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Lessons learned from community and citizen science monitoring on the Elwha River restoration project

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Community and citizen science (CCS) projects – initiatives that involve public participation in scientific research – can both sustain and expand long-term monitoring of large dam removal projects. In this article, we discuss our perspectives on CCS associated with the Elwha River dam removals. We summarize how the public has been or could be involved in monitoring and distill lessons learned for other large dam removal projects. Much of the Elwha monitoring involved technical field work requiring training and incurring potential liability risks, guiding projects towards smaller-scale public involvement. Partnering with organizations that have capacity for volunteer management expanded CCS opportunities and provided logistical support to project managers committed to public engagement. We found that many projects engaged with students and/or with paid or unpaid interns; compensating participants in various ways can help to create reciprocal relationships that support long-term monitoring. In the future, other large dam removals could consider planning ahead for community involvement in dam removal monitoring to accommodate the technical and potentially hazardous nature of the work – broadening who may be able to participate. In addition, involving community members in setting research agendas could be an important first step in engaging them in long-term monitoring, in turn facilitating multi-generational research at the timescale of landscape-level changes. Finally, explicit relationship-building with Indigenous communities can enhance the benefits of community engagement in dam removal science for all involved.

KEYWORDS

citizen science, community science, dam removal, Elwha River, watershed restoration

1 Introduction

Large-scale dam removal can benefit from community and citizen science (CCS) that includes public engagement in directing research agendas, participation in long-term monitoring, and collaborative analysis, interpretation, and application of research results. The Elwha River dam removals are a prominent success story for watershed-scale restoration (Allan et al., 2023), and this success can be attributed in part to substantial CCS endeavors. As a group of Elwha scientists and scholars of public engagement, we characterized past, current, and potential CCS projects associated with the Elwha River restoration (Eitzel et al., 2023). In this Perspectives article, benefiting from our collective knowledge of CCS and experience working on the Elwha, we summarize the various projects described in Eitzel et al. (2023), distill lessons learned from the variety of CCS initiatives that emerged from Elwha ecosystem restoration, and provide guidance for future dam removals and similar large-scale restoration projects. As in Eitzel et al. (2023), we define CCS projects as those that involve local and/or non-local individuals without formal training in the research topic, including projects in which participants may be financially compensated or receive academic credit for their work.

1.1 Why community and citizen science in large-scale watershed restoration?

CCS projects can vary widely in how many people they engage in what stages of the research process, ranging from contributions to only one aspect (e.g., data collection) to community-driven projects where participants determine research questions and methods as well as implementing the work (Shirk et al., 2012). Use of CCS in environmental monitoring is attractive for multiple reasons (Conrad and Hilchey, 2011; McKinley et al., 2015; Jadallah and Wise, 2023). It has the potential to cost-effectively expand the scope and scale of data collection through the participation of volunteers, and the diverse perspectives and experiences of participants can encourage a more thoughtful research approach featuring a wider range of questions. CCS may also provide a variety of benefits to participants and their communities such as learning (National Academies of Sciences, and Medicine, 2018), enhanced connection to place (Newman et al., 2016), and a sense of agency with respect to environmental issues and policy and management processes (Jordan et al., 2012). Such benefits are even more significant when CCS projects center the contributions of marginalized and underrepresented communities (Soleri et al., 2016). Ideally, all of these benefits mutually reinforce one another, enhancing the sustainability of research and monitoring programs.

These co-benefits are particularly important for watershed-scale restoration projects such as large dam removal, where many individuals and communities are involved and the scope of data collection often outstrips typical monitoring budgets (Aceves-Bueno et al., 2015). Most published dam removal studies do not implement pre- and post-monitoring, and research projects are often short-term and/or focused on narrow parameters (Groves, 2019). In addition, because dam sites are highly varied, most dam removals will have different ecological response trajectories, even if they follow similar generalized forms (Bellmore et al., 2019). Because specific and detailed data are essential to inform decision-making during dam removal, local community members are ideal allies to expand monitoring. Finally, in situations that are contested or controversial (which dam removals often are), community-based approaches to monitoring can contribute to consensus-building (Fernandez-Gimenez et al., 2008).

2 Background: community and citizen science on the Elwha

2.1 The Elwha River restoration project

Among the nearly 4000 dams that have been removed globally in the last 50 years (Ding et al., 2019), the Elwha River in Washington State, USA (Figure 1) remains a prominent success story for advocates, scientists, resource managers and policy makers alike (O'Connor et al., 2015). Two dams were built on the River in 1913 and 1927 without fish passage, drastically curtailing habitat for multiple anadromous fish species, damaging the connections of the Lower Elwha Klallam Tribe (a member of the Lower Elwha Tribal Community) to culturally-significant practices and places, and reducing the delivery of sediment and wood to the lower river and nearshore (Winter and Crain, 2008). Following sustained advocacy by the Tribe and other groups, the dams were removed from 2011 to 2014 in one of the largest and best-studied large-scale dam removal efforts to date.[1]

As part of the dam removal effort, various formal and informal teams of scientists and resource managers came together to coordinate, facilitate, develop, and implement interdisciplinary research, education, and public outreach programs in the Elwha River watershed and nearshore coastal areas. These consortia of tribal, federal, state, educational, and community groups hosted the 2022 Elwha River "ScienceScape" symposium to mark the 10-year anniversary of dam removal, synthesize the first decade of system responses, and plan for the next ten years of Elwha monitoring – with CCS playing a central role in that future effort. As part of this focus on CCS, we (ScienceScape organizers, participants, and scholars from the University of California, Davis Center for Community and Citizen Science) documented examples of CCS on the Elwha (see Eitzel et al., 2023), which we summarize below.

2.2 Foundations of Elwha community and citizen science

Elwha CCS emerged, in part, from a long tradition of community engagement in, and care for, the Elwha River watershed. We first recognize the deep and traditional knowledge of the Elwha (ʔéʔɬx̣ʷaʔ) River ecosystem held by the Klallam (nəxʷsƛ̓áy'əm') people as foundational to CCS on the Elwha. While Indigenous Knowledge Systems are a distinct way of experiencing and understanding the

1 More than 250 studies of the Elwha dam removals have been published as of August 2023: https://www.zotero.org/groups/4740476/elwha_bibliography.

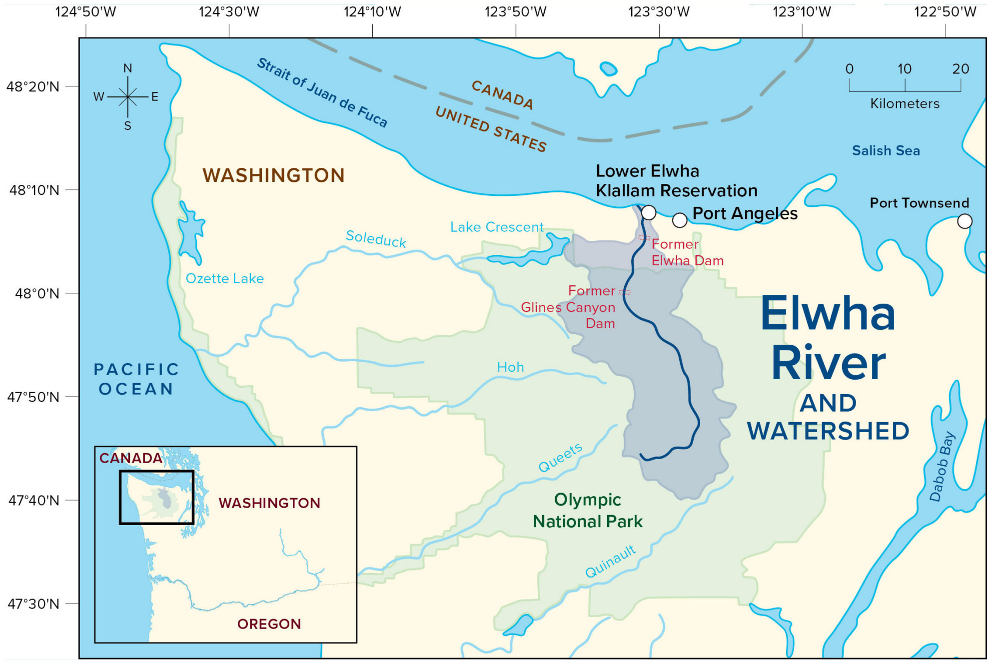

FIGURE 1
The Elwha (ʔéʔɬx̣ʷaʔ) River is located in Washington State, USA, on the Olympic Peninsula west of Seattle and south of the Strait of Juan de Fuca. Much of the watershed (smaller blue area) overlaps Olympic Peninsula National Park (larger green area), and the Lower Elwha Klallam Tribe's reservation lies to the east of the mouth of the River. Modified from Eitzel et al. (2023) under a CC-BY license; base map from iStock contributor Cartarium; Olympic National Park boundary from National Park Service map on Wikimedia Commons; watershed boundary from Fraik et al. (2021) under a CC-BY license.

world and its ecosystems, there are many elements of Indigenous Knowledge and management that overlap with some conceptions of CCS, particularly community-driven CCS (Tengö et al., 2021). In this sense, we acknowledge that the Lower Elwha Klallam Tribe has passed stories through the generations about their interactions with fish and wildlife, about their creation story along the Elwha River, and about their traditional fishing and hunting practices. We also recognize their early and consistent advocacy for the dam removals, their research (including their support of the Elwha ScienceScape group), and the cultural, emotional and economic cost to the Tribe of the ongoing fishery closure associated with the dam removals (Mauer, 2021).

In addition to the Klallam peoples' traditional and ongoing knowledge and relationship to the River, there have been other local residents who have advocated for the River and the fish. For example, Port Angeles local Dick Goin was a pulp-mill worker and fisherman who kept detailed fish catch records on the Elwha from the late 1950s–2010s. His extensive observations of natural history (e.g., species-specific run timing and spawning locations) are noteworthy because they demonstrated salmon declines over many decades. Dick's advocacy was particularly effective because he built relationships with many groups with differing perspectives and was able to motivate collective action.

2.3 Recent and current community and citizen science projects on the Elwha

During and since the dam removals, CCS participants have been involved in Elwha monitoring in a variety of ways, though none of the Elwha scientific literature mentions CCS as such (Eitzel et al., 2023). Explicit efforts facilitated community engagement at various points: prior to dam removal, the Elwha Nearshore Consortium (ENC, 2015) brought together local and regional scientists, citizens, and managers to understand and promote the Elwha nearshore. Recommendations from these meetings informed much of the nearshore work done prior to, during, and after the dam removals. Since 2022, the ScienceScape group that emerged around the Symposium events has been working on a more coordinated plan for Elwha CCS in the future. In the interim, however, there was not an overarching strategy or funding source for CCS in research and monitoring. This reflects the somewhat *ad hoc* nature of the monitoring effort in general, which began as a ground-up undertaking rather than a centralized directive.

Even without an explicit strategy for CCS, a diversity of different types of projects emerged (see Eitzel et al., 2023 for details). Projects varied in terms of number of participants from 1 to 2 people for vegetation sampling and plant identification, up to thousands for engagement with online biodiversity platform iNaturalist. Projects included several types of participants: K–12 students, undergraduate students, retirees, and tourists/visitors. Though most projects were biologically oriented, some were sediment-oriented. Projects also varied in terms of duration/longevity, with some projects running from the early 2000s (pre-dam removal) to present and some having begun in the summer of 2022. Some projects were designed to involve volunteers from the beginning and some benefited from serendipitous overlap of volunteer skills and availability. Future work could explore how these different types of projects have evolved over time.

A commonality among Elwha CCS projects is that many project leaders needed assistance engaging and managing volunteers. Some project leaders met this need through partnerships with other organizations who had volunteer management skills. Most volunteer projects were typically small-scale, with just a few people who were either already highly skilled (e.g., expert botanists) or who could be trained to do highly-skilled tasks (Figure 2). Reliance on skilled or knowledgeable individuals is unsurprising, as field science has long relied on the help of local experts (Vetter, 2016). Engagement in Elwha CCS often came in the form of both paid and unpaid internships, and/or as part of educational opportunities (largely K–12 or undergraduate students) – again unsurprising, as educational CCS projects in environmental science are common and well-studied (National Academies of Sciences, and Medicine, 2018). Each of these strategies (working with small numbers of volunteers, engaging with educators and their students, and/or using an internship structure) had key benefits for project managers: assistance in volunteer training, management, and engagement; easier data quality control; and built-in liability management for potentially hazardous activities. These strategies also offered benefits for participants in the form of compensation, work experience, and/or educational credit.

2.4 Proposed community and citizen science work on the Elwha

Even after 20 years of intensive study there are still many remaining questions as the Elwha River and its associated ecosystems continue to change. Maintaining long-term monitoring programs is essential to understand these changes, particularly in light of shifting baselines due to climate disruption (Lower Elwha Klallam Tribe, 2022). To support these needs, the ScienceScape group that emerged around the 2022 Symposium is now engaged in a systematic planning process around CCS in the Elwha watershed, reflected in Eitzel et al. (2023). As a result, the proposed projects we documented cover a wider range of topics and academic disciplines than the current projects have. The proposed projects require a range of different resources (e.g., volunteer management, data quality control, support for staff or volunteers, evaluation of tools for data collection) and differ in the stage of partnership development and planning (e.g., some are entirely new ideas and others are novel partnerships between well-established entities). The ScienceScape group is exploring what might be needed to sustain a more coordinated CCS effort (including supporting an Elwha CCS coordinator position), and future work could explore how CCS on the Elwha evolves with the benefit of

FIGURE 2
Participation in Elwha research is often small-scale (involving small groups) due to the technical and safety challenges of some projects. **(A)** NOAA researchers and student intern ford the Elwha to access a long-term benthic invertebrate monitoring station. (Image from Eitzel et al., 2023 under a CC-BY license.) **(B)** A volunteer from Clallam County BeachWatchers uses a radio-frequency identification (RFID) reader to locate tracers on the beach of the Elwha River delta in March 2009, prior to dam removal. (Photo by Ian Miller.)

more coordinated planning. Finally, there are also activities underway to enable the public to view the data they have collected, which can be another important form of positive feedback and benefit for participants (de Vries et al., 2019).

3 Discussion: lessons learned from Elwha community and citizen science

In this section we distill lessons learned from Elwha CCS, and identify possible areas for future development of Elwha CCS and ways that partners are, or could be, addressing barriers and challenges – many of which are common to CCS projects in other contexts (Burgess et al., 2017).

3.1 Current advances: what worked in Elwha community and citizen science

3.1.1 Lesson: partner organizations can help with volunteer coordination capacity

One theme among successful Elwha CCS projects was finding ways to address the additional administrative burden of managing volunteers. Some project leaders were able to overcome this limitation by partnering with external organizations with volunteer coordination expertise and capacity. In some cases, these long-term partnerships pre-dated Elwha dam removal monitoring. The Elwha coastal processes research of Miller et al. (2011) and Miller and Warrick (2012), for example, was made possible by connections with a local BeachWatchers program, which provided volunteer coordination and engagement services. Similarly, the Washington State Department of Natural Resources partnered with the Clallam Marine Resources Committee, The Coastal Watershed Institute, Peninsula College, Western Washington University and the University of Washington to work with volunteers to complete nearshore ecosystem and geomorphological studies (Parks et al., 2013; Parks, 2015). Many of the proposed Elwha CCS projects involve similar partnerships. The smaller size of the Elwha watershed and the relatively tight-knit community of researchers who work in the area lent itself particularly well to this type of informal relationship building. For other dam removal and restoration projects that span larger and potentially more demographically diverse regions, it could be particularly important to intentionally create opportunities for such collaborations before projects get underway.

3.1.2 Lesson: compensation for participants enables engagement

Supporting participants in various ways is important. Many Elwha project managers deliberately chose models in which participants were compensated in some way (e.g., financially, with academic credit, and/or training or resume-building activities). While some participants can afford to volunteer their time, labor, and skills, broader engagement includes supporting participation for those who cannot afford it. We note that compensation is an important form of reciprocity, which is key in research partnerships with communities (Wilmer et al., 2021) and often underlined by CCS researchers as critical to project longevity and ethical commitments. On the Elwha, programs including Washington Conservation Corps, AmeriCorps, and the Indian Youth Service Corps provide mechanisms for participant reimbursement.

3.1.3 Lesson: individuals committed to participatory work need support

We also note that many of the examples in Eitzel et al. (2023) were the work of specific individuals and organizations who highly value and have been committed to engagement with the public in their work. Some Elwha projects included planned participation by local citizens (Parks et al., 2013; Parks, 2015; Shaffer et al., 2017) and many additional unplanned CCS projects emerged despite the technical and liability challenges involved. This shows a commitment to community engagement on the part of scientists and an openness to the opportunities for collaboration that can arise in the course of long-term monitoring projects. It was often these individuals who – driven by their own commitments – jumped through bureaucratic hoops to develop partnerships and engage in CCS. This is an encouraging finding, but we feel this also points to the importance of broad multi-institutional support of CCS, as a way to remove barriers for individual scientists.

3.2 Future directions: opportunities for CCS research and practice

Though CCS on the Elwha contributed in critical ways to monitoring aspects of the Elwha system over the last decade, there are areas in which CCS could be expanded in scope and impact both on the Elwha and beyond.

3.2.1 Opportunity: plan ahead to expand beyond small-scale engagement

Fieldwork in the Elwha watershed and nearshore can require airplane, boat-based and in-water activities (wading, snorkeling, diving), wildlife interactions (e.g., fish identification and tagging), or hiking to remote locations – all of which can expose researchers to potentially hazardous conditions and may require specialized training (Hilperts, 2010). This often means that projects require significant planning in order to involve volunteers, and because many projects in the Elwha typically were not designed for CCS participants, these projects were often able to involve volunteers only on a small scale. This approach may miss opportunities to broaden engagement with diverse members of the public, thus limiting who can engage with science (Walker et al., 2021).

On the other hand, other large-scale environmental monitoring programs have demonstrated that systematic planning for CCS can help to expand participation. For example, in California's Marine Protected Areas, where CCS was an explicit priority within a broader monitoring framework, tens of thousands of people have participated across many different projects (Meyer et al., 2017; Freiwald et al., 2018; Meyer et al., 2022). While this example operates on a much larger scale than the Elwha watershed and coastal system, the wide range of project types (many different topics, approaches, and ways for participants to engage) is instructive, when considering some of the constraints described above: we underline that even in a highly technical context with safety concerns, there are still ways to plan ahead for larger-scale volunteer involvement. Likewise, there are opportunities to think specifically about including participation when planning watershed monitoring (Metcalfe et al., 2022), and guidance for how to do so (Meyer et al., 2020).

3.2.2 Opportunity: sustain research over generations through community co-production

Many Elwha scientists do not live on the Olympic Peninsula and many local residents hold nuanced forms of place-based knowledge. Maximizing opportunities for equitable interaction, engagement, and learning between scientists and residents can foster the co-production of knowledge in which diverse insights can support a thriving river and coastal system. Long-term engagement can assess the community benefits and potential negative impacts of CCS projects (Walker et al., 2021). At the same time, the timescales of biophysical change occurring in the watershed and adjacent coastal system last for multiple human careers and/or generations. We therefore point out that these forms of engagement can increase a sense of investment and ownership in the knowledge generation process, potentially sustaining monitoring efforts over the same multi-generational timescales.

3.2.3 Opportunity: engage participants throughout the research process

We note that much of the Elwha research and monitoring has been motivated by policy associated with the dam removals. Research therefore has been designed to test hypotheses related to the recovery of fish populations and restoration of sediment flow and other biophysical processes. While these issues may overlap to varying degrees with community interests, we note that this is not the same as a research and monitoring agenda that is actively shaped by community members. This therefore represents one potential growth area for Elwha CCS. Expanding participation means more than increasing the number of participants; it can also mean engaging them in more parts of the scientific process, including setting agendas and formulating questions (Shirk et al., 2012), as was done in the past with the Elwha Nearshore Consortium. The ScienceScape group made an important step towards assessing communities' current interests during the summer 2022 public event by asking event attendees to articulate questions of interest (Eitzel et al., 2023).

3.2.4 Opportunity: seek ways to build relationships with tribal community members

Tribal engagement is key in large-scale restoration projects (including dam removal) for justice and ethical reasons, as well as ecological and management reasons (via important Indigenous Knowledge about the system; Fox et al., 2017). However, attending to the way in which Tribal communities are engaged is essential to realizing the potential benefits for all involved. The ScienceScape group is currently working on more intentional engagement within the Lower Elwha Klallam Tribe. Though scientists working in the Tribe's Natural Resources Department do extensive research on all aspects of the Elwha River and some are Tribal members themselves, recent initiatives prioritize sharing research results directly with the community (e.g., outreach events on the reservation and articles in the Tribal newsletter). Finding forms of research communication that are accessible and of interest to community members is a key first step which could be followed by future efforts to engage Tribal members in additional aspects of research planning and monitoring processes.

4 Conclusions

Our exploration of CCS in the Elwha has uncovered the sometimes-hidden role that many kinds of participants have played in advancing knowledge about this system as it responds to a major restoration event. It also reveals the ways in which structural realities of professional monitoring – the policies, procedures, and physical realities of these projects – have shaped participation over more than a decade. On the Elwha River and coastal system, with no explicit long-term plan for public engagement in research and monitoring, the resulting CCS tended to include small numbers of people. But we found that CCS still happened, and contributed to Elwha science in important ways. Upcoming dam removal projects, take heed of this lesson: having a coordinated, intentional plan for CCS (e.g., following Meyer et al., 2020) – created in parallel with the political, economic, and engineering planning needed for removing the dam(s) – could expand the potential for CCS to benefit dam removals, for dam removals to benefit communities, and for communities to stay engaged in these long term management and decision-making processes.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

ME, RM, SM, AK, CJ, CB and HB contributed to conception and design of the paper. ME wrote drafts of the manuscript. All authors contributed to manuscript revision and read and approved the submitted version.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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