as the water quality is consistently affected by an aging infrastructure and regional development pressures.

The primary mission of the GLWQD is education and outreach. The program works on some remediation identification and permitting, but all the programming generated by the agency has a component of education and outreach. Because of this mission, a single catalyst event is not the inciting incident for the program's genesis in 2008. Rather, the program was formed more broadly as part of a general response to the increasing development pressures in Gallatin County. Until about 2018-2019 long-term trend analysis was never a goal of the program managers or volunteers; this sets the Gallatin Stream Teams apart from the previously discussed programs even further. The program has completed several enrollments, re-enrollments, and evaluation processes due to its dramatic flexibility. The current program manager described this as simply chasing grants but going through these stages has also created a path to direct use of volunteer-produced data and supports the Water Quality District's educational mission. By re-enrolling and evaluating and reforming the program regularly, the GLWQD has created paths for their volunteer collected data to be used in several governance processes even if they are a non-regulatory agency. The funding they secured from their many partnerships allowed the program to continue to function and move forward with its education and awareness mission. The GLWQD also lends its credibility to the volunteers who collect the data, and the credibility of information produced by the programs is rarely challenged.

Most forms of the Gallatin Stream Teams have been contributory, while there is evidence of non-expert engagement, there is almost no non-expert contribution to program goals and procedures. This is to be expected with the outreach-driven nature of the program. The location in one of Montana's more urban counties also changes the dimensions of citizen participation. I have observed that in these five case studies, the programs with more rural characters tended to have more non-expert participation.

Phases 1 and 2 While the Stream Teams has existed in several distinct forms most recently, they enrolled with the City of Bozeman and MSUEWQ to monitor Bozeman/Sourdough Creek for non-point source pollutants related to human waste from aging septic systems. Upon completing that research process, the program entered an evaluation period. Subsequently, the program director moved to shift the volunteer monitoring program to become a single part of a larger GLWQD monitoring network.

Phase 3 This phase was skipped during the last complete lifecycle of the program. This is likely because the water monitoring effort with the City of Bozeman lasted less than 5 years, leaving little time for re-enrollment with new actors or programs.

Phase 4 After evaluating their role with the City of Bozeman in their last enrollment, the program manager for the Gallatin Stream Teams is changing directions once again, attempting to be part of a larger worknet for a longer period. The program is now enrolling in a larger program with MSUEWQ and other actors as part of the larger water quality monitoring network created by its operating agency. The program is still committed to its mission of education but is also becoming one part of a new much larger data collection worknet in the Gallatin Valley. As part of this larger network, the program is shifting to producing data for long-term monitoring for trend analysis.

An Outreach Program First While program managers have been responsive to volunteer feedback, volunteers are not incredibly important to the worknet surrounding the Gallatin Stream Teams as it relates to the use of data and re-black boxing of controversies. Volunteers often did not have strong relationships with other actors outside the program and there appears to be some separation between their volunteer life and personal/professional life. For example, even highly motivated volunteers discussed sharing their volunteer experiences less frequently or in more specific contexts than volunteers with other programs.

> “I don't know if anybody here [Bozeman] knows that I have anything to do with that [Gallatin Stream Teams] at all. Maybe some of my closer friends because, ‘Where are you?’ and I'm like, ‘Oh, yeah. I'm standing outside the sewage treatment plant in a gallant river’, but, I don't really talk about the water monitoring stuff that much.” – Gallatin Stream Teams Volunteer

While the volunteers do have significant educational takeaways from their experiences, which is the historical driving goal of the program, these volunteers are more akin to research instruments than research partners. This is not atypical of PPSR programs and does not contradict the educational aims of the program. Indeed, the program is successful at increasing public awareness and generating data that are used in public decision-making processes. This may be because its structure combined with the frequent re-enrollment could have reduced volunteer advocacy.

4. Sun River Watershed Group Water Monitoring Program

Key Actors	Program manager, keystone volunteer, paraprofessional contracted staff, Sun River, Great Falls Schools	
Inciting Incident	Completion of trend analysis (previous phase 4)	"We've hired Adam to do trend analysis in the past. He just completed a trend analysis of 15 years worth of data in 2019." - Program Manager
Program Goals	Re-establish the program, create a plan to monitor additional restoration projects	"A question I've been really looking at is, how do we make our monitoring meaningful, and how do we know if we're meeting our objective? What is our objective?" - Program Manager
Program Age	~22 Years	
Data Use Victories	Early forms of the program contributed to TMDLs, informed restoration projects	"The previous coordinator was doing a lot of water quality projects or projects to reduce erosion or hopefully reduce nutrient inputs, and the monitoring was supposed to help monitor long-term nutrient inputs." - Program Manager
Data Use Barriers	Lengthy trend analysis process	"They've [SRWG] definitely done some trend analysis on the last 20 years of data... But I think that's, obviously, something they're looking to do more, too. It's where they can actually pinpoint projects." - Volunteer

Case Background and Previous Lifecycles The Sun River Monitoring program is one of the most mature programs included in these case studies. The program operated in a collaborative form from the early 2000s to 2018. The purpose of the program is primarily to monitor the Sun River before and after it passes through the City of Great Falls. The program is administered by the Sun River Watershed Group (SRWG). The watershed itself is in northwestern Montana and the SRWG works extensively in the rural western sections of the watershed. The SRWG has historically focused on remediation projects for disturbed streams. The original monitoring program was very much an extension of this original mission. While it was co-created in nature, the research design focused on providing data on areas with previous remediation projects and the identification of new areas to be remediated.

The program has always had a key education and outreach component. The key volunteer who helped to begin the earlier form of the program was a teacher and many of the early volunteers became involved with the program through local schools. This one actor preserved much of the education and outreach components of the program while program directors focused much more on research design and informing conservation decision-making. Much like the Madison Stream Team, this program was quickly re-enrolled in a state TMDL process. However, this process was completed in 2004 and the program continued to follow the same methods and procedures for the next fifteen years. This continuous long-term monitoring was always focused on the same six sites and progressed steadily without any major re-enrollment. This has allowed MSUEWQ to perform a trend analysis on the program’s volunteer-collected dataset. The program has recently completed an evaluation phase primarily due to leadership change at SRWG.

Phase 1 The completion of a long-term trend analysis and the arrival of a new program manager has thrust the SRWG monitoring program into a new phase 1. The new program manager hopes to shift the focus of the program more towards education and outreach, as captured in this interview with the new program manager:

> "The person who ran the Watershed Group before me ran it very differently and had a different approach and different focus. Not quite as outreach driven, didn't update the website,… didn't have a Facebook page. [But they] really did a great job of doing a lot of on the groundwork." – Sun River Monitoring Program Manager

Phase 2 The new iteration of the program has just entered phase 2. As part of this change, most of the monitoring in the 2020 and 2021 seasons was conducted by contracted employees, not a volunteer. "Volunteers" accompanied contracted employees on monitoring days and were trained on procedures the day of (although many had some familiarity with water monitoring). Different volunteers accompanied the contracted employees every month. Contracted employees were AmeriCorps members with the Big Sky Watershed Corps or employees from neighboring Conservation Districts with temporary contracts to work with the SRWG. This program structure which relies on the recruitment and enrollment of actors from outside of the watershed to do most of the labor begins to challenge the definition of a volunteer water monitoring program. Is the monitoring being done by volunteers or is this just an outreach and training program that has become part of natural resource workforce development? No matter what it is, the program is certainly still responsive community-based research.

Phases 3 and 4 While the previous iteration of the program completed a full lifecycle, this current iteration has yet to begin any re-enrollment. It is important to note that the program's current extremely contributory mode of operation is temporary and a result of the new program manager taking their position during a global pandemic. The current manager is working to restructure and re-enroll the program.

An outlier among outliers This program is an interesting case. It appears that historically, the first and final phases of other programs' lifecycles are brief. But in this case, the evaluation period, while brought on by one of the more typical catalysts, leadership change, has been extended by extenuating circumstances such as the global covid-19 pandemic. Despite its modern ultra-contributory form of operation, the program has maintained significant momentum due to its long history. Reflecting on how the program continues to operate despite this is a testament to the resilience of Montana's conservation organizations and communities.

5. Clearwater Resource Council Adopt-a-Stream

Key Actors	Seeley and Salmon Lakes, City of Seeley Lake, septic systems, program managers, volunteers, Rice Ridge Fire	
Inciting Incident	Proposal of Seeley Lake sewer (Adopt-A-Lake), Southwest Crown Restoration project (Adopt-A-Stream), delisting (Both)	"And they were removed from listing because there was insufficient data to maintain the listing.... So that closed doors for funding to do any kind of work." - Program Manager
Program Goals	Discover if the lakes have improved enough to be de-listed by DEQ	"So our goal was to try to get as much as we could, information that would tell us what the trophic status of the lakes was and potentially whether or not they were actually changing, had they improved or not." - Volunteer
Program Age	~8 Years (Adopt-A-Stream), ~14 Years (Adopt-A-Lake)	
Data Use Victories	Capitalization on natural experiment, individuals using data for protests/decision-making	"We had the Rice Ridge Fire in 2017... And several of our monitoring sites were within the fire boundaries ...it was too good of an opportunity to have three years of prefire data to follow it up with three years of postfire data." - Program Manager
Data Use Barriers	Legislation, salience, and public will prevent data from being used for sewer	"Part of our goal was to have people understand what the role of nutrient loading and other kinds of things might have in the lake and how that works...I don't think that has made a difference in the sewer discussion." - Volunteer

Table 7 - Adopt-a-stream case summary

Case Background and Previous Lifecycles The Adopt-a-Stream program is the third prong of a trident of monitoring programs operated by the Clearwater Resource Council (CRC). CRC is based in the town of Seeley Lake, one of the largest in a series of small towns in the Upper Clearwater watershed. The watershed is inside Missoula County, and while this is one of the largest urban counties in Montana, the region has a distinctly rural character and is dependent on amenity tourism driven by its scenic lakes.

While this is a monitoring program that focuses on tributaries, much like the previous cases, the Adopt-a-Stream program focuses more on monitoring tributaries that feed directly into lakes, specifically Seeley and Salmon Lake in the Clearwater Watershed. As it is part of a multi-program approach, Adopt-a-Stream has always been enrolled alongside its sister program Adopt-a-Lake. Actors have also begun the creation of an Aquatic Invasive Species (AIS) Monitoring Program. The Adopt-a-Stream and Adopt-a-Lake programs have slightly different inciting incidents; however, the presence of Adopt-a-Lake was part of what drove actors to generate Adopt-a-Stream. Both programs were also initiated as responses to a controversy, or something being un-black boxed.

<u>Phase 1</u> Adopt-a-Lake was formed in response to the potential presence of human septic waste in the major lakes. The town of Seeley Lake and its surroundings do not have a municipal wastewater system. Concerns surrounding the overreliance on aging septic systems are what drove retired and part-time scientists to organize the initial lake monitoring program. The sewer debate was focused on two major lakes, Seeley and Salmon Lakes. This period is recalled as a harrowing time by local community members, who often discussed it during interviews in hushed tones or were uncomfortable giving firm opinions about the controversy. The sewer issue appears to have been more focused on “who will pay for this” and the lack of support from Missoula County rather than ecological need, despite the program being partially rooted in addressing this concern. Data were not used as part of the debate surrounding whether the city of

Seeley Lake should construct a sewer, and this pressing sewer issue has been dropped, for now, but the scars in the community are still felt.

In addition to the sewer issue, DEQ delisted several lakes and streams in the region as impaired on a TMDL. The areas had previously been listed as impaired because of the region's history of logging and clearcutting which put an incredible sediment burden on the lakes and tributaries. Residents were not clear as to why they were being delisted, as they believed DEQ did not collect enough new data to reach an appropriate conclusion. This catalyst event served to re-enroll Adopt-a-Lake and incite the formation of Adopt-a-Stream as programs opposed to DEQ's anti-program. The program managers and volunteers capitalized on the introduction of a project, the Southwest Crown Collaborative watershed restoration, to study the effects of the region's deforestation and new road on the tributaries and lakes. Initially, the Adopt-a-Stream program could be described as rudimentary, volunteers described simple monitoring procedures such as steel depth gages and measuring flow by observing an object moving downstream. However, as will be illustrated they quickly enrolled with different actors to provide the funding to purchase improved monitoring equipment and pay for water sample testing from reputable labs on their own.

Phase 2 In their initial enrollment, both programs were co-created by local volunteers and part-time staff at the CRC. This lent to an attitude of volunteer stewardship and ownership of the program and a general feeling of legitimacy in the process of challenging DEQ through data collection. However, like the previous cases in this study, the program was able to secure more resources and eventually enroll with DEQ to work towards re-black boxing the de-listing controversy.

Phase 3 Adopt-a-Stream completed its enrollment with DEQ in 2017 after finishing data collection for the TMDL but was quickly re-enrolled after a fire significantly impacted the region. Concerns returned that the loss of forest could once again impact the total dissolved solids in the watershed's waterbodies. Researchers from the University of Montana (UM) in Missoula and the Forest Service helped secure funding for the program to return to its previous monitoring sites. The researchers took advantage of this natural experiment to develop research attempting to compare the three years of pre-fire data to three years of post-fire data. This process was completed in 2020, the year of the Covid-19 pandemic and the beginning of the previous program manager's move into complete retirement.

Phase 4 With the end of its first two enrollments and the presence of a new part-time program manager, the program began to shift. AmeriCorps members from the Big Sky Watershed Corps began to be hosted by the CRC. While members brought increased capacity to the agency, they also became the primary collector of data at the sites monitored by the Adopt-a-Stream program. Adopt-a-Stream is no longer functioning, and volunteers are often unclear as to why.

A dramatic shift While volunteers formerly felt incredibly integral to their co-created program, going so far as to use data they collected as parts of small-scale protests against local development actions, they now feel disconnected from something that used to be part of their day-to-day lives.

> "But we have lost touch with what's going on with them. And I feel bad about that. I really-- I honestly was thinking that this morning. I don't know what they're doing"
> – Adopt-A-Stream Volunteer

The other two PPSR programs have also been scaled back and have moved from co-created, to collaborative, then finally to contributory. Adopt-a-Lake volunteers now only drive CRC staff out to sites on the volunteer's boat, partially this is due to CRC acquiring newer more complex monitoring equipment. Other researchers have noted that when new technologies are introduced that reduce the work done by volunteers, volunteers receive fewer benefits from their participation, which could be an unforeseen issue for this program. CRC has been effective at securing funding and dramatically increasing its capacity to perform professional water monitoring, thereby reducing its need to enroll with other actors. However, this has come at the cost of citizen participation. While so far, the increased capacity has been nothing but beneficial to the CRC, the loss of citizen participation could lead to future issues with data legitimacy (Kimura and Kinchy, 2019; Stepenuck and Genskow, 2019).

Barriers to Data Use in Montana's Local Governance

Previous work has identified several barriers to data sharing in the Marcellus Shale Water Monitoring Network in Pennsylvania (Brasier et al. 2017). Researchers noted that in this data-sharing network, key barriers to sharing data were credibility, resources, and legislation (Brasier et al. 2017). In my observations, I identified three similar but distinct barriers in the Montana water monitoring worknet studied as part of this research, as well as the strategies adopted by actors to work around these barriers. Due to the highly collaborative and partnership-based approaches visible in the re-enrollment present in many of the cases described here, only one of those barriers to data use observed by Brasier et al. (2017) was present in the Montana worknet: Legislation barriers. The responsive and collaborative approach present in Montana avoids issues of resource allocation, as water monitoring groups work closely with actors who have access to federal grants and resources as opposed to adopting a potentially hostile stance toward them. Deep collaborations have also alleviated issues of credibility and legitimacy between state agencies and communities. Programs gain credibility in the eyes of the state when they enroll with state agencies like DEQ, while DEQ and NorthWestern Energy gain legitimacy in the eyes of communities that host a VWMP. Instead, the historical collaborative approach in Montana has created different barriers to data use in the worknet, chiefly the saliency of programs' data to drive decision making and the time it takes for data to become valorized for research.

Saliency

One of the largest issues with sharing water quality data is their lack of saliency in the context of Montana. Many landowners and other stakeholders are far less concerned with water quality than water quantity. The general perception is that Montana's watersheds are clean, while years of extreme drought have placed quantity at the forefront of concern. Because of this, there is much less public demand for quality information. In addition, while quantity and quality are intimately connected, different state agencies are responsible for water quality and quantity governance. This is a state-sanctioned separation of the two elements into different spheres. While this makes regulation complicated, it may also have the effect of separating the two dimensions in the mind of the Montanan as one volunteer pointed out when they discussed how they did not spend much time with water quality before their volunteer monitoring efforts:

> "It's kind of just increased my awareness of some of those things from the water rights world. You're just kind of in the quantity standpoint. So, it's been kind of fun to get back into some of the quality and some of those other aspects that I just don't think about in the day-to-day" – Gallatin Stream Teams Volunteer

Enrolling with other water quality programs is an effective strategy for programs to avoid this saliency problem in some cases. By creating a guaranteed path toward data use, the actors behind the program can safely know that their data are being shared. The downside of this collaborative approach is the data collected by the program can be less meaningful to local stakeholders, creating a different or localized saliency problem. The only program to avoid this issue of saliency is the Musselshell Salinity Monitoring Program. While like the rest of Montana, the Musselshell is in extreme drought, dissolved salts are potentially lethal to cattle as mammals cannot drink saline water. The quality issue is just as relevant to local landowners and producers and as one volunteer noted, they use the data regularly to drive personal decision-making:

> "So they'll [Ranchers] bump in and it's just basically asking is it going up? Is it getting up in a dangerous area or is it nice? … So it's just them just kind of curious because I know ranchers that they'll get a stock pond or something that they get a fence off because the water's gone bad on them. Yeah. And so they're concerned, always on it." – Musselshell Salinity Monitoring Program Volunteer

The problem of saliency is not easily solved. Water quality is key to the health of any community and many volunteers and program managers expressed their support for data collection for its own sake.

Legislation

Much like the Pennsylvania case observed by Brasier et al. (2017), legislation is a key factor in stifling the sharing and use of volunteer-generated data. Legislative barriers have been identified several times as significant barriers to climate-related research and climate adaptation over the last decade (Cosens et al., 2014). While state agency employees who implement regulatory programs may place value on the data collected by volunteers, they are often restricted by what they can use, due to state water quality data standards. One regulator consistently returned to this refrain:

> "Like I said earlier, you asked, is there data I trust? Well, there's data I can legally use, and there's data I can't. I think it doesn't matter." – Montana Department of Environmental Quality Employee

In this same interview, the DEQ employee expressed that many of the programs are doing important and useful monitoring and following the Clean Water Act they often check data repositories for volunteer collected data, but the data is often not something they are allowed to consider for TMDL processes if they do not meet the standards of the Clean Water Act. However, TMDLs are one of the driving actors in many of the volunteer water monitoring worknets, often serving as a catalyst for other actors as part of the inciting incident. While TMDL plans are a document produced by state agencies for the EPA, they are only a starting point for regulatory action that can reduce non-point source pollution. Often data to inform the TMDLs is all volunteers contribute to state-level governance. Specifically, volunteer data is not considered when determining water quality standards across the state, meaning the volunteers are not particularly influential on governance in the state of Montana.

Data are much more influential on local governance decisions. Often Conservation Districts use volunteer collected data to drive the selection of remediation sites. As Conservation Districts have no legal restriction on what data can be used for these decisions, volunteer collected data become more useful for Conservation Districts and watershed coordination councils than they are for state-level governance. Recent shifts in the Montana legislature have led to a mandate that DEQ adopt primarily narrative standards for certain water quality metrics. While this can be seen as an attempt to undermine DEQ's ability to make data-driven decisions, it could also be an opportunity for volunteer-collected data to be valorized in the eyes of the legislature.

Data Purgatory

The final barrier to data use in the Montana worknet is “Data Purgatory”. I call on images of purgatory here to describe a state in which volunteer collected data are in the process of being valorized by professional scientists to be used in long-term trend analysis. This process may not appear to be a barrier to data use for those of us who are engrossed in research every day. Instead, I see what Kuhn describes as normal science playing out in front of us (Kuhn, 1970). In ecology and hydrology operating in its current normal form, a long-term trend analysis is the natural result of background monitoring. However, data purgatory is a barrier to the use of data in governance. Preparing data for analysis is a rigorous process that in the eyes of scientific institutions can only be done by professionals. Thus, it is only researchers who choose which data to valorize or validate, and this can lead to disconnectedness with program volunteers.

Data purgatory is a more membranous barrier for volunteer collected data than the other barriers, as this barrier has often been overcome (such as in the Sun River or in the Madison case where the barrier is in the process of being overcome). When programs enroll with research institutions like Montana State University or the University of Montana, the data will eventually become valorized. This valorization is partially because MSUEWQ has focused on providing workshops and training to help programs begin the trend analysis process themselves or to set their data up for successful trend analysis. Dr. Sigler at Montana State University has also worked to collect volunteer data in a Montana-specific online hub mirroring EPA’s Water Quality Exchange (WQX), with both portals utilizing Environmental Quality Information System (EQuIS).

> “I have, over the years, created a strategic plan with the Data Hub where we are trying to get all of the data into the big national WQX database, which is the long-term data repository. But then the Data Hub is a sister database to that other one

> that is explicitly for making data easily visualizable by the public. And so it's our goal, and we're moving towards that to have the-- and we do have the workflow for supporting groups to get their data into this national-level database first" – Dr. Sigler

This allows data to be accessed and visualized by the public during the long process of data purgatory and acts as a quality assurance process allowing DEQ to quickly access data that meet Clean Water Act standards. The programs enrolled in the data hub have data that could possibly emerge from purgatory and be used for trend analysis; interview data suggest this has already occurred in the case of the Sun River Watershed Water Monitoring Program, which has over 20 years of monitoring data.

Data purgatory remains a barrier because of the re-enrollment process. As programs need to adapt to the changing conditions around them, they may change which metrics they monitor and what sites they study. Programs may not be able to produce five to ten years of consistent monitoring data in a single site needed for robust trend analysis. This is further complicated by volunteer turnover. These challenges related to program evolution and re-enrollment do not exclude data from being used in further analysis but extend the purgatory period while the data must be cleaned by university staff before they reach a form that is acceptable to the academy.

Effectively because of a need to survive, collaborate, and pursue good governance, the programs may produce less than perfect science. While volunteer monitoring program produced data are often challenged because they are collected by non-experts, this is not the source of the long purgatory period in Montana. Because of the detailed training and existing expertise held by volunteers in these five cases, the data purgatory period is not a result of non-experts meddling in science, but instead the lack of support for crucial water monitoring funding from state and federal sources.

I close this section by saying data purgatory is not a “good” or “bad” process. It is partially necessary for the programs to participate in normal science (Kuhn, 1970). However, it is an important barrier to acknowledge when one of the stated goals of every program is to produce data for trend analysis and many of the programs experience long purgatory periods. Data purgatory asks us to question what the purpose of programs is: to provide data for governance decisions (which they cannot do because of legislative barriers), to educate participants, or to provide data for long-term analysis.

CHAPTER FIVE

DISCUSSION

Given the distinct barriers to the use of volunteer collected data in the state, the worknets of natural resource governance studied in this research appear to be distinct from other researched volunteer water monitoring networks where the credibility of volunteers is more commonly questioned (e.g., Brasier et al. 2017). While here I examined only five volunteer monitoring programs, many Montana-based organizations like the Blackfoot Challenge have been setting standards for North American conservation collaboration for decades (Blackfoot Challenge, 2022; Gilbert, 2022). One interviewee enthusiastically described the collaboration-based ethic of natural resource governance commonly found in the state as "the Montana Model" (Gilbert, 2022). While I recognize that this highly collaborative context allows for more reflexivity to community needs, better distribution of resources, and the assuaging of ethical concerns, Montana has become hyper-dependent on collaboration (Blackfoot Challenge, 2022). In many ways collaboration is a black box in Montana, it is assumed that collaboration will function as intended in that community concerns and stakeholders are inputs and that good governance is the outcome.

In the previous Chapter, I explored how this collaborative context fundamentally changes the way that data are moved throughout and used within the water resources worknets surrounding volunteer monitoring programs. I identified three barriers to the sharing and use of volunteer-collected data in these highly collaborative environments: Saliency, Legislation, and Data-Purgatory. I focus this discussion on re-affirming the strengths of the collaborative approach, as well as taking a final look at the three barriers to data sharing in the Montana worknet while suggesting possible paths towards minimizing the impacts of these barriers on future volunteer water monitoring efforts in Montana.

Barrier: Saliency

Fundamentally, volunteer water monitoring is a form of co-production of knowledge. Other researchers have noted the benefit to all stakeholders when knowledge is co-produced, especially by allowing research to be more flexible in responding to and representing community needs and desires (Church et al, In Press). This stands in opposition to the historical process of extractive research, or “helicopter research”, where researchers extracted data from communities without significant community input (Church et al, In Press). Even if programs shift over their lifetime to be less collaborative and more contributory, they are still potentially less exploitive and more responsive than the data collection efforts of professionals. Communities are often concerned that career researchers are part of the helicopter tradition, as one volunteer noted:

> “But the part that may lack some of my trust is depending on others that are Forest Service … That [the Forest Service Employees] take things for granted like I did when I first came up here, that the professionals that are caring for our forest, caring for our watershed don’t have the passion that they need” – Adopt–a–Stream Volunteer

When community-based monitoring programs are enrolled with agencies like the Forest Service or DEQ, it can lend legitimacy to those programs in the eyes of volunteers. But often volunteers were initially critical of these agencies or remain critical of them even as they work alongside them.

These partnerships formed between diverse actors in the worknet have also helped ease problems with volunteer credibility that have been noted across other cases by several authors (Kimura and Kinchy, 2019; Kosmala et al., 2016). While many interviewees expressed concern with the credibility of volunteer collected data, the credibility was reaffirmed repeatedly using volunteer collected data and through the process of the valorization of the volunteer collected data by professional scientists. Working alongside state agencies allows programs to perhaps skip the credibility challenges present in other VWMPs (Kosmala et al., 2016). This is because programs often follow specific guidance directly created by the actors with which they enroll, creating an immediate trust as they are submitting sampling analysis plans to the agencies. This has the effect of creating oversight by the very actors that could call their data into question.

However, saliency remains an issue when it comes to the use of data outside of state agencies. Problems with saliency seem to be most evident in actors who do not participate in the program, as one program manager described:

> "If you haven't done water monitoring, it seems like…I feel like it's hard to pinpoint the importance of it." – Madison Stream Team Program Manager

It could be argued that the issue with the saliency of volunteer data stems from a lack of ecological literacy or systems thinking amongst watershed community members. But findings and data can be received differently depending on how a data point or finding can contribute to an individual's existing worldview as opposed to a simple lack of ability or knowledge (Kahan et al., 2011). I suggest that the issues with saliency persist, not because of a lack of knowledge, but instead from a mismatch of priorities: while water quality is important to all western watersheds (and is one of the easiest issues for a volunteer water monitoring program to examine), water quantity remains a more visible issue.

The Bonney et al. (2009) typology of non-expert involvement can be imagined as a scale of co-production, where knowledge from co-created programs is the most co-produced while knowledge from contributory programs while being the least co-produced. Recall that one of the outcomes of re-enrollment from the partnership model is the shift of programs to more contributory forms over time. This means as programs mature and enroll with other monitoring efforts there is a potential to co-produce less knowledge. I suggest that while co-production of knowledge is not always the method that will achieve the most measurable results, making meaningful co-production a central tenant of Montana VWMPs studied in this research may alleviate some saliency concerns (Church et al., In Press). Finding a way to continue "the Montana model" of collaborative conservation while preventing re-enrolled programs from becoming less co-produced and more contributory, will allow the programs to have their maximum amount of reflexivity to key stakeholders. Co-produced knowledge from volunteer water monitoring should be more salient to communities when program goals are responsive to local desires.

<u>Barrier: Legislation</u>

The legislative barriers to data use are difficult to overcome. These were the barriers noted both by us and by earlier research efforts in distinct contexts (Brasier et al., 2017; Cosens et al., 2014). Unfortunately, there is little the lone practitioner, academic, or community organizer can do to address this issue directly.

Legislation that impacts the use of volunteer collected data may have been designed to foster good data-driven decision-making. For example, representatives of both DEQ and NorthWestern Energy expressed having to meet both higher data quality standards and higher water quality criteria through the state, than is mandated by the Clean Water Act or the EPA. These requirements simply impose standards on data collection that are far beyond what scientists and state agency staff believe are needed to establish credibility. Opportunities to use data generated from sources that have historically struggled with establishing credibility (like volunteer collected data) are often only opened when pathways to data-driven decision-making are under attack in legislation.

It is easy to affirm that state and federal legislators need to work on providing pathways for the use and sharing of volunteer collected data. However, this is a call to action for so few. I suggest that addressing the barriers unique to the “Montana model” of conservation will be a more likely path toward successful governance.

Barrier: Data Purgatory

The final barrier to the use of volunteer-collected data was data-purgatory. Data-purgatory is simply the long period between data collection and valorization and use by a research scientist. This purgatory period is not long due to negligence but a necessity, as the process of science moves slowly due to the reflexive nature of the expert consensus system (Oreskes, 2019). Recall, however, that this process is the most membranous barrier, and by its very nature the data will cross it. Ultimately, this too is simply a problem of salience, as data are simply not useful to scientists until the credibility of volunteer collected data is reaffirmed by the scientific community. Kimura and Kinchy (2019) observed a similar issue, noting that sometimes professional scientists will simply discard volunteer collected data even if it is credible.

While this issue of outright discarding is not present in Montana due to the collaboration between monitoring programs and MSUEWQ, science operating at its historical pace still does not produce results fast enough to account for the dramatic changes to socionatural systems from anthropogenic interference (Cosens, et al. 2021). Site selection for remediation was mentioned several times by interviewees as a way program managers have used data. I suggest that program managers include a data use element in their sampling analysis plans and this element focus on how they might be able to use data to inform future remediation projects. In addition, some decision-makers used iterative models to help predict outcomes and drive decision-making. These models used years of historical data to understand the nature of Montana's irregular rivers but often excluded volunteer collected data either due to a lack of salience or a lack of historical data at consistent sites. I also suggest that after completing the initial trend analysis, programs consider how the data they collect might be able to contribute to predictive modeling.

A focus on project selection and project outcome monitoring should not detract from the collection of long-term datasets for trend analysis. The valorization of data for trend analysis will continue, but it will no longer be "purgatory" if the data are valorized faster for other purposes such as site selection or to inform models.

Future Dimensions

Any time a researcher is investigating the process of technoscience, actor network theory (ANT) is always an option for analysis. I recognized that this is the approach that should be taken when studying complex relationships formed when many actors attempt to resolve scientific controversy and allowed concepts from ANT to inform my analysis. However, this was not a complete ANT. This work was too narrow in scope and completed over too short a period to perform a detailed ANT analysis. The analysis presented in the previous chapters is in many ways preliminary. Continued study of the five included cases is needed to complete an understanding of the worknet. This research should include more participant observation and more conversations with more decision-makers working in communities that have a VWMP. One way I am expanding upon the existing case studies is through a longitudinal exit survey of volunteer water monitors across the state of Montana. Four of the cases in this research have agreed to participate alongside two other programs. To design the survey, I used an informed nested mixed methods approach. Information garnered from the interviews was used to design salient questions for the survey making it more reflective of volunteer experiences.

One important dimension unexplored in this work is a thorough exploration of the mechanics behind how scientists utilize and valorize volunteer collected data. I suggest that a longitudinal ethnographic approach be adopted. This is more in line with traditional actor network approaches to studying technoscience (Latour, 1987; Latour, 2010). One interviewee did discuss the processes by which their colleagues valorized or ignored "citizen science" programs. I suggest that exploring this process in depth will reveal how the academy can become a stronger ally of citizen groups focused on local governance.

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APPENDICES

APPENDIX A

INTERVIEW GUIDES

INTERVIEW GUIDE: Volunteer

Section 0. Warm-Up/Icebreakers
Check in with them, remember to thank them for their time! Remind, them that this interview is about {Name of program}. Remind them participation is voluntary and ask for permission to record.

Section 1. Program and Personal Information
Q1. Please describe your role as a volunteer for {program of interest}.

- How long have you volunteered with {program of interest?
- Have you attended any large-scale water monitoring events (like blitzes)? What did you do during these events?
- Have you engaged in any long-term monitoring (like traditional stream teams)? Can you describe what you did during this monitoring?
- Have you trained other volunteers in an official capacity? Can you describe that experience?

Q2. How, if at all, are you involved in research/program design?

- How if at all are you involved in data analysis?

Q3. To the best of your knowledge, what are {program of interests} primary goals?

- How, if at all, does your volunteer work contribute to science?
- How does your work as a volunteer address environmental issues in {Watershed}?

Section 2. Scientific Literacy/Ecological Literacy
Q4. We are interested in discussing the value of science and how it applies to your experience as a volunteer. The following question is very broad, and you do not need to have a perfect answer. How do you define “Science”?

- How do you define “Citizen Science”?

Q5. In what ways has your participation in this program enhanced your understanding of science?

- How has your participation enhanced your understanding of how {Watershed} works?
- How has your participation enhanced your understanding of the ecology of {Watershed}?

Q6. What role does science play in your day-to-day life?

- Do you consider yourself to be a scientist? Why or why not?
- Do you think what you are doing as a volunteer is science? Why or why not?
- Do you think what you are doing as a volunteer contributes to science at all? Why or why not?

Section 3. Use of Data and Diffusion

Q7. We are interested about how, if at all, you talk about your experiences with water monitoring. Can you tell me about a time where you have discussed your volunteer experiences or other water quality issues with family? → prompt about where the conversations happen, what was discussed, use maps in prompting

- What about a time when you have had a similar discussion with friends?
- What about a time when you have had a similar discussion with strangers?
- Are there any other types of people you've had these kinds of conversations with?
- Do you ever try and link these discussions to your program's goals? How?

Q8. I am interested in exploring {program of interests} reach. Especially related to these types of conversations we just spoke about. How far away from here have you had a conversation related to your program?

- Was this conversation facilitated by social media? Travel? How did that play a role in the tone and content of the conversation?

Q9. Do you think about the volunteer experience during other points in your life? When, if ever do you, do this?

- How do you relate your experience as a volunteer to your daily life?

Q10. How, if at all, has support for water resources in {Watershed} changed over the past 5 years?

- Why do you think that is?
- How, if at all, did your work as a volunteer help change support for water resources in {Watershed} over the last 5 years/your time as a volunteer? (Whichever is shorter)

Section 4. Saliency and Legitimacy of Water Data

Q11. We are interested in finding out about how you use different sources of information to make decisions relating to water use. What information sources do you find to be trustworthy? What information sources do you find to be untrustworthy? Why?

- Support with examples, journals, social media, news media, friends

Q12. Are there any sources that you trust more than scientifically collected water monitoring data when learning about Water? What are they?

- Why do you trust these sources more?
- What about sources you trust when learning about {Watershed}?

Q13. In your opinion, does it matter who collects water data? Why?

- How confident do you feel about the data collected in your program? What about the data you collected yourself?
- How do you feel about data collected by volunteers overall?
- What about data collected by the USGS/DEQ/researchers at a university? Why?

Q14. We believe your {program of interest} does work in the {Watershed} [use map to demonstrate watershed locations, prompt about areas outside of home watershed, prompt if watershed definition "makes sense" to them.]

- What does {Watershed} mean to you?
- How long have you lived here?

Q15. Can you think of anything you do to protect water resources in {Watershed}?

- How has your experience as a volunteer contribute towards your decision to protect or not to protect water resources in {Watershed}?
- How would you respond to a program to protect water resources in {Watershed} that was accompanied by a utility rate or tax increase?

Q16. Finally, we are interested in your thoughts about water in general. What does water mean to you?

- What about water data?

INTERVIEW GUIDE: Decision Maker

Section 0. Warm-Up/Icebreakers
Check in with them, remember to thank them for their time! Remind, them that this interview is about {Name of program}. Remind them participation is voluntary and ask for permission to record.
Section 1. Personal Information
Q1. What is the primary role of your position?

- How if at all does your position relate to water resources?

Q2. Do you have any professional goals related to environmental policy? What are they?

Section 2. Scientific Literacy/Ecological Literacy
Q3. We are interested in discussing the value of science. The following question is very broad, and you do not need to have a perfect answer. How do you define "Science"?

- How do you define "Citizen Science"?

Q4. How do you engage with science in your day-to-day life?

- Do you consider yourself a scientist? Why or why not?

Section 3. Use of data and diffusion
Q5. Are you aware of {program of interest}?

- What is your impression of {program of interest}?
- *Be prepared to define volunteer water monitoring.*

Q6. How, if at all, has support for water resources in {Watershed} changed over the past 5 years?

- Why do you think that change has happened?
- What do you think the role of {program of interest} was in this change?

Q7. We are interested about how, if at all, you have been approached by individuals to discuss water resource issues. Can you think about a time recently where someone has discussed water monitoring with you? → prompt about where the conversations happen, what was discussed, use maps in prompting. Be prepared to define volunteer water monitoring.

- What about a time when you have had a similar discussion with a family member?
- What about a time when you have had a similar discussion with friends?
- What about a time when you have had a similar discussion with strangers? Were any of these conversations facilitated by travel or the internet?
- Have you ever approached someone to start a similar conversation? Can you tell me about a time where you have?
- Were these conversations ever linked to {program of interest} or any other specific volunteer water monitoring programs? How?

Q8. We are also interested in your decision-making process. Do you regularly use any scientific information in your decision making, why or why not?

- Are there particular sources of scientific information that you trust more than others? What are they?
- Are there particular sources of scientific information that you trust less than others? What are they?

Section 4. Saliency and Legitimacy of Water Data
Q9. We are interested in what sources you use to make decisions related to water use issues. What information sources do you consider trustworthy? What information sources do you find untrustworthy? Why?

- Support with examples, journals, social media, news media, friends, individual scientists, extensions

Q10. Are there any sources of information that you trust more than scientifically collected water monitoring data when making decisions about {Watershed}? What are they?

- Why do you trust these sources more?

Q11. How do you use water data in your official decision making?

- Can you tell me about a time when you used water data collected by {program of interest}?
- How, if at all, do you use these data in your personal life?
- Can you tell me about a time when an individual has asked you to use water data to make a decision?

Q12. In your opinion, does it matter who collects water data? Why?

- Do you trust data collected by volunteers? What about data collected by the USGS/DEQ/researchers at a university? Why?
- How does this trust/lack of trust effect your decision making?
- What kind of water data would you like to see that would help you make decisions? → be prepared for quantity answers, prepare examples of water data

Q13. We are interested in issues relating to the {Watershed}, use map to demonstrate watershed locations, prompt about areas outside of home watershed, prompt if watershed definition “makes sense” to them.

- What does {Watershed} mean to you?

Q14. Can you think of anything you do to protect water resources in {Watershed}?

- How do you think information about local water issues has affected how receptive you are to helping address these issues?
- How has data generated by {Program of interest} help you adopt any of these practices?

Q15. Finally, we are interested in your thoughts about water in general. What does water mean to you?

- What about water data?

INTERVIEW GUIDE: Program Managers

Section 0. Warm-Up/Icebreakers
Check in with them, remember to thank them for their time! Remind, them that this interview is about {Name of program}. Remind them participation is voluntary and ask for permission to record.
Section 1. Program and Personal Information
Q1. Please describe your role in your organization.
- What about your role with volunteers?
- How long has the {program of interest} been operating? *(If unknown)*
- How long have you been working at your organization?

Q2. Please tell me about your volunteer water monitoring program.
- What roles do volunteers play in water monitoring? Could you describe any other ways volunteers contribute to your program?
- In any given year, about how many staff members work on this program? What about unpaid volunteers? Do these numbers remain consistent throughout every year?

Q3. We believe your program does work in the {Watershed} [use map to demonstrate watershed locations, prompt about areas outside of home watershed, prompt if watershed definition "makes sense" to them.]
- What does {Watershed} mean to you? What does your work in {Watershed} mean to you?
- How long have you lived in {Watershed}?

Q2. What are the primary goals of your volunteer water monitoring program?
- How did you come up with these goals? Are they listed in any public facing documents?
- What questions are your program trying to answer?
- How, if at all, does your program contribute to science?
  - Do you consider your program scientific research? Why or why not?
  - Do you consider yourself to be a scientist? Why or why not?
- Do you have any educational or outreach initiatives? Can you tell me about them?
  - How might these initiatives help you to achieve some of your previously stated goals?
  - Do you think these initiatives help foster scientific inquiry? Ecological Literacy? How?

Q4. Can you walk me through one of your recent water monitoring events that involved volunteers?
- How, if at all, are volunteers involved in research design?
- Does your program involve volunteers in data analysis at all? How?
- What methods did you use to collect water data in this event?

- What water metrics (types of water data) do you typically collect?
    - Are there any types of data you avoid collecting? Why?

Q5. We are interested in how your organization uses and disseminates your data. How does your organization use volunteer collected data?

- Can you take me through how your organization uses this data in its decision making?

- How are the data collected by your program used by groups outside of your organization?
    - How did these groups become aware of your organization?
- How, if at all, do you use these data in your personal decision making?
- Can you tell me about a time when these data have been used in state level policy making? → Prompt about local level.
- Can you tell me about a time where you have tried to convince an individual to use your data?
- What types of water quality data are useful for achieving your program's goals?
- Can you tell me about a time where the credibility of your organizations data was challenged?
- Do you use water data from any other organizations? What organizations and why?
- What sources of water data to you find especially trustworthy? Are there any sources of water data you find to be especially untrustworthy? Why?

Section 3. Use of Data and Diffusion

This next series of questions will begin to move away from discussing your program and will instead focus on your personal experiences. I will give you a moment to switch gears…. Are you ready to begin?

Q7. We are interested about how, if at all, you talk about your experiences with water monitoring and organizing your program. Can you tell me about a time where you have discussed your work with others?

- prompt about where the conversations happen, what was discussed, use maps in prompting. What was the setting of the conversation, bar, conference, family dinner, church etc.
- What about a time when you have had a similar discussion with friends?
- What about a time when you have had a similar discussion with strangers?
- What about a time when you have had similar discussions with colleagues/peers?
- Do you ever try and link these discussions to your program's goals? How?

Q8. I am interested in exploring your program's reach. Especially related to these types of informal conversations we just spoke about. How far away from here have you had a conversation related to your program?

- Was this conversation facilitated by social media? Travel? Conferences? How did that play a role in the tone and content of the conversation?
- Why did you mention your program?

Q9. How, if at all, has support for water resources in {Watershed} changed over the past 5 years? {Or their time in the watershed, whichever is shorter}

- Have you noticed a shift in public support? What about decision maker support? Why do you think that is?
- How do you think the presence of your program affected support for water resources in {Watershed} *over the past 5 years/course of the program's lifetime/their time in the watershed {Whichever is longest}?*

Section 4. Saliency and Legitimacy of Water Data

Q10. In your opinion, does it matter who collects water data? Why?

- How confident do you feel about the data collected in your program?
- What about data collected by volunteers overall?
- (If low confidence) What would it take to make you more confident in volunteer collected data?
- → Prompt them on how their answers effects the management of their program

Q11. Finally, we are interested in your thoughts about water in general. What does water mean to you?

- Why is data about water quality useful?

APPENDIX B

CODEBOOK

Codes

Name	Description
1_Substantive_Codes	Descriptive codes that provide insight
1_A_Organizational_History	Codes relating to the evolution of the cases
1_A_a_Leadership_Change	Interviewees discuss taking on new leadership roles or how changing leadership of a program has effected its structure.
1_A_b_Goal_Setting	Interviewees discuss program goals or goal setting processes
1_A_c_Inciting_Incedents	A discussion of a single incident that helped begin or dramatically alter a programs structure. Can be an inciting incident of a VWMP or other program
1_A_d_General_History	Relevant histories of the programs unconnected to the previous codes
1_B_Collaborations	This code signifies their are more than one organization working on a project/program.

Name	Description
1_C_Autologgers	Interviewees discuss the use of autologgers in their program. Autologgers have been shown to correlate with disengagement and issues with clear goal settings (Jalbert and Kinchy, 2016).
1_D_Educational_Activities_Programming	Interviewees describe their participation in some kind of educational or outreach programming, This can include participation, design, or general discussions of outreach
1_E_Diffusion_of_Information	This code indicates discussions of the diffusion of water information. As opposed to learning this code highlights conversations. Not clear "teaching/learning" relationships.
1_B_b_Formal	Diffusion occurs in a formal setting or situation; Examples may be presentations to watershed groups or diffusion that occurs during monitoring events. Intentionally communication strategies

Name	Description
	may be included in this code as well as conversations with ecology and hydrology professionals.
1_E_a_Informal	Diffusion has a sense of informality or comfort. Diffusion coded here takes place with friends or family members or outside of formal settings such as on the river or in the home,
1_F_Stewardship	Interviewee expresses an attitude of watershed stewardship or directly addresses watershed stewardship ("being a good steward"...)
1_G_Communication_Barriers	Interviewee identifies common scientific communication challenges
1_H_Covid_19	The Covid-19 pandemic or its effects are mentioned
1_I_Local_Knowledge	Interviewee demonstrates or utilizes local knowledge of watershed issues. Knowledge that they brought to the program from informal settings

Name	Description
1_J_Learning	Interviewee discuss learning processes, demonstrates something they have learned, or talks about observing learning. This code is further subdivided into different kinds of learning/cognitive engagement according to Philips et al. 2019. This subdivision only occurs in volunteer interviews.
1_P_a_Behavior_Changed	Participants adopt a new behaviour as a result of participating in a program or as a result of their career as a water professional. This code was developed previously to the application of the Philips et al, 2019 learning outcomes of engagement framework. It is included with the learning codes because it is a learning outcome of the framework.
1_P_b_Experential_Learning	"Something they learned because of direct observation or "hands-on" experience with the project." - Philips et al. 2019

Name	Description
1_P_c_Project_Resources_Artefacts	"Using project resources and artifacts for new knowledge acquisition" - Philips et al. 2019
1_P_d_Learning_from_Others	Social Learning "Learning through interactions with others" - Philips et al. 2019
1_P_e_Increased_Awareness	"Increased awareness of some phenomenon as a result of participation" - Philips et al. 2019. Typically, this is increased environmental or ecological awareness.
1_P_f_Scientific_Understanding	"New understanding of or appreciation for citizen science, how science works as a function of engaging in science practices, or understanding of citizen science or their role in science through citizen science" - Philips et al. 2019
1_P_g_New_Skills	"New skills or tool use acquired as a function of practice" - Philips et al. 2019

Name	Description
1_K_Data	A parent code for all codes relating to data, data use, data collection, etc.
1_K^(-1)_Data_Ignored	Used to indicate when interviewees do not know how data are used, do not use data themselves, or express uncertainty with how data are used/analysed. This code is only applied for VWMP data
1_K^(-1)_b_Other_Data	This code is for when data from non volunteer sources are not used or passed up. Do to the structure of the interviews this code is sparesly used.
1_K_a_Use_of_Data	Interviewee discusses a time when data were used in decision making or as part of communications/outreach. This code focuses on VWMP data but includes all data used for any purpose, this is an aggregate code.
1_K_a_1_Volunteer_Data	Volunteer Data are used in communications or to drive decision making. Volunteers are aware of program

Name	Description
	goals and how they relate to the use of their data.
1_K_a_2_Other_Data	Other sources of data are used to drive decision making. Importantly this shows volunteers and decision maker data literacy and connects to trust.
1_K_b_Data_Hub	Data being deposited in a Hub/clearinghouse.
1_K_c_Hard_Facts	Someone mentions facts, the settling of something, or the idea that data speak for themselves
1_K_d_Data_Purgatory	Data in a Hub are being waited on. Waiting for Go-data. Data are being processed or valorised by a professional (Adam).
2_Theoretical_Codes	Prescriptive codes that identify what theoretical links
2_1_ANT	Codes relating to actor network theory. These codes are broad. Each classification (case) will have its own unique

Name	Description
	controversies, programs, and actors. These codes are used to provide lists for future analysis
2_1_A_Actors	This code denotes that the interview has identified an object as an actor in their worknet
2_1_B_Programs_and_anti-Programs	This code denotes a participant discusses one of the programs in their worknet.
2_1_C_Controversies	An interviewee discusses something that has not yet been decided upon or finalized. A lot of the time these are conventionally controversial, but the code specifically means that truth or a way forward are still at large.
2_2_Construction_of_Scientific_Facts	Theoretical codes related to STS
2_2_A_Volunteers_as_Instruments	Volunteers are being used as instruments in one organizations "laboratory". Volunteers are doing tasks on the low end of the engagement spectrum.

Name	Description
2_2_B_Research_Questions	There is a clearly defined research question or objective
2_2_C_Research_Design	This code indicates a discussion of research design. This code is extremely common across the cases. Much like the ANT codes this code cannot be used on its own for analysis but instead can be used as a pointer to understand how each classification (case) is structured.
2_2_D_Volunteers_Engaged	Volunteers taking roles beyond data collection instruments. Volunteers doing something at the higher end of the participation spectrum.
2_2_E_Professional_Scienitsts	Non-volunteer actors collecting/analysing data. Discussion of the role/participation of professional scientists in data collection.
2_2_F_Non_experts	Discussion of the value or role of non-experts to data production

Name	Description
2_3_Trust	Codes related to theories of trust/establishing trust/trust vs use
2_3_B_Saliency_Credibility_Legitmacy	Where does trust generation sit in the Cash et al. framework?
2_3_B_a_Credibility	A source or data is credible or reliable
2_3_B_a^(-1)_Lack_of_Credibility	
2_3_B_b_Saliency	A source or type of data is Salient or useful
2_3_B_b^(-1)_Insaliency	
2_3_B_c_Legitimacy	A source is discussed as legitimate. Parallel to affinitive.
2_3_B_c^(-1)_Illegitamate	
3_Interview_Group	
3_A_Volunteer	
3_B_Program_Manager	
3_C_Decision_Maker	