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To cite this article: Kathleen Torso , Courtney Marie Cooper , Andy Helkey , Chris Meyer , Anne L. Kern & Chloe Bradley Wardropper (2020): Participatory research approaches in mining-impacted hydrosocial systems, Hydrological Sciences Journal, DOI: [10.1080/02626667.2020.1808218](https://doi.org/10.1080/02626667.2020.1808218)

To link to this article: <https://doi.org/10.1080/02626667.2020.1808218>



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Published online: 15 Sep 2020.



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Participatory research approaches in mining-impacted hydrosocial systems

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ABSTRACT

As demonstrated by Indigenous and rural scholars, participatory research approaches can facilitate capacity building, promote data accessibility, and accomplish community goals within complex hydro-social systems. To demonstrate challenges and opportunities for participatory research, we describe hydrosocial territories in a mining-impact region in northern Idaho. We then compare two community-university partnerships in the study region, which included Tribal and non-Tribal rural communities. We find that the Participatory Action Research and Indigenous Research Methodologies frameworks provide a robust set of practices and methods for conducting more equitable and inclusive research. Further, participatory research approaches in research involving mining-impacted hydrosocial systems should: (1) build from established programs, goals, and practices; (2) identify respectful levels of partnership engagement, and (3) recognize partnership limitations. Future inquiry in complex hydrosocial systems should continue to build from the existing collection of participatory scholarship to address power imbalances and cultural differences and implement non-intrusive approaches to evaluate outcomes.

ARTICLE HISTORY

Received 17 August 2019
Accepted 18 June 2020

EDITOR

S. Archfield

GUEST EDITOR

M. Sanderson

KEYWORDS

hydrosocial territories;
Participatory Action
Research; Indigenous
Research Methodologies;
mining-impacted regions

Introduction

The emerging field of hydrosocial research offers promise for understanding regarding the relationships between water and society (Linton and Budds 2014). However, there is a lack of clear direction on how to design equitable and inclusive interdisciplinary research that addresses traditional power imbalances in communities and between researchers and communities (Jepson *et al.* 2017, Wutich *et al.* 2019). Scholars have advocated for replacing linear models of knowledge production, where knowledge has a unidirectional flow from researchers to communities, with participatory research where knowledge is co-created (Mach *et al.* 2020). While participatory research approaches are more often discussed in hydrosocial research, they are also important to researchers in sociohydrology (Wesselink *et al.* 2017). For instance, participatory research approaches can provide ways for models in hydrosocial to be more reflective of a reality in which values, norms, and behavioral responses influence governance outcomes (Roobavannan *et al.* 2018). In this paper, we refer to research about water and society as hydrosocial research for simplicity, noting Ross and Chang (2020) recent argument that hydrosocial research and sociohydrology are “two sides of the same coin.”

Participatory research fits within a number of methodological frameworks (e.g. Hall 1992, Cornwall and Jewkes 1995, Ferreira and Gendron 2011, Mackenzie *et al.* 2012), but at its core, this research aims to guide inquiry that addresses systemic power imbalances through capacity building to promote community voices and goals, improve data accessibility, and enhance scientific literacy (Finn and O’Fallon 2015, Marques

et al. 2018). Participatory research is often conducted through partnerships between university researchers and communities (e.g. Martenson *et al.* 2012, Datta *et al.* 2015, Caxaj 2015). Participatory approaches, while time intensive, can guide research in more equitable and inclusive directions that are sensitive to local contexts and meet rigorous standards for scientific research (Hacker 2013). A primary reason for the growing popularity of participatory research is the recognition that social context and community partnerships have value (Leung *et al.* 2004, McMillan 2012, Wilmsen *et al.* 2012). Hydrosocial researchers have used participatory research to integrate different forms of knowledge and knowledge production systems in efforts to diffuse and contextualize power (e.g. Berry *et al.* 2018, Wutich *et al.* 2019) and advance water security and water governance (e.g. Zoanni 2017, Arsenault *et al.* 2018). Recommendations and best practices for conducting equitable and inclusive participatory research is important because a robust collection of case studies is needed to guide future research.

In this paper, we compare two participatory research partnerships related to environmental contamination, water, and society within the same mining-impacted region of northern Idaho, USA. The region includes a rapidly growing urban center, a rural Tribal community and other rural communities that were established to support natural resource extraction. The Tribal research partnership is between the Coeur d’Alene Tribe and university researchers, while the Silver Valley partnership is between university researchers, community members in an area known as the Silver Valley, and the Panhandle Health District (District). This paper’s reflection is guided by

our perceptions and experiences as members of the partnerships. In the following sections, we provide a description and history of the region, followed by a summary of both partnerships and the participatory approaches employed. In our descriptions of the research partnerships, we acknowledge researcher positionality, as positionality is influenced by cultural norms as well as education and professional fields which drive personal interests, research directions, and collaboration (von der Porten *et al.* 2016). Then we reflect and compare the application of participatory research approaches between the two research partnerships by analyzing three primary research elements of the partnerships. The elements include: (1) establishing a research agenda; (2) promoting community voices and goals, data accessibility, and literacy; and (3) maintaining ethical partnerships. Structuring the comparison around the three primary research elements provided a way to compare participatory research approaches between the two partnerships even though they were guided by different participatory research frameworks.

Our analysis is based on formal conversations conducted with five key partnership members during the spring and summer 2019. Members were selected based on their involvement with each study or program affiliated with the community-university partnership and specific knowledge of the partnership objective and affiliated studies. The research design was reviewed by the University of Idaho's Institutional Review Board for the use of human subjects (please refer to Supplemental Material, letter of IRB approval). Interview participants are given pseudonyms to ensure confidentiality. The findings from our partnership comparison

inform a set of recommendations for conducting participatory research about water and society in rural and Indigenous communities.

Study region: hydrosocial territories

One way to understand complex narratives about water and society is by describing characteristics of *hydrosocial territories*. Hydrosocial territories are “socially, naturally and politically constituted spaces that are (re)created through the interactions amongst human practices, water flows, hydraulic technologies, biophysical elements, socio-economic structures and cultural-political institutions” (Boelens *et al.* 2016). We use the hydrosocial territories concept to frame our overview of mining impacts in the study region in order to show the complexity of efforts to manage mine waste contamination and to briefly map and characterize complex jurisdictional boundaries that influenced the development of the two community-university partnerships.

The study region is located in the northern Idaho panhandle and is composed of the Coeur d'Alene and lower St. Joe subwatersheds, spanning a mining-impacted drainage area of 5,225 km² nested within the greater Spokane River Watershed (USGS 2013) (Fig. 1). Within this drainage area, the Coeur d'Alene River flows west from the Idaho-Montana state line for approximately 85 kilometers before reaching the dam-controlled Coeur d'Alene Lake (Restoration Partnership 2018). About 109 million metric tons of mine tailings were produced through mining activities in the Silver Valley and an estimated 60% of these materials washed into the mainstem

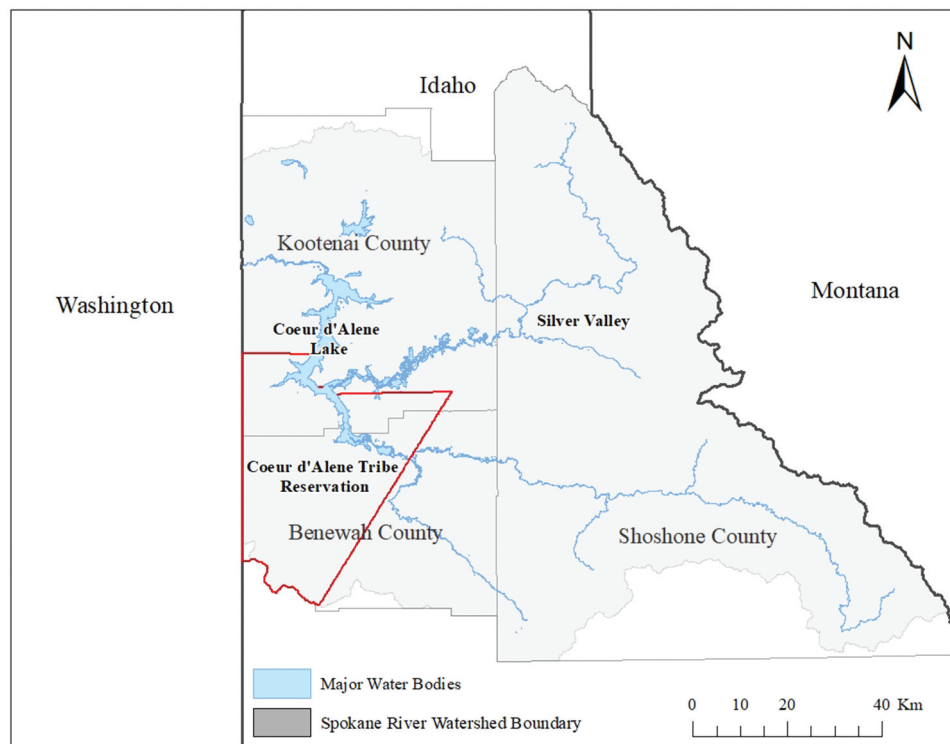


Figure 1. Map illustrating the hydrosocial territories of the study region, which includes three counties (Benewah, Kootenai, Shoshone), jurisdictional boundaries of the Superfund Site, as well as geographical boundaries for the Spokane River Watershed, Coeur d'Alene (CdA) subwatershed, and St. Joe subwatershed. HUC = Hydrologic Unit Code. Source: USGS Watershed Boundary Dataset, Alta Science and Engineering, Coeur d'Alene Tribe of Indians (accessed at Koordinates.com).

and adjacent floodplain of the Coeur d'Alene River (NRC 2005). In 1983, the region was listed as a Superfund site on the National Priorities List under the Comprehensive Environmental Response, Compensation, and Liability Act or CERCLA (NRC 2005).

Since then, the US Environmental Protection Agency (US EPA) has conducted extensive Superfund remediation (under CERCLA), at the Bunker Hill Superfund Site in the Silver Valley (NRC 2005). The most intensive Superfund remediation activities have occurred in a 21 km² area known as “the Box,” which once contained a lead smelter and extensive mining infrastructure. In addition, a large portion of the region was listed on CERCLA’s National Priorities List, which initiated a Natural Resource Damage Assessment and Recovery (NRDAR) process that continues to prompt restoration and remediation activities. The region remains heavily contaminated at abandoned mine sites and in the mainstem, tributary streams, and floodplain of the Coeur d'Alene River where the mine waste was directly discharged and is now distributed by annual high flow events (Gustavson *et al.* 2007, Bookstrom *et al.* 2013, Langman *et al.* 2018). A 2009 settlement with ASARCO Mining and Smelting Company for US\$436 million provides resources for continuing restoration and remediation activities within the boundaries of the Institutional Controls Program (Restoration Partnership 2018).

The hydrosocial territories of the region are socio-politically divided by county boundaries (NRC 2005, US Census Bureau 2010). The Coeur d'Alene Tribe’s reservation boundaries overlap with Benewah County, the Silver Valley is in Shoshone County, and the growing city of Coeur d'Alene is located in Kootenai County (Table 1). The socio-demographic characteristics in Benewah and Shoshone County are similar; their populations are poorer, more rural, and less educated relative to Kootenai County, and most other counties in Idaho. Over 20% of Shoshone County’s population under the age of 65 is on disability (benefit). Benewah County contains the smallest population, with 8.5% of its population being American Indian and Alaskan Native. Kootenai County, Idaho’s third largest county, reflects a growing population and a socio-economic status that either exceeds or is similar to average for Idaho. Coeur d'Alene Lake is a primary reason for growth in Kootenai County as shoreline development, featuring

multiple resorts and residential development, has increased in recent years (Criscione 2018).

Investigating the nature of the hydrosocial relations experienced by the Tribe as well as rural communities in the Silver Valley following the collapse of the mining industry provides insight into the different ways that Shoshone and Benewah County have arrived in similar socio-demographically underprivileged positions relative to Kootenai County and the rest of Idaho. Events in the 1970s, including a downturn in the global economy, a public health crisis from acute lead toxicity, and new environmental regulations, brought an end to primary mining activities in the Silver Valley (Mix 2016). Blood lead screenings in this decade revealed that 99% of Silver Valley area children had a blood lead level greater than 40 micrograms of Pb per deciliter of blood (µg/dL), with the highest recorded at 164 µg/dL (Idaho Department of Health and Welfare 1976, von Lindern *et al.* 2003). Subsequent Superfund cleanup in the Silver Valley included remediation of 7,153 properties and removal of primary mining infrastructure. As of 2018, social and economic conditions are slowly improving as economic redevelopment activities progress and childhood blood lead levels approach national averages (Helkey 2018). Redevelopment strategies in the Silver Valley have included development of trails and recreation areas that further contribute to the strong connection with place found in Silver Valley communities.

Remediation activities, such as source control and water treatment remedies, are a major focus of management in the Silver Valley (BEIPC 2019). The Panhandle Health District manages two programs that support continued efforts to protect human health and the existing environmental remedy – the lead health intervention program and the Institutional Controls Program (Panhandle Health District 2018). Local control of these programs has allowed the District to develop – and continually adapt – programs that are more effective in protecting health in the tightknit communities of the Silver Valley. For instance, in 2018, the District posted new warning signs at popular recreation areas to better communicate remaining health risks from primary contact with lead contamination (Helkey 2018). The new signs were developed in close consultation with community groups.

Although the socio-economic situation in Benewah County appears similar to that of Shoshone County and the Silver

Table 1. Select socio-economic characteristics of counties in the study region.

Demographic	Benewah County	Shoshone County	Kootenai County	State of Idaho
<i>Population</i>				
Total	9,226	12,796	161,505	1,787,065
Population density (per km ²)	31.1	12.7	288.3	49.2
<i>Race</i>				
White	86.6%	94%	94.5%	93.0%
American Indian and Alaskan Native	8.5%	1.8%	1.3%	1.7%
<i>Education</i>				
High school graduate or higher	88.3%	85.6%	92.5%	90.6%
Bachelor’s degree or higher	15.1%	11.6%	24.9%	26.9%
<i>Health</i>				
Disability, under the age of 65	13.2%	20.3%	9.1%	9.3%
<i>Income & Poverty</i>				
Mean household income	\$46,507	\$39,091	\$54,457	\$53,089
Persons in poverty	14.7%	18.8%	10.3%	11.8%

Valley, the hydrosocial narrative of the Coeur d'Alene Tribe is quite different. The Coeur d'Alene Tribe has been and continues to be disproportionately impacted by hazardous waste as a result of Federal Indian policy guided by the ideals of the Doctrine of Discovery¹ and Manifest Destiny² (Royster 1993). The Coeur d'Alene Tribe is a sovereign nation that has occupied the region since time immemorial (Frey and Stensgar 2012). Mining activities in the Silver Valley were a primary driver for European settlements and a source of disruption and severe hardship within the Coeur d'Alene Tribal community (Mix 2016). To maximize the economic potential of the region, the Coeur d'Alene Indian Reservation boundary was finalized under an executive order of 1891, which subsequently reduced Tribal authority over ecosystem governance (Woodworth-Ney 2004). Mining challenged the Coeur d'Alene Tribe's ability to self-govern by transforming the social and ecological landscape. The mining industry directly threatened the Tribe's water security and governance, a common outcome for many mining impacted Native American Tribes across the western United States (e.g. Montoya 2017, Curley 2019a, 2019b). Today, metal contamination jeopardizes the well-being of the Tribal community by limiting access to culturally significant foods and recreational activities. For example, contaminated wetlands throughout the lower reaches of the Coeur d'Alene River have compromised flora and fauna that are culturally and spiritually significant to the Tribe such as water potato (*Sagittaria latifolia*), a traditional food source for the community (Campbell *et al.* 1997). Collectively, contaminated resources threaten the cultural values and subsistence practices of the Tribe, thereby affecting their self-determination.

Mitigation efforts administered by the Tribe reflect a holistic perspective focused on improving ecosystem health

from a seventh-generation perspective (LMP 2009). The Tribe prioritizes restoring damaged ecological and cultural resources (i.e. water potato) through mitigation, remediation, and restoration methods. These methods are informed by scientific monitoring and management efforts administered by scientists employed by the Tribe and the State of Idaho (LMP 2009). Scientific data is a critical component for the preservation of place and acknowledgement of Tribal sovereignty (i.e. inherent right to govern) for Native Nations (McCarty and Lee 2014). The Tribe's sovereignty within reservation boundaries and its aboriginal territories, which expand beyond the catchment boundaries, has supported these efforts.

The diversity of priorities and stakeholder groups in this region, along with years of contentious governance, have led to the establishment of several carefully planned collaborative institutions in the region. These institutions include the Basin Environmental Improvement Project Commission (BEIPC) and the Restoration Partnership (Fig. 2). Together, these collaborative bodies set joint priorities and resolve conflicts between groups. BEIPC was established by the Idaho Legislature under the Basin Environmental Improvement Act of 2001 (section 39–8105) to coordinate environmental remediation, natural resource restoration, and related measures to address water quality and heavy metal contamination (State of Idaho 2002). BEIPC's purpose and function are outlined by a Memorandum of Agreement between seven primary governments including the federal government, Coeur d'Alene Tribe, States (Idaho and Washington), and the three counties (Benewah, Shoshone, Kootenai) (State of Idaho 2002).

The Restoration Partnership is a product of years of planning and a series of lawsuits. Partners – called Natural Resource

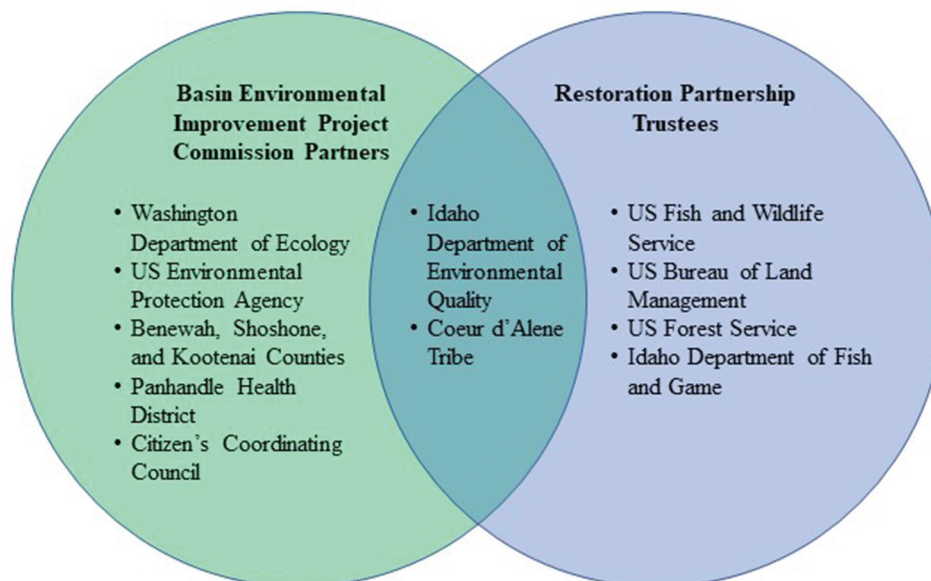


Figure 2. Primary partners included in collaborative groups related to mining impacts.

¹The Doctrine of Discovery was an international legal principle that justified the settlement of non-European territories inhabited by Indigenous communities by European nations (Miller 2011).

²Influenced by the Doctrine of Discovery, Manifest Destiny was a concept implemented by the American government to give reason for the westward expansion and conquest of Native American Tribal territories to spread the religious and governance practices reflective of the American society (Miller 2011).

Trustees in CERCLA – include the Tribe, State of Idaho, and Federal government. A series of lawsuits between Trustees and mining companies, including the 2009 settlement with ASARCO Mining and Smelting Company, provides the Trustees with resources for conducting restoration and remediation activities within the boundaries of the Institutional Controls Program (Restoration Partnership 2018). In 2018, a final Restoration Plan, aligned with the Environmental Impact Statement for recovering damaged natural resources through NRDAR, was finalized with a goal of restoring, rehabilitating, replacing, or acquiring the equivalent of the natural resources and the services they provide injured by mine water contamination (CdA Natural Resource Trustees 2018). The two research partnerships described in this paper aimed to contribute to research that benefit the participants within these existing collaborations.

Theoretical frameworks

Reciprocal relations are a core value across participatory research approaches and invoke intimate, mutual obligations between place and people (Diver 2018). Reciprocal relations have been explored in hydrosocial research directly and in the common pool resources literature. Increased reciprocity motivates collective action by influencing social norms and individual decision-making (Ostrom 1990). In Indigenous communities, participatory research is more than a research practice, it is a political and ethical undertaking; Indigenous knowledge is rooted in a holistic knowledge system that is inseparable from the socio-cultural, political, legal, and relational structure (Mach *et al.* 2020). Diver (2018) contends that reciprocal relations are important in communities “seeking to regain not simply benefits, but rather mutually beneficial relationships and responsibilities to land, water, and resources” (p. 406).

Acknowledging the cultural values of the Coeur d’Alene Tribe, the Tribal partnership drew from of Participatory Action Research (PAR) approaches grounded in the fundamental principles of Indigenous Research Methodologies (IRM). For the Silver Valley partnership, PAR provided guidance for co-producing knowledge with a community group focused on ensuring that people can live safely in a place with a long history of industry and extraction. These frameworks

guide research development and help researchers to recognize elements of ethical research. Common elements of IRM and PAR include: (1) establishing a research agenda; (2) promoting community voice and goals, data accessibility, and literacy; and (3) maintaining ethical partnerships (Fig. 3). Ultimately, these frameworks helped researchers address questions summarized in Chambers (1998, p. 284): Whose categories and concepts count? Whose values and criteria? Whose preferences and priorities? Whose analysis and planning? Whose action? Whose monitoring and evaluation?

Participatory Action Research

Participatory Action Research (PAR) aims to facilitate more equitable and inclusive research by placing the research process in the hands of the community (Cornwall and Jewkes 1995, Curwood *et al.* 2012). The premise of PAR is that models making causal inferences about human behavior are more likely to reflect the local context when the “human beings in question participate in building and testing them” (Argyris and Schön 1989, p. 613). PAR offers guidance for engaging community partners throughout the research process (Fig. 3). Community partners aid in articulating research goals and assist in research design and implementation (Hacker 2013). Ideally, as a partnership develops, the decision-making power shifts as community partners take on more control of the research. Throughout the partnership, researchers should ensure that the project remains responsive to community voices and goals by employing iterative cycles of inquiry, action, and reflection (Mackenzie *et al.* 2012). When community partners control partnership activities, research outcomes are more likely to persist (Schensul *et al.* 2008). The success of PAR depends on the strength of partnership, skills of researchers, and the ability to sustain research outcomes (Greenwood *et al.* 2018).

Indigenous Research Methodologies

While socially responsive, the guidance of PAR on its own does not provide adequate direction for forming equitable and inclusive partnerships with colonized Indigenous communities. Historically, Indigenous communities, such as Native American

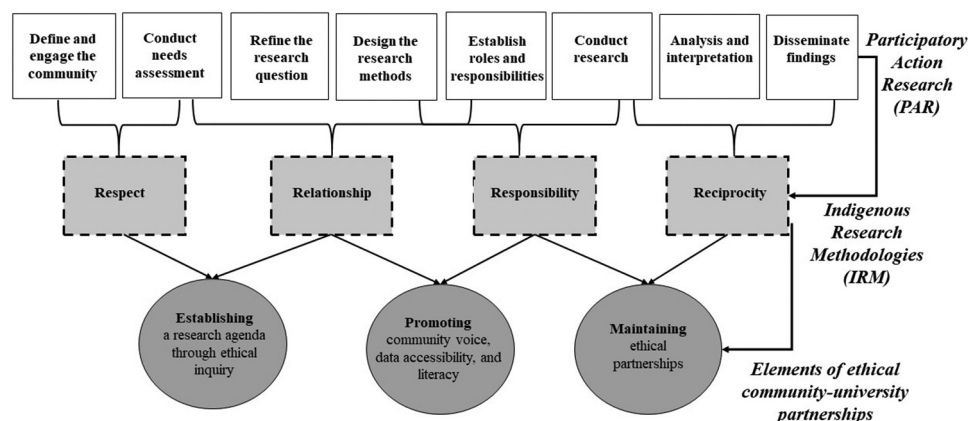


Figure 3. Conceptual diagram illustrating the three partnership elements and the iterative cycles of inquiry, action, and reflection employed in participatory research approaches.

Tribes, have been severely mistreated by western researchers (Mello and Wolf 2010, Hodge 2012, Mitchell 2018). The disrespect and mistreatment of Indigenous communities during and after the research process stem from a colonialism mentality (Smith 2013). The acknowledgement of colonialism in research led Indigenous scholars to develop IRM, which aims to decolonize the research process by elevating Indigenous epistemology and principles through ethical relationships (McGregor *et al.* 2018, Mitchell 2018). Over the past 20 years, Indigenous scholars have advocated for the use of IRM facilitated through PAR to form ethical, trusting, and lasting relationships with Indigenous communities (Brayboy and Deyhle 2000, Bang and Medin 2010, Kovach 2010, Smith 2013, Wilson *et al.* 2015, Peltier 2018). As articulated in Wilson (2001), IRM offers a fundamentally different paradigm because knowledge is not owned by an individual entity, rather, it is “*shared with all of creation . . . It goes beyond the idea of individual knowledge to the concept of relation knowledge*” (pp. 176–177).

Among Indigenous people, relational knowledge includes water not as just a physical substance but as an important link across all relations, an entity that connects, nourishes, and stewards (Arsenault *et al.* 2018, Wilson and Inkster 2018). Grounded in the Indigenous principles of the four Rs (i.e. relationship, respect, responsibility, and reciprocity), IRM offers an approach to inquiry that recognizes the importance of community control in sustained capacity building (Evans *et al.* 2009). Applying principles for building relationships and respect helps to initiate partnerships, while responsibility and reciprocity are appropriate for promoting community goals and maintaining trust (Kovach 2010). PAR can sometimes have constructive applications in Indigenous communities because the framework includes acknowledgment of relational knowledge (Datta *et al.* 2015). However, in order for PAR to be effective, Indigenous scholars emphasize that research must have empathy for their participants and aim to be accountable to the community (Smith 2013, Wilson *et al.* 2015).

Partnerships in the study region

The two research partnerships described in this paper were associated with doctoral students’ dissertation research and began in the spring of 2016. Both students were National Science Foundation’s Integrative Graduate Education and Research Traineeship (NSF-IGERT) fellows. The IGERT program provides students with an interdisciplinary water resources education that promotes socially responsible practices in research and the development of innovative problem-solving approaches (e.g. Cosens *et al.* 2011). Students received training on topics such as science communication, Tribal sovereignty, conflict mediation, and values. The two doctoral students, also the lead authors of this manuscript, led the design and implementation of the research, providing a suitable opportunity for comparison between projects. Both students are female scientists raised and educated under a western Eurocentric lens, and neither student had prior experience working or living in the region. The projects conducted within the partnerships were conceived as primary deliverables for the students’ dissertations. Both partnerships included research designs that relied on primary data collection and projects aimed at capacity building by

promoting community voice and goals, increasing access to scientific data, and improving scientific literacy of local citizens. Table 2 provides an overview of the projects conducted through both partnerships. In addition to working towards community capacity building goals, the final deliverables from these projects contribute to more generalizable scientific research outcomes.

The Tribal partnership, between the Coeur d’Alene Tribe and university researchers, supports existing Tribal efforts to mitigate water quality issues stemming from toxic metal contamination within the lower reaches of the Coeur d’Alene subwatershed and St. Joe subwatershed through an interdisciplinary framework that draws from approaches in community engagement, aquatic ecology, and education. The doctoral student connected with the Tribal partnership had training and a disciplinary background in science, informal education, and management. The Silver Valley partnership with the District, occurred in the upper reaches of the Coeur d’Alene River subwatershed in the communities near the Superfund site. The student’s training and background in the Silver Valley Partnership focused in law, policy, and management. The Silver Valley partnership assesses risk perceptions and behavioral responses to lead contamination among residents and community leaders to inform the District’s risk communication strategies.

Coeur d’Alene Tribe (Tribal) partnership overview

The Tribal partnership and collaborative research commenced informally during the summer of 2015, while the doctoral student served as an intern for the Tribe’s Department of Education (DoEd) and Lake Management Department (LMD). Primary research studies were guided by an interdisciplinary research framework and stemmed from conversations during the student’s summer internship experience (Repko 2008). This framework relied on research approaches in community engagement, aquatic ecology, and science, technology, engineering, and mathematics (STEM) education to support the Tribal community’s existing water quality mitigation goals. The researcher consulted with educators and ecologists from the Tribe throughout all phases of the studies.

The studies conducted through the partnership included a limnological study and a culturally-relevant STEM education study involving Coeur d’Alene Tribal youth. The limnological study was conducted with the Tribe’s LMD and explored the role of aquatic macrophytes in metal and nutrient distribution within temperate lakes. The LMD and the Tribe’s DoEd collaborated with the graduate student to develop and implement a STEM education study which entailed the evaluation of a culturally-relevant STEM program and affiliated internship on Tribal youth interest in STEM. The STEM education program and internship focused on the development of Tribal leaders in STEM to manage their impaired waters, while the limnological study provided valuable scientific data on the distribution and cycling of metals within a lake ecosystem. When combined, the studies explored how interdisciplinary approaches support the Tribal community’s capacity to mitigate their contaminated water resources as a sovereign nation.

Table 2. Primary partnership projects.

Partnership project titles	Summary	Capacity building goals
<i>Silver Valley</i>		
Behavioral responses to Pb contamination in a mining-impacted area	Community survey of resident's perceptions and behavioral responses to lead contamination. Supported by pilot grant program.	<ul style="list-style-type: none"> • Data accessibility • Community engagement • Resource generation
Can we have healthy living environments in mining-impacted communities?	Case studies-based curriculum development about the Health District's risk communication strategy.	<ul style="list-style-type: none"> • Policy recommendations • Risk communication strategies • Curriculum development
A Q methodology approach to identifying environmental health and economic development perspectives	Interviews and card sorting activity (Q method) to understand how leaders view tradeoffs between environmental health and economic development.	<ul style="list-style-type: none"> • Policy recommendations • Data accessibility
Silver Valley science and technology fair	An annual event to exchange information between community members, environmental managers, university students, and researchers.	<ul style="list-style-type: none"> • Community engagement • Information dissemination
<i>Tribe</i>		
Variations in aquatic macrophyte phenology across three temperate lakes	Phenology assessed through the collection of water quality parameters, biomass and biovolume. Results informed the experimental design for lake enclosure experiment.	<ul style="list-style-type: none"> • Data accessibility • Sampling methods • Community engagement
Metals and Nutrients Association with Macrophyte Senescence and Decomposition in Thompson Lake	Temporal change within the physicochemical environment as well as nutrients and metal concentration was examined in two enclosure types (plants vs. no-plants)	<ul style="list-style-type: none"> • Data accessibility • Contamination management • Community engagement
Supporting Native American Community Leadership through Culturally-Relevant STEM Education	Culturally-relevant STEM programming to further youth interest in STEM. Impact of study was evaluated through a case study research approach.	<ul style="list-style-type: none"> • Literacy • Community engagement • Curriculum development and instruction

Silver Valley partnership overview

The partnership with the District began during conversations with District employees at quarterly BEIPC meetings and other community events. These conversations inspired the development of a research project to better understand residents' behavioral responses (e.g. avoiding contaminated areas) to lead contamination. The District's interest in the partnership objective developed from concerns that people were not taking adequate steps to avoid lead contamination, particularly while recreating in area rivers and working outside. District employees expressed strong connections to the Silver Valley, as evidence by their long employment tenure in the region and interest in building community capacity. The objectives and research design implemented in the Silver Valley partnership were co-developed between District employees and university researchers. An initial study, about residents' behavioral responses contributed a social science perspective to the existing data and research studies about blood lead levels in children and physical data about contamination in the environment (e.g. Spalinger *et al.* 2007). A follow-up study focused on how community leaders prioritize economic development and issues related to environmental health, including regional water quality impairments.

As the partnership formed, the District was also implementing a new risk communication campaign that involved posting updated signage at public recreation access points. As a result, the researchers and District employees developed and

tested a college-level curriculum focused on a critical illustration of the rationale behind the new risk communication strategies (Cooper *et al.* In Review). The team also worked together to establish a science and technology fair in the Silver Valley, now in its third year, the event attracts around 200 industry representatives, non-profit groups, agency personnel, and students.

Comparing elements of participatory research

In this section we compare participatory research approaches guided the Tribal and Silver Valley partnerships. Specifically, we examine how these frames helped guide each partnership through three distinct elements: establishing, promoting, and maintaining (Fig. 3). By focusing on these three elements we reflect on similarities and differences between the partnerships even though they were guided by different participatory research frameworks. Reflecting on these three elements is important, regardless of the participatory research frame.

Establishing inclusive and equitable research agendas

Initially, university researchers attended events hosted by community partners without discussing specific research agendas. Participation in events included volunteering at education programs and attending culturally significant events such as community dinners and outdoor recreational

activities. Attending events without a specific research agenda allowed researchers to learn about the complex hydrosocial territories and provided time for cultural and social recognition (Kovach 2010). Both doctoral students devoted a significant amount of time to establish an authentic relationship within their respective communities since they were not former residents of the region or members of the community. Research questions in both partnerships originated from ideas that aligned with existing programs, scientific reports and data, as well as community goals. However, formal community needs assessment was not conducted in either partnership as recommended in PAR (Hacker 2013). Both the District and the Tribe already had goals and ideas in place regarding approaches for conducting scientific research investigations.

The doctoral student formed an authentic relationship with the Tribe by attending events and interning with the Tribe's LMD and participating in a culturally relevant STEM camp affiliated with the Tribe's DoEd. These experiences provided the doctoral student with an opportunity to learn about the community and culture as well as existing programs and research needs. Stemming from these experiences, the limnological study was informed by five years of data collected by the Tribe's LMD on the fate and transport of metals within aquatic ecosystems. The culturally-relevant STEM program and affiliated internship opportunity built from existing programs and previous research partnerships. A community partner with the Tribal partnership highlights the importance of positioning research alongside community goals and programs by urging researchers to "*start the relationship early and let the Tribe's needs guide you*" (Sam, March 2019). Taking the time to form a relationship with the partner, allowed the doctoral student and additional researchers to educate themselves about the Tribe's unique cultural and connection to their land. This additional time allowed them to recognize existing efforts as well as community voices and goals in each study.

In the Silver Valley partnership, informal interviews and participant observation were essential for establishing research projects that aligned with community goals. Initial conversations with community leaders improved the researchers' understanding of health issues and community goals. Conversations focused on identifying different perspectives about healthy living environments in the Silver Valley rather than focusing on a specific research question. The participatory approach was reinforced by a District employee who suggested that "*it's important to constantly check in with the people who are in the thick of it to understand the small bits of information that mould ideas and dictate decision making,*" adding that researchers should "*attend community social events to become a familiar face*" (Cindy, June 2019). In both cases, university researchers provided space for community partners to share their stories, interests, and experiences. As researchers without prior experience in the region, attending community events helped researchers to develop reciprocal relations themselves and to better understand existing relations.

In both partnerships, roles and responsibilities were defined by both formal (e.g. Institutional Review Board, IRB, protocol)

and informal agreements (Leisey 2008, Cross *et al.* 2015). However, the partnership with the Coeur d'Alene Tribe required two IRB protocols, one with the University and one through the Tribe. The need for two or more IRB protocols is not uncommon in participatory research (Kelley *et al.* 2013). The Silver Valley partnership did not have this same experience as the District regularly works with University researchers and operates through service agreements. The need for careful consideration of possible ethical issues outside of those considered by University IRB protocols is an important component of establishing community-university partnerships. Flicker *et al.* (2007) stress that traditional university review protocols may not sufficiently address the ethical research dilemmas. In addition to developing protocols and designing research, the establishment phase provided time to identify the resources and expertise needed to complete studies that would build community capacity.

Promoting community voice, data accessibility, and literacy

Once the partnerships formed, it was important for university researchers to continue building trusting relationships, learning about community goals, and understanding existing research infrastructure and projects (Kovach 2010, Hacker 2013). Both the limnological study and the study about behavioral responses to lead contamination exemplify how partnerships can improve access to scientific data and advance community goals. The Silver Valley partnership supports a need to better protect human health through improved risk communication while the Tribal partnership supported science data that will help recover culturally-important, injured resources. The projects that formed within the two partnerships took these directions because of the goals of their community partners. However, because the researchers and community partners formed relationships prior to beginning research, the studies also developed around the doctoral students' background, strengths, and expertise. Working on projects, based on both community goals and the students' expertise helped to ensure more sustainable projects.

The limnological study with the Tribe filled an ecological research gap within the LMD. In addition to providing scientific data, educational programming was a primary outcome. The STEM education study evaluated a six-week internship and affiliated STEM program. This informal educational opportunity relied on the local environment and cultural knowledge to educate Native American youth on the environmental hazards impacting their local waterways. The results of this study indicate that an increase in youth relationship to place and comprehension of STEM strengthened their interest in pursuing a career path in STEM fields for the Tribe. The Silver Valley partnerships provided the District with support for improving their risk communication strategies, including funding for research from two small pilot grants. Participating in community outreach activities was also important in the Silver Valley partnership. Members established and organized an annual educational science and technology fair in the Silver Valley. At the fair, college students and local primary school students interacted with education and outreach groups,

industries, and non-profits to learn about health and environmental contamination. The fair expands the District's outreach capacity and provides an opportunity for community engagement.

Open communication within the partnerships allowed university researchers to alter research designs when necessary in order to redirect the research to meet capacity building goals. For instance, during conversations conducted with the Tribe a community partner emphasized that, "*it is key to be upfront and open, what it is the University is getting from it and what the Tribe or community is getting from it*" (Julie, March 2019). Interviews associated with the Silver Valley partnership reinforced the importance of open communication. An interviewee stated that "if you (the researcher) are trying to do some research that could help the community, then you absolutely have to involve them. Otherwise, you might be missing the point in terms of what you come up with" (Sarah, June 2019). In the two partnerships, open communication allowed the research studies to align with the goals of the community partners. These examples are central to the rationale behind conducting research through practice described in relational knowledge paradigms and through participatory research approaches (Wilson 2001, Datta *et al.* 2014).

Maintaining ethical partnerships

Maintaining trusting relationships through the duration of a partnership requires commitment between partners and frequent reflection (Kovach 2010, Hacker 2013). Partnership personnel must remain dynamic and flexible in order to adjust to changing circumstances (Wallerstein and Duran 2006, McMillan 2012). To mitigate impending change, Indigenous scholars advocate for community participants to provide the "final say" in the development, implementation, and dissemination of research (Kovach 2010). However, transitioning between personnel and projects can present issues because building trusting relationships requires an investment of time and resources (Christopher *et al.* 2008).

The doctoral student and affiliated Tribal partner worked to sustain the partnership by broadening access to a place-based science curriculum and integrating activities into informal and formal curricula. Currently, the curriculum provides "*a groundwork for other informal curriculums . . . It is something that was easy to follow for other resource managers*" as expressed by a DoEd employee affiliated with the Tribal partnership (Julie, March 2019). The limnological study drew from multiple scientific disciplinary approaches for studying contaminated aquatic environments. An aquatic ecologist with the LMD thought the data affiliated with this study was "*very helpful in assisting [LMD scientists] to understand the role of macrophytes (aquatic plants) in contaminated aquatic environments*" (Tom, March 2019). The LMD will implement the data into a lake wide model to study the biogeochemical cycling of metals and the impact of remediation methods on lake ecosystem function. Developing datasets that community partners can use is a recommended method in PAR as data sharing promotes community capacity building (Datta *et al.* 2014).

The Silver Valley partnership relied on techniques from PAR to sustain knowledge developed through the research studies. For example, prior to conducting a survey of residents within the Silver Valley, the researchers pre-tested the instrument with residents at events and reviewed preliminary results with the District. Pre-testing the tool provided an opportunity for reflection, which allowed the survey instrument to become more reflective of community goals. Further, the survey was distributed through the drop-off, pick-up method, which is a recommended method in PAR practices as it capitalizes on the social exchange theory, allowing researchers to briefly interact with community members who participate in data collection (Trentelman *et al.* 2016). The District will be able to use the data, as well as project deliverables, to improve their risk communication strategies.

Continually planning for and applying to future opportunities was integral to maintaining relationships in the Silver Valley partnership. After initial data collection, the University researchers and an employee from the District attended a workshop together at the Socio-Environmental Synthesis Center to collaboratively develop curriculum to teach both the lay public and college students about the health risks of lead contamination. In late phases of the Silver Valley partnership, the University researchers helped to secure additional funding and mentor another doctoral student to continue working towards partnership goals. In addition, the final project in the partnership was designed primarily as a reflective study for the doctoral student. The project assessed environmental health (e.g. good water quality) and economic development. Results from this study contribute to broader discussions about future decision-making and policies in the Basin.

Recommendations for participatory research

Both PAR and IRM provided guidance for conducting more inclusive and equitable research processes. Partnership limitations were related to traditional barriers in participatory research such as the researchers' positions as students and partners' time (Chambers 1997, Mackenzie *et al.* 2012). Because these limitations were made transparent from the onset of the projects, the researchers were able to form lasting relationships within the communities and lower barriers that may be experienced in future partnerships between the university and community partners in the region. The emphasis on process and the time lags between project implementation and outcomes posed more formidable barriers to partnership success. Reflecting these challenges, several lessons emerged within each element of partnership development: (1) build from established programs, goals, and personnel, (2) identify respectful levels of community engagement, and (3) recognize partnership limitations. These lessons learned are relatively simple and supported by an extensive collection of research about participatory process. Their simplicity reiterates the importance of developing context-specific approaches to participatory research and provide starting points for developing participatory research.

Building from established programs, goals, and personnel

Wilk and Jonsson (2013) indicate that participatory research approaches often, “fail to acknowledge and address the plurality of standpoints, uneven power dynamics, conflicting stakes, and distributive inequalities” (p. 697). While true, this critique also applies to research based on one-way knowledge flows. In the partnerships explored here, spending extra time in the beginning to establish relationships helped to balance power throughout project implementation. Both partnerships formed around established programs, goals, and personnel, and neither of the graduate students had existing reciprocal relations within the study region. Working with established partners allowed the research studies to better align with other ongoing projects and goals in the region. In both partnerships, community partners goals prioritized reducing existing health and economic disparities in the region. Understanding the hydrosocial dynamics was important to developing research studies within each partnership. In addition, it allowed university researchers to build on the existing community of practice, limiting the possibilities of research fatigue, and redundancy.

Identifying respectful levels of community engagement

The university researchers within both partnerships found participatory methods essential for identifying a respectful level of community engagement. For the partnership with the Tribe, researchers found guidance from IRM was particularly useful in building ethical relationships during the first year of the partnership. Establishing trusting relationships lowered other barriers to participatory research by decreasing the additional resources needed to engage communities. Learning about community goals and issues prior to initiating research provided the time needed to define realistic goals and objectives for the research projects. Although not always the case, both partnering entities had specific research interests and needs, which guided the projects that developed from the partnerships.

Recognizing partnership limitations

Identifying an appropriate balance between developing graduate students’ disciplinary depth and community capacity building is important both for ensuring that students are well-directed and that the research processes leads to a bi-directional flow of knowledge (Morse *et al.* 2007, Duchelle *et al.* 2009). This is a critical step that requires careful consideration on both sides of the partnership. If not properly addressed, proposed research may not be completed, which can jeopardize the partnership. Researchers conducting participatory research must also acknowledge structural constraints and provide extra time to complete projects that align with their values and the values of the partnered community (Flicker *et al.* 2007, Long *et al.* 2016, Halbe *et al.* 2018). Establishing relationships early on helps to identify disciplinary expertise among the partnership and build a support network for navigating structural constraints to conducting participatory research.

Non-structural barriers to participatory research remain more challenging to overcome. One such barrier is the challenge of documenting outcomes for research where measures

of success are embedded in the process. Participatory research provides limited guidance for best practices in evaluating participatory research outcomes (Mach *et al.* 2020, Turnhout *et al.* 2020). While important, monitoring and evaluating outcomes is both a logistical challenge and can compromise the iterative nature of a participatory process (Anticono *et al.* 2013). Whether participatory research has a positive impact is ultimately a subjective judgement made by the people involved in the research projects (Martenson *et al.* 2012). Focusing on outcomes can lead to unidirectional knowledge exchange that detracts from the goals of participatory research and shifts power back to the researchers (Mach *et al.* 2020).

Creating venues for open forums and community advisory boards is essential for effective monitoring and evaluation (Hacker 2013). For the two partnerships explored here, the doctoral students were encouraged by mentors and through the guidance of participatory research methods to evaluate project impacts by creating an open forum for iterative knowledge exchange. Once space for knowledge exchange emerges, it is possible to understand how research outcomes can be more equitably evaluated. Systematically monitoring decisions in open forums is ideal for building understanding of outcomes but such monitoring must be implemented in ways that do not compromise the organic nature of knowledge production (Mukherjee *et al.* 2018, Mach *et al.* 2020). Future participatory research should continue to develop methods for participatory research that include clear, flexible, and minimally intrusive methods for monitoring and evaluating project outcomes. Recognition of the diversity of approaches for participatory research is necessary for evaluating, funding, and advancing the processes that lead to more equitable approaches.

Conclusion

Qualitative assessment of the three elements between the partnerships evaluated in this study provided an approach for comparing processes based on different participatory research frameworks. Future research may benefit from continuing to establish clearer guidance for comparing between projects and across hydrosocial territories. While any such analysis is subjective, additional methods for documenting how participatory research approaches lead to more equitable and inclusive outcomes are needed. Prioritizing equitable and inclusive participatory research helps to ensure that research reflects the complex realities of hydrosocial territories. We demonstrated the application of PAR and IRM through two partnerships involving Tribal and non-Tribal rural communities in a mining-impacted region. Inquiry about how to design more equitable and inclusive research must address power imbalances, cultural differences, and complex questions about hydrosocial relations. Participatory research does not make these difficult questions related to these issues disappear, rather it makes these questions explicit and provides an opportunity for researchers and community members to work together to balance power. Researchers conducting participatory research should utilize participatory frameworks to guide research that are sensitive to local contexts and meets rigorous standards for scientific research. Participatory research frameworks such as PAR and IRM prioritizes community capacity

building through equitable partnerships that acknowledge and embrace relational knowledge alongside scientific inquiry.

Acknowledgements

This manuscript would not have been produced without the continued support and guidance of the Coeur d'Alene Tribe and community, Panhandle Health District, and the Silver Valley community.

Disclosure statement

The authors have declared that no competing interests exist.

Funding

This research was funded by the National Science Foundation's IGERT Program (Award Number 1249400) and the Mountain West Clinical Translational Research – Infrastructure Network under a grant from the National Institute of General Medical Sciences of the National Institute of Health (Award Number 2U54GM104944).

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