Braiding Partner Interests into a Youth Water Quality Monitoring Program

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ABSTRACT

Many of America's cherished national parks are seeing a domino effect of ecological change triggered by climatic shifts. Long-term monitoring offers an opportunity to document baseline conditions, detect change, and make informed decisions about how to address our uncertain future. Given the National Park Service's commitment to embedding science-informed practices into all aspects of the agency's work, we recently established a multi-entity partnership to improve direct experiences with water science in park-based youth programs that conduct monitoring, for the sake of both youth science literacy and long-term monitoring. Here, Grand Teton National Park, Teton Science Schools, and the University of Wyoming Science & Mathematics Teaching Center share an approach and lessons learned from an ongoing project to foster engagement of 5th-graders via water quality monitoring opportunities along the Snake River. We forged a partnership that evolved, much like the ebb and flow of the braided channel of the Snake. Insights include some of the challenges in identifying meaningful project elements and creating age-appropriate scientific monitoring protocols that meet converging goals and values.

A DYNAMIC RIVER OF BRAIDING PARTNERS

If you were to wander along a stream in Grand Teton National Park (GTNP) flanked by yellow-leaved cottonwoods in autumn, you might just stumble across an energetic scene. You would find backpacks in a clearing, plastic tubs and ice cube trays filled with water and set near the water's edge, and a group of enthusiastic local elementary school students with boots and dip nets investigating the stream and its bed. Field educators and chaperones would be working with these students to turn over rocks and transfer macroinvertebrates into tubs, use water chemistry measurement tools, characterize the living and non-living components of the stream, and record what they are finding. Later that day, these students would move indoors to create presentations to share how their field investigations wove together to help them better understand the unique and braided waterways in their home valley. Figure 1 shows snapshots of what this learning might look like.

Stream monitoring projects like this are common in educational settings across the world because these activities are highly engaging and can connect to issues of water quality, local ecosystems, and stewardship, among other topics. While many citizen- or community-science projects engage learners in stream monitoring (e.g., Blackfoot Challenge 2022 and Johnson and Jelks 2023, among countless other municipal, state, and non-profit programs), many similar projects are run primarily for their educational value (e.g., Hotaling et al. 2012; The Watershed Institute 2024) due to significant concerns with the logistics, data quality, and time needed for research-quality contributions (e.g., Swenson and Nyquist 2024). Engaging students with investigations in their local places offers meaningful opportunities to weave disciplinary learning into students' lived experiences. Furthermore, decades of research have demonstrated that long-term, standardized monitoring offers an invaluable tool to scientists and communities interested in the function of river ecosystems and how rivers are responding to stressors such as climate or land use change (e.g., Firehock and West 1995; Buss et al. 2015).

Given that many of America's national parks are seeing and experiencing domino effects of ecological change triggered by climatic shifts (Gonzalez 2020), varied bio-physical and human system monitoring done in park-based educational settings provides an opportunity to help document baseline conditions, detect change, and inform decisions about how to address our uncertain future. Further, the National Park Service has articulated a commitment to embedding science-informed practices into all aspects of the agency's work (NPS 2023). At this confluence of interests, opportunities, and needs, we realized that we had an opportunity to braid our interests and collaboratively develop a GTNP-based youth stream monitoring program. We leveraged an existing partnership

OVERLEAF **Kelly Warm Spring, Grand Teton National Park.** NATIONAL PARK SERVICE

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FIGURE 1. Three photos showing the learning progression across Teton 5th youth programming field days in Grand Teton National Park. The left photo shows students beginning their stream investigation, the middle photo shows them processing and identifying macroinvertebrates, and the right photo shows presentations at the end of the field day. TETON SCIENCE SCHOOLS

between GTNP, Teton Science Schools, and University of Wyoming's Science & Mathematics Teaching Center and their converging desire to support stream ecology education. Through a grant, we were able to expand this partnership to include University of Wyoming ecology researchers from the Departments of Zoology and Physiology and Botany and the Wyoming USGS (US Geological Survey) Cooperative Fisheries and Wildlife Unit. Much like channels of tributaries to a river such as the Snake River in GTNP, each of our four teams has added momentum, influence, and complexity to our efforts to develop stream monitoring protocols that support both long-term scientific monitoring and youth learning.

THE CHANNELS: WHY AN INTEREST IN WATER MONITORING?

In this article, our partnership team delves into the dynamic ways that we engaged in collaborative work to develop a youth-based monitoring project. We share our four teams' motivations for collaboration—think of these as separate channels in our braided river, each starting from its own separate place. We then share the ways we connected and integrated our motivations and efforts into a program—consider this as the confluence of our channels into the main river stem, whose dynamic flow allows for continual idea mixing and flow changes as waters ebb and flow. We finish by sharing our lessons learned along the way and our next steps as a team—these ideas will help illustrate the current and future flow of the braided partnership river. Insights include some of the challenges in identifying meaningful project elements and creating age-appropriate scientific monitoring protocols at the confluence of goals and values across our four teams. We begin by sharing each team's motivations for collaborating on a youth-based monitoring program, then how they merged into a productive confluence.

GRAND TETON NATIONAL PARK'S CHANNEL: UNDERSTANDING AND COMMUNICATION

Wherever possible, GTNP education work aligns with resource management needs. Understanding the function of the Snake River has been a growing concern among GTNP scientists, and current research collaboration with the University of Wyoming is critical in expanding baseline data for comparison as water and climate patterns shift. As a headwaters in the Greater Yellowstone Ecosystem, the Snake River is a highly dynamic, braided, and multi-threaded waterway (see Figure 2; NPS 2024) comprising critical ecosystems and ecosystem services, recreational opportunities, economic value, and social interests, both locally and far downstream. Shifts in flow regimes, both climate-driven and human-regulated (e.g., release schedules from Jackson Lake Dam), underscore compelling ecosystem interactions such as increasing pathogen prevalence in popular fish species (Fetzer et al. 2020), fish population changes (Walters 2016), and changes in river channel structure (Nelson et al. 2013) that impact vegetation patterns (Marston et al. 2005). Likewise, GTNP is interested in the river's recreational

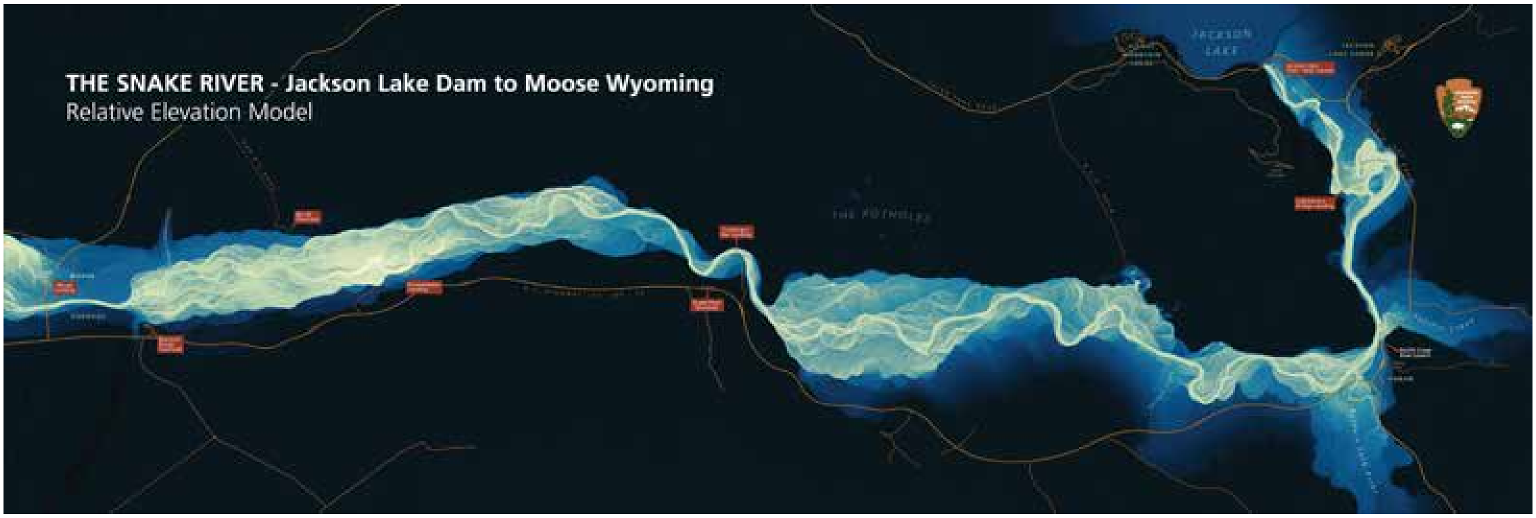


FIGURE 2. Map of the Snake River riverbed, including its paths and braids over time. Map created by Madeline Grubb, reproduced with permission from the National Park Service. The map can be found, along with more description of the Snake River, at https://home.nps.gov/grte/learn/nature/snake-river-rem.htm (NPS 2024). The caption for the map on that webpage reads, "The varying elevation of the streambed is visualized with a blue color gradient, showing how the river's flow has eroded the landscape over time with altering paths of travel."

opportunities and their impacts on local jobs and revenue, such as angler choices under different climate futures (Hofstedt 2024) and fisheries management strategies to maximize recreational revenues (Loomis 2006).

Exploring values and value systems provides an additional bridge between economic and social interests in the Snake, including how different groups connect with the water for its intrinsic (i.e., meaning-related), relational (i.e., connections, relationships, and memories), or instrumental (i.e., water as a means to an end) value to them (Pokharel 2024). While outside of GTNP boundaries, down-river agriculture impacts of and on the Snake River have ecosystem, social, and industry implications. These include the need for adaptive governance to manage variable groundwater and surface water availability (e.g., du Bray et al. 2018) and for critical examinations of farmers' vulnerability and capacity related to water policy changes (e.g., Hawes et al. 2022). The Snake River is also a highly significant place for associated Tribes, and GTNP works to formally strengthen those connections with Tribes by caretaking those significant places.

Our GTNP education team seeks to use park experiences and resources, such as the Snake River watershed, to spark curiosity that leads to a better understanding of the park and the world. Teachers and schools depend on these in-park experiences to, as they put it, "learn from the real thing." When the lessons are tied to active scientific research and have real-world implications, the learning impact is deeper and "stickier"; kids remember it long past their field experiences. Our park education team pursues partnerships with educational and research groups who share these interests because the collaborations help to create, refine, and contribute to these "sticky" learning experiences. In the 2010s, GTNP and Teton Science Schools ran a community science project at Kelly Warm Spring monitoring invasive fish species and related disease. Not only did the work lead to a reduction in non-native fish dumping (the spring has been the target of illegal dumping of aquarium fish for decades), it also provided engaging science that teachers referenced over the rest of the school year. With water being a central management concern as our climate transitions, our park education team was particularly interested in whether a project could similarly link student science skills with Snake River monitoring.

TETON SCIENCE SCHOOLS' CHANNEL: FIELD-BASED LEARNING PROGRAMS

As an educational non-profit in its sixth decade of facilitating field-based learning with students of all ages, Teton Science Schools' history and current programming are rich with examples of engaging youth with science research. For instance, Teton Science Schools ran the Wyoming Stream Team program in partnership with and with funding from the Wyoming Department of Environmental Quality from 1993 to 2014. The state-wide monitoring program focused on assessing and improving stream function, and its educational program trained teachers and students across Wyoming to collect data that could be used by other teachers and students, as well as local communities. The Teton Science Schools organization holds these historical data and continues to use sampling protocols to support similar student learning. Tapping into university and national park research interests offers an opportunity to resurface previously collected stream data, revive standardized data collection with youth, and explore data uses such as detecting threats to stream function and encouraging stewardship.

The Teton Science Schools' field education team works to weave authentic science research into youth programming in several ways. Typical residential programming with local and visiting school groups lasts up to one week and includes a field research project, which might employ one of a set of standardized protocols. These protocols are designed to allow for varied forms of student-led inquiry while enabling all field groups to contribute their data to ongoing monitoring efforts related to snow depth, snow-water equivalent, elk and bighorn sheep behavior, animal scat and tracks, wildflower phenology, soil moisture, or stream function. The students complete and contribute data sheets as part of a long-term, multi-group data set. While most of the data students collect and analyze are for educational purposes and not academic research, students are guided to tie their research days to science monitoring in other ways that help them contextualize their findings.

One youth program that engages in scientific monitoring is *Teton 5th*, a program for local students that braids interests and efforts from Teton Science Schools and GTNP. Every fall since 1971, Teton Science Schools has hosted every Teton County (WY) fifth grader on its Kelly Campus in GTNP for a place-based, overnight experience in the students' home national park. The goal is to give these students the opportunity to connect to their home ecosystem in new ways. As with most Teton Science Schools field education programs, the Teton 5th program facilitates student-led research projects that allow students to think critically about environmental issues facing their own community, while also enjoying lighthearted exploration. This format is particularly valuable in Teton 5th, where students engage in all of this learning through exploration in their local place, including the nearby national park.

Our Teton Science Schools team was motivated to explore how Teton 5th students' research projects could contribute to longitudinal scientific monitoring, both to support researchers' interests and to make engagement meaningful for students. The opportunity to possibly share some of the student-collected monitoring data with university researchers has motivated the team to explore multiple ways youth might contribute to academic research projects, both specific to Teton 5th and more broadly in all field education programs.

UNIVERSITY RESEARCH SCIENTISTS' CHANNEL: LONG-TERM MONITORING

Consistent, long-term water quality monitoring is needed to understand anthropogenic impacts on freshwater ecosystems and how they relate to multiple stressors, including land use change and climate shifts. Synthesis studies suggest that water quality monitoring programs across the United States focus on a biased set of ecosystems, typically large water bodies near populated areas that are rarely resampled more than a few times over several decades (Stanley et al. 2019). For states like Wyoming that are large and sparsely populated, increasing the consistency and coverage of monitoring poses a major challenge given the limited resources of federal and state agencies and non-profit groups that conduct most of this work. For university researchers, monitoring is difficult to fund given the typical duration of grants (3–5 years) and the need for hypothesis-driven proposals that are better suited than monitoring data to many funding agencies. Despite those limitations, long-term monitoring is critical to document baseline conditions, detect change, and make informed decisions about how to address our uncertain future (Magnuson 1995: 448–464).

A lack of monitoring data leaves us with uncertainty about whether current conditions are a departure from baselines. For example, harmful algal blooms are an emerging concern in Wyoming, posing threats to human and animal health and threatening ecosystem services provided by lakes and rivers. In 2017, only three water bodies across the state were listed as having had a harmful algal bloom; that number steadily increased to over 50 in 2024. However, managers and scientists lack data to understand whether the increase in alerts is due to major declines in water quality or increased awareness and reporting of blooms. Some methods, such as long-term satellite remote sensing data, can provide insights (Sillen et al. 2024) but have limitations compared to *in situ* sampling. Additional monitoring in this region is particularly critical to understand future impacts of climate on water resources.

Our team perceives that long-term, consistent programs such as the one launched in this partnership can achieve multiple goals. First, they can address the need for additional consistent monitoring data, and second, they can provide outreach opportunities for science researchers to engage with students and the public to generate interest in aquatic ecosystems and water quality. While it is challenging to generate high-quality data based on short-term field experiences with limited expertise and equipment, commitments to programs such as this can overcome some of those obstacles and provide important information. Additionally, doing this work in the Snake River watershed and GTNP is well suited to generating data on ecosystems that are likely to experience strong impacts from future climates, highlighting the value of consistent and relevant data.

UNIVERSITY EDUCATORS' CHANNEL: TEACHER PROFESSIONAL LEARNING

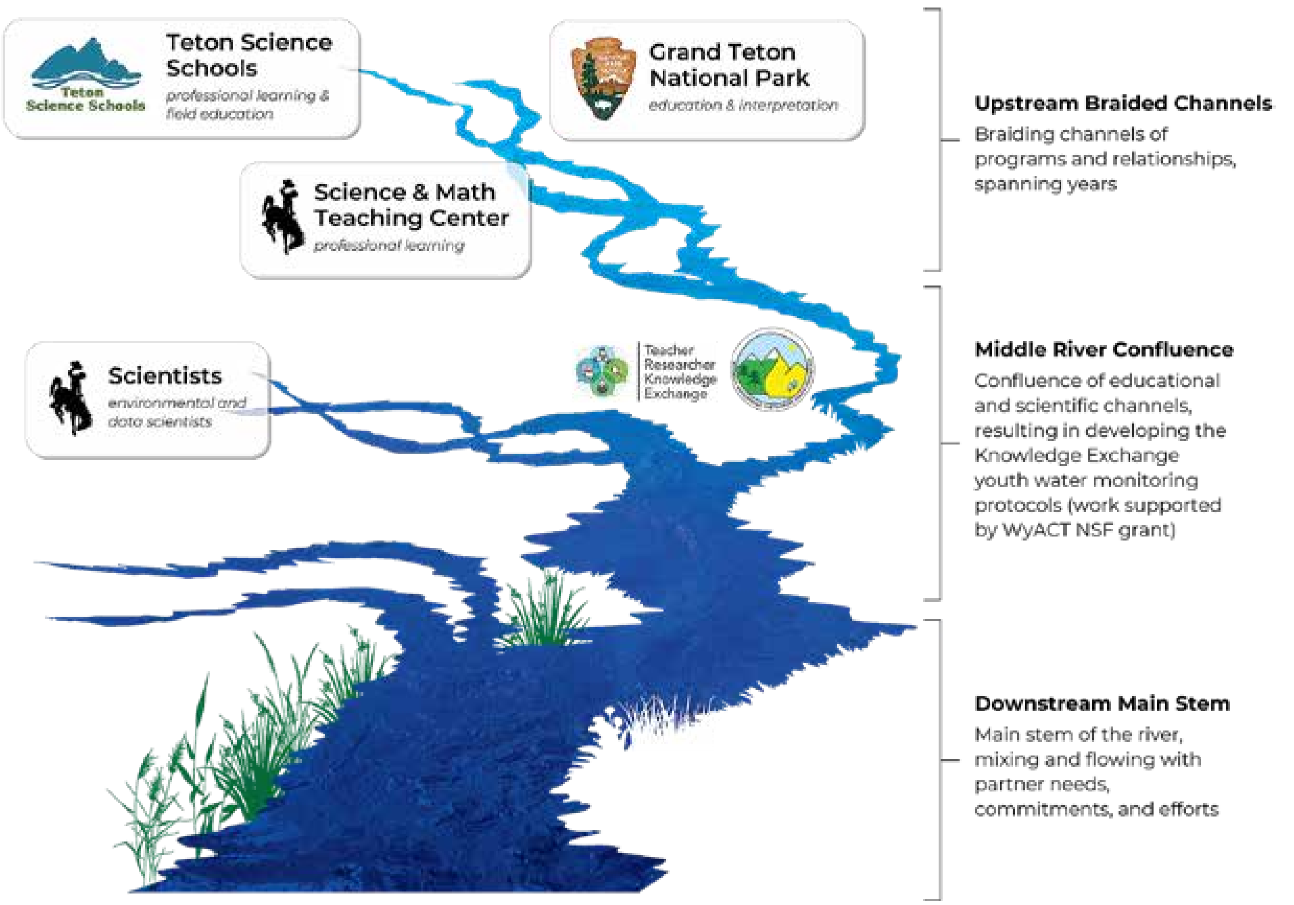
Our University of Wyoming Science & Mathematics Teaching Center educator team has been focused on supporting in-service K–12 science teachers around the state of Wyoming through facilitated professional learning experiences that are responsive to participant needs (Inouye and Gunshenan 2024). We have a growing interest in bringing current Wyoming-based research and data into the hands of Wyoming educators, rooted in both best practices in science teaching and learning (National Academies of Sciences, Engineering, and Medicine 2018; National Research Council 2012) and consistent requests from educators in the state. This interest is further bolstered by consistent researcher colleagues' interest in better understanding the K–12 context for their outreach or broader impact efforts.

The Science & Mathematics Teaching Center frequently bridges disciplines in support of high-quality learning. Our educator team sees the complementary interests of science researchers and K–12 educators as an opportunity to explore how to best facilitate exchanges of thinking, expertise, and knowledge. Given our strong relationships with GTNP and Teton Science Schools partners, as well as University of Wyoming researcher colleagues, our team was interested in bringing them all together to explore and refine the most impactful ways we might facilitate a collaborative and interdisciplinary exchange.

THE CONFLUENCE OF PARTNER MOTIVATIONS AND INTERESTS

All streams contribute something important to a river, and each of these collaborators' motivations contributes something important to our park-based program. A grant proposal presented an opportunity for these braiding channels to intertwine, ultimately converging into a strong science and science education partnership. The Science & Mathematics Teaching Center led the grant-writing effort with the aim to develop an educational program to complement climate science research proposed by a team of university researchers. We reached out to long-term collaborators in GTNP's education team and Teton Science Schools' professional learning and field education teams to jointly conceptualize an interdisciplinary program called the Teacher Researcher Knowledge Exchange. The result was a plan for facilitated, collaborative spaces where K–12 educators and researchers can directly learn from each other, find common ground, and produce useful and usable resources. Figure 3 represents the

FIGURE 3. Network of braided partner connections.



ways that the partnership grew from existing and new relationships in the context of the Knowledge Exchange. The team submitted this proposal as part of a University of Wyoming-run National Science Foundation grant, which was eventually funded as Wyoming Anticipating the Climate-water Transition (WyACT).

Now formally connected, the partners each had something to contribute to the research and education project and a desire to find a productive blend with the other partners, in the same way that the confluence of streams blends their waters. This stage of the collaboration is represented in Figure 3 as a series of upstream braided channels that converge. Regular monthly check-ins and larger annual meetings allowed these partners and key science researchers from WyACT to share their interests, needs, goals, possible points of convergence, and next steps. Through these conversations, the GTNP education team and Teton Science Schools expressed interest in revamping the long-standing Teton 5th youth program, and specifically its field science investigations. Teton 5th had most recently included the aforementioned Kelly Warm Spring invasive species monitoring projects, but changes in funding and the near-complete eradication of the invasive species left the program team in search of a new monitoring project. In parallel, WyACT researchers' nearby work included waterway monitoring, and they expressed interest in leveraging the human power that a coordinated youth program could offer to some labor-intensive monitoring work. To meet these needs, we then began exploring whether and where we could access the grant's science to develop a new protocol that could be used by 5th graders, address GTNP interests, and establish a long-term monitoring program for research scientists' use. This stage of the collaboration is represented in Figure 3 as the middle section of the main stem of the river.

Our project planning conversations had three aims in mind: (1) identifying overlaps in programming and research needs, (2) maximizing chances for 5th graders to connect with the project and their communities, and (3) identifying structures that would boost project sustainability. To address the first aim, a wide range of protocols could fit the need for establishing student-accessible monitoring work. Conversations to hone in on protocols especially revolved around what data students could feasibly collect, and how these data could be valuable to researchers and students. In service of reinforcing connections between possible monitoring work and student community connections (the second aim), conversations centered on means of bridging students' field sampling with data analysis and interpretation that could help them contextualize the monitoring project in their home place. With regard to the third aim, the team consistently discussed means of building team capacity to carry out monitoring (e.g., field education staff training), partnering for sustainable data management (e.g., simple data entry and university-supported database maintenance), and reinforcing the partnership to nimbly respond to evolving needs. In Figure 3, these interactions are represented in the middle section of the river, where existing partners continue their involvement and new ones might join to help address evolving needs.

THE DYNAMIC FLOW: THE PARK-BASED YOUTH LEARNING PROGRAM'S EVOLUTION

The partnership continued to flow and braid over time as different program structures allowed us to address partner motivations and needs. The group ultimately worked to prepare field protocols, develop data collection tools, design instructional resources and framing to bring the protocols into the field, and train field staff to both facilitate learning and share data with researchers. In the first year of work, four protocols were created:

- Bioassessment sampling of macroinvertebrates to characterize stream function and condition,
- Real-time sampling of water quality with a probe that measures physiochemical parameters in the field,
- Measuring *chlorophyll a* from rocks in the river bed as a proxy for ecosystem productivity, and
- Establishing vegetation and soil transects perpendicular to streambeds to explore trends in water availability in riparian zone, coniferous, and sagebrush plant communities.

The four protocols were grouped, meaning that each was designed to be carried out at each sampling location. In this way, the collected samples could together offer a snapshot of stream and surrounding plant community function for aquatic and plant community ecologists to interpret in their work. The protocols were prepared by University of Wyoming education and research teams, and data management specialists drafted a web-based interface to input and then centrally house field data. The education team then hosted a protocol piloting workshop with researchers, data managers, field educators, and senior leadership from both Teton Science Schools and Grand Teton National Park. This workshop allowed us to test the protocols, refine them and the data collection application, and collaboratively develop framing to use with youth groups. The field education participants in this group acted as trainers who then brought these refined tools back to their full team, who in turn implemented the protocols in their youth programming.

Based on feedback, we further refined protocols for use in our second year of work. The water quality sampling remained intact, but changes were made in each of the other protocols:

- Macroinvertebrate bioassessment sampling was simplified and designated as educational rather than contributing to research, given the technical difficulties encountered with youth accurately identifying macroinvertebrates to the family level.
- Transects were simplified to remove vegetation sampling and instead focus on patterns in soil temperature and moisture.
- *Chlorophyll a* sampling was eliminated for logistical reasons and replaced with photograph-based snow monitoring (snowtography) that pairs with the soil moisture protocols.

Snowtography protocols use snow sampling and photography along a transect to capture more nuance in snowpack deposition and movement, especially in transitions between plant communities (e.g., from a sagebrush community into an aspen community). The soil and snowtography protocols are paired to help establish patterns of water's movement into the soil. However, neither of these protocols is tightly tied to the macroinvertebrate and water chemistry sampling in the first protocol. Youth program partners chose to allow this separation because the methods still supported researchers' interests, and this range allowed for youth involvement in winter sampling as well as summer/autumn sampling. In other words, this shift made relevant field sampling protocols more accessible to GTNP-based youth programming. As a result, the program's flow today is more streamlined, focused, and consistent, as represented in the downstream reaches of the main river stem in Figure 3.

LOOKING BACK UPSTREAM: REFLECTIONS ON THE TEAM, PROGRAM, AND NEXT STEPS

Developing these protocols collaboratively afforded our team ongoing opportunities for reflection, communication, and adjustment. As a result, we have learned about our process and identified synergies and tensions in considering the different river channels each group occupies, the ways the channels might braid together, the places they should stay separate, and the ways they might exceed the sum of their parts and mix in the mainstem. In this section we share a synthesis of the synergies and tensions encountered over two years. In the panels of Figure 4, each synergy is paired with a tension that our team sees as related. Each panel represents a synthesis of all collaborators' reflections.

As noted in Figure 4, while role diversity was a fundamental strength to our process, the range of needs and ideas represented also meant that tensions arose. These were often productive and helped our team to more fully consider our plans and protocols, but they still posed some challenges to our process. In reflection, our team noted that these synergies and tensions equally helped us to better scope and plan for an effective set of protocols.

LOOKING DOWNSTREAM: AN INVITATION TO CONSIDER COLLABORATIVE YOUTH MONITORING PROJECTS

Our park-based youth program's strength continues to stem from the dynamic and powerful contributions of our science and education partners. Each partner is committed to working to resolve programmatic tensions and reinforce synergies in braiding together high-quality education and science connections. The multi-entity team learned (and continues to learn) about the process of developing and refining a monitoring project that carries meaning for multiple audiences. As others have found (e.g., Johnson and Jelks 2023), protocols such as these hold promise for high-quality longitudinal monitoring, but work remains to increase protocols' broad accessibility and accuracy. We currently stand more equipped to make generalizations about monitoring program planning that might, in turn, support others considering multi-group partnerships and youth-based monitoring programs that could contribute to scientific interests. We invite members of similar partnerships to explore the richness in Figure 4's takeaways from our process and apply them to their own contexts.

In addition, we have a final foundational and structural recommendation to share: all partners agree upon the importance of having a project facilitator. This role, which might be shared by more than one person, includes establishing and maintaining structures for regular collaboration and discussion so that the group is able to stay on the same page, pivot as needed, take advantage of emergent opportunities, and think through how to engage everybody in conversations when hiccups occur. The facilitator or facilitators continually probe to see how things are going, follow up to coordinate group problem-solving, and design spaces for individual check-ins and collaborative time. Commitment to fostering relationships with all partners is an essential facilitator role, whether these relationships already exist or are

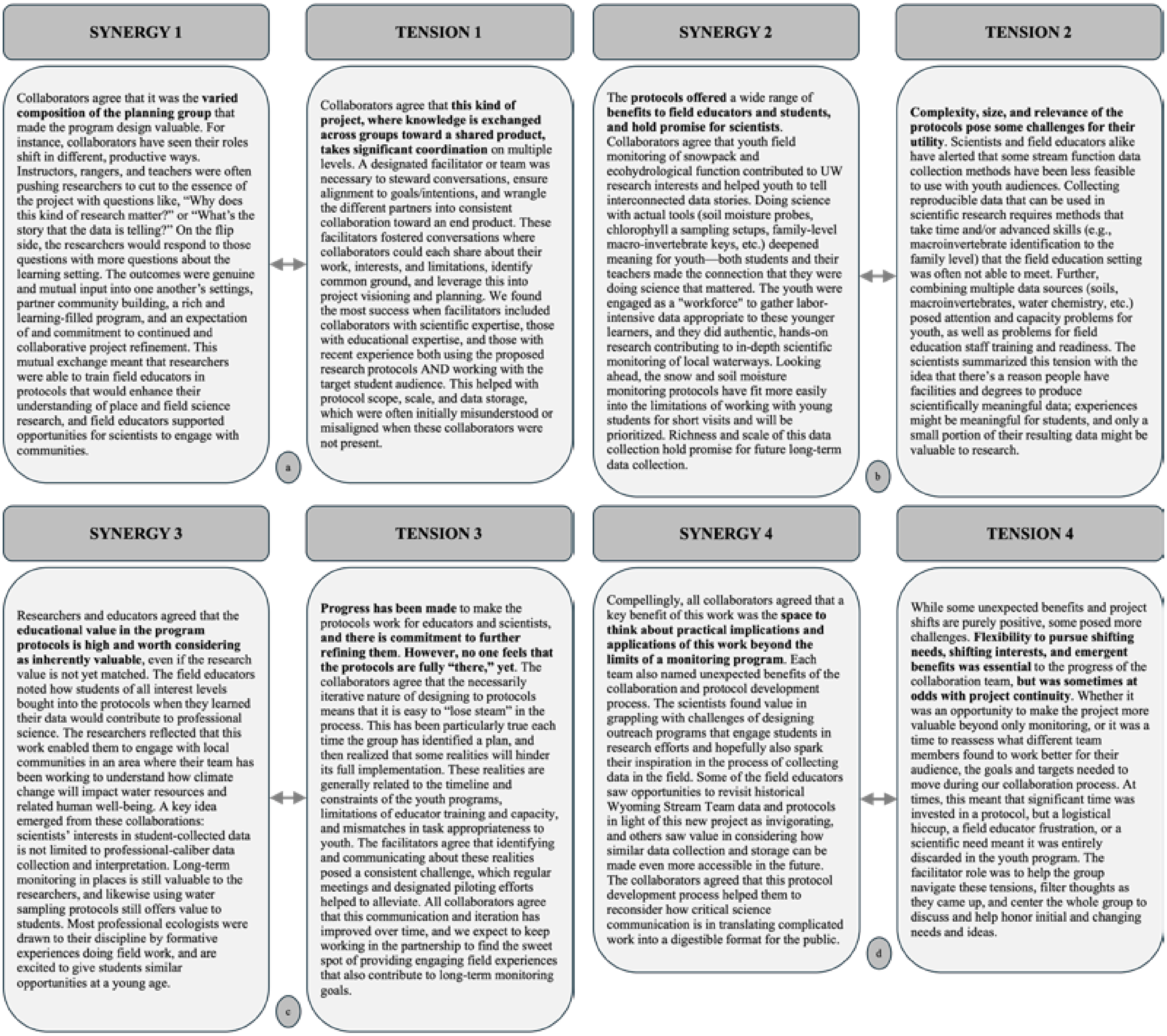


FIGURE 4. Four paired synergies and tensions identified by program partners during planning and reflection work. Each of these core synergies and tensions was agreed upon by all collaborators (i.e., Grand Teton National Park and Teton Science Schools field educators, University of Wyoming scientists, and University of Wyoming educator-facilitators). Each panel (a–d) shares a paired synergy and tension that our team sees as related.

built through the collaboration. In our process, this allowed for the facilitators to support the braiding of the river and the multiple channels coming together in productive confluences. Our facilitators (the Science & Mathematics Teaching Center educator team) came into this project with previous partner relationships, built over the course of several years. While these existing relationships might not have been critical to the success of the project, we found them to be invaluable to productively moving ideas into actions. In a program setting where these relationships are not yet established, we strongly recommend designating time to build them. Even if relationships already exist, designating time and structures to strengthen them, as our team did, is well worth the effort.

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REFERENCES

Blackfoot Challenge. 2022. Community education. https://blackfootchallenge.org/community-education/

Buss, D.F., D.M. Carlisle, T.-S. Chon, J. Culp, J.S. Harding, H.E. Keizer-Vlek, W.A. Robinson, S. Strachan, C. Thirion, and R.M. Hughes. 2015. Stream biomonitoring using macroinvertebrates around the globe: A comparison of large-scale programs. *Environmental Monitoring and Assessment* 187(4132). https://doi.org/10.1007/s10661-014-4132-8

du Bray, M.V., M. Burnham, K. Running, and V. Hillis. 2018. Adaptive groundwater governance and the challenges of policy implementation in Idaho's Eastern Snake Plain aquifer region. *Water Alternatives* 11(3): 533–551. https://www.water-alternatives.org/index.php/alldoc/articles/vol11/v11issue3/452-a11-3-5

Fetzer, W., R. Al-Chokhachy, J. Baldock, C. Johnson, D. Miller, A. Walters, and C. Whaley. 2020. Developing a baseline understanding of gill lice distribution, prevalence, and infestation intensity in the Upper Snake River watershed. *UW-NPS Research Station Annual Report* 43: 26–31. https://journals.uwyo.edu/index.php/uwnpsrc/article/view/6763

Firehock, K., and J. West. 1995. A brief history of volunteer biological water monitoring using macroinvertebrates. *Journal of the North American Benthological Society* 14(1): 197–202. https://doi.org/10.2307/1467734

Gonzalez, P. 2020. Human-caused climate change in United States National Parks and solutions for the future. *Parks Stewardship Forum* 36(2): 188–210. https://doi.org/10.5070/P536248262

Hawes, J.K., M. Burnham, M.V. du Bray, V. Hillis, Z. Ma, and K. Running. 2022. Social vulnerability to irrigation water loss: Assessing the effects of water policy change on farmers in Idaho, USA. *Environmental Management* 69: 543–557. https://doi.org/10.1007/s00267-021-01586-4

Hofstedt, P. 2024. Angler preferences under alternative climate scenarios in northwestern Wyoming. Master's thesis, University of Wyoming. https://uwyo.idm.oclc.org/login?url=https://www.proquest.com/dissertations-theses/angler-preferences-under-alternative-climate/docview/3094915782/se-2?accountid=14793

Hotaling, L., S. Lowes, R. Stolkin, P. Lin, J. Bonner, W. Kirkey, and T. Ojo. 2012. SENSE IT: Teaching STEM principles to middle and high school students through the design, construction and deployment of water quality sensors. *Advances in Engineering Education* 3(2).

Inouye, M.C., and C.I. Gunshenan. 2024. Responsive facilitation: Validating constructs to support in-service science teacher professional development. *Teacher Development* 28(4): 494–514. https://doi.org/10.1080/13664530.2024.2323577

Johnson, T., and N.O. Jelks. 2023. Implementing community-engaged ecological research in Proctor Creek, an urban watershed in Atlanta, Georgia, USA. *Ecological Applications* 33(5): e2792. https://doi.org/10.1002/eap.2792

Loomis, J. 2006. Use of survey data to estimate economic value and regional economic effects of fishery improvements. *North American Journal of Fisheries Management* 26: 301–307. https://doi.org/10.1577/M05-116.1

Magnuson, J. 1995. The invisible present. In *Ecological Time Series*, T. M. Powell and J. H. Steele, eds. Boston: Springer. https://doi.org/10.1007/978-1-4615-1769-6_20

Marston, R.A., J.D. Mills, D.R. Wrazien, B. Bassett, and D.K. Splinter. 2005. Effects of Jackson Lake dam on the Snake River and its floodplain, Grand Teton National Park, Wyoming, USA. *Geomorphology* 71: 79–98. https://doi.org/10.1016/j.geomorph.2005.03.005

National Academies of Sciences, Engineering, and Medicine. 2018. *How People Learn II: Learners, Contexts, and Cultures*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24783

NPS [National Park Service]. 2023. *National Park Service Climate Change Response Strategy 2023 Update*. Washington, D.C.: National Park Service, 2023. https://www.nps.gov/subjects/climatechange/upload/NPSClimateChangeResponseStrategy2023.pdf

NPS. 2024. Tracing the braids of the Snake River—Relative elevation models. Grand Teton National Park, Wyoming. https://home.nps.gov/grte/learn/nature/snake-river-rem.htm

National Research Council. 2012. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

Nelson, N.C., S.O. Erwin, and J.C. Schmidt. 2013. Spatial and temporal patterns in channel change on the Snake River downstream from Jackson Lake dam, Wyoming. *Geomorphology* 200: 132–142. http://dx.doi.org/10.1016/j.geomorph.2013.03.019

Pokharel, P. 2024. Using storytelling to understand recreationists' and farmers' relation to water in the Snake and Green River watersheds. Master's thesis, University of Wyoming. https://www.proquest.com/docview/3059906151/6F93C8A752A643D5PQ/1?accountid=14793&sourcetype=Dissertations%20&%20Theses

Sillen, S.J., M.R.V. Ross, and S.M. Collins. 2024. Long-term trends in productivity across Intermountain West lakes provide no evidence of widespread eutrophication. *Water Resources Research* 60(6): e2023WR034997. https://doi.org/10.1029/2023WR034997

Stanley, E.H., S.M. Collins, N.R. Lottig, S.K. Oliver, K.E. Webster, K.S. Cheruvelil, and P.A. Soranno. 2019. Biases in lake water quality sampling and implications for macroscale research. *Limnology and Oceanography* 64(4): 1572–1585. https://doi.org/10.1002/lno.11136

The Watershed Institute. 2024. StreamWatch Schools. https://thewatershed.org/streamwatch_schools/

Swenson, R., and C. Nyquist. 2024. Studying K–12 and post-secondary teachers' reflections on the value of a citizen science project for fostering learning: The case of a winter stream project. *Interdisciplinary Journal of Environmental and Science Education* 20(3): e2410. https://doi.org/10.29333/ijese/14636

Walters, A. 2016. The importance of context dependence for understanding the effects of low-flow events on fish. *Freshwater Science* 35(1): 216–228. https://doi.org/10.1086/683831