Restoring FOSSIL CREEK

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An environmental science class teams up with a local university to conduct a longitudinal study

Kathleen Flaccus, Julie Vlieg, Jane C. Marks, and Carri J. LeRoy

At 6 A.M. on the first day of winter break, a van full of high school students and teachers set out for Fossil Creek in Arizona to conduct measurements for an ongoing environmental project (which monitors changes to the creek). The group had a long day ahead—hiking about 7 km down to Fossil Creek, wading in cold water to retrieve samples, and carrying about 13 kg of wet sample bags back up the trail. Later that day, collected samples were analyzed in an aquatic biology lab at Northern Arizona University (NAU). That cold, winter day ended with students saying that participating in the project was a great way to begin winter break.

The students participating that day were already familiar with the project. As volunteers, they had spent part of the previous summer collaborating with a professor and a graduate student from NAU to design the project, set up a study, and hike in the Fossil Creek Wilderness area to find the best field site to take samples. Today, the project continues to be part of an ongoing Research Experience for Teachers (RET) grant funded by the National Science Foundation (NSF).

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The perfect project

The project didn't start off being funded by RET, however. Instead, the project began when science teachers at Sinagua High School in Arizona sought a way to engage students in field research. We wanted to find a relevant field problem that:

- Students could understand and relate to;
- Offered the chance to apply scientific concepts and inquiry;
- Could be completed in a reasonable amount of time without making students miss too many classes; and
- Was affordable in our school district, which has no money for field trips.

It goes without saying that the project also had to be interesting and fun, both for students and teachers.

We came up with the idea for our project by listening to reports about Fossil Creek on the local news. Fossil Creek had been dammed for the past 90 years, and plans were underway to restore the stream. The creek runs through Central Arizona and flows from the high plateaus to the desert, cutting through the same formations that form the Grand Canyon. Water originates in springs, flowing only about .5 km before a dam diverts nearly all the flow into a flume, which takes the water another 6 km to the oldest hydroelectric plant in Arizona.

After flowing through the generating station, a separate flume picks up the water again and carries it to another power plant. For almost a century, Fossil Creek has only had seepage water—but things are about to change. American Rivers, Arizona Public Service (APS), and the U.S. Forest Service (USFS) have been working on decommissioning the power plants and restoring the creek.

The decommissioning of dams has become a hotly debated topic nationally, as the economic and environ-

FIGURE 1

Fossil Creek monitoring study.

The monitoring study consists of:

- *Fish behavior studies.* Students snorkel in the creek with a fish biologist from the USDA Forest Service. While observing fish, students wear the proper equipment; there is also one student on shore for every student in the water (for safety and to record data). Students look for differences in fish behavior upstream and downstream from the dam. All the fish upstream from the dam are natives, but downstream the natives mingle with nonnatives. The only way to monitor differences between upstream and downstream fish is to swim with the fish and note behavior, position in stream, and feeding.
- *Response to fishing.* High school students spend two days just fishing. Students then compare creel counts from year to year. These studies have proved most interesting to the AZGFD because the studies provide usable data for their reports.
- *Water chemistry (pH, temperature, nitrates, dissolved oxygen, and carbon dioxide).* Fossil Creek is a travertine stream system and the chemistry is extremely dynamic. In fact, our next study will analyze travertine (calcite or $CaCO_3$) deposition in the stream. When flows are restored at Fossil Creek, travertine should naturally deposit once again, creating deep pool and waterfall habitat for several species of imperiled fish.
- *Aquatic invertebrate studies.* Students collect aquatic insects and compile checklists on the presence or absence of each species. This is used to determine if population composition changes over time.
- *Repeat photography.* We have complete records of photo sites for five years, both upstream and downstream from the dam. These may be the most telling evidence of changes that take place after the dam is removed.
- *Riparian habitat transects.* We collect vegetation data (species composition, density, and canopy levels) on the plants adjacent to the stream to determine if the riparian habitat changes over time. The riparian habitat is the most important and most endangered habitat in Arizona.
- *Small mammal trapping transects.* A former student now studying zoology at NAU helped us set up this part of the study. While the vegetation transects indicate habitat health, mammal live traps indicate which mammals actually use the habitat. A permit is obtained to set traps at sunset and check and release the animals before dawn. Only the university student handles animals and measures the length of special characteristics for each species for identification. Animals are also photographed before being released.

mental costs of aging dams become more understood. An estimated 85 percent of U.S. dams will be near the end of their operational lives by the year 2020 (Doyle, Harbor, and Grant 2003), and the negative environmental impact of dams is causing some groups to take a hard look at possible stream and river restoration projects.

In the case of Fossil Creek, many stakeholders—including environmental activists, the power company, resource managers, university professors, and state agencies—filed multiple papers on social, political, and biological issues with the Federal Energy Regulatory commission to decommission the power plant. "The decision to decommission the plants weighed the cost-benefits, but in the end it was simply a unique opportunity to return 14 miles of stream to its original condition" (APS 2002).

However, no project is as straightforward as it seems. Even though this project had support from all sectors, roadblocks arose. The application to decommission was initially denied, allowing many concerns to be raised. A major ecological concern was that the short section of creek upstream from the dam was home to one of only two native fisheries in all of Arizona. The dam protected the native species from invasive nonnatives; therefore, the dam could not simply be removed. Ultimately, the final decision was to lower the dam to a height of approximately 3.7 m without removing it completely. This will leave a small artificial waterfall to act as the fish barrier.

Water ownership issues also came into play. The Arizona Game and Fish Department (AZGFD) filed for an in-stream flow right and a nearby community filed for water rights, with municipal priority. Native American groups advocated for the dam's removal. The mix of ecological, political, economical, and recreational issues had the makings of a perfect project for environmental science students. We just had to develop the project in a way that enabled students to conduct authentic science.

Getting started

We began a monitoring project that required students to obtain the same measurements every year and, as a result, quantify the changes to Fossil Creek caused by restoring the flows (see Figure 1 for a listing of the measurements). The importance of longitudinal measurements like these cannot be overstated. The data collected will ultimately provide an invaluable annual record for students, working scientists, and the wider community as changes are monitored over time.

This particular longitudinal study is important because it monitors not only change through time, but also through an extreme event—removing a dam and restoring a stream. We called all the involved agencies and asked for help (USFS, the AZGFD, and the NAU biology department).

The resource management professionals were incredibly generous with their time and expertise. They were more than willing to spend time teaching students both in the classroom and in the field. Every year students from the Marks Aquatic Biology Lab at NAU have helped high school students in the field and lab identify aquatic insects.

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Last year our project really took off. We received a call from a professor in NAU's biology department to set up a more formal partnership. To expand our Fossil Creek research, she offered us expertise, funding, resources, and mentoring. The professor submitted a proposal for a RET supplement grant through NSF. Within several weeks the project was funded, and we began work immediately. A graduate student was assigned to be our mentor, the lab was available for use whenever we needed it, and we had use of field equipment that our school could not afford. Each teacher involved in the project also received a generous stipend.

A commitment

This RET-funded project required a huge commitment from students, much more than a class activity, so we recruited a volunteer team of eight students. Students did not receive any academic credit for participating in the project, which was viewed as an enrichment activity. As part of the grant, the research had to relate to the NSF-funded research already undertaken by the professor. Therefore, we decided to conduct a leaf litter study in Fossil Creek, using two different species of trees—*Populus fremontii* S. Wats. and *Alnus Oblongifolia* Torr.—and two sites, one upstream from the dam and one directly downstream (see Figure 2, p. 40, for details on the leaf litter study). We met during the summer, over breaks, during lunch, after school, and on weekends; sometimes we had to take a day off school to work in the field. In each step of the project, students, teachers, and mentors worked closely together.

The research is still in progress and we hope to publish our results at the end of the project. Whether or not we reach this goal, the project is already successful. Through the RET, teachers have gained the confidence to expand field research in environmental science classes. We have learned an amazing amount about the ecology of streams, how to design valid field experiments, and how to weigh bags of leaves and identify insects in the lab. Students also used knowledge gained through this project to take first place in the aquatic biology section of the International Canon Envirothon (see *www.envirothon.com* for more information).

Benefits

The feedback from students and parents has been overwhelmingly positive. One student said she had never really liked science before and now she plans to work in natural resource management. A parent called to say how thrilled she was that her son was involved in this project because he had always felt like an outsider and this project made him feel a part of something. For teachers, the experience has been even more rewarding. Being involved in research and extending that to students is the most fun we have teaching. One professor said, "seeing such an enthusiastic group of high school students and teachers has renewed my hope in public education."

The benefits to the university are also significant. NAU is concerned about recruiting students in environmental sciences, and projects such as this are an excellent recruitment tool. One student who started in this project has decided to major in biology at NAU, and others are considering NAU as a top choice. These students already feel comfortable in the biology labs at the university.

One of the main objectives of NSF is educational outreach. University researchers involved in NSF research are encouraged to facilitate outreach programs with local agencies, schools, and youth groups; the RET program is a wonderful way to educate graduate students in informal education, teachers and students in scientific research, and the community in the importance of these collaborations.

How teachers can get involved

The RET has been a fantastic partnership for our high school's teachers and students. We have learned research skills, received needed funding, collaborated with mentors, and worked in a university laboratory. Working in authentic field research incorporates the *National Science Education Standards* (NRC 1996), addresses all parts of Standard I at the Distinction Level for Arizona State Standards (ADE 1998), and meets the field/laboratory requirements for Advanced Placement Environmental Science curriculum (The College Board 2003). The best part of the partnership for us has been the ability to work beside professors, graduate students, and our students on research.

RET supplement is intended to facilitate professional development of K–12 science teachers through research experience at the cutting edge of science. Current NSF grantees can apply for this supplement to support K–12 teacher involvement in the research covered under their existing grant. The budget includes a teacher's stipend and up to $1000 for materials, equipment, software, and other supplies to develop classroom instructions and experiments. The Directorate for Biological Sciences at the NSF encour-

FIGURE 2

Leaf litter study.

Leaves that fall into streams form the base of the aquatic food web. Once in the stream, the leaves are grazed on and shredded by aquatic insects, which provide food for larger organisms and release chemical nutrients for algae. Factors that affect leaf litter decomposition affect the entire aquatic food web.

Students initiate the leaf litter study in autumn, when leaves naturally fall from trees. Students collect the leaves in the watershed of the stream with a sort of "tree diaper"—a big tarp hanging in the branches—before leaves actually reach the ground. Most of the fieldwork is done after leaves fall—during the winter, when we return these leaves to the stream.

To construct leaf-holding bags, students sew plastic mesh bags together with fishing line—the mesh allows aquatic insects to move freely in the leaf litter. During the winter, the leaves previously collected by the diaper are separated by species, dried, weighed, placed in mesh bags, and randomly assigned positions and harvest times. Students and teachers then hike all the bags down to the creek and place them in the water, at positions upstream and downstream from the dam.

To harvest the bags, we again hike down to the stream and pull up one third of the bags (leaf bags are collected from the stream three times during the course of the winter—at 10 days, one month, and four months after placement). Back in the lab, we empty each bag and remove all aquatic organisms big enough to grab with a pair of tweezers. These are preserved for later study. We take small samples from some of the leaves, which are later analyzed for fungi. The leaves are dried and weighed. The final weight is compared to initial weight for an indication of decomposition rate, and thus nutrient supply to the aquatic ecosystem.

Our specific study is investigating the decomposition rates above and below a dam to see the dam's effect on the nutrient flow in the stream. Leaves from two different tree species are used in each area to see if observed changes are species specific.

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ages its grantees to "make special efforts to identify talented teachers for participation in this RET-supplement opportunity" (Clutter 2002).

Several ways exist for teachers to get involved in an RET. Teachers should find researchers doing work in areas of interest and talk to them (as stated, the researcher is eligible to apply for the RET supplement if they are currently working on an NSF grant). Another possibility is to find out about current NSF awards available on *www.nsf.gov/home/grants/grants_awards.htm*. Projects also exist designed especially for groups of teachers and some of these can also be viewed on the NSF website. Any K–12 teachers interested in research should get involved!

We plan to continue to use our research skills as the dam is decommissioned this year, and expand the research conducted by our regular classes. We also will continue our discussions with students about the political, economic, environmental, and social implications of decommissioning this dam. Next year when the stream is restored, there will be many scientists and researchers collecting data and analyzing changes. High school teachers and students will be beside them, researching their own projects. ■

Kathleen Flaccus (e-mail: kflaccus@apscc.org*) and Julie Vlieg (e-mail:* jvlieg@apscc.org*) are both science teachers at Sinagua High School, 3950 East Butler Avenue, Flagstaff, AZ 86001; Jane Marks (e-mail:* jane.marks@nau.edu*) is a biology professor and Carri J. LeRoy (e-mail:* cj12@dana.ucc.nau.edu*) is a graduate student, both at Northern Arizona University, Flagstaff, AZ 86011.*

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On the Web

Additional details on Fossil Creek's geology can be found with the online version of this article at *www.nsta.org/highschool#journal*.