CITIZEN SCIENCE AND ECOLOGICAL RESTORATION

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THE BACI EXPERIMENTAL DESIGN AND ECOLOGICAL RESTORATION

Monitoring the effectiveness of ecological restoration is challenging because natural systems are highly variable across space and time, and strongly related to climate (Stenseth et al 2002). In order to fully understand the impacts of restoration, researchers have to use an experimental approach known as a Before-After-Control-Impact (BACI) design. In the restoration setting, the Before and After of the BACI design refers to pre- and post-restoration conditions, while the Control is an unrestored comparison site and the Impact is the restored site (Underwood 1994). By comparing the relative change in variables of interest at the Control and Impact site, the BACI design allows researchers to account for pre-existing site conditions and natural variation due to broad-scale environmental factors like climate that are unrelated to the restoration treatments.

The challenge of the BACI design is that it requires a lot of data: for every post-restoration sample at the restored site (After-Impact), you need three other samples (Before-Control, Before-Impact, After-Control). Effective monitoring designs also require long-term data collection because environmental systems are highly variable and may take several years to respond to restoration. The extensive data requirements of the BACI design is one of the reasons why it is so rarely used in ecological or restoration studies (Rumps et al. 2007, Christie et al. 2019), and why many practitioners may see it as cost-prohibitive to include in their projects.

CITIZEN SCIENCE AND RIVER RESTORATION

Citizen science – where volunteers or students collect data as part of scientific investigations – presents a unique approach for restoration monitoring. Citizen science is well-suited for restoration monitoring because it allows environmental managers to raise awareness of restoration efforts through directly engaging with the public while also generating the type of large data sets necessary for effective monitoring. Public awareness and support are well-known social dimensions of ecological restoration that are critical to the implementation and long-term success of projects (Rumps et al. 2007, Perring et al. 2015). When citizen groups get involved in restoration monitoring, particularly through site-specific ongoing stewardship programs, environmental managers can increase public support of projects that are frequently conducted with taxpayer or other public funds.

In the last 30 years more than 14 billion dollars have been spent on river restoration projects in the United States alone (Bernhardt et al. 2005). The focus of many of these projects has been to improve spawning habitat for endangered fish (Brown and Pasternack 2009); unfortunately, the highly mobile nature of fish, particularly anadromous (migratory) species, makes it difficult to use fish populations as a response variable in restoration monitoring. Stream macroinvertebrates, however, represent a viable alternative to fish for monitoring the biotic response to stream restoration. That's because stream macroinvertebrates have a relatively small spatial range, and they are well-known indicators of the stream habitat conditions typically impacted by restoration including temperature and other water quality parameters, substrate, and nutrient cycling. Perhaps most importantly, stream macroinvertebrates represent a transformative link in the food web and are an important food source for fish and other riverine organisms.

There is a growing body of evidence that citizens can collect data that can be used in BACI designs for river restoration monitoring, including the use of stream macroinvertebrates (Njue et al. 2019, Edwards et al. 2017), and several examples of successful monitoring projects have been published. We will talk about one example of a successful project in this article.

CASE STUDY: ROCK CREEK

Rock Creek is a small salmon-bearing stream in the Clackamas River watershed located in northwest Oregon (US). In 2010 we had the opportunity to monitor the restoration of Rock Creek using a BACI-designed approach with data collected by student citizen scientists. The goal of the Rock Creek restoration project was to increase stream habitat complexity, reduce overall stream velocity, provide rearing and resting areas, and promote ground water exchange (Figure 1).

Figure 1: Rock Creek before (A) and after (B) restoration. Image credits: Clackamas River Basin Council (A) and Portland State University Environmental Professional Program (B). From Edwards, Shaloum and Beddell (2018).

Our project, called the Watershed Health Education Program, is a collaboration between Clackamas County Water Environment Services, Clackamas High School, and Portland State University. In the fall of 2010, we began monitoring the stream invertebrate communities of Rock Creek (Impact stream) and Balch Creek (Control stream) with students from Clackamas High School and Portland State University. We used a non-lethal quantitative technique for collecting stream macroinvertebrates, identified specimens to the family level, and verified the students' data (Edwards 2016). For this study, we monitored both Balch and Rock Creek for three years before restoration construction and two years post-treatment; we are continuing our post-treatment monitoring of both streams with the Watershed Health Program.

We used a trait-based approach to analyze the data (Poff et al. 2006). Traits are characteristics of an organism such as feeding strategy or life history and are useful in monitoring because they allow for mechanistically linking changes associated with the stream macroinvertebrate community to restoration treatments. We assessed several traits in our study of Rock Creek including life history characteristics (voltinism and development) and disturbance tolerance, which allowed us to examine the effect of restoration construction disturbance and recovery to baseline conditions. Another advantage of using traits is that they allow for integration of citizen science data with professional data. In stream macroinvertebrates, traits are generally similar between family and genus level taxonomy, therefore data sets with different taxonomic resolution can be compared or augmented.

Over the six-year study, more than 1,800 high school students and 550 college students participated in collecting stream macroinvertebrates. During the life of the project we collected more than 500 samples and 14,000 macroinvertebrates from both streams. Student data showed a clear response of sensitive and long-lived stream macroinvertebrates to the restoration construction disturbance, and we were able to use student data to detect the recovery of stream macroinvertebrates to pre-restoration conditions in Rock Creek.

To this day, students continue to collect macroinvertebrate samples from both creeks and to monitor the long-term effects of the restoration as part of the Watershed Health Program. The data generated by students in this project show that citizen scientists can be an active part of restoration monitoring and make it possible to collect long-term or intensive data sets that are often out of reach for researchers and practitioners. This study represents one of the few BACI-designed studies of stream restoration monitoring, and the findings add to our understanding of how stream macroinvertebrates respond to restoration construction disturbance (Edwards et al. 2018).

THE SOCIAL DIMENSION OF RIVER RESTORATION

Engaging the public and stakeholders is an important aspect of ecological restoration. The Rock Creek case study illustrates the value of engaging with citizen scientists for both scientific data collection and to increase public involvement with local restoration programs. Through student participation in the project, Clackamas County Water Environment Services was able to document increased public awareness of the restoration efforts in the county. In 2017, more than 75 students packed the Clackamas County Board of Commissioners meeting to symbolically vote with their scientific posters to continue funding for education programs related to stream restoration (Figure 2). Commissioners later commented that this meeting had the highest attendance they had ever observed.

The overall aim of the Watershed Health Education Program is to raise public awareness and support for river restoration. We found that authentic learning experiences helped students develop a deep connection to important local natural resources, and that they shared that interest with their friends and families through conversations about specific river restoration projects and local water quality concerns. Our hope is that these conversations will magnify the effects of the program and strengthen public support for river restoration in the area.

Figure 2: Students attended a 2017 Clackamas County Board of Commissioners meeting to symbolically vote with their scientific posters to continue funding for restoration education.

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