




Community and Citizen Science on the Elwha River: Past, Present, and Future

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About this report

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The Center for Community and Citizen Science, based at the UC Davis School of Education, uses research, teaching, and service to help scientists, communities, and citizens collaborate on science to address environmental problems as a part of civic life. More at education.ucdavis.edu/ccs. The ScienceScape is a group of scientists who work together to plan and coordinate monitoring of the Elwha River.

Resources Legacy Fund (RLF) works with philanthropists to conserve land, water, and ocean resources while advancing healthy communities and social equity. The Open Rivers Fund (ORF) is a ten-year program of RLF that was launched in November 2016 and capitalized by the William and Flora Hewlett Foundation. ORF supports local community efforts to remove obsolete dams, modernize infrastructure, and restore rivers across the western United States. ORF focuses on removing barriers that impair river function and pose challenges, costs, or risks to communities. ORF aims to create significant economic and environmental benefits, but also to build technical knowledge, organizational wherewithal, and public awareness in order to advance the field of dam removal. More at **openriversfund.org**.

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Executive Summary

This report reflects on the past, present, and potential future of community and citizen science (CCS) in the Elwha River watershed, with particular focus on the years before and after a major restoration event: the removal of two dams that had impacted the river system for a century. We ask: how does CCS feature in the Elwha story and how could it feature? We use the term CCS to reference the broad range of ways in which members of the public might participate in authentic science and monitoring processes, including students and both paid and unpaid interns: participants are individuals contributing to scientific projects without prior formal training in the topic.

Removal of the Elwha dams was a large-scale, complex project, and communities had an important role to play: the Lower Elwha Klallam Tribe (LEKT) and other local groups were a large part of the original drive to remove the dams. Some funding and policy requirements for monitoring are ending, but there is still much to learn from the changes happening in the Elwha, requiring ongoing research and monitoring. In 2022, the Elwha scientific community came together in a multifaceted effort called the "Elwha ScienceScape" to mark the ten-year anniversary of dam removal and to plan for future monitoring. One of ScienceScape's priorities is expanding CCS efforts, and because the Elwha dam removal is a powerful international symbol of large-scale watershed restoration, ScienceScape is well-positioned to inform and emphasize the potential role of CCS in dam removal worldwide.

This report presents insights about Elwha CCS from an academic literature review and discussions with scientists and many others that have been working in the Elwha. We found that the history of CCS on the Elwha is important but understated, with few scientific papers acknowledging support by volunteers of various kinds. Recent and ongoing CCS projects on the Elwha tend to be focused on biological phenomena, and most are associated with educational opportunities (across many types of institutions) and paid internships. We also noted that most Elwha CCS projects required volunteers with particular pre-existing skill sets (e.g., botanical knowledge) or time to impart specialized training (e.g. boat use), leading many projects towards engagement with a smaller number of volunteers.

Partners working in the Elwha are considering a wide range of potential new CCS projects, and these ideas are in varying stages of development. Many new projects would broaden public involvement in terms of the opportunities available, and increase the variety of focal topics for research and monitoring. This increased breadth is promising: there are indications that the local community's interests also range widely, from fish recovery after dam removal to dam removal impacts on humans.

Elwha CCS projects have encountered some challenges and barriers, including the administrative burden of coordinating volunteers and managing liability concerns. But Elwha ScienceScape scientists are committed to the value that CCS brings both to the research itself as well as to those who participate in these projects. CCS can be a way to increase equity in science and engage people who would not otherwise participate in research, and in many cases the research simply wouldn't be possible without their help. Support with project administration, volunteer management, and data management could help in expanding CCS efforts and broadening their inclusivity. More systematic tracking of CCS projects to assess how they contribute to research and to community and participant benefit could be helpful in establishing and maintaining a long-term CCS strategy in the Elwha.

Introduction and Background

This report reflects on the past, present, and potential future of community and citizen science (CCS) in the Elwha River watershed, with particular focus on the years prior to and following a major restoration event: the removal of two dams that had been impacting the river system for a century. The report is a collective effort of researchers from the University of California, Davis Center for Community and Citizen Science and the Elwha Research Consortium—a group of scientists with long-term involvement in Elwha River research and monitoring. To mark the 10-year anniversary of the Elwha dam removals, a group of Elwha partners held a series of events under the banner of "Elwha ScienceScape." This was a broad effort to take stock of science on the Elwha to date and discuss future plans. As part of this reflection, ScienceScape organizers felt it was important to explicitly consider the role of non-professional scientists in Elwha science. Our goal in this report is to reflect the history and current progress of CCS on the Elwha River and share plans for future projects to involve the public in monitoring the ecosystem's changes post-dam-removal.

While the Elwha is a very specific context, our goal in developing these insights to share with a broad audience is to support discussion about the role that CCS can play in dam removal throughout the world. In addition to highlighting valuable lessons and useful examples from recent years, this report helps to imagine how the scope of CCS could be expanded in the future as the Elwha River continues to change. Dam removals elsewhere in the world can look to the Elwha for inspiration as they consider how CCS may be incorporated into their projects. We begin with background on CCS, dam removal, and the Elwha.

Community and Citizen Science (CCS)

In this report we use the term "community and citizen science" (CCS) to reference the broad range of ways in which members of the public might participate in authentic science and monitoring processes (i.e., not solely for education/outreach benefit, but also contributing to scientific research results). This includes participating in any part of the scientific research process including generating research questions, helping design study plans, collecting data, and even co-leading investigations.[1] Our broad definition does not specify who "the community" or specific members of the public should be, as there may be many different communities (e.g., Tribal nations and affiliates, local residents, and recreational visitors and ecotourists from nearby and abroad) and types of individuals who could engage with CCS around different projects. In this report, for specific research projects, we indicate who the participants are or could be, and we encourage others working on CCS to be clear, specific, and intentional in thinking about including all impacted and/or interested and related communities. Academic and other literature from a wide variety of disciplines has used varied definitions of what is included under the umbrella of CCS[2]. In this report we chose to include paid and unpaid interns, high school and undergraduate students, and professional scientists volunteering outside their main field of research. We also included participants from more traditional citizen engagement pathways (such as Americorps and Veterans Conservation Corps). Generally, we consider "public participation" to be individuals contributing to scientific projects without prior formal training in the topic, many of whom were or are physically present during field work.

One direct benefit of CCS is the expansion of data collection and analysis that public participation can bring to researchers. But beyond this expansion of the spatial and temporal scale of data collection, broadening participation in scientific research and monitoring can also improve interaction and trust across interested groups. This can support learning, improve buy-in, and reduce conflict among diverse groups when collaborative projects are designed with those goals in mind. Deliberately inclusive participation also brings new ideas to the table (including potentially overlooked non-Western scientific perspectives) and can provide ongoing hands-on educational opportunities for students interacting with a wide range of scientists.

The large scope and the complex social-ecological context of major river restoration efforts like dam removal affords opportunity for public participation in research and monitoring.[3,4] We believe this benefits the people, watershed, and science in many of the ways outlined above and affords novel opportunities yet to be embraced.

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[1] For a discussion of the degree of participation in CCS projects, see Shirk et al. 2012. Public participation in scientific research: a framework for deliberate design. *Ecology and Society 17*(2): 29.

[2] For more discussion of terminology and definitions in CCS, see Eitzel et al. (2017) "Citizen Science Terminology Matters: Exploring Key Terms." *Citizen Science: Theory and Practice. 2*(1), p.1. DOI: 10.5334/cstp.96

[3] For more information on dam removal and CCS, see Meyer et al. (2020). A manual for planning your community-based citizen science monitoring project for dam removal and watershed restoration. UC Davis Center for Community and Citizen Science. https://education.ucdavis.edu/sites/main/files/ccs_manual_dam_removal_and_watershed_restoration_final_online.pdf

[4] One entry point for exploring broader literature related to CCS and conservation is the "Further Reading" appendix of the above-referenced manual, which is regularly updated: https://docs.google.com/document/d/185UZIg_jQ4b0rFFAVi1vikc8AfJGo61nGBEk9qFqjzw/edit?usp=sharing

Elwha Dam Removal

Aerial photograph of the Elwha River flowing through the remains of the Glines Canyon Dam during the third year of the dam removal project. Photo by Jeffrey Duda, USGS

Dam removal has increasingly been recognized as a restoration strategy with potential for significant social and ecological impacts on river systems. While many of these impacts are positive (e.g., improved fish passage), negative impacts may also occur (e.g., short term negative ecological effects from increased sediment transport, disruption to traditional practices). How a particular river responds to dam removal is shaped in part by the social, political, and biophysical context of its watershed. Research and monitoring are therefore crucial components of dam removal, helping to support adaptive management practices that respond to changes in the watershed during and after restoration projects. More generally, research and monitoring can also provide insights to inform the emerging science of dam removal. Of large-scale dam removals, the Elwha River dam removals are arguably the best-studied to date.

The Elwha River runs from south to north on the Olympic Peninsula, the ancestral lands of the Klallam people. The Elwha empties into the Strait of Juan de Fuca at the Lower Elwha Klallam Tribal Reservation near Port Angeles, WA. The upper 83% of the watershed lies in Olympic National Park. Two dams were built on the river in 1913 and 1927, largely to provide electricity for the local lumber and paper industry and the local town of Port Angeles. By the 21st century, energy to support industries and communities could be more sustainably obtained elsewhere. After decades of lobbying by the Lower Elwha Klallam Tribe and their allies, driven by concerns over declining fish populations, coastal erosion, and safety, the Elwha River Ecosystem and Fisheries Restoration Act was passed by the U.S. Congress in 1992. Between 2011 and 2014 the dams were removed, marking the largest dam removal and watershed-level restoration project to date. The cumulative effort required extensive coordination between Tribes, agencies, academics, and non-governmental organizations (among others). The removal of the dams is featured in the documentaries “DamNation” and “Return of the River.”

The Elwha has undergone a remarkable transformation. After dam removal, much of the sediment previously held behind the dams migrated downriver into the Strait of Juan de Fuca within months (rather than years), reforming a delta at the rivermouth[5] and extending available freshwater and estuarine habitat to the west of Port Angeles. Farther upstream, passive and active revegetation efforts on the former reservoirs have led to well-established trees and other plants,[6] though some areas are revegetating more slowly. These improve habitat and food for deer, elk, small mammals,[7] and large predators like mountain lions. Several species of salmon and trout quickly moved past the dams to access historic spawning habitat. By summer 2022 all species of spawning fish present before the dams blocked upstream access have now been observed above the former locations of both dams, though some species have yet to recover to historical population levels, individual size, or life history diversity (for example, multiple runs per year).[8] Some of these observations were supported by CCS monitoring processes (see below, and Tables 1 and 2). As of 2022, the salmonid fishery remains closed in order to support recovery, though this closure is not without significant cultural, emotional and economic cost to the Lower Elwha Klallam Tribe.[9]

[5] Warrick et al. (2019). World’s largest dam removal reverses coastal erosion. *Scientific Reports, 9*(1), 1–12.
[6] Chenoweth et al. (2022). Planting, seeding, and sediment impact restoration success following dam removal. *Restoration Ecology, 30*(3), e13506.
[7] McCaffery et al. (2020). Small mammals and ungulates respond to and interact with revegetation processes following dam removal. *Food Webs, 25*, e00159.
[8] Duda et al. (2021). Reconnecting the Elwha River: Spatial patterns of fish response to dam removal. Frontiers in Ecology and Evolution 9:1–17.
[9] Mauer. (2021). Unsettling resilience: colonial ecological violence, Indigenous futurisms, and the restoration of the Elwha River. *Rural Sociology, 86*(3), 611–634.

The ScienceScape Effort and CCS on the Elwha

Given the historic magnitude of the Elwha dam removals and the unique opportunity to study ecosystem restoration at a watershed scale (see page 4), communicating project outcomes has always been a central theme of Elwha research efforts. Beginning in 2004, interested scientists, managers, and educators began meeting annually to start planning for dam removal. With support from a 5-year National Science Foundation (NSF) grant from the Research Coordination Network (RCN) Program, the Elwha Research Consortium (ERC) was created in 2005 to coordinate, facilitate, develop, and implement interdisciplinary research, education, and public outreach programs in the Elwha River watershed. The ERC was co-led by College of the Environment (Western Washington University), Peninsula College, the Lower Elwha Klallam Tribe, Olympic National Park, NOAA's Northwest Fisheries Science Center, and the Biological Resources Division of USGS. It also included nine state, educational, and community groups. The number of additional collaborators increased with each annual ERC meeting held through 2009. In some years, additional meetings focused exclusively on Elwha nearshore research and on educational outreach.

With the end of the NSF-RCN grant in 2009, ERC meetings became more sporadic and coordination by Western Washington University and Peninsula College staff decreased. In 2010, a subset of the ERC met at the annual meeting of the Northwest Chapter of the Society for Ecological Restoration. To bookmark the beginning and end of active dam removal, the ERC came together again to host two major science symposiums. The first occurred in 2011 as part of a week-long series of events launching the official start of dam removal to share baseline data collected before dam removal and to lay out collective monitoring plans for during and after dam removal. The second symposium in 2015 focused on observations of the recent dam removals. Beyond the initial rapid changes that occurred in the watershed that were presented at these events, the effects of dam removal will continue to play out over many decades. Therefore, to mark the ten-year anniversary of dam removals and to plan for future long-term monitoring, the Elwha scientific community came together again in 2022 in a multifaceted effort coined "Elwha ScienceScape." Supported by the Resources Legacy Fund (RLF), the Lower Elwha Klallam Tribe and several federal and academic members of ERC hosted a two-day virtual planning workshop in April 2022, a public lecture series at Peninsula College in Port Angeles in August 2022, and a science symposium at the NatureBridge Olympic National Park Campus in September 2022.

An overarching goal of Elwha ScienceScape organizers was to expand CCS efforts. As several of the agency-based funding sources for Elwha dam removal near their end, there is a need to find ways to support ongoing monitoring far into the future as the river continues to change. One possible pathway for ongoing support is to foster public participation: collaboration with local communities builds greater monitoring longevity, makes for better science, and empowers those most affected by project outcomes. Elwha ScienceScape organizers reached out to the UC Davis Center for Community and Citizen Science to help make CCS a focus of ongoing and future Elwha research. Researchers from UC Davis assisted with the planning of the 2022 Elwha ScienceScape events and integrated CCS into facilitated conversations at the events around past, present, and planned monitoring and other activities.[10] Prior to and between organized events, UC Davis researchers also met individually with Elwha researchers and members of associated communities to discuss CCS collaborations.[11] Those interested in Elwha CCS established monthly committee meetings to support ongoing and future projects.

[10] CCS-focused contributions included a presentation on CCS and set of brainstorming-focused breakout sessions in the April 2022 workshop and a presentation of CCS on the Elwha to date and CCS-focused breakout session at the September 2022 Symposium.
[11] We engaged in conversations with approximately 13 different researchers in geomorphology, vegetation, wildlife ecology, fish ecology, and river foodweb ecology.

Through ScienceScape, Elwha scientists have been actively engaging in the topic of CCS. During discipline-specific breakout groups at the Elwha ScienceScape Symposium in 2022, CCS was mentioned frequently as a part of future plans for Elwha research, emerging as an important aspect of ongoing work on the Elwha. There was strong interest from scientists in communicating more effectively with the public and addressing questions about human impacts of dam removal. In a breakout session focused specifically on CCS, the group expressed strong interest in working with youth, and in particular with Tribal youth as an integral part of planning for future monitoring. Several in the group saw the potential for connecting with educators in Olympic National Park, programs at Peninsula College, and school programs at NatureBridge in particular. ScienceScape attendees noted that more frequent, qualitative data collected by CCS groups could complement the less frequently but more systematically conducted scientific efforts. More frequent, less quantitative data could help document the long-term benefits of dam removal or the influence of other factors, such as climate change. It was generally recognized that there are advantages to having an overlap between CCS data collection and agency data collection as the latter faces declines in spatial and temporal coverage for some scientific disciplines.

The Elwha is a powerful international symbol of large-scale watershed restoration, and Elwha ScienceScape is positioned to emphasize the potential role of CCS in dam removal. Collaborators from Elwha ScienceScape and UC Davis Center for CCS have written this report to help address the question: how does CCS feature in this story and how could it feature?

Past, Present, and Future of CCS on the Elwha

In the following sections, we describe the foundations of CCS on the Elwha and provide an overview of recent and ongoing as well as proposed and potential CCS projects.

Foundations of Elwha CCS

Recognizing that Indigenous Knowledge Systems[12] are a distinct way of experiencing the world and understanding ecosystems, there are many elements of Indigenous Knowledge and management that overlap with some conceptions of CCS, particularly community-driven CCS.[13] In this sense, we first recognize the deep and traditional knowledge that the Klallam people hold of the Elwha (ʔéʔɬx̣ʷaʔ) River ecosystem. The Klallam (nəxʷsƛ̓áy̓əm̓) people have lived on the Elwha River since time immemorial and have 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 particularly recognize the knowledge held by Lower Elwha Klallam Tribe as well as their advocacy and research, including their support of the Elwha ScienceScape effort.

[12] In this report, we use "Indigenous Knowledge Systems" to refer broadly to a variety of different terms including "Traditional Ecological Knowledge," "Traditional Knowledge," "Indigenous Traditional Knowledge," "Native Science," and other related terms. For a recent example of discussion around this terminology, see the "Guidance for Federal Departments and Agencies on Indigenous Knowledge" (Available at: https://www.whitehouse.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf)

[13] Tengö et al. (2021). Creating synergies between citizen science and Indigenous and local knowledge. *BioScience, 71*(5), 503-518.

In the late 1950s through 2010s, Port Angeles local Dick Goin, a pulp-mill worker and fisherman, kept a detailed account of his catch and natural history observations (including species-specific run timing and spawning locations), demonstrating salmon declines over many decades. Goin's records and advocacy motivated action across many different groups, and as his data gained broader attention, he became a voice for the return of salmon to the river – opening doors to conversations about dam removal among community members who identified with his personal perspective. The 2016 documentary film "Memory of Fish" tells Goin's story.

CCS in the Elwha Scientific Literature

Elwha researchers have involved the public in their past research. To summarize this work, we used a keyword search to review a selection of Elwha research publications[14] to determine how CCS may have played a role in Elwha science and monitoring. In addition to "citizen science," terms considered synonymous were included in the search (e.g., "community science" OR "volunteer science" OR "public participation in scientific research"). For articles containing these keywords, we noted where in the publication citizen science was acknowledged and/or how volunteers contributed to the study. Gray literature was not included in this review.

Table 1. Number of articles potentially mentioning Community and Citizen Science (CCS) in the Elwha academic literature.

	Pre-removal	During Removal	Post-removal
Physical Sciences *(geomorphology, hydrology)*	1/34 (1%)	1/34 (1%)	2/34 (2%)
Biological Sciences *(fish, fisheries, ecology, mammals, plants)*	6/61 (6%)	2/61 (2%)	13/61 (14%)

[14] Elwha Bibliography, retrieved from Zotero website 12/1/2022: https://www.zotero.org/groups/4740476/elwha_bibliography/library. Note that this literature is focused on biophysical monitoring of the river. We did not search social science literature, and this could be a fruitful avenue for further study.

The papers reviewed represent multiple disciplines, ranging from geomorphology to fisheries, with over half published post dam removal (Table 1). Citizen science was not reported as such in any of the publications reviewed; however, many mentioned or thanked specific volunteers or volunteer groups (i.e., Washington State University BeachWatchers, Dungeness Wildlife refuge volunteers) for their assistance with field data collection or sample processing. Acknowledgement sections of 14 papers, most of which have been published in the last decade (post-dam-removal), mentioned such groups. An additional eight publications referenced field assistants generally or by name in the Acknowledgements, but whether these represented volunteer or community and citizen science contributions was unclear. The publications that acknowledged such individuals or groups tended to be research related to biological or ecological sciences rather than physical sciences (e.g., geomorphology).

This is unsurprising, because CCS can sometimes play an important, but unseen role in more formal scientific work. Some publications may use data from CCS projects without describing or even acknowledging them.[15] Our review highlights that CCS on the Elwha related to dam removal and recovery is reported neither thoroughly nor systematically in the peer-reviewed literature to date. We noted that the practices around how to acknowledge contributions to research varied widely across the literature review. Highlighting these contributions more clearly and prominently in the peer reviewed literature could help researchers and community members better understand and address strengths, challenges, and future potential of CCS in the Elwha.

Terminology is also an evolving discussion in CCS. Many of the practices and projects encompassed by "community and citizen science" (e.g., amateur astronomy, the Christmas Bird Count) have been a part of science for longer than the terms themselves have existed. Frequently project leaders and participants say they didn't know they were doing CCS, because that was not what it was called when they engaged in the activity.[16] In addition, some groups may explicitly prefer not to call their work CCS. The pattern of CCS occurring without explicit recognition is not unusual.

Regardless of the terms used, on the Elwha, participatory work has been an important component of the research done before, during, and following dam removal, at least in some disciplines. And more recently, particularly as part of the Elwha ScienceScape, there has been a concerted effort by professional scientists, educators, and outreach coordinators to deliberately engage in and envision CCS projects. In the next section, we describe some of these recent participatory projects on the Elwha, including some activities that began with the 2022 Elwha ScienceScape effort and may continue.

Recent and Ongoing CCS on the Elwha

Since the beginning of pre-dam removal monitoring, Elwha researchers have engaged in CCS through a variety of formal and informal mechanisms. Through conversations with Elwha ScienceScape researchers, we generated a list of CCS projects currently underway or recently completed. We asked about general characteristics of the participants (e.g., were they students, retired, local, etc) and how many individuals participated, for how long, and how frequently. We also tried to document types of activities conducted, the length of projects, what organizations were involved, and the roles of participants.

[15] For an example of this phenomenon in bird watching and citizen science, see Cooper et al. (2014) The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. PLoS ONE 9(9): e106508. doi:10.1371/journal.pone.0106508

[16] See Eitzel et al. (2017) for more on how CCS terminology has evolved.

Table 2. Recent and current Community and Citizen Science (CCS) projects on the Elwha River, gathered from informal conversations with ScienceScape researchers who worked on these projects. iNaturalist data was retrieved from inaturalist.org.

Project Description	Number of Participants, Characteristics	Participant Activities	Duration/Frequency	Organizations Involved
Nearshore Fish Monitoring Biotic: beach seine survey of fish Abiotic: Corresponding water quality and habitat (substrate/vegetation)	• 16 volunteers/interns (including tribal) / Veteran Conservation Corps / AmeriCorps / Beach Watchers / high school, college work study	Assist on small boats beach seining, lab sample analyses, data entry, and small projects on aspects of research that involve reports and data analyses	Every year over 6 months, for 18 years	• National Oceanic and Atmospheric Administration (NOAA) scientists • Agency partners (including Tribes) • Veteran Conservation Corps • AmeriCorps • Students: high school and undergrad • Internship programs (NOAA, agency partners, minority) • Beach Watchers • Coastal Watershed Institute
Freshwater Foodweb Monitoring Biotic: periphyton, benthic invertebrates, drift invertebrates, juvenile salmonid diet Physical: river substrate, velocity, and riparian canopy characteristics Chemical: nutrient concentrations	• NOAA, Lower Elwha Klallam Tribe (LEKT), and United States Geological Survey (USGS) scientists worked with various interns and volunteers on a formal and informal basis for 10+ years of sampling. In a given year there were typically from 4–12 participants. Over the years, somewhere in the range of 40+ different people participated. The core agency/tribal group of scientists in a given year was typically 4.	Collect regular monitoring data on biotic, physical, and chemical characteristics across a network of 40+ sites in the Elwha and Quinault watersheds. Interns assisted with data entry, database management, sample processing, data analysis, and manuscript preparation.	• 10+ years of sampling • Frequency varied from once a year to monthly • Most commonly, sampling occurred 2 x per year • Duration of sampling: 1–2 weeks	• NOAA scientists • USGS scientists • LEKT scientists • Americorps interns • Veteran Conservation Corps • Students: high school and undergrad • Intermittent participation by other community volunteers
NSF Research Experience for Undergraduates Coordinated by Peninsula College and Western Washington University in conjunction with the Elwha Research Consortium, to allow undergraduates to study science alongside faculty and agency mentors assessing environmental conditions in the Elwha watershed and surrounding areas prior to dam removal.	• National Science Foundation (NSF) Research Experience for Undergraduates (REU) grant to Peninsula College	Approximately 20 students worked with approximately 5 mentors fields of microbial ecology, wildlife ecology, and fisheries.	• 2005–2010; Undergraduates worked on year-long projects.	• Peninsula College • Western Washington University • Olympic National Park (ONP) • NOAA Fisheries
NSF REU-High School Summer Program High School students from the Lower Elwha Klallam Tribe participated in two NSF-supported research experiences designed to help tribal youth explore the scientific and cultural dimensions of the Elwha River Restoration Project.	• 10 LEKT high school students	Their first program was run by Western Carolina University, OPI, and the LEKT, where students explored the watershed, analyzed water samples from various reaches, and learned more about their tribe's ancient cultural links to the valley. The second program allowed these students to join the college-level REU students for three weeks, where they helped study amphibian distributions, soil nutrients, GIS, and invasive plants with three PC faculty.	Summer 2006	• Western Carolina University • Lower Elwha Klallam Tribe • Olympic Park Institute (OPI), now known as NatureBridge • Peninsula College
Oregon Museum of Science and Industry (OMSI) Salmon Camp Summer camp program geared towards engaging Native American middle and high school students in Science, Technology, Engineering, and Mathematics (STEM) and information technology (IT) career exploration. The natural resources camp experience was a way to make this learning both engaging and rigorous, with lots of depth.	• 4 OMSI camp staff • 10 students • 4 NOAA researchers • 2 NOAA undergraduate interns	OMSI Salmon Camp spent a week with NOAA scientists collecting baseline data prior to Elwha dam removal on a reference reach of the Quinault River. Students and OMSI education staff assisted with physical habitat channel surveys and freshwater foodweb monitoring.	Summer 2006 – one week	• OMSI • Native American Youth and Family Association • Columbia River Intertribal Fish Commission • NSF • NOAA Fisheries
Undergraduate Research Coursework Students participate in collection of scientific data as a part of a field course or topical course on the Elwha. (e.g., courses in marine geophysics and vegetation restoration)	• Marine sedimentary processes – every other year, group of 8 students • Vegetation restoration - every year, total 23–28 students	Students collect data as part of the field course activities. Measurements vary from project to project depending on current funding	• Marine sedimentary courses 2012–2020 • Vegetation courses since 2018, Elwha-specific courses since 2018	• University of Washington • Peninsula College

Project Description	Number of Participants, Characteristics	Participant Activities	Duration/Frequency	Organizations Involved
Coastal Watershed Institute Internship Program Students work in paid 2-year internships on a variety of research projects (e.g., nearshore monitoring, beaver monitoring via camera traps) and organize public outreach events	• Average of 5 paid student interns per year • Approximately 30 people per community engagement workshop	Students conduct research, present their work at scientific conferences, in social media posts, and scientific publications, and organize science community engagement workshops where science leaders present on topics of importance to the general community (students coordinate with community, attend and present at the meeting and provide meeting synopses)	• Internship program: 2002–present, 20–30 hours per month • >3 community engagement workshops per year beginning in 2007	• Coastal Watershed Institute
Water Quality Sampling Assessing specific aspects of water quality at particular times (rather than collecting ongoing measurements)	• Educators and students from Nature Bridge • 1–2 Community members from Port Angeles and Sequim in each Streamkeepers survey	Water quality measurements, flow measurements, coliform bacteria and *e. coli*	• NatureBridge intermittently 2012–present • Streamkeepers: half an hour, 6–12 times per year, since 2008	• NatureBridge educators and students • Clallam County Streamkeepers
iNaturalist Volunteered presence-only biodiversity data, within the Elwha watershed and nearshore	• 1,389 observers, 1,378 identifiers, 11,432 observations • General public/online	Observing and documenting a wide range of biodiversity, crowdsourcing identification of organisms	• 2012–2022, intermittent but consistent	General public
Water Temperature Monitoring Water temperature has a strong influence on the productivity and diversity of freshwater ecosystems. NOAA is collaborating with multiple partners to maintain a network of continuously-monitoring temperature loggers from the headwaters to the mouth of the Elwha. With this data, a predictive temperature model has been built to better understand how salmon respond to thermal changes associated with altered landscape processes and climate change.	• NOAA (2), LEKT (2), and ONP (2) scientists worked together in to install an initial network of 20+ loggers. NOAA is coordinating with local agencies, environmental groups, and educational partners to download and maintain this network. The number of community and student participants is currently estimated at 10, but is continuing to expand.	Quarterly downloading of data from temperature sensors; maintenance and relocation as needed. As the NOAA data portal is rolled out, participants will be able to compare their real-time data collection to historic values and generate their own hypotheses and study questions	• Quarterly field trips; duration varies from 1–4 days depending on number and location of loggers visited.	• NOAA scientists • LEKT scientists • ONP scientists • Clallam County Streamkeepers • Friends of ONP/Olympic Peninsula Hikers • Seattle University students • Western Washington University, College of the Environment extension students
Camera Trap Photography Tracking wildlife using camera traps throughout the watershed	• 1 local college botany Professor and her undergraduate students	Collecting camera data cards, changing out batteries	• Every 2 months, year round for the last 18 months	• LEKT Department of Natural Resources • Western Washington University students/professor
Benthic Macroinvertebrate Processing Benthic macroinvertebrate sampling is at the core of the long-term freshwater foodweb monitoring and interpreting the effects of dam removal on benthic ecosystems. Sample processing is time-consuming and costly.	• NOAA (1) and Evergreeen State College Faculty (1) are teaching undergraduate students basic benthic macroinvertebrate identification to help sort backlogged samples. Students are able to use the data for individual capstone projects, and if desired, contribute to analyses and reporting of long-term monitoring outcomes. So far only 2 students but more are being recruited.	Sort out invertebrate specimens from sample debris and categorize into major taxonomic orders. Generate study hypothesis, data entry, data analyses.	• Ongoing as student schedules allow, and timing of their capstone projects	• NOAA • Evergreen State College • Western Washington University, College of the Environment extension students
NOAA CCS Internships Several years in a row, NOAA has had interns focused on supporting Elwha CCS.	• 1 undergrad through NOAA Hollings Scholars • 1 undergrad through José E. Serrano Educational Partnership Program with Minority Serving Institutions (EPP/MSI)	Interview and record audio from scientists about CCS activities that could be done on the Elwha, draft a volunteer handbook, assist with salmon monitoring and survey field work, design an online database for tracking volunteers.	• Spring and summers of 2021 and 2022	• NOAA Fisheries
Vegetation Field Sampling Tracking vegetation changes pre, during, and post dam removal informs the understanding of ecological recovery.	• 2 expert volunteer botanists, retirees from Sequim	Characterizing vegetation plots in detail, to species	• Once in summer of 2022, approximately 100 hours between the two volunteers	• USGS scientists • LEKT restoration volunteers

Project Description	Number of Participants, Characteristics	Participant Activities	Duration/Frequency	Organizations Involved
Stable Isotope Sampling Isotopes can be used to trace the flow of marine-derived nutrients through the aquatic food web as adult salmon return from the ocean to spawn in their natal fresh waters.	• 14 education staff from NatureBridge (NB) led 125 8th–12th grade students from Washington, Colorado and Texas.	NOAA and USGS scientists worked with NB staff to develop a field-based curriculum and sampling method. Visiting students collect periphyton and benthic macroinvertebrate samples. These samples were then passed on to NOAA/USGS for processing and chemical analyses. As the NOAA data portal is rolled out, participants will be able to compare their real-time data collection to historic values and generate their own hypotheses and study questions.	• Spring–Fall 2022	• NOAA scientists, USGS scientists • NatureBridge educators and students
Small Mammal Monitoring Traps on former reservoirs to track the recovery of this component of the ecosystem	• Occasional involvement by 1-2 volunteers and students	Assisting in setting and baiting traps	• Infrequent	• LEKT DNR • USGS
Shoreline Processes Research Collection of data on sediment transport and shoreline morphology at sites on the Elwha River delta, before dam removal, to better understand the fate of dam removal sediments in the coastal environment	• Between 2007 and 2019 community scientists, primarily associated with the Clallam County BeachWatchers program (now defunct), Peninsula College, the University of Washington, and the Washington Conservation Corps, assisted with the collection of field observations on the beach of the Elwha River delta and its associated littoral cell (including on Ediz Hook). Approximately 25 community scientists participated, contributing an estimated 200 people-hours to the project.	Surveying shoreline morphology, collecting grain size samples, and placing, tracking and recovering sediment tracers	• Between 2007–2019 by arrangement	• Washington Sea Grant • USGS • University of California, Santa Cruz • Clallam County BeachWatchers • University of Washington ESS Department

Table 2 demonstrates the wide range of CCS activities within the Elwha watershed, varying substantially across factors such as number and type of participants, focus of the scientific work, nature and duration of participant involvement, and the institutional collaborations that enabled CCS engagement. These results illustrate the breadth of CCS in general – there are many ways in which people who are not professional scientists may contribute to the work of science and monitoring in this ecosystem. Sometimes these collaborations happened serendipitously and other times they were implemented following careful design.

Consistent with the results of our literature review, most of the Elwha CCS activities we documented were focused on biological phenomena (temperature monitoring being one exception). Some activities are long-standing, while others began more recently (with the most recent being summer of 2022). A majority of projects involved a relatively small number of volunteers (with isotope sampling and iNaturalist being the notable exceptions). Some of these small-scale projects were not designed specifically to include or rely on volunteers, but took advantage of opportunities that arose when volunteers with specific knowledge and abilities became engaged (for example, the vegetation monitoring in summer of 2022). In other cases, scientists developed partnerships with organizations such as NatureBridge's Olympic National Park campus or with Clallam Streamkeepers, specifically to build in a CCS component to their work. Although we do not have data about the motivations of participants, it is notable that some were involved as students or interns, and thus engaged specifically to receive training and/or qualifications related to their work. For others, we do not have specific insights about the motivations for volunteering time, skills, and energy on a project.

Potential CCS on the Elwha

Past and ongoing experiences with CCS in the Elwha, along with the motivation to sustain and build on Elwha science, form a rich foundation for discussions about the ways in which Elwha CCS could continue and expand into the future. Many researchers involved with Elwha ScienceScape are interested in and creative about envisioning how the public could be involved in their research projects and help to meet a demand for future monitoring. Discussions of CCS also raised ideas for new projects that could fill information gaps, and/or address community interests and priorities. In this section, we summarize these ideas, noting that this report is a snapshot in time, and collaboration and planning among partners is an ongoing process.

Table 3. Proposed and future Community and Citizen Science (CCS) projects on the Elwha River, gathered from informal conversations with ScienceScape researchers who are working on or proposing these projects.

Project Description	New Project? New Collaboration?	Resources Required	Current Status	Organizations Involved
Subtidal Dive Surveys Tracking the influence of sediment on marine community and water quality over time	Existing CCS program, novel collaboration with agency scientists to continue existing monitoring	• Support for ReefCheck to add more sites and harmonize protocols • Time for review and discussion of ReefCheck protocols	Discussions underway for ReefCheck to add several sites to next year's survey; ReefCheck is applying for funding to support this	• Washington Sea Grant • Reef Check California
Bird Monitoring Surveying species using the river mouth and estuary, possibly using eBird as a database	New monitoring/data gap, possible connection with existing eBird volunteers	• Highly skilled volunteers • Volunteer managers • Access to some locations	Initial meetings with partners/volunteers	• Lower Elwha Klallam Tribe Department of Natural Resources (LEKT DNR)
Vegetation Mapping Detailed drone imagery captured on the river before, during, and after dam removal could be classified to better understand vegetation dynamics. On the ground confirmation via transect measurements could also be obtained by volunteers.	New project/data gap, existing tools, new collaboration	• A way to test tools for the vegetation mapping, and for training volunteers to use the tool • Volunteers with some level of technological proficiency	Initial ideas discussed, need to explore tools and find volunteers	• United States Geological Survey • University of California, Davis
Photopoints / Photo Resurvey Tracking landscape changes over time by encouraging the public to take repeat photographs and share them, using physical frame to encourage them to use the same location	Expanding existing photo resurveys by installing frames and encouraging participation. Building on work from 2003–2007 with Surfrider Foundation	• Access to locations for frames • A way to accumulate photos • Advertisement to the public to contribute photos • Time to find old photo survey data from 2003-2007 and potentially include them in future plans for the project	Need to find locations to put the resurvey frames and a way to advertise to the public to contribute photos	• Washington Sea Grant • Olympic National Park
Grain Size Surveys Document substrate changes as sediment moves through. Cobble, to sand and back to a former baseline	New tool, new collaboration	• App and associated database for taking photos and storing/analyzing them • Volunteers to go out and do surveys	Need to test out apps and tools to determine if coarse-grained sediments can be captured	• USGS • University of Washington • Washington Sea Grant • Army Corps of Engineers
Back Country Survey Backpacking enthusiasts could be engaged to help with redd surveys, temperature loggers, eDNA, etc.	New collaboration; National Oceanic and Atmospheric Administration (NOAA) scientist gave a presentation at meeting of Friends of Olympic National Park in Nov. 2022. Group composed largely of retired Parks Service employees; i.e., many avid backpackers who know the Elwha well. Others in community also attended meeting.	• Scientists to spend time up front orienting volunteers to sample locations and protocols. To reach remote locations, volunteers will need bicycles to get to trailhead. From there, appropriate hiking and backpacking equipment, depending on distance to sites. For temperature loggers, only a smartphone is required.	Initial contacts made; first volunteer from Friends of Olympic National Park attempted logger retrieval 12/7/22. Orientation scheduled with other volunteers on 1/12/23.	• Friends of Olympic National Park • Olympic Backpackers Facebook Group
Nearshore Fish Monitoring Fish surveys with beach seine: document changes in salmon and forage fish abundance in nearshore, done from shore with a tote or in a net	Continue collaboration with Tribe, Colleges/Universities, Veteran Conservation Corps (VCC), Americorps but also add in Northwest Indian College and Tribal Youth Corps, would also like to engage local fisherman and county volunteers, salmon enhancement groups, fishing derby folks	• Someone to organize and track volunteers and paperwork, potentially cover insurance/liability, manage gear lending library. Volunteers with boats a possibility or equipment to deploy from shore (like All-Terrain Vehicle).	Issues being addressed in ScienceScape grant, also applying for other funding sources, and making connection with new collaboration interests	• LEKT • Americorps • VCC • Northwest Indian College • Tribal Youth Corps • Clallam County • Fiero Marine Life Center
American Conservation Experience Intern The ScienceScape group is funding an internship through American Conservation Experience, in part to support CCS on the Elwha. They will coordinate CCS projects across disciplines.	New position meant to synthesize and support a broad range of projects, and create a template for a possible ongoing position.	• Support for intern	Position has been filled, intern will begin in 2023	• LEKT • American Conservation Experience

Project Description	New Project? New Collaboration?	Resources Required	Current Status	Organizations Involved
Collaboration with Local Higher Education Institutions Supporting Peninsula College "Guided Pathways" track focused on the Olympic Peninsula via guest lectures, connections with the Longhouse ʔaʔkʷustəŋáwˀtxʷ House of Learning, hosting a gear lending library for local volunteers, providing greater Elwha-related internship opportunities to students.	New collaborations between Elwha scientists and Peninsula College and other faculty on a variety of projects	• Support from Peninsula College administration • Corporate sponsors for donations of personal safety gear • Support for student internships	In discussion – working with various Peninsula College staff/faculty to find opportunities for collaboration At least one field trip is planned in spring to support Western Washington University extension students in the College of the Environment	• Peninsula College • Western Washington University, College of the Environment • LEKT • Washington Sea Grant
Fish Genetics Using genetic data to understand population size and health	Expanding on some existing connections, but largely new connections	• Time to work with fishers to discuss sampling; time to build those relationships, especially with Tribal fishers • Resources to run genetic analyses • Fish tissue samples from fishers	Idea stage, waiting on fishery being open, still need to build new and expand existing partnerships with fishers	

Table 3 describes some of the ideas for potential CCS activities in the Elwha, drawn from a variety of discussions with Elwha ScienceScape partners. It is important to note that there may be many different motivations for initiating a CCS project. In some cases there may be a demand for continued data collection which is not feasible due to a reduced capacity on the part of professional scientists (for example, due to funding constraints). As illustrated in Table 3, there are various ways that CCS can play a critical role if there is a good fit. Subtidal dive surveys, which may be continued by volunteers with the Reef Check program, are one example where an existing CCS program can begin operating in the Elwha to help bridge the gap. Other cases, such as the idea of working with various groups to do back-country surveys, may require creating a novel CCS project. Such partnerships can help to address a scientific funding shortfall, but CCS activities also come with resource needs which are often qualitatively different from the needs of monitoring conducted by paid professionals (see "Resources Required" column of Table 3). In some cases, the resources required are not monetary but include making introductions and building relationships. For example, Tribal, sport, and commercial fishers may be able to provide tissue samples to fish biologists studying population genetics. Community-based CCS often benefits from long-term relationships, so although the fishery is still closed, relationships could still be built or expanded in anticipation of future work together. It is also important that the broader scientific community is aware of the economic, cultural and emotional cost of the fishery closure to the Klallam people. Out of respect for this perspective, scientists at the 2022 Symposium and afterwards reflected that more actively collaborating with Tribal members and their youth might provide additional avenues to interact with the river and the fish in absence of traditional practices while the fishery is closed. This also might provide future employment options as well as a greater opportunity for information exchange and communication in both directions.

CCS in the Elwha may also stem from specific community interests that are not already addressed by ongoing monitoring activities. New questions emerging from past scientific findings could be well addressed by CCS. Regardless of the initial impetus, developing a new activity generally requires an iterative process of determining the appropriate partnerships, essential requirements of monitoring activities, availability and capacity of participants, funding needs and a variety of other considerations. The "Current Status" column of Table 3 illustrates some of these processes for proposed project ideas, as of early 2023.

Community Questions and Interests

Much of the Elwha dam removal science and monitoring work to date has focused on questions driven by policy and management interests. As we consider the decades to come, and the potential role of CCS, it is worth considering how that work has also addressed or could better address community interests and questions. We asked registrants of the Elwha ScienceScape public event, "Elwha Ecosystem Restoration – 10 dam-free years and counting," what they wanted to know about how the river has changed. Upon registration, participants were prompted to submit a response to the following question: "What are you interested in finding out about how the Elwha has changed over the ten years since the dams were removed?" We grouped the responses by topic and tallied up each topic (see Table 4).

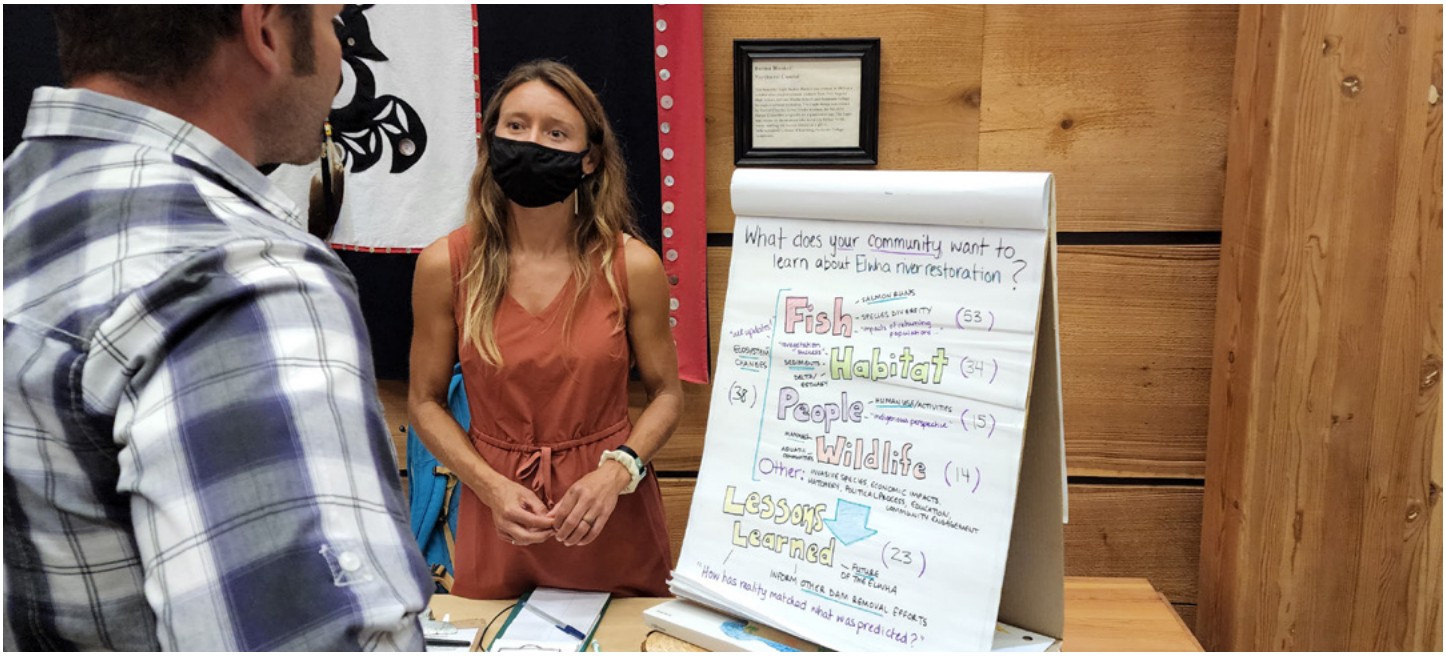

Table 4. Summary of community interests in Elwha research topics from ScienceScape public event in August 2022.

Topic	Number of Responses	Keywords or Subtopics
All	21	Everything, all updates, new stories to share
Ecosystem	17	Interactions among components, adaptation
Fish	53	Repopulation, recovery, return, impacts on species shifts
Wildlife	15	Impacts on repopulation
Landscape	28	Invasive species, revegetation, estuary, river channel, sediments
People	15	Cultural impacts, human use changes, public access
Dam removal process	12	Science of dam removal, influence on other dam removal projects

Of the more than 200 registrants for the event, 141 individuals answered the question about the Elwha. The 141 responses collected varied from highly specific (i.e., How has the biodiversity differed …") to broader (i.e., "all relevant changes"), but the majority reflected one or more of the following topics of interest: ecosystem, fish, wildlife, landscape, people, and the dam removal process (Table 4). Fish were the most frequently mentioned topic, including questions about specific salmon populations as well as species diversity shifts. Other less common but notable shared interests were economic impacts, cultural implications and whether reality has matched what was predicted to occur.

During the public event poster session, these survey results were presented to attendees and some participants were asked if they felt their questions were answered or addressed at the event (see photo). The only topic that some participants felt was lacking was information about the impacts of the dam removal on humans. Although attendees of this outreach event were not likely to be a representative sample of the broader public, their responses still demonstrate shared interests among different groups (local scientists, education partners, community members, etc.), and helped to identify possible research or communication gaps/opportunities.

Conclusions

Having discussed CCS with scientists working on the Elwha River, examined the published academic literature, and summarized the interests of event participants at the public ScienceScape event, we have sketched out the current and potential scope for CCS projects around dam removal monitoring on the Elwha. We conclude our report by exploring the themes that emerged from the Elwha ScienceScape events and our ongoing conversations. We then highlight challenges and solutions associated with CCS projects on the Elwha, discuss the advantages of CCS, and end with possibilities for future CCS engagement on the Elwha.

Themes

Across all the CCS projects, past, present, and proposed, we saw a diversity of needs and models of engagement, and substantial creativity and willingness to try new approaches to conducting rigorous science and engaging with the public. Some projects were planned in advance to include volunteers, while others capitalized on opportunities associated with specific volunteers engaging with scientists in fortuitous but less-planned ways. Many of the projects required highly trained volunteers with expert knowledge or certifications, while some projects could benefit from crowdsourcing and other less-skilled input. Some projects required assistance with volunteer management (including training in how to collect data and management of paperwork and liability requirements), while others needed assistance with data management (including quality control/quality assurance, harmonizing into a consistent format, and storage and sharing strategies). Some prospective project ideas can serve multiple topics at once (for example, iNaturalist monitoring of biodiversity, or photopoints/photo resurveys to track changes in vegetation and geomorphology). In other cases a single research question requires multiple partners (for example, temperature logging in different locations with varying accessibility). Additionally, some projects require prioritizing cultural sensitivity, relationship-building and trust. For example, working with Tribal communities on their research priorities can differ from using intensive data gathering events to engage iNaturalist contributors.

Across many of the existing projects, however, there was a consistent need for highly skilled volunteers, which meant that existing and planned projects tended to engage with smaller numbers of volunteers with specialized backgrounds or who could be more specifically trained to do complex tasks. Keeping the community at large supportive, enthusiastic and informed is also needed, and while the ScienceScape events of 2022 take a step in that direction, there are many other avenues for outreach that could be fruitful.[17] In addition, there is an intention among ScienceScape scientists to broaden participation beyond this model and improve the two-way communication CCS can enable. We explore some of the challenges and solutions associated with existing projects to highlight where participation could be broadened further.

Challenges and Solutions

The Elwha CCS projects, past, present, and future, cover a wide range of diverse topics and configurations. Many of these projects have encountered challenges, and many people involved have found creative ways to continue. Barriers can occur at any stage including: red-tape to work with volunteers from within agencies, lack of long-term interest/commitment from volunteers, difficulty tracking volunteers, lack of funding to support the CCS component of a science project, difficulty harmonizing data and finding public ways to share it, or issues in accepting data from the public. Some barriers are logistical and some are institutional, while others relate to the time and effort required to build trust, for example with LEKT and other entities (including those from historically different political backgrounds). We summarize these in Table 5.

[17] For example, reaching out to local newspapers and the LEKT Tribal newsletter to share information and stories about Elwha science; hosting additional public events for smaller audiences and with presentations aimed at lay audiences (in particular, holding events like this on the LEKT reservation); and developing an easily-accessible website that shares all the Elwha data sources that have been collected over the years.

Table 5. Challenges faced by Elwha Community and Citizen Science (CCS) projects, solutions to those challenges, and examples, gathered from informal conversations with ScienceScape researchers who worked on these projects.

Challenge	Solution	Examples
Highly skilled participants necessary	• Draw on scientist and local interested community network to find partners and/or to handle training	• Vegetation sampling volunteers found via LEKT's volunteers • Subtidal dive survey team connected with ReefCheck through UC Davis team
Safety concerns	• Modify/divide tasks amongst participants to isolate risky tasks • Allow more time for training	• Handling small mammals incurs risk, but volunteers can bait and set traps without direct contact • Students can sample stable isotopes in the food web at the water's edge while educators can wade further into the river
Liability and paperwork	• Working with agency outreach and education staff to streamline process and use existing bureaucratic mechanisms • Creating a method to track volunteers' availability, certifications, and liability waiver status	• Freshwater foodweb monitoring team working on streamlining process of volunteer onboarding • Nearshore Fish monitoring team created a Google form and spreadsheet to help track volunteer logistics
Accessibility of sites and equipment	• Lending library of tools • Splitting up project between groups of volunteers with different abilities • While the fishery is closed, building/expanding relationships with fishers	• Freshwater foodweb monitoring team developing lending library of waders and other equipment • Temperature loggers divided up between front country and back country with different volunteers for each location
Ongoing volunteer engagement	• Engaging volunteers in collecting data • Sharing collected data with volunteers • Flexible scheduling to provide opportunities for volunteers with less flexible work schedules and child care routines • Building meaningful reciprocal relationships	• Building relationships between scientists and local fishers, including Tribal members • Hosting and advertising an intensive data collection effort like "Elwha Big Day" for eBird records • Positioning photopoint/photo resurvey frames in popular locations • Having volunteers remove blank images from camera trap data before processing • Data portal being developed for volunteers to access data collected
Data management and analysis	• Students working with teachers can help with data QA/QC • Dedicated intern can help with data QA/QC • Technical assistance in evaluating data acquisition and storing tools and apps	• NatureBridge and undergraduate institutions (e.g., University of Washington) pair skilled educators with students • ScienceScape hiring an intern to help coordinate and centralize data collection on Elwha monitoring projects • Partners at UC Davis helping to evaluate imagery analysis tools for drone imagery or grain size analysis
Funding needed	• Networking between partners of different sectors (e.g., academic, nonprofit)	• ReefCheck talking with various partners to explore different sources of funding for subtidal dive surveys

Many of the challenges encountered by Elwha CCS projects can be addressed by making use of internal and external networks of scientists, educators, and their institutions. For example, in an educational context, to address data quality challenges, instructors can help ensure the quality of data collected by their students. To address challenges around liability and paperwork, projects can leverage some agencies with education and outreach teams that may have existing administrative tools. In other cases, partnering with an organization that already engages and manages volunteers can be an effective way to establish shared goals and leverage that resource. Entities like the UC Davis Center for Community and Citizen Science can help to connect different organizations, evaluate CCS tools, and facilitate long-term solutions.

We also acknowledge that, in some cases, CCS is not an optimal solution for research (for example, handling endangered species during fish tagging and tissue sampling).[18] In addition, in the past, the Coastal Watershed Institute[19] has worked with volunteer data collectors and has found that an optimal way to engage the public is through a robust paid internship program with an outreach component; this has proven to be a more effective use of time and resources. In CWI's internship program, college students gain training in nearshore ecosystem science and experience in management of shorelines, as well as logistics for organizing public engagement. CWI is also able to leverage and expand the reach of the students' work through public presentations (but not necessarily volunteer data collection as in CCS). Though CWI's interns focus on outreach, this type of program in which a small number of trained, paid individuals organize or manage different forms of public engagement could be a potential solution for CCS projects where data quality and volunteer management are challenging.

Advantages and Strengths of CCS for Dam Removal

Implicit in the discussion of challenges is the fact that barriers are often worth overcoming, in light of the potential benefits of CCS. The potential for long-term stewardship, learning and education outcomes for participants (particularly students), engaging historically marginalized groups, mutual understanding and trust among scientists and other groups, and cost-effective data collection are among the many potential gains for engaging non-professional scientists in research and monitoring. Of course, the actual benefits depend on many factors including project structure, type of research, and personal values of the researchers involved. Below we include two testimonials on the benefits of CCS from Elwha ScienceScape scientists involved with CCS projects on the Elwha.

"For much of the long-term monitoring that we have done on the Elwha, both the extensive temporal and spatial scale at which data was collected would not have been possible without community science. As with many projects, the riverine food web research program did not have enough funding or personnel to collect and process data at the scales needed for a project of this magnitude. Researchers quickly realized they needed to utilize an 'all hands on deck approach' and every field collection project over the last 18 years has featured a different cast of characters. Sometimes this meant scientists from other agencies and unrelated fields helping out, often it included Lower Elwha Klallam Tribe staff members who came from programs other than fisheries; local high school and college students frequently assisted, as did members of Washington Conservation Corps, the Veterans Conservation Corps, and Americorps members—most coming from other agencies or non profits where they worked on different projects.

[18] For a look at the different situations in which CCS may or may not be appropriate, see Pocock et al. 2014. "Choosing and Using Citizen Science: A Guide to When and How to Use Citizen Science to Monitor Biodiversity and the Environment." Centre for Ecology and Hydrology.
[19] https://coastalwatershedinstitute.org

"For the majority of these community scientists, it was their first experience collecting stream ecology data, and consequently every sampling trip began with a training day. This iterative process led us to become very efficient and systematic in how we collected our data over time. With people coming from such varied backgrounds who wanted to know the why behind every technique, it also forced us to closely reexamine our typical collection protocols, and readjust as appropriate. As new people came and went over the week, team members who had only just started sampling recently were able to help train new arrivals.

"But beyond necessity or efficiency, this community approach enriched our science in so many ways. We always tried to make sure that every crew member had the opportunity to rotate through the different sampling tasks. Consequently, they gained a better understanding of our overall research objectives, and brought new ideas that helped us improve our study design. Colleagues from different agencies and fields who joined us provided a natural avenue for cross-pollination and opportunities for interdisciplinary collaboration. For other volunteers who didn't come from traditional academic backgrounds, it was exciting to watch as they realized they too were scientists. And the joy and enthusiasm nearly every student and intern expressed at the opportunity to be even a small part of the Elwha Restoration Project reminded us how fortunate we were to be able to study and learn on this river thanks largely to the generosity and hospitality of the Lower Elwha Klallam Tribe."

"Stewardship, in addition to gratitude, are two cornerstones that give my life the most meaning. In my professional life ecology is my passion. Being able to participate on this project with so many brilliant scientists was one of my career highlights. I enjoyed using all aspects of my formal education and work experience to date to work on successfully documenting the impact such restoration efforts have on salmonid and forage fish enhancement and conservation. In my personal life I am also dedicated to try to help improve the lives of children, family members from the Native American/Alaskan Native community, and those who have not had the same educational and socio-economic opportunities I was given. I feel that involving citizen scientists and students in fieldwork on the Elwha going forward could include many who have been disenfranchised from the scientific process. Additionally, it allows for succession planning so that individuals such as myself can 'pass our batons' to the next generation. Because I strongly feel that we have the same responsibility to be good stewards of salmon and the environment as we do to provide a legacy for those that follow us on this earth."

In preparing this report, we did not measure the benefits of CCS in a systematic way. However, beyond the testimonials above, the broad-based enthusiasm for and ongoing commitment of many Elwha ScienceScape participants to CCS – demonstrated in our conversations and events throughout 2022 – shows the potential for great benefit. We are also better positioned, as a result of this reflection, to systematically document CCS in the years ahead.

Future Directions for CCS Work on the Elwha and Beyond

Our suggestions are intended primarily for ScienceScape scientists and their partners in the Elwha. However, the Elwha River dam removals are a global symbol of what is possible with watershed-scale restoration projects. In that sense, we hope other large-scale dam removal projects can learn from and build upon these insights. Table 6 summarizes our suggested future directions in three areas: administrative support for projects, better measurement of CCS, and questions to ask in order to improve Justice, Equity, Diversity, and Inclusion.

Table 6. Suggestions for Future Community and Citizen Science (CCS) Work on the Elwha.

Areas for Structural and Administrative Support	Ways to Better Measure CCS	Questions for Improving Diversity, Equity, and Inclusion
• Assistance for scientists in navigating administrative burdens when including volunteers • Assistance with data management, including quality control, storage, and sharing • Assistance matching technical skills and abilities with projects • Assistance aligning goals of education, stewardship, and data acquisition	• Make volunteer contributions clearer in academic papers, both in acknowledgments and authorship • Ask participants and scientists what benefits they derive from CCS and what motivates them to participate • Assess community benefits from CCS projects, for example answering questions of concern • Quantitatively assess the contribution of volunteers to scientific findings	• How can we leverage partnerships to honor and uplift the perspectives of non-dominant communities? • How can we center reciprocity and maximize positive impacts for volunteers and partners? • How can we design projects that broaden participation across their stages – from defining research questions to disseminating findings?

Suggestions regarding administrative help reflect the reality that CCS often involves significant additional labor on the part of project leaders. This is because successfully managing volunteers requires significant coordination, and because CCS is often accomplished through multiple partnerships. Efficiencies can be achieved by sharing capacity (e.g., for data management or volunteer coordination) across projects, and communicating proactively about ways of removing or surmounting barriers.

Tracking and assessing CCS projects can provide valuable information that helps to sustain and grow these projects over time. If we understand benefits to, and motivations of participants, for example, projects can be adjusted to better facilitate and expand participation. We may learn, for example, what kinds of compensation (financial or otherwise) are needed to facilitate participation. We could also learn how data could be shared in meaningful ways so that participants can understand and use the results from their CCS work and/or see its impact on the issues that originally motivated them.[20] Such assessments of CCS can also inform the broader monitoring strategy for the watershed by helping to identify potential partners in measurement plans and the roles that volunteers could play in that broader strategy. Finally, tracking and assessing CCS activities can help to make the story of Elwha CCS more visible to funders and other partners working in the Elwha, thus aiding with fundraising, and potentially volunteer recruitment and retention.

This report has made multiple references to the idea of engaging broad audiences in CCS projects, and one way of thinking about broad engagement is to focus specifically on Justice, Equity, Diversity, and Inclusion. For example, engagement with LEKT and other Tribal entities is an ongoing process for many of the past, present, and proposed CCS projects in the Elwha – and long-term commitment to these processes is important to their success. As CCS projects and opportunities expand in the Elwha, so too could conversations about who has access to these opportunities, and who *should* have access. Information gathered during the ScienceScape public event is one approach to encouraging input on such issues, and this kind of community engagement could continue as part of CCS project planning. Beyond the potential benefits of CCS participation for the participants themselves, we also point to the many ways in which CCS projects benefit from diverse experiences and perspectives that participants bring, especially when coming from outside the traditional bounds of Western science.

Several additional points for future discussion have emerged. First, explicit conversations about the relative prioritization of CCS projects may be useful. Choosing which projects to emphasize for existing funding and grant applications, as well as volunteer and professional scientist time and labor, could work to counter – or could exacerbate – equity concerns. One example of an approach to prioritization is the current work of the CCS subcommittee on how to engage LEKT Tribal community members in existing CCS projects and then to learn what other projects may be of interest. Second, much of the CCS to date has been driven by scientists, agencies, and policy. Another area for growth is to get a better picture of what community availability and interests are; Tables 4 and 5 are a starting place, but more work is needed. Finally, in addition to scientists, project managers and participants, there are many other individuals involved in supporting CCS projects in other roles – for example, journalists and documentary filmmakers who communicate to the broader public about the potential benefits of CCS. Engaging with the wider range of individuals involved in supporting CCS in different ways could also open avenues for understanding how to sustain projects.

In closing, we recognize that the work to sustain CCS involves a great deal of collaboration, brainstorming, conversations, and networking. This mirrors the history of professional science in the Elwha, which has been highly collaborative across both institutions and disciplines. Our summary reflects the presence and impacts of CCS in a dam removal context that originally had no coordinated plan for public participation in the research. Even without a specific plan, there are strong foundations, meaningful achievements, and auspicious signs. ScienceScape is currently establishing a paid position that will aid with coordination of CCS projects in different areas, setting the scene for an even greater reach of CCS on the Elwha in the future. This raises the question for other dam removal sites: How could dam removal projects and outcomes be enhanced with a coordinated plan for CCS? What we have learned on the Elwha can serve as an example of the promise and potential of CCS for greater benefits of dam removal for watersheds, individuals, and communities.

[20] Participants also often value acknowledgment in publications; for more on potential participants' preferences around communication, see de Vries, M, et al. 2019. Citizen Scientists' Preferences for Communication of Scientific Output: A Literature Review. *Citizen Science: Theory and Practice, 4*(1): 2, pp. 1–13. DOI: https://doi.org/10.5334/cstp.136

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