RIVER VOICES

SCIENCE FOR RIVER ADVOCATES

October 2016 Issue

A RIVER NETWORK PUBLICATION

connecting people · saving rivers

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MISSION, VISION, AND FOCUS

River Network empowers and unites people and communities to protect and restore rivers and other waters that sustain all life. We envision a future of clean and ample water for people and nature, where local caretakers are well-equipped, effective and courageous champions for our rivers. Our three strategies for focused investment are strong champions, clean water, and ample water.

IN THIS ISSUE

When you hang out with young kids, they love to ask you a million versions of *why*. 'Why is the sky blue', 'why is there snow in winter', 'why does the dust stick to my shoes', etc. That innate intellectual curiosity about how the world works is present within each of us. When my kids were younger, we'd jump into those questions vigorously and see where they would lead us. Our time in the outdoors, particularly on rivers, would spark more appetite for the *why* game than anywhere else.

The *why* game is also essential to our work in river and watershed conservation. We all need to be able to understand the behavior of the physical and natural world so that we know where our water comes from, how healthy it is today, and what we can do together to protect and restore the functionality of the systems this water flows through so that they can continue to support and sustain all life.

In this issue of River Voices, we have a great collection of articles from leading scientific voices to get you thinking about how our rivers work, how we use science to help spark our communities and our society to do more, and opportunities to deploy science to better communicate what our rivers need to remain healthy, thriving, and sustainably managed. **Thank you contributors!** Rivers are the pulse of our planet, and just like our own bodies, using these vital signs to identify opportunities to become healthier is crucial. Science can help.

HERE ARE A FEW OTHER IMPORTANT ANNOUNCEMENTS FROM YOUR FRIENDS AT RIVER NETWORK:

- Check out our new online environmental flow and water security science module.
- If you are a member, get your local event listed on our website or sign-up for a rain barrel event.
- Support us through your donations and become a member.

Enjoy, and I look forward to seeing many of you in Grand Rapids, MI for River Rally 2017!

Nicole Silk, President
River Network

LANDSCAPE AND SOCIAL PRINCIPLES RELATED TO RIVER RESTORATION

by Robert Naiman, Professor, University of Washington with contributions from Courtland Smith (Oregon State University), and Bruce Rieman (US Forest Service)

In recent decades, understanding of the ecology of river basins (i.e., landscapes) and how societies shape them has advanced substantially. Landscapes are a product of their history, carrying the overt and subtle imprints of past natural events and human activities. Landscapes are now understood to be heterogeneous and integrated natural and socioeconomic systems that are continually changing. Despite complexities, biophysical and socioeconomic knowledge can be applied to manage landscapes for the mutual benefit of human societies and nature. River corridors and their adjacent lands have served throughout history as critical focal areas for human activity and development. Resilient landscapes, and their resilient human societies, have a well-developed capacity to adapt and persist in changing conditions, and have internal self-sustaining capabilities.

A comprehensive landscape approach is essential for understanding the interdependence of habitats, fish and wildlife, water quality and people in river basins (**ISAB 2011**, **Rieman et al. 2015**, **Speed et al. 2016**). Often there is considerable local and scientific knowledge about fisheries, aquatic and wildlife ecology, geology and geomorphology, stream and river processes, sociology, anthropology, economics, and political science. However, inadequate attention is often given to developing a sufficiently broad conceptual framework—both ecologically and socially—for interpretation and application of successful restoration activities.

PLANNING FOR RIVER RESTORATION

Conservation and restoration depend on constraints imposed by landscapes and by people. It is generally best to focus on natural processes and variability rather than attempt to maintain or engineer a desired set of conditions through time. For example, establishing ecologically meaningful flow regimes for water as well as sediments, paying close attention to habitat connectivity for mobile organisms, and conducting monitoring that directly informs an adaptive management process. Further, conservation and restoration are done within the context of people's capacities, interests, and values, and when neglected, result in many landscape ecological solutions being impeded or disregarded because they did not fit the cultural context. For a landscape approach to be effective, people must be engaged in the process and must understand the relevant science.

There are well accepted principles that underlay a *comprehensive landscape approach*, and these can be used to guide conservation and restoration activities (see references above). The principles fall into four themes: *socioeconomic, landscape, integrative, and adaptive*, three of which are discussed in this article.

SOCIOECONOMIC PRINCIPLES

Socioeconomic engagement will help restoration planners understand and act on the intimate interplay of societies with ecosystems. Effective actions within larger landscapes follow from the actions, incentives, and values of people who live in the area or are concerned about sustaining its resilient habitats and populations.

People respond better to positive incentives than disincentives.

While altruism is generally associated with conservation and restoration behavior, for non-altruistic individuals, incentives can promote actions and behaviors that result in effective conservation and restoration. Incentives have to be created for individuals and organizations to adopt behaviors that influence actions compatible with conservation and restoration goals.

Values affect understanding and acceptance of knowledge.
People often make decisions based more on personal values and beliefs than on facts. Research suggests that, when challenged with facts that they question, people fall back on personal values to set their course of action. Often people reject information because it does not fit their values and beliefs.

LANDSCAPE PRINCIPLES

Comprehensive landscape ecology underpins a broader approach for understanding and acting to conserve and restore healthy patterns and processes in river basins.

Ecological and socioeconomic systems are continually changing.
Landscapes, ecosystems, habitats, fish and wildlife populations, and socioeconomic systems are influenced by disturbances, climate, social and cultural forces, internal interactions, and histories. Thus, they are dynamic and changing. Dynamic conditions tend to support diversity but also contribute uncertainty in prediction of future conditions. Given current climate trends, the influx of non-native species, and changing human population and technology, uncertainty and surprise are inevitable. This emphasizes the importance of adaptive capacity, which reflects having adequate diversity in materials, organisms, and knowledge to be able to respond to change.

Context matters.
Higher-level constraints limit the potential conditions that can exist or be created in the future. For instance, the characteristics of rivers, streams, and their channels depend on fluxes of water, sediment, wood, and materials from other parts of the basin. Habitats and populations are inextricably connected with, and dependent on, conditions in riparian areas, broader watersheds, and terrestrial ecosystems. Thus, management of riparian zones and uplands influences aquatic ecosystems, and management of aquatic ecosystems cannot be effectively isolated from management of terrestrial systems. Similarly, socioeconomic systems are affected by higher-level governance, economic, and cultural structures and processes, and by existing social, cultural, and economic patterns.

Spatial structure contributes to the dynamics and persistence of populations.
The spatial structure of habitat (e.g., landscape pattern) is the template for the ecology and resilience of populations. Thus, spatial structure has become an important focus of ecological research and provides a fundamental element for recovery efforts in river basins. The sizes, shapes, numbers, locations, and connections of natural elements (e.g., habitats, populations of plants or animals) can promote or limit the diversity and resilience of landscapes and their inhabitants. Natural elements that occur in multiple, independent units (modularity), and possess greater heterogeneity (diversity), increase their capacity to be adaptive or resilient in the face of future stress and disturbance. Modularity allows units of some elements to persist or even flourish when others of their kind fail. Linkages among redundant elements support movement of organisms and materials (i.e., “connectedness”). When elements are too loosely or too strongly connected, they are unable to provide adaptive feedbacks (e.g., recolonization, susceptibility from disease) that can limit damage or support recovery from unfavorable conditions.

Populations are basic units of conservation and restoration.
Recently there has been a focus on conservation of “populations” as evolutionarily significant units (ESUs) or distinct population segments that may extend across landscapes and persist indefinitely through time. Restoration actions are most meaningful when they contribute significantly to positive change in population level processes. A population perspective considers the networks of habitats in which individuals can complete their life cycles, and considers whether habitat networks are large and complex enough to retain genetic diversity and to absorb disturbance.

ADAPTIVE CAPACITY PRINCIPLES

Adaptation in cultural systems occurs through experiments, learning through education, and revision of values, strategies, and plans.

Collectively, these lead to the maintenance of resilience and adaptive capacity in natural-cultural systems. The process of adaptive management is a major strategy to build adaptive capacity. Analogous ecological and evolutionary processes control adaptation, resilience, and adaptive capacity in nature.

Diversity is fundamental to adaptive capacity. Biological diversity follows from landscape and habitat diversity. Diversity provides the raw material for reorganization following environmental changes and allows persistence in varying environmental conditions. Diversity also is fundamental to the adaptive capacity of cultural systems. For instance, diverse portfolios are one of the ways socioeconomic systems build adaptive capacity and hedge against risk. Education, diverse cultural values and behaviors and new technologies can help deal with existing or anticipated problems and build adaptive capacity.

Ecological functions can be retained even when all native species cannot be conserved or restored. Ecological health implies diversity in biological structure and function. Although the easiest way to maintain biological diversity, and often the most culturally acceptable way, is to maintain native diversity, ecosystem function does not necessarily require this. Most ecosystems have been substantially altered by people and often non-native species now are present or naturalized. Although "keeping the pieces" is a cardinal rule of intelligent tinkering, including in conservation and restoration, the loss of native species is sometimes irreversible and contemporary thinking suggests that restoration or maintenance of important ecological functions can be achieved, in part, with ecosystems that include non-native species.

Experimentation increases adaptive capacity by creating new knowledge. Experimentation to actively learn about mechanisms and uncertainties is the essential feature associated with adaptive management. However, experimentation, or even the acknowledgement of uncertainty, is not central in most management efforts. Large-scale management experiments require the effective integration of research and management, policy and governance, and acknowledgement that more knowledge is needed. Experiments explore uncertainties, assess the results of actions, promote active learning, encourage public input, and help adjust strategies and plans to create new or revised actions.

Active experiential learning is an effective form of education. Active experiential learning is necessary for effective education, including adult education. Active experiential learning increases understanding of new principles and techniques and improves the capacity to implement new ideas. With better knowledge, people are capable of more effective action.

WHAT DOES SUCCESS LOOK LIKE?

What will it take to be successful? The path requires continual learning and adaptation. Most river basins will experience a future that is outside the bounds of previous experience—a serious social-environmental issue that lives with us today. There are, however, ways to prepare for an uncertain future. These require the integration of local with basin-wide decisions and actions. Collectively, there are opportunities to be successful when one recognizes that:

- Success is a process, not a state of completion, and it demands unparalleled communication and cooperation
- Change is continual: sustained monitoring and active learning will be always required
- Early and extensive public engagement is needed at all scales of social organization (e.g., homeowners, counties, sub-basins)
- Socioeconomic and ecological issues must be addressed simultaneously and with an integrated approach, keeping in mind that the Basin's natural environments sustain the personal wellbeing of its people.

DANCING WITH SCIENTISTS TO PROTECT RIVERS

by Mary Freeman, U.S. Geological Survey

Five-thirty on a recent, weekday afternoon, six of us huddle around a worn, wooden table in a downtown watering hole. We're there as an ad-hoc committee of our local watershed association to chew over reports of a foul-smelling algal bloom in the Broad River, in rural northeast Georgia. Some of us live along the river; all of us care about it as a place to escape the heat and bustle of the city. The river hosts thriving recreational canoeing, a camp for inner city kids, a state park, and extensive woodlands that are home to deer, turkey and uncounted other wildlife. Flow in the river is altered by only a few, small water diversions and minor discharges of treated wastewater. But this summer, a dry one, a local college professor sent us a message: he visited the river and found dense algae covering rocks in areas that would usually be covered by swift flow. Initial water samples showed high levels of phosphorus, although samples taken a few weeks later did not. What to do? We need some science.

Science gives us a basis for understanding why things happen, and importantly, for predicting what will likely happen next, given a set of conditions. We're all familiar with examples. Will the river flood given projected rainfall? The answer depends on understanding watershed hydrology. What caused a fish-kill and is it likely to happen again? The answers require understanding how nutrients or contaminants interact with streamflow levels and water temperatures to cause stress in fish, possibly by way of algae or other organisms.

Through collaborations, scientists and river advocates can provide information the general public needs to understand what is happening with their streams and water resources. For instance, USGS scientists have partnered with the Chattahoochee Riverkeeper, the National Park Service, and others, to provide real-time estimates of E. coli levels at popular recreation spots in the Chattahoochee River, near Atlanta GA. The science behind this **Chattahoochee BacteriAlert project** includes statistical modeling to relate bacteria levels to the clarity of the water, or turbidity. Turbidity reflects runoff that carries bacteria and, unlike bacteria, is relatively easy to monitor in real-time. So, scientists are using instantaneous measurements of turbidity to predict, on an hourly basis, whether the Chattahoochee River is safe for swimming, information that river users can access on-line. Users can also find a wealth of information at the web-site about the river, bacteria and associated health risks, and the science behind the E. coli estimates. Science and science outreach clearly are useful tools for champions of the Chattahoochee River.

In my day job, I'm a scientist. My expertise concerns the fishes and invertebrates that live in streams and rivers. Much of my professional work entails answering questions of how human actions—water diversions, dam operations, riparian management, and so on—are likely to affect populations of stream critters. Who cares about this and how does it get applied? Some people care about their local fishing stream. Others are concerned with avoiding regulatory risk under, e.g., the Endangered Species Act or equivalent state legislation. Sometimes, advocates care just because they value the species. Salmon are iconic (and in some cases endangered) in the Pacific Northwest, and have been an impetus for dam removals. Rivers in other parts of the US may lack salmon but host other species that inspire protection. In northwest Georgia, the Coosa River Basin Initiative hosts a yearly "**biodiversity bash**" to celebrate their river system's exceptional diversity of fishes and mussels. Near my home, our watershed group sponsors a canoe trip each May to view the shoal lily in full bloom on the Broad River.

The careful dance between communities and scientists is what drives science-based conservation. The dance is this: people set the objectives to be achieved through conservation, based on the things they value. Science gives us a way of predicting whether particular actions are likely to support, or detract from, achieving those objectives. River advocates do the hard work of articulating why communities should care about "natural capital," about clean and ample water in our streams and not solely coming from the tap. Scientists study the natural mechanisms that link our actions to ecosystem properties—streamflow, water quality, biodiversity—and the attendant services to communities. But, can science tell us what to value? To paraphrase others, one person's pristine wetland is another's mosquito-infested swamp. Scientists can elucidate consequences of either protecting the wetland or draining the swamp. Communities, and society at large, must decide what we want our waterways to do for us.

Most often, arguments for protecting and restoring natural waterways center on economics and public safety: savings in water treatment and storage costs, the benefits of stream-side greenways for recreation and for buffering our homes from flood waters. Sometimes, the arguments are about biodiversity for its own sake. Science comes into play when we need to know how changes in land-use or water management are likely to affect those ecosystem services we value, including survival of native species. Sometimes we want to know the benefits of restoring species, and those may be unexpected. Ecologists have discovered that salmon returning to their natal streams to spawn bring with them nutrients from the ocean that can fuel local foodwebs, increasing growth of juvenile fish and even riparian trees. This is not a scientific reason to restore salmon runs; rather, it is a scientific discovery that may help society make decisions about whether and how to restore salmon.

So the dance is complicated. Science can reveal phenomena that inspire wonder and motivate a desire to conserve species, wild places, ecosystems. Science can usefully alert the public to potential benefits and risks of our actions or inactions. Back in the pub that evening in August, we are putting on our dancing shoes. We've already contacted a local university scientist who will take her aquatic biology class out to our river in the next week to collect algal and water samples. We'll then ask her questions: What did you find? Why would we see algal blooms now? Are these algae toxic? Could blooms recur next summer? Could extensive algal blooms threaten our population of shoal lilies? The professor may alert us to possible effects on other species—the Broad River burrowing crayfish or Bartram's bass. She may help us design a monitoring program for algae or nutrients to figure out causes of the blooms. Science helps advocates understand possibilities; advocates set the agenda. Back and forth, this partnership between scientists and communities strengthens our collective understanding and capacity for protecting the things we value about rivers.

Mary Freeman serves on River Network's Scientific and Technical Advisory Group

Credit: Joe Cook

NEW APPROACHES AND NEW PLATFORMS CATALYZING ENVIRONMENTAL RESTORATION

by John Dawes, Executive Director and Founder, Chesapeake Commons

Organizations and individuals working to restore our nation's rivers face an exciting new frontier where technology is redefining the way we leverage data to catalyze citizen engagement, make decisions, and garner restoration outcomes. Open Source communities and corporate players are pioneering new products and frameworks that can make non-government organizations, government agencies, and foundations significantly more effective in carrying out their most important work. This article will cover some of the most promising platforms and frameworks created by those working in and outside the environmental space. We will also provide some helpful tips that will illuminate the need for careful planning and management related to software intensive projects so that the end product will benefit the stakeholders served.

PLAN AND EVALUATE ROI CAREFULLY

At the onset of any application development project or consideration of adopting a new technology, stakeholders and the technical service providers need to question the value in what they are building. Under many corporate models, a full Return on Investment (ROI) analysis and user demographic evaluation will be conducted to determine if it's cost effective to transform a concept into fully operational web or mobile application and the same rings true if organizations are in the market for a new piece of software. We're certainly not advocating for this comprehensive of an approach for small environmental NGOs, but feel it's important to strike a balance. Stakeholders seeking to build their own systems must be clear on how the outputs and functionality of their proposed app will lead to desired outcomes of their user base and it's the responsibility of any development firm to set realistic and transparent expectations of what functionality can be achieved in a given scope of work. During the planning phase, at minimum, all constituents working on the project should have a very good idea of who their app or new system targets and how many individuals are in the given demographic. This will allow you to compare the cost of development to the number of potential users in your defined market segment to see if your concept is cost effective and viable.

FIVE TECHNOLOGIES WORTH WATCHING

While it's nearly impossible to summarize the entire landscape of technology and the environment, there are some fantastic resources available that cater to environmental technologists of all skillsets. We've pulled together a list of five items so that we could painstakingly select platforms or frameworks that fall into categories that appeal to organizations in need of a solution that is ready to use or supportive of custom development.

It's important to note that all frameworks falling into the custom development category trend toward open-source and have extensive development communities backing them. This often indicates a large support group and economies of scale for refining code libraries that can serve as the building blocks for your new application.

READY TO USE

Libra–A "user first" portal for accessing Landsat 8 Imagery

For those who have spent time downloading and working with Landsat Imagery products for remote sensing, it is no secret that searching and downloading this invaluable, free data is time consumptive and cumbersome. Meet Libra, a web based application built by Development Seed that enables users to easily sort, browse, and download over 275 terabytes of open Landsat Imagery. Libra takes the painful and slow process of drawing a bounding box to browse imagery by loading in imagery products based on panning and zooming. Users are able to quickly filter by date as well as cloud coverage which greatly speeds up the process of identifying imagery products that can or cannot be used for remote sensing projects. Libra includes visual tools like a histogram on filters to help users intuitively understand the implications of their filtering choices. The system also provides thumbnail previews of each image so that users can immediately see the product they are accessing before committing to a long download.

For more information visit:
https://libra.developmentseed.org/

You should check out these other great data portals too (Google Earth Engine, eRAMS, and USGS National Water Census Data.)

- **https://earthengine.google.com/**
- **https://erams.com/**
- **http://cida.usgs.gov/nwc/**

WikiWatershed—Fresh Water Stewardship Web Tools

Created by the Stroud Water Research Center, Wiki Watershed is a platform that consists of a suite of tools that support citizen scientists, municipal planners, and educators. Built on a variety of open source frameworks, Wiki Watershed allows users to leverage a total of six applications that range from Environmental DIY, a social network for sharing ideas and design specs for open source environmental monitoring and water quality sensor projects, to Model My Watershed, a web based application that helps users to easily run scenarios and analyze how best management practices and land use change affect nutrient and sediment flows in a watershed.

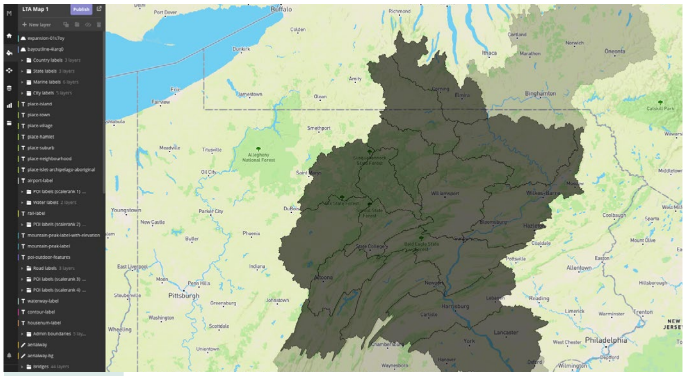
With respect to Model My Watershed, Stroud has managed to make a highly complex stormwater model easy to use for any decision maker on the national scale. The user interface is intuitive and any scenario a user creates can be saved and shared with other conservation partners. For example, our team was able to easily locate an area we interested in restoring, evaluate the estimated quantities of stormwater runoff, nutrient, and sediment delivery to the edge of stream, and plan practices that would mitigate these threats to water quality. What's more is that the platform enabled us to create these scenarios in a matter of minutes instead of hours. As higher resolution land use land cover and imagery data become available, the accuracy of this system continue to improve making precision conservation planning available to any restoration professional with a user account.

For more information visit:
http://wikiwatershed.org/

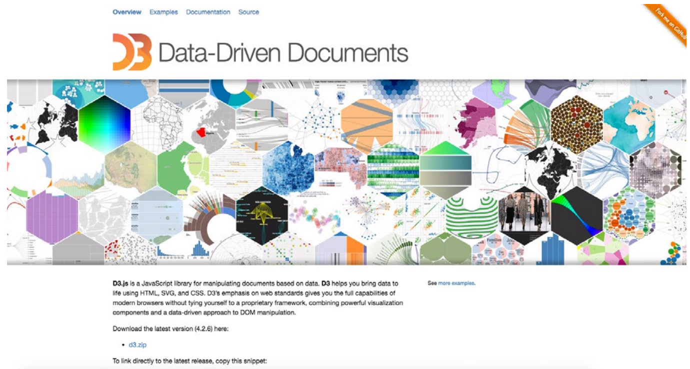
DMR Pollutant Loading Tool

Developed by the Environmental Protection Agency (EPA), the Discharge Monitoring Report Pollutant Loading Tool allows users to identify point source facilities and estimate pollutant loading rates affiliated with their NPDES permits. Pollutant loadings are presented as pounds per year and as toxic-weighted pounds per year to account for the variability in toxicity among pollutants. The system can be used to ranks dischargers, industries, and watersheds based on pollutant mass and toxicity. This is one of the only systems developed by a government entity that we have found that presents "top ten" lists to help users determine which discharges are important, which facilities and industries are producing these discharges, and which watersheds are most negatively affected. EPA's DMR Pollutant Loading tool is perfect for organizations wishing to conduct cursory compliance sweeps against a list of facilities and the platform enables new users to execute EZ Searches to get a feel for how the system works. Most importantly all the data behind the DMR Pollutant Loading Tool can be accessed via spreadsheet or the systems application programming interface, which allows users to create custom information products out of EPA data.

For more information visit:
https://cfpub.epa.gov/dmr/index.cfm



Mapbox



D3js

CUSTOM DEVELOPMENT

Mapbox—An open source mapping platform for custom designed maps
Traditionally, Geographic Information Systems that share data or an analysis online have been solely focused on creating configurable web mapping applications that allow users to perform endless analytical tasks. Many of these systems put the map and spatial analytics first and focus less on user experience and design. Shaking up the industry, Mapbox is one of the first companies to create a business model around using web maps exclusively for application development, instead of desktop analysis. The company offers an array of toolsets and APIs that enable their user base to very closely integrate maps into the user experience and build web mapping applications that are highly customized. The foundation of Mapbox's technology stack makes their base maps the fastest on the market and incredibly easy to incorporate into mobile application development. Most importantly the documentation provides clear and useful examples of how users can leverage Mapbox's APIs to create powerful and useful mapping applications. While the Mapbox does charge by service tier, we've found the staff to be incredibly helpful and generous with their time to field questions and issues via email or over the phone.

For more information visit:
https://www.mapbox.com/

D3js—A JavaScript library for manipulating documents based on data using HTML, SVG and CSS
Whether you need to create a real-time dashboard or a simple data visualization, D3js has your organization covered. Standing for Data-driven Documents, this JavaScript library is regularly used to create a nearly endless amount of charts, maps, and data visualizations. Focusing on web standards, D3 enables users to apply data-driven transformations to documents in the browser. Instead of focusing on specific features, D3js makes document manipulation efficient, allowing for more flexibility. Products built with D3js are typically supported across most modern browsers and include transitions that help make visualizations fun and engaging. This free library was created by Mike Bostock a data visualization specialist at the New York Times.

For more information visit:
https://github.com/d3/d3/wiki/Gallery

CONCLUSION

With a massive uptick in our ability to access and even create software, it's easy to become paralyzed by the flood of differing applications and frameworks for helping move your mission forward. But don't panic because the landscape also offers us nearly endless possibilities to harness new systems and approaches. With curiosity and a willingness to learn, discovering and using new technologies can help any organization expedite positive, lasting changes to water quality.

RIVER ADVOCATES AND THE MASTER VARIABLE

by Adam Griggs, Science Manager, River Network

The term "master variable" started appearing in the scientific literature of stream and river ecology about twenty years ago. Being around fifteen at the time, it's a fair bet I was still blissfully unaware of peer-reviewed journals, still playing and fishing in streams rather than studying them, and the revelation of the master variable escaped me. Fast-forward fifteen years, though now working as a researcher and river ecologist, I still hadn't learned that lesson or yet considered the variable in my work. When you're working in the Chesapeake and Potomac basins, there's a pretty big focus on water quality. The variables we examine for water quality are usually measureable, relatable, and enforceable (well, sometimes). Water quantity, as I experienced it in the eastern U.S., was just that, quantity. I knew there were plenty of people working on quantity issues, ensuring the drinking water of the Washington DC area, but in my work it seemed very much an after-thought. I hadn't yet thought about quantity as being more than just the amount of water in a river. I hadn't thought about quantity as flows, or realized that flows are about much more than just 'how much.' I hadn't thought about flow as the 'master variable'.

THE NATURAL FLOW REGIME

Environmental flows are indeed about more than just how much. How much is important, but so are the aspects of how long, and how often, and flows for who or what? A natural system, undisturbed by human uses, would have a "natural flow regime" (see box). Each watershed is unique of course, and each watershed's version of a natural regime is also unique, with watersheds sharing similar geologies and climate being more alike than a system at some distance under different conditions. The timing, duration and magnitude of a river's flows shape its ecology, its chemical nature, and the intricacies of its shape, channel, banks, and relationship with its floodplain. Natural events and cycles become cues in the life histories of aquatic organisms, spurring freshwater eels to migrate to the sea, for instance and mussels to extend their lures in hopes of finding their larval host fish. Flows are also key in influencing the seasonal deposition of soils and nutrients in riparian, floodplain, and coastal areas, enriching those systems and potentially increasing their health and productivity. A natural flow regime includes disturbances such as floods and periods of drought, and intermediate levels of disturbance are thought to support the highest numbers of species. The transport of sediment and nutrients, and just about anything else, are also intimately tied to flows, with certain constituents entering river systems in pulses during precipitation, while others are being diluted by them. Deviation from natural flow regimes and increased levels of disturbance can have cascading effects on how the entire river system functions.

Flow Terminology

ENVIRONMENTAL FLOWS–"describe the quantity, timing, variability, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human well-being and livelihoods that depend on these ecosystems."[i]

NATURAL FLOW PARADIGM–"The full range of natural intra- and inter-annual variation in hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems."[ii]

INSTREAM FLOW–"[a]ny quantity of water flowing in a natural stream channel at any time of year. The quantity may or may not be adequate to sustain natural ecological processes and may or may not be protected or administered under a permit, water right, or other legally recognized means."[iii]

DESCRIBING FLOWS AND MEASURING ALTERATION

Human-caused alteration of natural flow regimes result from a number of causes including surface and groundwater withdrawals, damming of rivers, the conversion of natural landscapes to human uses, and through the frequency and intensity of weather events exacerbated by climate change. Flows can be measured and described in a variety of ways, including: visual and physical assessments of water levels and habitat condition, real-time measurements of volume collected across a network of discharge gages, or hundreds of hydrological statistics and models that can assess different aspects of a river's measured or modeled hydrograph. A hydrograph is a graphical representation of flows occurring over a period of time, often months or years. Hydrological statistics can measure nearly any pattern you can think of that might be described from a hydrograph's lines, the most famous (but not necessarily the most useful) of these being the 7Q10, or the lowest 7-day average flow that occurs once every 10 years. Other metrics might calculate the average number of high pulses in a year, or the rate of change or 'flashiness' that is observed when storms move through a river's watershed. Generally, dams and reservoirs tend to homogenize and reduce flows, withdrawals contribute to low surface or groundwater levels, and urbanized areas can increase the flashiness, magnitude and frequency of high flows, and the magnitude, frequency and duration of low-flows. Alteration from natural flow regimes can be measured by comparing the data from a river's hydrograph to that of a less-disturbed condition. This may be performed by looking at historical data collected before the watershed was developed, by making comparisons to a similar yet undisturbed nearby watershed, or increasingly, because neither of the first two exist, by modeling what a river's hydrograph would look like in an unaltered 'reference' condition. Measures of alteration can then be applied against measures of stream health, like aquatic life indicators, or standards designed to protect human designated uses under the Clean Water Act.

ALTERED FLOWS AS A CAUSE OF WATERWAY IMPAIRMENT

Because flow alteration and hydromodification—including surface and ground water withdrawals, dams and impoundments, diversions or extreme low or high flows, and impervious surfaces that increase runoff and decrease baseflow—affect the chemical, physical, and biological integrity of our waters, they are considered pollution **under the Clean Water Act** and should be identified and listed as a cause of impairment of state water quality standards where appropriate. **In EPA's 2015 guidance to states** on how to monitor and report on the status of their waters, the Agency made clear that states should consider how to "more fully understand the impacts and causes of all types of pollution on our nation's waters," with an emphasis on hydrologic impairment.

EPA further detailed how states could apply biological narrative or numeric flow criteria or, in the absence of such, collect and assess additional data and information that may indicate a designated use is not being fully supported. EPA emphasized greater use of external datasets such as USGS gage data, StreamStats, or dam inventories, and the greater use of field personnel's visual observations and qualitative evaluations of flow levels and habitat alteration resulting from altered flows.

EXAMPLES OF ADVOCATES WORKING TO RESTORE NATURAL FLOWS

Given the importance of this master variable in the health of our rivers, watershed groups are increasingly working to protect and restore environmental flows. Organizations including **The Nature Conservancy** and the **Instream Flow Council** have been building a foundation of science, policy, and practices for working to improve flows in our rivers. Today, river protection organizations have numerous resources and experiences to draw from to include these aspects in their conservation work. For example, the **Hydropower Reform Coalition** has used the concepts of instream flows and environmental flow needs of fish and other aquatic life to advocate for and guide both dam removal and dam operation that has resulted in improvement of aquatic habitats. There are numerous opportunities to improve reservoir operations that improve downstream conditions for fish and other communities. Examples include establishing guidelines that require major changes in outflow to be made in steps rather than sudden large shifts, managing flows to improve fish habitat, or operating to achieve seasonal thermal targets. Similarly, there are opportunities to improve river flows via water withdrawal permitting. **The Harpeth River Watershed Association**, for example, helped advocate for the use of the best-available science to help construct new withdrawal guidelines for the City of Franklin, Tennessee that work to protect the Harpeth River from low-flow conditions, while securing investments in future monitoring.

BRINGING FLOW INTO YOUR WORK

To investigate if your watershed is experiencing altered flows or unsustainable water-use, check out our **Science Module on Environmental Flows and Water Security**. This resource should help you get started, with videos explaining the concepts of environmental flows and water budgets, along with demonstrations of online tools that provide easy access to flow and water-use data and statistics. You'll also find links to other great resources from The Nature Conservancy and The Instream Flow Council, and new data resource portals from the USGS, One Water Institute, and the Freshwater Network that allow you to quickly develop custom results and charts from gages in your watershed.

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[i] Brisbane Declaration, "The Brisbane Declaration: Environmental Flows Are Essential for Freshwater Ecosystem Health and Human Well-Being: Declaration of the 10th International River Symposium and International Environmental Flows Conference, 3–6 September 2007, Brisbane, Australia," (2007).

[ii] N.L. Poff, et al., "The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards," Freshwater Biology 55, (2010), 147–170.

[iii] T. Annear, et. al. Instream Flows for Riverine Resource Stewardship, Revised Edition. Instream Flow Council. (2004).

COMMUNICATING SCIENCE EFFECTIVELY USING KILLER GRAPHICS AND COMPELLING STORIES

by Jane Thomas and Bill Dennison
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What is science communication and why is it important? At the Integration and Application Network (IAN), University of Maryland Center for Environmental Science, we work to improve the communication of scientific findings to both peer and non-peer scientists and to the wider audience of resource managers and interested lay people. Our IAN team defines science communication as the successful dissemination of knowledge with a wide range of audiences including non-scientists. Good science needs to be disseminated using good communication principles so that the science can contribute to furthering our understanding of nature and to solving societal problems such as environmental degradation. Historically, it is clear that the most successful scientists are skilled at communicating their ideas. Think of Charles Darwin, Albert Einstein, and Rachel Carson: all talented scientists whose communication skills fundamentally changed how we view the world around us. Most scientific training is focused on the technical and analytical skills needed to obtain and interpret scientific data. But little training is devoted to communicating science and the little training that does occur is focused on communicating exclusively to peer scientists. The term 'science communication' often refers to journalists who write or produce science stories for mass media consumption. Our efforts at IAN target practicing scientists who need to improve their skills in communication to broader audiences, but science communicators and journalists will also find some value in the topics presented here.

Stakeholder workshops that synthesize the current state of research and management can and should be utilized as opportunities to storyboard science communication products.

Throughout the 20th century, science was proclaimed as the solution to the problems of land degradation and pollution resulting from earlier discoveries during the agricultural and industrial revolutions. As a result, there is now an increasing focus on linking funding for science with practical solutions to environmental problems. This creates a dilemma, for science alone will not create widespread change, mainly because the channels to use this information and create change are poorly developed. In order to create changes in behavior and beliefs of the interested public, broader and more effective communication of the new scientific insights being gained is required. Therefore, utilizing current research effectively will require new tools to facilitate effective communication, not only to scientific peers, but also to resource managers, decision-makers, and ultimately, the general public.

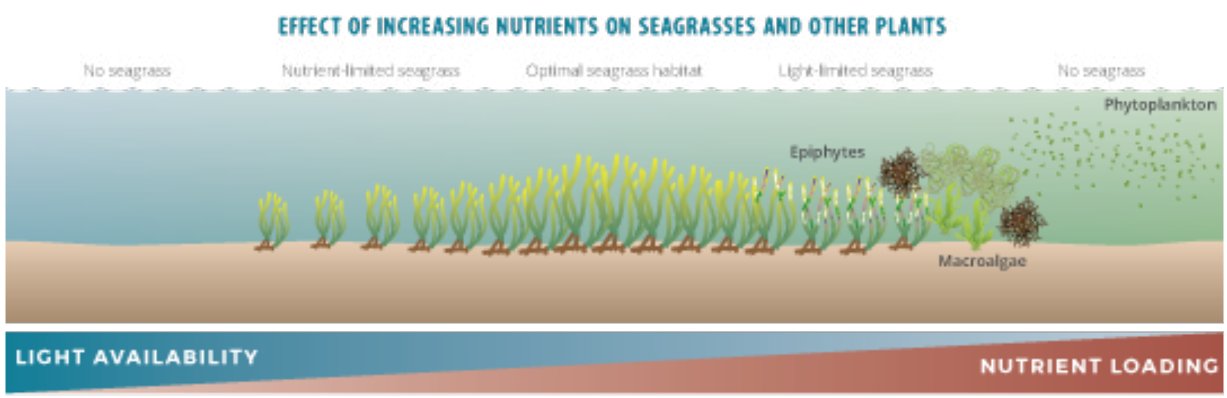
The essence of effective science communication is the development of *content-rich, jargon-free, communication-based* materials. *Content-rich* refers to communication that is replete with data and ideas. *Jargon-free* refers to the elimination of shorthand notation that scientists use to communicate within their peer groups—this means removing acronyms and maintaining a common language basis for explaining concepts. *Communication-based* refers to focusing on the intended audience and providing an even broader base of accessibility for a wider audience.

So what are some of the tools IAN has been developing to communicate science effectively?

CONCEPTUAL DIAGRAMS

Conceptual diagrams are incredibly powerful tools for synthesizing information in an attractive and informative manner, and can be designed with readily available computer software. Conceptual diagrams are ‘thought drawings’ that provide representations of ecosystems or other complex natural processes. One reason why conceptual diagrams are so effective is that they can be used in products intended for audiences ranging from the general public to subject experts. Conceptual diagrams, in contrast to scientific data and graphs, invite two-way communication with stakeholders and co-production of these diagrams with stakeholders is an important workshop technique that we use regularly.

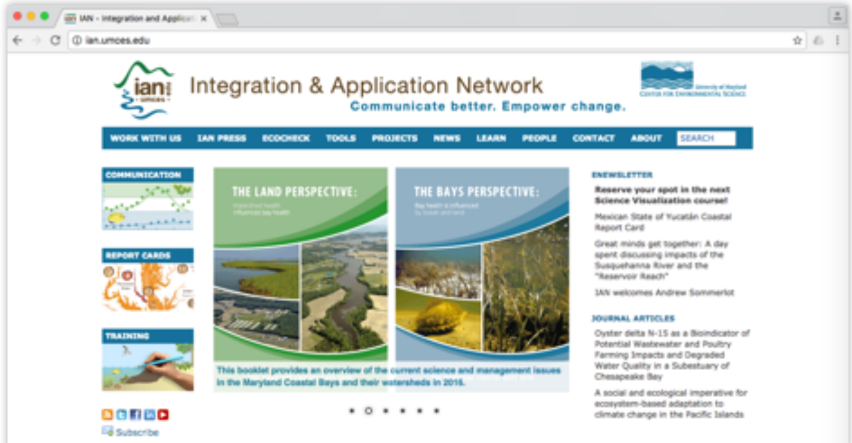
Depending on complexity, it will take at least a day or two to create a first draft of a conceptual diagram on a computer. Most of this time will be spent creating the base of the diagram—the representation of the system being depicted. Once this is done, the base can be populated with symbols relatively quickly using a ‘click and drag’ technique, although editing of existing symbols and creation of new ones is usually required. Conceptual diagrams typically require multiple iterations before a final draft is approved by all the stakeholders involved but they can be used many times in a variety of products.



This is one example of a conceptual diagram, depicting the change in aquatic primary producers as nutrient loads increase. This diagram has been used for many years in various forms which is a testament to the effectiveness of conceptual diagrams as a science communication tool.

SCIENCE VISUALIZATION TRAINING

IAN staff are passionate about sharing their experience and training scientific colleagues in academia, NGOs, and agencies to become more proficient in science communication. IAN staff regularly travel to a variety of locations to deliver short immersive science communication training sessions from one to several days in duration. In addition, IAN has recently developed a semester-long course which is delivered via interactive video connections using a 'flipped' or 'inverted' classroom in which the lecture content and tutorials are provided via short YouTube videos and class time is spent reviewing and critiquing student projects (www.sciencevisualizationclass.wordpress.com). Students synthesize class-time discussions via blogs, which are posted on the IAN website (www.ian.umces.edu).



Our IAN website was designed to provide resources for scientists, communicators, and ourselves. It is updated constantly with new material, which also provides content for our social media posts.

DEVELOPING NARRATIVES FOR SCIENCE COMMUNICATION

An important part of science communication is developing effective narrative structure ('stories') for dissemination. IAN has embraced the tenets of developing narrative structure espoused by Randy Olson, author of 'Houston, We have a narrative: Why science needs story" and "Don't be such a scientist: Talking substance in an age of style". A compelling narrative structure can be achieved using the "And… but… therefore… (ABT)" template. Most scientists write using an "And… and… and… (AAA)" template which is boring and offers no real resolution or interest. Switching to the ABT template results in a more engaging narrative where the and connects ideas, the but creates conflict, and the therefore offers resolution. We regularly solicit input from stakeholders to formulate key statements using the ABT template. The ABT structure, with its succinct background, conflict, and resolution framework, creates the most memorable method to deliver facts and information. But these short statements take time to create, and in fact can prove to be harder to produce than writing multiple paragraphs of the same information. Therefore, it is imperative that time is taken to craft these statements, with care in word choice, to make them meaningful statements.

WEBSITES AND SOCIAL MEDIA

Detailed planning and scoping at the initiation phase of a website will reduce the work required for future expansion. In addition to the time-intensive initial planning and development stages, it is equally important to allot sufficient resources for the long-term commitment of maintaining, updating, and enhancing the website. Regular blogs, e-newsletters and IAN Press products are posted on the IAN website in which advances in science communication are provided.

Social media is an extremely effective way of reaching many people very quickly. To maintain relevance and keep people engaged, social media needs to be updated frequently with posts containing only the latest information and commentary. The key to success in social media is making connections with other users by tagging them or sharing their posts.

In conclusion, effective communication has the power to influence opinion, change behavior, and build consensus. So, selecting appropriate communication products and distributing them to targeted audiences helps to engage the community and educate it about issues facing their ecosystems. We use science communication to make a difference in the world. We aim to make a global impact with our science communication applications. Learning how to communicate science is as important a skill as learning how to do science. It is one thing to learn how to collect and analyze data–it's a whole other thing to learn how to effectively communicate science.

connecting people · saving rivers

MISSION, VISION, AND FOCUS

River Network empowers and unites people and communities to protect and restore rivers and other waters that sustain all life. We envision a future of clean and ample water for people and nature, where local caretakers are well-equipped, effective and courageous champions for our rivers. Our three strategies for focused investment are strong champions, clean water, and ample water.

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