The Fish Weir

A Culturally Relevant STEM Activity

by Anne Kern, Melinda A. Howard, Aimee Navickis Brasch, Fritz Fiedler, and Jillian Cadwell

Curriculum and instructional strategies that are personally meaningful are key to engaging students from diverse ethnic and cultural backgrounds. A "one size fits all" approach to curriculum development does not always translate to accessible education for many students, particularly in science, technology, engineering, and mathematics (STEM) education (Lynch 2001). Meaningful and relevant activities that demonstrate a direct application of STEM to the lives of students or their communities can increase engagement in STEM (Jarosz 2003). Specifically, students are more likely to relate to instructional activities that draw on historical references, descriptions, examples, and analogies related to their communities. For example, Native American students have been traditionally marginalized in STEM education, yet tribes throughout North America have STEM-rich histories that provide many examples upon which engaging lessons can be developed.

The Fish Weir Engineering Challenge described in this article provides one example of how cultural and historical STEM practices can be integrated into science and engineering lessons for Native American students. Although we discuss this lesson in specific context to Native American students, it can be adapted to meet other cultures or curricular goals. *Fish weirs* are an ancient technology used around the globe for centuries in places including Asia, Europe, and the Middle East. These traps were built from rocks, pilings, or wooden posts that are designed to direct the movement of fish in streams or tidal waters. While all fish weirs maintain the goal of directing and trapping fish, they are specifically designed to meet the unique conditions of their landscape and water bodies and the biology of the fish they catch. Furthermore, fish weirs are still being used today for scientific monitoring or, in some cases, for illegal fish harvests (Jha 2013). The Fish Weir Challenge activity allows students to explore how tribal communities (as well as other communities) have used engineering practices to adapt fish weirs to various environmental conditions and community needs over time.

In this lesson, students will gain a hands-on experience with engineering by designing, building, and testing a model fish weir. They also explore the rich historical and cultural traditions of this ancient method of gathering an important—and in some cases, the only—food source. This activity and its associated lessons are designed to engage students in the skills and practices aligned with the science and engineering practices (SEPs) of the *Next Generation Science Standards* (*NGSS*). An *NGSS* crosscutting concept (CC) associated with this lesson is the Influence of Science, Engineering, and Technology on Society and the Natural World. In addition, while the central focus is on learning about and using engineering skills, there are a number of *NGSS* disciplinary core ideas (DCIs) that can be integrated and extended in this lesson (see standards sidebar on p. 50; find additional standards connections with the online version of this article at *www.nsta.org/middleschool/connections.aspx*).

For Native Americans dependent on inland water bodies for food, fish weirs were used to catch large quantities of migratory fish such as salmon. By drawing on students' curiosity about their community's history, culture, and ancestors, STEM practices become evident as accessible and necessary contributors to the growth and heritage of their community. In this sense, the fish-weir activity enables students to identify with STEM by providing a culturally relevant STEM context (Cajete 1999).

The Fish Weir Engineering Challenge (Figure 1) was developed to address the strategies suggested in the *NGSS* for teaching science to students from diverse racial and ethnic backgrounds. The *NGSS* advocate that science and engineering lessons for traditionally marginalized students be "relevant to their lives and future," which can be accomplished by including "community involvement and social activism" and providing "multiple representations and multimodal experiences" (NGSS Lead States 2013, Appendix 7, case study 2). The Fish Weir Engineering Challenge aims to make science

FIGURE 1 Unit overview

Lesson	Objectives	Approximate time*
Lesson 1: Identify the Challenge	Identify the engineering challenge and define the design constraints that limit a successful design.	One class session
Lesson 2: Develop Background Knowledge	Students develop background knowledge relevant to the challenge including: introduction to fish weirs; the history, application, evolution, and size of fish captured. *Recommend tribal community speaker to provide this lesson.*	One to two class sessions
Lesson 3: Plan	Students work collaboratively in teams to brainstorm multiple fish weir designs, evaluate the pros and cons of possible designs, and develop a conceptual plan (drawing) of their design.	Two to three class sessions
Lesson 4: Implement	Student teams build a model size fish weir model.	Two to three class sessions
Lesson 5: Test and Evaluate	Test, Evaluate, and Rebuild/Improve fish weir model including; test model to determine if design constraints are met, evaluate the strengths and weaknesses of the solution, improve the design as needed, and retest. The process is repeated until the model is successful. Students draw their "as built" design and provide an explanation of how and why their design works.	Two to three class sessions

*One class session = 30 minutes; 4 to 6 hours to complete unit and engineering relevant for Native American students by acknowledging the science and engineering practices of their ancestors, providing a relatable, hands-on engineering experience and inviting the community to participate in sharing knowledge and teaching lessons.

Lesson 1: Determine the challenge

Imagine a stream so crowded with fish that you could use their backs as steppingstones to cross! Imagine it being like this only a few weeks out of the year when the fish return from their ocean habitat to lay their eggs in the stream and die. What if you and your community ate so much fish that it made up at least half of your diet throughout the year? Imagine having no grocery stores, only the land around you to provide your food. How could you gather enough fish during this short window of time to feed everyone in the community, young and old?

The scenario presented above introduces students to the Fish Weir Engineering Challenge. Students are first asked to think of the kinds of foods their ancestors may have eaten. They should note that in the "old times," there were no grocery stores or restaurants where they could grab a quick meal. They are then asked to consider ways they could gather enough food to feed not just their family, but also their entire community. They should brainstorm answers to the question, "How could you capture the most fish in a limited timeframe?" It is not uncommon for students to propose a "hook-n'-reel" method; however, they quickly determine that this is not a very efficient method. This conclusion provides the opportunity to introduce students to the technology their ancestors used: fish weirs, which were engineered to efficiently capture a vitally important food staple. In North American river systems, fish weirs were used to capture migratory fish during their seasonal spawning periods. Of particular importance were anadromous fish, such as Pacific salmon, which annually swim upstream from their ocean habitats to their natal tributaries, where they spawn and die. The only opportunity to capture these (adult) fish in a river is during this migration period, generally spanning a period of only a few weeks.

After defining the challenge (i.e., design and build a model fish weir that will span a model stream and capture model fish), students are guided through the engineering-design process.

Lesson 2: Develop background knowledge

In this lesson, students develop background knowledge by familiarizing themselves with the history, construction, and use of fish weirs. Teachers are encouraged to compile resources for students to research the various construction elements of fish-weir design and uses over time (see Resources for suggested books, websites, and videos). Photos and diagrams of historical and modern fish weirs provide students visual interpretations of weirs' various designs and uses. These images offer inspiration and ideas to students as they enter the planning phase of the activity. Students should note which materials are used, how the materials are used in construction, and how the weir is placed in the water.

Fish-weir design is diverse in that they are adaptable to different landscapes, waterways, and targeted fish species. According to the type, size, and hydrological patterns of the water body, as well as the behavior and size of the fish species to be caught, weirs were engineered to guide and trap fish to meet a community's need for food (see Figure 2 for a fish weir, circa 1866). A key feature of fish weirs is that they direct movement of fish into a trap based on the directional movement of the species's seasonal migration. For example, as migratory salmon are returning to their spawning grounds, they swim upstream. Therefore, the weirs are placed in a manner that blocks their upstream passage. At this point, possible content-teaching extensions could be to discuss the lifecycles of salmon, as well as the movement of fish as a function of the body type and form (e.g., fish are able to swim with little resistance due to a fusiform body shape) (*NGSS* disciplinary core idea LS1.A; NGSS Lead States 2013).

Depending on the customs and protocol for harvesting salmon set by each community, fish weirs were erected and left in place until it was determined that enough fish had been harvested to feed everyone. Weirs were also constructed with gaps to allow some fish to escape and were often taken down at night until fishing resumed the next day. These practices are important to note because they allowed for sustainable harvests of salmon populations by ensuring at least half of the fish reach the spawning beds. In general, commercial fishing practices are not concerned about the sustainability and maintenance of fish life cycles; therefore, fish populations were decimated (Montgomery 2004). That, combined with migration-route obstruction by dams and various environmental impairments, resulted in the loss of migrating salmon in many inland streams. Therefore, the traditional use of fish weirs has largely been eradicated. If possible, we recommend inviting a knowledgeable tribal member to speak to the class about the customs and ceremonies surrounding these protocols, as this person can provide a rich background in the traditional ecological knowledge and sustainable management of salmon practiced by the tribe.

Today, fish weirs are used to manage and monitor fish populations (Figure 3). Although they may be constructed out of modern materials such as steel, their basic design mimics those of ancient fish weirs. Scientists and engineers working for tribal entities draw on the knowledge and experiences of elders and community members to understand native fish in their local streams and gain new understandings using data from modern weirs. This integrated knowledge is used to aid in the regulation, maintenance, and restoration of local water bodies and fish populations. If possible, these scientists and engineers may be invited to the classroom to give presentations to students on how the rich histories and culture of Native Americans are still used in today's science and engineering practices.

Lesson 3: Plan

In this lesson, students are directed to work in groups to draw a diagram of the fish weir they intend to build and eventually test in a model stream. The student groups may be formed in any way (e.g., random selection, formal groupings, existing cooperative groups) so there are no more than four students to a group. Students are shown examples of the various building materials and supplies they will be able to use (Figure 4). Students collaborate to draw one diagram of their conceptual design on a plan sheet (Figure 5) or plain graph paper. They are asked to consider various constraints that should be included in the specific designs of their models (*NGSS* disciplinary core idea ETS1.B; NGSS Lead States 2013), including the depth and width of the model stream, as well as the width of the model fish they aim to capture. Students might need assistance to understand which dimension of the fish should be measured. Water should be able to flow through the fish-weir structure, but not allow fish to pass.

Before proceeding to the next lesson, students should be given opportunities to discuss their plan with the teacher or other review partner (e.g., another student group, visiting engineer, or community member) for completeness. This mimics the process of "peer review" common in engineering practice. Students' plans should include a list of materials they intend to use and notation of the design criteria (i.e., length and height of weir, width between the slats of their fish-weir model). Students can also use this opportunity to ask questions or vet concerns.

Lesson 4: Implement

Student groups next use their plan as a guide to build a model fish weir. They can use various materials to build their models such as craft sticks (smooth or notched), dowels, toothpicks, twine, pipe cleaners, and string (Figure 5). We found that pipe cleaners worked particularly well as a binder, as they are easy to manipulate and handle. Students should frequently be reminded to follow their plan sheets, as this is an important practice in the engineering-design process.

Students generally find the building aspect of the lesson to be both rewarding and frustrating. For example, if students want to build a tripod structure as part of their weir design, they may find it difficult to bind the dowels near the peak and maintain an upright position.

Teachers may want to help students brainstorm

FIGURE 2 Salmon weir at Quamichan Village on the Cowichan River, Vancouver Island, ca. 1866

WIKIMEDIA COMMONS

FIGURE 3 Example of a modern fish weir

BACK TO THE EARTH ARCHIVES

ways of overcoming the challenges faced and encourage teamwork. Engineering requires perseverance, creativity, and collaboration to turn a plan into a working model (Figure 6).

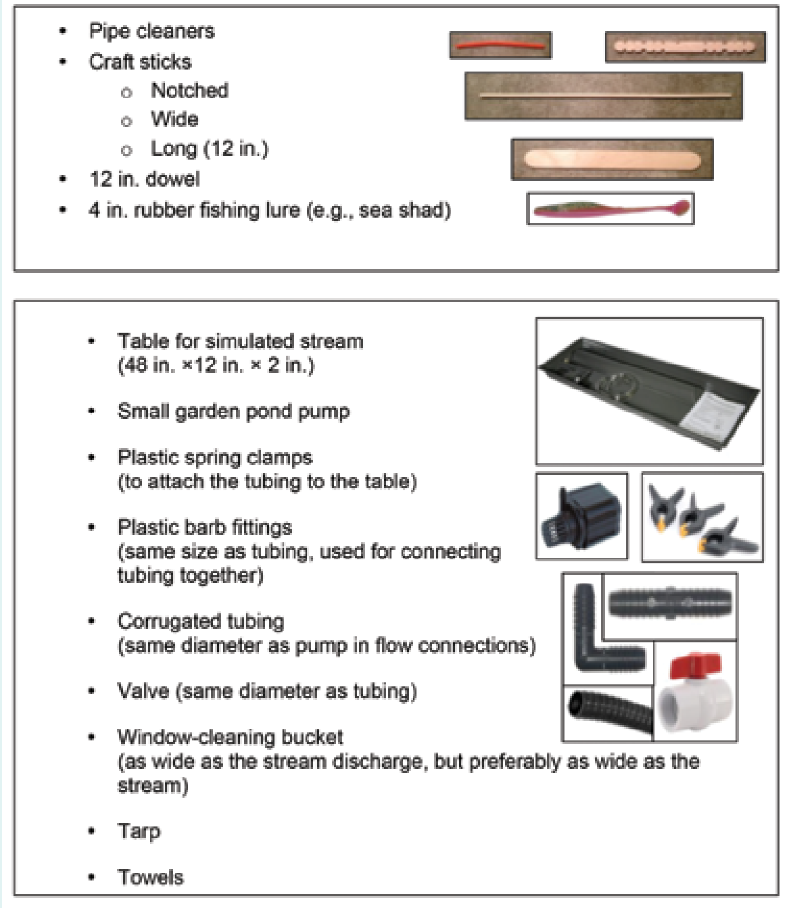
Some precautions and warnings should be considered before implementing the Fish Weir Engineering challenge. Due to the collaborative and hands-on nature of the activity, students should review and follow safety procedures for use of scissors, sharp objects, and other materials. Students should wear safety glasses during the construction and testing lessons. Due to the "wet" nature of this challenge, assuring that plenty of towels and waterproof traps are on hand will make clean-up and accidents more manageable.

Lesson 5: Test and evaluate

Next, students test how well their model works and consider if modifications might improve it. In our example, students test their fish weir in a flowing model stream (Figure 7). A model stream can be constructed from a commercially available, plastic stream table (see Resources) or large tray. A household aquarium water pump and five-gallon bucket are used to recirculate water through the model. The output water flow should be adjusted so that there is a steady but light flow of water in the stream to allow the model fish to "swim." For the "swimming" fish, we use common fishing lures, with the hook removed (Figure 7).

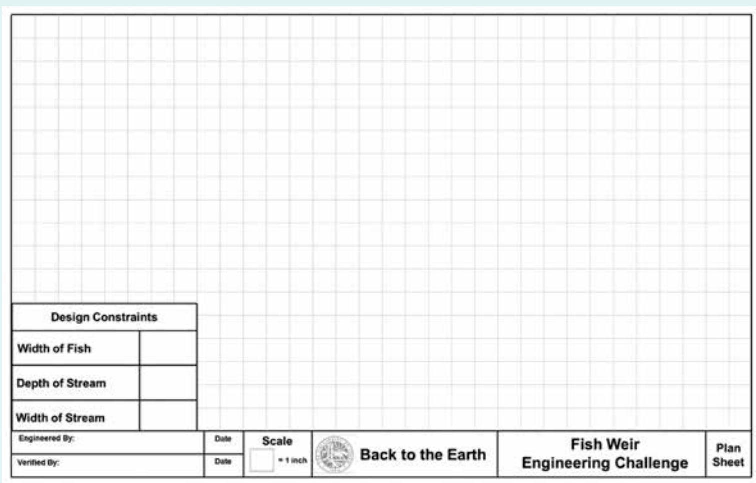
Although we describe salmon as swimming upstream, the model fish in this activity are passive and thus must "swim" with the current. Students place their models in the stream and first analyze the overall fit, stability, and durability of their weir, and then determine how effective the weir is at capturing the model fish. Students are provided opportunities to assess needed improvements and redesign their models for further testing. A success-

FIGURE 4 Equipment and supplies for fish weir engineering activity



SOURCE: BACK TO THE EARTH ARCHIVES

FIGURE 5 Fish weir engineering plan sheet

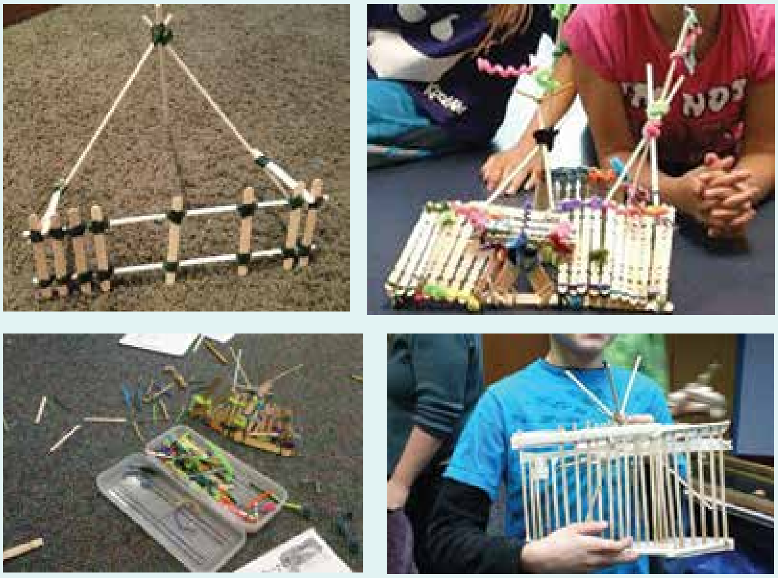


BACK TO THE EARTH ARCHIVES

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard MS-ETS1: Engineering Design *www.nextgenscience.org/msets1-engineering-design*		
Performance Expectation The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.		
Dimension	**Name or *NGSS* code/citation**	**Matching student task or question taken from the activity**
Science and Engineering Practices	Constructing Explanations and Designing Solutions	Students design a device to capture the most fish to feed the community.
Disciplinary Core Ideas	ETS1.B: Developing Possible Solutions • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. ETS1.C: Optimizing the Design Solution • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. *Note:* Other science *NGSS* disciplinary core ideas, such as MS-LS1.A: Form and Function, MS-ESS3.A: Natural Resources, and MS-ESS3.C: Human Impacts one Earth Systems (NGSS Lead States 2013), can be addressed throughout the activity.	Students work collaboratively in teams to brainstorm multiple fish-weir designs, evaluate the pros and cons of possible designs, and develop a conceptual plan (drawing) of their design. Students test, evaluate, and rebuild/improve fish-weir models, following steps including: test the model to determine if design constraints are met, evaluate the strengths and weaknesses of the solution, improve the design as needed, and retest.
Crosscutting Concept	Influence of Science, Engineering, and Technology on Society and the Natural World	Tribal elders can be invited to speak to students about the traditional ecological knowledge and sustainable management of fish practiced by Native Americans. Scientists and engineers working for tribal entities can discuss how history and native culture are still used in the regulation, maintenance, and restoration of local water bodies and fish populations.

FIGURE 6 Sample of fish weir models



PHOTOS COURTESY OF THE AUTHORS

ful fish weir model would stand upright in the model stream for an extended length of time and capture most of the "swimming" fish. As noted above, tribal communities highly value the sustainability of resources; thus, by allowing some fish to swim though the fish weir, tribal members are ensuring that the fish population will be sustained. Therefore, after students master the initial successful design, they may refine their model to accommodate more sustainable practices.

Students gain insight and learn from their peers by sharing and comparing their fish-weir designs at the end of this activity. In this whole-class discussion, teachers ask students to discuss why and how their models work and how they might improve their models to accommodate a changing environment or situation (i.e., faster stream, to catch different aquatic fauna and animals). This discussion reinforces the iterative process of engineering to modify designs according to changing needs or conditions.

Once students have completed the challenge and reflective discussion, they should draw an "as built" diagram of their final model, labeling significant features and providing a list of materials used. They should use a blank "Engineering Plan Sheet" (Figure 6) to draw these final designs. Engineers use "as built" drawings as an initial template for a blueprint design and scale-up of the models that will become structures. Students can also provide a written narrative describing the construction and materials of their models, as well as provide an explanation and justification for how their fish weir works. These activities provide useful assessment opportunities for the Fish Weir Challenge activity the enable links to the *Common Core State Standards* for writing as well as mathematics (see additional standards information with the online version of this article).

While the Fish Weir Engineering Challenge addresses the NGSS engineering and technology standards, specifically MS-ETS1: Engineering Design (NGSS Lead States 2013), numerous connections exist that extend this activity to other science disciplines, as well as other content areas. Other science NGSS DCIs, such as MS-LS1.A: Form and Function, MS-ESS3.A: Natural Resources, and MS-ESS3.C: Human Impacts one Earth Systems (NGSS Lead States 2013), can be addressed throughout the activity. Extension can also be made to basic physical science concepts, such as velocity, acceleration, and force and motion, as related to water flow and current. Other extensions exist linking the Fish Weir activity to content areas such as social studies, history, and language.

FIGURE 7 Students testing model fish weir in a flowing model stream

PHOTOS COURTESY OF THE AUTHORS

Conclusion

Although the Fish Weir Engineering Challenge was designed to specifically address engineering, science, and mathematics disciplines, we found this activity also provides fruitful ways to involve community members in cultivating student knowledge through their rich and honored history. For example, the Fish Weir Engineering Challenge led our students to build a full-scale fish weir with members of the community using natural materials (Figure 8). This weir was placed in a community stream and monitored for its effectiveness in capturing fish. In this respect, the activity was more than a valuable school lesson: It became a shared community experience. Several elders commented that it was the first time in over 100 years that the community worked together to build and place a traditional fish weir in their waters.

The Fish Weir Engineering Challenge provides students a culturally relevant experience for learning basic science content and crosscutting concepts (see standards sidebar). By designing and building models, students engage in science and engineering in ways that are steeped in their own history and culture. This activity allows students to experience STEM concepts that are relevant to their ancestors' lives and also to the lives of modern-day people. ■

FIGURE 8 Fish weir designed and built by students and community

PHOTOS COURTESY OF THE AUTHORS

Acknowledgments

Thank you to our partners for their ideas, direction, and guidance on the Fish Weir Engineering Challenge, especially the Spokane Tribe of Indians and the Coeur d'Alene Tribe. The material is based on work supported by the National Science Foundation under Grant No. 1139657. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

References

Cajete, G.A. 1999. *Igniting the sparkle: An Indigenous science education model.* Skyland, NC: Kivaki Press.

Jarosz, J. 2003. Engineering for Native Americans. *Winds of Change* 18 (3): 52–57.

Jha, A. *International Science Times.* 2013. Google Earth Images Help Researchers Identify Severe Persian Gulf Overfishing; Iran and Bahrain Violate U.N. Fishing Law. Nov. 27. *www.isciencetimes.com/articles/6414/20131127/google-earth-overfishing-persian-gulf-iran-bahrain-united-nations-law.htm.*

Lynch, S. 2001. "Science for All" is not equal to "One Size Fits All": Linguistic and cultural diversity and science education reform. *Journal of Research in Science Teaching* 38 (5): 622–27.

Montgomery, D.R. 2004. *King of fish: The thousand-year run of salmon.* Boulder, CO: Basic Books.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Ancient Fishweir Project—*www.fishweir.org*

Connaway, J.M. 2007. *Fishweirs: A world perspective with emphasis on the fishweirs of Mississippi.* Jackson, MS: Mississippi Department of Archives and History.

European archaeology abroad: Global settings, comparative perspectives—*www.sidestone.com/library/european-archaeology-abroad*

Fish weir: Ancient fishing tool of hunter-gatherers—*http://archaeology.about.com/od/fterms/g/fishweir.htm*

Fish weirs in Canada—*www.cbc.ca/news/technology/earliest-sign-of-human-habitation-in-canada-may-have-been-found-1.2775151*

Plastic stream tables—*www.sensoryedge.com*

Ross, J.A. 2011. *The Spokan Indians.* Spokane, WA: Michael J. Ross.

Royal fishing weir (fish trap)—*www.coflein.gov.uk/en/site/303159/details/RHOS+FYNACH+WEIR,+RHOS+ON+SEA*

TEDx Talk: In the place we now call Boston—*www.youtube.com/watch?v=ESIvZDOCUeU*

Pristine Native American fish weir (trap)—*www.youtube.com/watch?v=U5-dAfFv048*

Anne Kern (akern@uidaho.edu) is an associate professor and **Melinda A. Howard** is a doctoral student at the University of Idaho in Coeur d'Alene, Idaho. **Aimee Navickis Brasch** is a doctoral student, **Fritz Fiedler** is an associate professor, and **Jillian Cadwell** is an adjunct professor at the University of Idaho in Moscow, Idaho.