NWQEP NOTES

The NCSU Water Quality Group Newsletter

Number 131 | March 2009 | ISSN 1062-9149

NC State University
A&T State University
COOPERATIVE EXTENSION
Empowering People · Providing Solutions

NC STATE UNIVERSITY

IN THIS ISSUE

NWQEP NOTES is issued quarterly. Subscriptions are free. *NWQEP NOTES* is available on the World Wide Web at http://www.ncsu.edu/waterquality/issues/Default.htm. To request that your name be added to the mailing list, send an email message to wq_puborder@ncsu.edu.

Note: *NWQEP NOTES* is only provided electronically effective June 2007.

PROJECT SPOTLIGHT

The Use of Aquatic Insects to Assess the Effectiveness of Stream Restoration in North Carolina

Dave Penrose[1]
NCSU Water Quality Group
Director, Watershed Science

Introduction

Aquatic organisms have been used to assess the effects of water pollution for more than a hundred years. One of the oldest assessment methods—known as the **Saprobien System**—classified aquatic organisms according to their responses to organic pollution in slow-flowing streams (Kolkwitz and Marsson 1909). These organisms served as bioindicators that could be used to monitor the effects of organic matter in surface waters. In time, the notion of assessing a stream's health with bioindicators evolved into the concept of a stream having a **biological integrity** — a term that first appeared in the Water Pollution Control Act Amendments of 1972.

In the course of the past three decades, the concept of biological integrity—which refers to a stream's capacity to support life—and biological monitoring have become an integral part of State and Federal water-quality monitoring programs. Biological monitoring programs and narrative or **numeric biocriteria** are being used by most State water quality agencies to assess the water quality

[1]Dave Penrose is currently retired from North Carolina State University and has started a small consulting firm in Western North Carolina (http://ncwatersheds.com). Prior to his work at NCSU, Dave was employed with the NC Division of Water Quality as a benthic taxonomist and studied the impacts of both point and nonpoint sources of water pollution to aquatic insects. Much of his work in the last ten years has been assessing the effectiveness of stream restoration projects using biological tools and teaching taxonomic workshops.

Employment and program opportunities are offered to all people regardless of race, color, national origin, sex, age, or disability.
North Carolina State University, North Carolina A&T State University, U.S. Department of Agriculture, and local governments cooperating.

Printed on Recycled Paper

EDITOR'S NOTE

Biological monitoring to assess the health of a stream system has been in use for over one hundred years, and is now an integral part of State and Federal water quality monitoring programs. Biological monitoring to assess the effectiveness of stream restoration, however, is still in its infancy, partly due to the relatively new concept of stream restoration itself.

In this issue of *NWQEP NOTES*, our feature article discusses the use of benthic macroinvertebrates to assess the effectiveness of stream restoration projects in North Carolina. Collection methods, survey designs and metrics are described, as well as ways to account for data variability inherent in biological investigations. Three case studies examining the long-term biological response to stream restoration are presented. The results are mixed, with some projects demonstrating success and others not, even after eight years following restoration.

The author presents possible explanations for the case study results, and offers considerations for regulatory agencies responsible for issuing mitigation credits for stream restoration. It was apparent that the standard five years of post-restoration monitoring was insufficient to document recovery of benthic communities. Also, the author notes the importance of defining criteria for selection of streams for restoration. A preconstruction evaluation of stream health and potential for success is crucial, as a stream's biological community may be relatively intact to begin with, rendering the stream inappropriate for certain levels of restoration which could potentially do more harm than good. Finally, the author calls for the active involvement of restoration scientists to re-define stream mitigation policy by incorporating the use of biological criteria.

As always, please feel free to contact me with your ideas, suggestions, and possible contributions to this newsletter.

Laura Lombardo Szpir

Laura Lombardo Szpir
Editor, *NWQEP NOTES*
NCSU Water Quality Group
Campus Box 7637, NCSU
Raleigh, NC 27695-7637
Tel: 919-515-3723, Fax: 919-515-7448
Email: notes_editor@ncsu.edu

in streams and the effectiveness of restorations, to promulgate water quality standards, to aid in the interpretation of aquatic life use attainment, and to support regulatory decisions related to water resource management.

The use of stream restoration as a tool to mitigate for stream loss is a relatively new concept, and water quality monitoring of project effectiveness has been extremely limited (Palmer 2008). Perhaps the paucity of stream restoration data is due to the idea that "if you build it, they will come" - a field of dreams. The biological data presented in this article illustrate trends in the community structure of benthic insects following restoration. All of the projects selected for this summary contain new stream features; the pattern, dimension and profiles have all been modified as part of the construction process. This article discusses the use of benthic macroinvertebrates to assess the effectiveness of stream restoration projects.

Benthic Macroinvertebrates

Benthic macroinvertebrates, predominantly aquatic insects, comprise a varied group of organisms that live at least part of their life cycles within or on the sediment or other bottom substrates in the aquatic environment (Klemm et al. 1990). These organisms vary in size from forms small and difficult to see without magnification to other individuals large enough to see with the naked eye. Another definition is that benthic macroinvertebrates are those organisms that can be retained by a U.S. Standard No. 30 sieve. Many benthic macroinvertebrates are immature forms of insects that will emerge to the brief terrestrial phase of their lives and later deposit their eggs back to aquatic systems. Aquatic insects are key players in stream ecology because they are important in the diets of many fish species. A very common benthic macroinvertebrate, the mayfly nymph *Isonychia*, is illustrated in Figure 1.

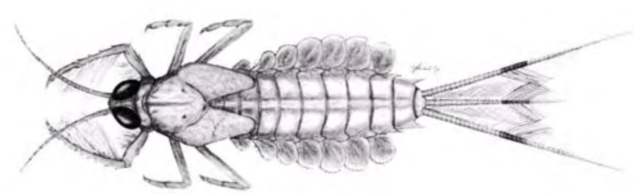

Figure 1. Mayfly nymph (*Isonychia* sp.); reprinted from Berner and Pescador (1988).

Benthic macroinvertebrates are effective water quality assessment tools for many reasons (Plafkin et al. 1989). A community of aquatic organisms is found in all aquatic habitats including very small perennial stream systems (1st and 2nd order) that normally support a very limited fish fauna. Even the most polluted stream generally has a community of tolerant benthic insects. Benthic macroinvertebrates are also easily and inexpensively collected. Perhaps most importantly, these communities integrate the cumulative effects of exposure to ambient conditions and short-term environmental perturbations. Sensitive species respond quickly to stress, while community shifts are generally more long-term. In addition, benthic macroinvertebrate communities respond to the various types of water pollution in predictable fashions (Hocutt 1975). Unstressed streams will support greater diversity and biological integrity than polluted streams, and as water pollution is introduced into a stream system, intolerant taxa (e.g., mayflies, stoneflies and some caddisflies) disappear and are replaced by tolerant species.

Scientists with the NCSU Water Quality Group have studied the responses of benthic macroinvertebrates in stream systems as a tool to assess the effectiveness of stream restoration projects. The practice of stream restoration is being commonly used in North Carolina's stream loss mitigation programs. It is generally assumed that as stream habitats are constructed via the restoration process and sediment transport is improved, that benthic macroinvertebrate diversity and occurrence of those species preferring a specific habitat type will increase.

Collection Methods

There are numerous standard approaches to collection of benthic macroinvertebrates, including dip netting, kick seining (Figure 2), Surber sampling, and artificial substrates. All of these methods strive to collect a representative and reproducible sample of organisms living in the aquatic system. The North Carolina Division of Water Quality (NC DWQ) has successfully employed a semi-quantitative, multi-habitat collection technique in its monitoring programs. Survey protocols for stream restoration monitoring, including sample collection and processing, mimic those described in the Standard Operating Procedure of the Biological Assessment Unit of NC DWQ (NCDEHNR 1997). Copies of this document can be obtained from NC DWQ's website (http://www.esb.enr.state.nc.us/BAU.html).

Standard qualitative collection methods are recommended for surveys conducted in all streams that are 3rd order or larger. This collection method consists of two kick net samples, three sweep net samples, one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections (Lenat 1988). Insects are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol. Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms from the samples. If an organism can be reliably identified as a single taxon in the field (e.g., *Isonychia*, see Figure 1), then no more than 10 individuals need to be collected. The primary output for this collection technique is a taxa list with a relative abundance (Rare, Common or Abundant) for each taxon.

Figure 2. Kick net sampling.

Stream mitigation projects are frequently conducted in small perennial streams having catchment sizes of less than one square mile (259 ha). Standard qualitative collection methods for these small 1st and 2nd order streams are inappropriate because small streams have fewer habitat types and the standard method is too intensive for these small streams. Therefore, an abbreviated collection technique is used in which only four samples are collected (rather than ten): one kick net sample, one sweep net sample, one leaf-pack sample and "visuals." Ephemeroptera, Plecoptera and Trichoptera (EPT, mayflies, stoneflies and caddisflies, respectively) are typically not early colonizers (Merritt and Cummins 1984, Palmer et al. 1997). Therefore, during these surveys that assess the colonization of new habitat, all organisms are collected and processed, not just EPT taxa. This collection method is referred to as a Qual-4 collection technique in the NC DWQ protocol. However, EPT taxa (see Figure 3) are sensitive indicators of water quality and are used by many regulatory agencies as assessment tools.

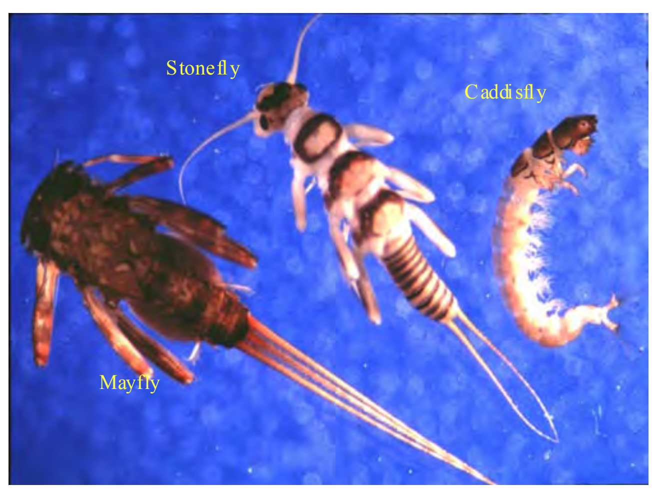

Figure 3. Ephemeroptera, Plecoptera and Trichoptera (EPT).

Survey Design. Once a collection protocol (standard qualitative collection or Qual-4) is determined, samples are then collected from a reference reach, from a site within the degraded reach prior to construction, and from a reach of the restored stream following construction. Ideally, the reference reach can be found above the proposed restoration reach. Reference data may be collected from nearby catchments as well. Initial investigations have illustrated that useful information can also be collected from stream reaches below the restoration reach. These data can be used to assess any improvements in downstream water quality conditions or habitat condition due to the restoration activities. Typically, biological data are not collected immediately following construction, as the restored stream reach is very unstable and instream habitat has yet to develop. Annual follow–up investigations are conducted after allowing the stream to equilibrate for one year, for the duration of the monitoring period. Because of significant lag time involved in habitat restoration and the time required for aquatic organisms to recolonize restored habitat, data from a typical 5 year monitoring protocol following construction is typically not long enough to document complete recovery.

Metrics

Recovery of biological diversity and community integrity within restored stream reaches is dependent upon rates of recolonization. This process is dependent on many factors, but most important are the proximity of **refugia** for aquatic organisms (pockets of quality habitat populated by benthic macroinvertebrates that can act as a source of organisms for recolonization) and the availability of a food supply. Headwater stream reaches or unaltered tributary systems (i.e., reference reaches) are usually considered primary refugia. Benthic organisms will drift in from these refugia to colonize restored reaches. Success of recolonization within restored reaches, including numbers of taxa and diversity relative to reference locations, are used as an indication of ecological function and restoration.

Analytical methods that have been used to compare population structures between locations include **taxa richness** (EPT and total) and **EPT abundance**. These protocols are used by many of the regulatory agencies to determine stream health. However, in a report to the U.S. EPA summarizing the results of a grant, the NC DWQ has proposed a **Dominant in Common (DIC)** matrix for success criteria (NCDENR 2002). The proposed success criteria (75% DIC) for this type of investigation is arbitrary and has not been accepted by regulatory agencies. This is a very simple comparison of the dominant taxa from a reference area (Common and/or Abundant taxa are used) to the restored area (Shackleford 1988). In other words, this metric is a comparision of the expected taxa (results from the reference condition) to the observed taxa (results from the restored reach of stream). The hypothesis is that a high Dominant in Common value (percent) would be expected between the reference and the test site if all habitat and water quality parameters were similar. It is expected that initial DIC values would be very low and improve as the new channel matures.

In addition to the DIC, another important metric is the number of keystone or habitat indicator species. These indicator taxa may have specific functional attributes that may also be useful indicators of stream health. Functional attributes, unlike taxonomic classifications, are characteristics like feeding type (e.g., filter-feeders vs. scrapers), adult flight patterns, drift ability, etc. (Poff et al. 2006). Indicator taxa may include those having a biotic index value of 2.0 or less (as defined by NC DWQ) or have specific habitat requirements indicative of a stable channel. An example would be the presence of a mayfly, *Serratella deficiens*, an organism that is not specifically intolerant, but is found primarily in aquatic macrophytes growing on stable habitat. Indicator taxa also include some riffle beetles such as Elmidae because of their preference for woody material in the stream.

Benthic macroinvertebrates exploit the physical characteristics of streams to obtain their food (Wallace and Webster 1996, Cummins and Klug 1979, Merritt and Cummins 1984). In addition, a relationship exists between a stream's riparian corridor and functional feeding groups of its resident biota (i.e., grazers, shredders, gatherers, filter-feeders, predators). Analyses of functional feeding groups can be used to assess the overall health of a stream. For example, filter-feeders tend to be characteristic of nutrient-rich, highly productive streams, while shredders are important components of forested areas of streams where leaves are the principal food inputs (Minshall et al. 1985). The absence of shredders from restored stream reaches may be an indication of incomplete recolonization within that reach or unstable, poorly retentive headwater streams.

As work continues with the development of success criteria, the development of microhabitats and their resident biota should be investigated. Figure 4 illustrates two productive microhabitat types (aquatic macrophytes and streamside root hairs) that should develop as streams mature and resident fauna become more abundant.

Data Variability

While variability introduced by sampling and measurement can be addressed by quality control procedures, populations of organisms in the natural world are themselves inherently variable. Sources of variability in biological investigations that should be accounted for in operating protocols include the following:

- The effects of seasonality
- The effects of between-year flow conditions
- Stream size differences

Figure 4. Common microhabitats found in healthy streams.

- Habitat/substrate variability
- Taxonomic quality control

Seasonality. Perhaps the most common source of variability in biological information is the potential effects of collecting data from different temporal periods. The ideal sampling procedure is to conduct surveys during each change of season (Gibson 1996), ensuring that the effects of purely seasonal variations in community structure are minimized. However, because benthic macroinvertebrates integrate the effects of stress over the entire year, and monitoring programs need to be cost-effective, a single consistent index period can be selected for biological monitoring of mitigation projects.

Population structures are seasonally variable within all biological communities. For most benthic macroinvertebrates, peak emergence and reproduction typically occur during the spring and fall seasons when food supply is abundant (Cummins and Klug 1979). Thus, one would expect to collect more taxa from streams during the spring and fall than during winter and summer (Figure 5). NC DWQ classification criteria for benthic macroinvertebrates were developed using data primarily from summer (worst-case conditions) collection periods.

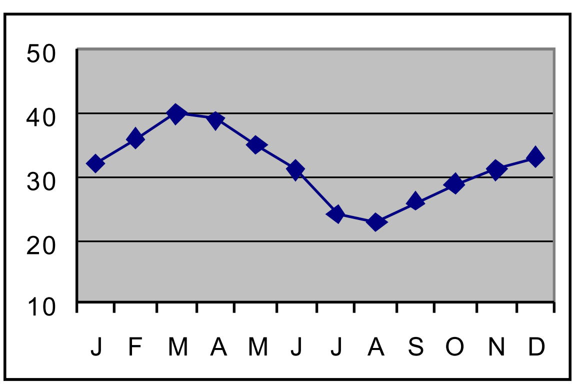

Figure 5. Hypothetical trends in taxa richness by month for aquatic insects.

To maintain seasonal consistency in the data, samples should be collected in similar seasons (months) for the entire monitoring period for each stream restoration project.

Stream Flow Variability. The spatial and temporal effects of both point and nonpoint sources of water pollution are affected by flow regimes. During high flow periods, nonpoint source pollutant loads increase and the effects of point sources are minimized because of dilution. During low flow or drought conditions, the opposite is observed such that point source pollution often is dominant and the effects of nonpoint sources are negligible. Significant differences in flow were noted during the preconstruction monitoring of many of the restoration projects conducted by NC DWQ in 2001 when compared to post-construction surveys. Drought or near-drought conditions were recorded at many sites in 2004 and 2007. This was particularly evident in smaller catchments. Because regional drought affects both reference and restored streams, negative effects of drought on benthic insect population can be accounted for by having good reference data for each project.

Stream Size Variability. To the extent possible, data should be compared only from similar sized stream reaches. The **river continuum concept** (Vannote et al. 1980, Minshall et al. 1985) predicts that habitat heterogeneity increases with stream size to approximately 4th order streams and then declines (Figure 6). The river continuum concept predicts that a stream ecosystem is comprised of a series of biological communities that merge into one another as the biota respond to changing instream physical/habitat and riparian conditions. Therefore, it is expected that as habitat heterogeneity increases, the potential diversity of the resident benthic community would increase as well and then decline as streams become much larger. Care should be taken not to compare data from streams of different orders, particularly when using data for reference conditions.

Habitat and Substrate. To maintain consistency in the data and to address potential variability in habitat and substrate between collection locations, dominant habitat (riffles, streambanks and leaf packs) should be surveyed at each location, and aquatic insect samples should only be collected for comparison from similar types of habitats.

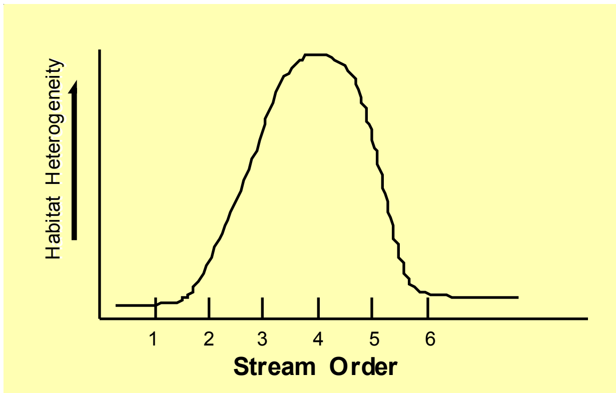

Figure 6. Habitat heterogeneity and stream order.

Taxonomic Considerations. Taxonomic identifications should be conducted to the lowest possible level and should be consistent throughout the survey period. Although family level taxonomy is often sufficient to determine non-impaired, moderately- impaired or severely-impaired water quality conditions, subtle differences in community composition will not be determined except by genus/species identification (Resh and Unzicker 1975, Klemm et al. 1990). It is anticipated that recovery (primary succession) of the benthic macroinvertebrate fauna within restored reaches will be subtle. Accurate genus/species level taxonomic identification is essential to assess recovery of these lotic communities. In addition, many taxonomic families have wide ranges of tolerance (i.e., Hydropsychidae, Chironomidae). Recovery following disturbance can be complete within a relatively short period of time (Yount and Niemi 1990). However, this will be dependent upon the accessibility of unaffected upstream and internal refugia, which serve as sources of organisms for repopulating.

All identifications should be made using the most up-to-date, regional taxonomic keys. A list of taxonomic keys for the United States has been included in the revised Rapid Bioassessment Protocols document (Barbour et al. 1999). Most organisms may be identified using only a dissection microscope, but Oligochaeta and Chironomidae must be slide mounted and identified at high magnification.

Case Histories

Biological data from stream restoration projects in NC and elsewhere across the U.S. have not been collected consistently or in sufficient quantity, hampering efforts to assess project effectiveness (Palmer 2008). Catchment-scale assessments of restoration projects over multi-year time periods are urgently needed. Scientists at North Carolina State University have collected data from 16 stream restoration projects for as long as 8 years following restoration activities, representing an unusually long-term assessment. Three short case studies from western North Carolina are illustrated here; the locations of the case studies are shown in Figure 7. In each case study, the restored stream reach had the pattern, dimension and profile modified as part of the project – essentially a new stream was constructed. Annual surveys of biological data may continue at these case study sites for at least five more years.

Jumping Run Creek, Alexander County, NC. Annual benthic macroinvertebrate samples have been collected from three locations in this project, located at a dairy farm, since 2000 to assess the restoration of Jumping Run Creek (Figure 8). Qual-4 collections were used at all locations during each survey. Station 1 is located above the restoration project in a relatively stable reach of Jumping Run Creek, serving as the reference site, although there is some sedimentation and bank erosion at this location. The catchment above this reach contains mostly pasture and receives some storm water from residential development.

Station 2 is located within the restored reach of Jumping Run Creek. Prior to construction, the stream was very unstable at this point and cattle had free access (Figure 9). Sand and silt dominated the substrate, bank erosion was severe and the tree canopy had been reduced or eliminated in some places. Futhermore, it appeared that this reach of Jumping Run Creek had been channelized in the past. As part of this project, herbaceous vegetation was planted in the new riparian buffer.

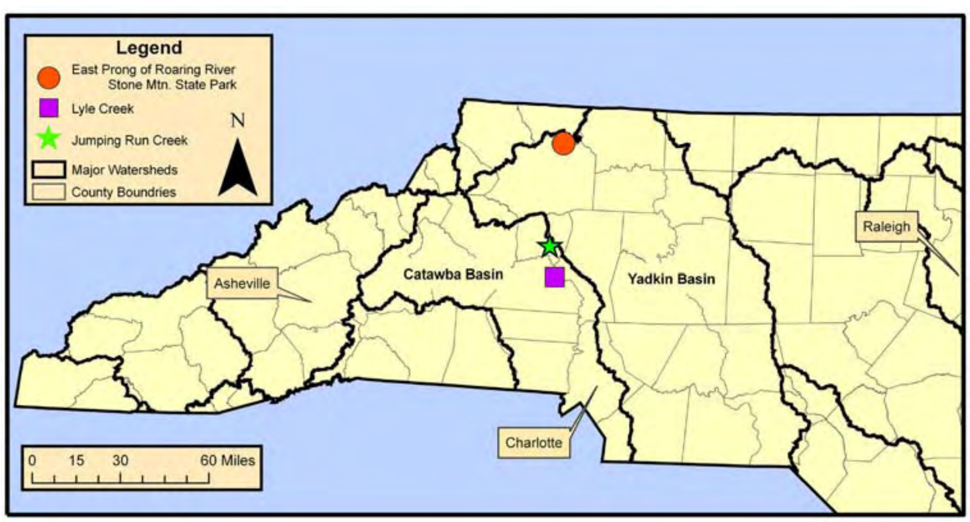

Figure 7. Case study locations in western North Carolina.

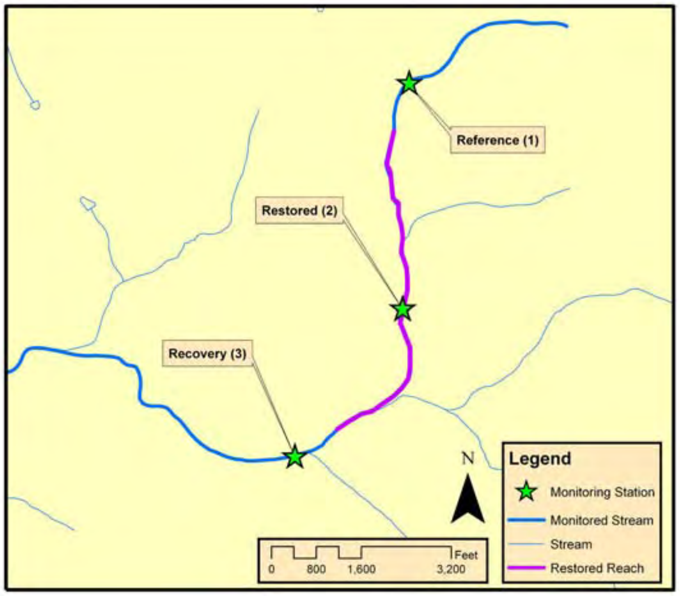

Figure 8. Location of macroinvertebrate monitoring stations for Jumping Run Creek.

Figure 9. Jumping Run Creek prior to restoration activities – 2000.

Station 3 is below an unnamed tributary (UT) of Jumping Run Creek that drains the farm property. Jumping Run Creek at this point appeared to be more stable, had a much wider riparian zone, and was selected as a downstream recovery station, downstream of all restoration activities. Cattle had access to the stream prior to restoration, and *Physella* (an air breathing snail) was very abundant, suggesting accumulation of fine particulate organic material (FPOM) and occasional low DO values. Cattle access has been eliminated since restoration. Tables 1a and 1b summarize the data from these three locations during pre-construction (2000) and during seven post-construction surveys (2002 through 2008). All samples were collected from these locations in October or November of each year.

Taxa richness and EPT abundance values from the upstream reference site (Table 1a) indicate relatively stable conditions and a surprising number of intolerant (indicator) species over the monitoring period (21 indicator taxa were collected from this site in 2005). However, the number of EPT taxa dropped off significantly in 2007 and 2008. This trend may have been due to very low flow conditions due to the drought, or upstream impacts. Many of these intolerant taxa were completely eliminated downstream of this location prior to construction and replaced by tolerant filter-feeding taxa, presumably responding to the input of fine particulate organic matter from the pasture prior to construction. Dominant in Common percentages of 25% at both downstream locations prior to restoration suggest that some intervention and/or restoration were necessary (Figures 10 and 11).

Table 1a. Summary statistics from the reference site at the Jumping Run Creek Stream Restoration Project, Alexander County, NC (2000-2008)

Station 1, Upstream Reference								
Metric/Year	10/00	10/02	10/03	10/04	10/05	11/06	11/07	11/08
Years after Constr.	PreC	2	3	4	5	6	7	8
Total Taxa Richness	43	37	44	41	44	35	23	28
EPT Taxa Richness	19	20	19	20	24	23	13	13
EPT Abundance	67	88	87	88	88	77	45	45
# Indicator taxa	10	12	14	19	21	15	11	9

Table 1b. Summary statistics from the restored and recovery sites at the Jumping Run Creek Stream Restoration Project, Alexander County, NC (2000 – 2008).

	Station 2, Restored Reach								Station 3, Recovery							
Metric/Year	10/00	10/02	10/03	10/04	10/05	11/06	11/07	11/08	10/00	10/02	10/03	10/04	10/05	11/06	11/07	11/08
Years after Constr.	PreC	2	3	4	5	6	7	8	PreC	2	3	4	5	6	7	8
Total Taxa Richness	38	12	20	27	43	22	20	17	31	28	44	44	42	34	35	27
EPT Taxa Richness	8	3	12	11	17	3	5	6	9	7	16	16	18	13	15	14
EPT Abundance	39	7	34	39	61	7	7	19	47	28	71	54	93	68	72	60
DIC (%)*	25%	5%	29%	30%	55%	27%	15%	28%	25%	16%	47%	60%	50%	47%	69%	65%
# Indicator taxa	2	0	5	6	13	3	2	1	4	0	6	12	13	9	11	11

*Dominant in Common metric was calculated using Abundant and Common taxa.

During the first investigation following construction (2002), the number of taxa and EPT abundance values declined dramatically at Station 2 within the restoration reach and then rebounded through the third, fourth and fifth years following construction with a DIC of 55% in 2005 (Figure 10). However, these numbers declined in years six through eight following construction (2006-2008) with EPT taxa richness very similar to the first post-construction survey in 2002. Many taxa were common or abundant at the upstream reference and at the downstream recovery site during the course of this investigation, but absent in the restored reach (e.g., *Stenonema pudicum*, *Baetis pluto*, *Neophylax*, *Eccoptura xanthenes*).

Taxa richness and DIC values are similar to pre-construction data at Station 2, suggesting that in-stream habitat conditions and the benthic fauna within this reach have not improved during this 7-year monitoring period. One issue is that this reach of Jumping Run Creek is dominated by a series of large cross vanes that were constructed during the restoration process. These large cross vanes have produced very long pools and very short, unproductive riffles. These habitats are not conducive to the establishment of a diverse benthic fauna and resulted in very low DIC values following construction. In addition, beaver populations have been noted in the catchment, although not at Station 2 specifically.

However, benthic data from the recovery site on Jumping Run Creek (Station 3) clearly indicate an improvement in biological conditions (Figure 11). Very low DIC numbers were recorded prior to construction and during the first collection following construction (2002). However, these DIC values and the number of EPT taxa increased during year 3 and have remained high during all subsequent investigations. These data suggest that the restoration work on Jumping Run Creek has improved the water quality and biological condition of the stream below the construction reach. The explanation for a biological response **downstream** of the restored reach is unclear. The replanted riparian zone in the restored reach may have reduced downstream nutrient and sediment concentrations, resulting in a positive response from the benthic community.

UT Lyle Creek, Catawba County, NC. Benthic macroinvertebrates were collected at two locations at this project (Figure 12) using the Qual-4 collection method during each survey. Reference data were collected from a reach of UT Lyle Creek above the restoration reach (Station 1). The catchment at this point is mostly forested with relatively stable banks and a good riffle pool sequence; however, non-point pollution sources including storm water exist above this location. The stream at this point was fairly incised but revealed sufficient habitat along the banks and stable gravel/cobble riffles. Station 2 is located at the lower reach of the restoration section within a former pasture. Cattle obviously had access to this reach of the stream as the banks were eroding and the substrate was dominated by fine material. Data were collected from these locations during December surveys following construction in 2003 through 2008.

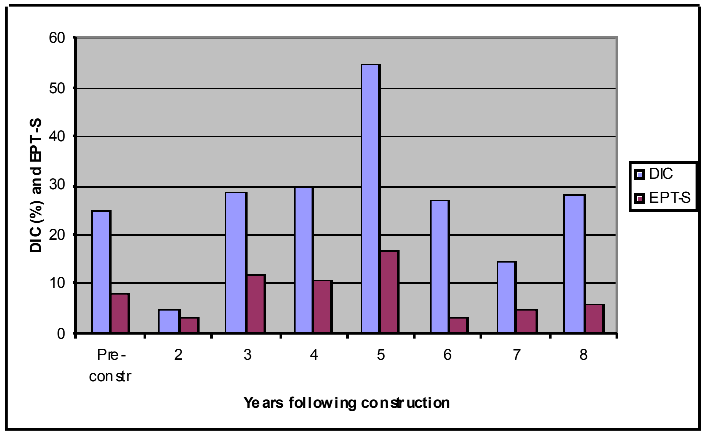

Figure 10. Dominant in Common (%) and EPT taxa richness from Station 2, in the restored reach of Jumping Run Creek (2000-2008).

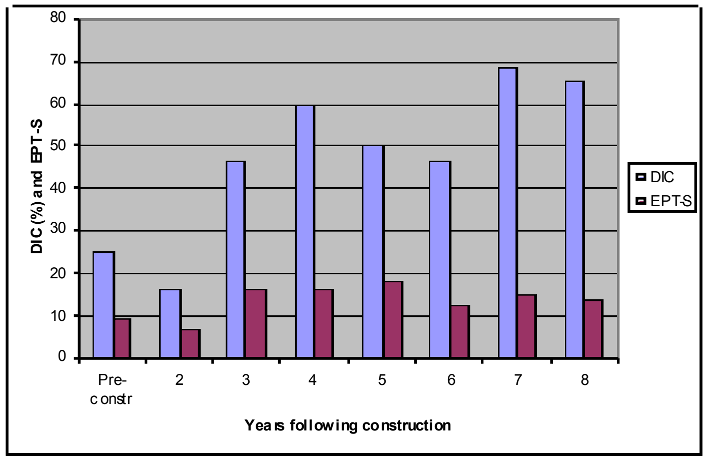

Figure 11. Dominant in Common (%) and EPT taxa richness from Station 3, in the recovery location of Jumping Run Creek (2000-2008).

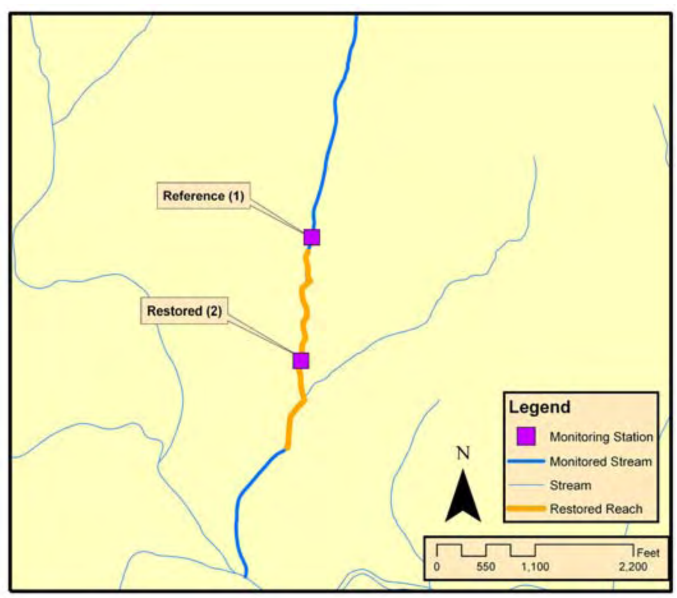

Figure 12. Location of macroinvertebrate monitoring stations for UT Lyle Creek.

Table 2. Summary statistics from the stream restoration project at UT Lyle Creek, 2001-2008 (Catawba County).

	UT Lyle Cr. Station 1, Reference							UT Lyle Cr. Station 2, Restored						
Metric/Date	12/01	12/03	12/04	12/05	12/06	12/07	12/08	12/01	12/03	12/04	12/05	12/06	12/07	12/08
Years after constr.	Pre	2	3	4	5	6	7	Pre	2	3	4	5	6	7
Total Taxa Richness	44	45	30	40	42	23	39	51	30	32	36	39	23	33
EPT Taxa Richness	16	22	14	21	21	12	18	17	9	14	15	17	10	17
EPT Abundance	94	114	71	104	97	63	72	84	33	51	79	72	25	79
DIC (%)*	-	-	-	-	-	-	-	72%	34%	50%	48%	58%	36%	84%
# Indicator Taxa	10	10	12	14	16	9	14	7	4	8	6	14	5	10

*Dominant in Common assessment used Abundant and Common taxa in this assessment

The benthic macroinvertebrate community at the reference reach has been variable between monitoring years. Taxa richness values (both total and EPT numbers) were much lower at the reference site in 2004 and 2007 (Table 2). These lower numbers may be a response to scour associated with extremely high flows following hurricanes Ivan and Francis in September 2004 and perhaps much lower flows during drought conditions in 2007. Interestingly, the extremely high flows in 2004 (three years following construction on Figure 13) did not appear to affect recovery of the restored reach as both DIC and EPT taxa richness increased. However, very low flows in 2007 (six years following construction) may have been partially responsible for much lower DIC and EPT taxa richness values at the restored reach. Prior to 2007 it appeared that a general trend towards recovery was noted in the restored reach. The benthic fauna rebounded in 2008 as all metrics increased and the DIC value attained the preliminary success criteria initially proposed to the U.S. EPA (NCDENR 2002).

Figure 13. Dominant in Common (%) and EPT taxa richness from Station 2, in the restored reach of UT Lyle Creek (2001-2008).

Stone Mountain State Park (Wilkes County, NC). Studies indicated that downstream reaches of the East Prong of the Roaring River (Figure 14) in Stone Mountain State Park had severe bank erosion due to past agricultural practices. Restoration of the East Prong in 2000 included stabilizing the eroding banks, providing in-stream habitat, and reestablishing

Figure 14. East Prong of the Roaring River, Stone Mountain State Park.

pattern, dimension and profile. The total length of the project was 10,633 linear feet (3,241 m) in two major reaches of the river. Benthic macroinvertebrate samples were collected from three locations (Figure 15) using a full-scale standard collection method during all surveys. Reference data (Station 1) samples were collected from a site above both restoration reaches within a stable section of the East Prong. Two downstream stations were also sampled. Station 2 is within a stable reach of the East Prong but below a restored section of the East Prong; this reach was not manipulated during the construction. Station 3 is within the downstream restoration section and within a reach that was restored and is essentially a new channel. Data were collected during the months of September or October during all surveys. Tables 3a and 3b summarize the data collected from this investigation and Figures 16 and 17 illustrate the trends in data.

Relatively stable conditions have been recorded during all surveys at the reference reach (Table 3a). The exceptions appear to be the data collected in 2006 and 2008 six and eight years following construction when only 32 and 30 EPT taxa were collected, respectively. Lower numbers of indicator taxa were also found at this site during the last two years of monitoring. More than forty EPT taxa were recorded from all three locations in 2003, but only the reference location remained high in 2004. Station 2 declined sharply in taxa richness in 2004 (four years following construction, Figure 16) following extremely high flows after hurricanes Ivan and Francis (interestingly, this was not the case at the downstream restored location, Figure 17). Dominant in Common values at Station 2 averaged 62.5% during this monitoring period suggesting stable conditions at this location.

The biological fauna at the lower site within the restored reach (Station 3) appear to be much more variable than the upstream location. Lower EPT taxa richness, abundance and DIC values were noted throughout the monitoring period following restoration at Station 3. A surprisingly large number of EPT taxa were collected from this reach in 2003 and 2004 following construction, suggesting that water quality conditions were good and that the stream is recovering from stress associated with the restoration. However, the number of taxa in common with the reference reach (DIC) declined significantly in 2006 and 2007, six and seven years following construction. Differences in taxa richness between these two sites were due to the much lower numbers of caddisfly and stonefly taxa. Mayfly taxa have been extremely high at this location during all surveys (range = 16-21 taxa). Most mayfly taxa are proficient drifters and can repopulate newly restored reaches faster than stoneflies (which are either predaceous or shredder taxa) or caddisflies. The much lower numbers of stoneflies and caddisflies are most obvious during surveys conducted in 2001/2002 immediately following restoration and 2006/2007 (six and seven years following construction). The loss of many taxa within these two groups is primarily responsible for much lower DIC comparisons noted during these two periods. It is very likely that the lowered DIC values in 2001/2002 are directly related to restoration activities in this reach. Recovery appeared to be occurring during 2003 and 2004, but a reversal in this positive trend was observed in 2006 and 2007 possibly related to project maintenance activities that began in 2005. Maintenance included rebuilding some of the cross vanes and re-establishing stable banks, both of which had failed during the monitoring period.

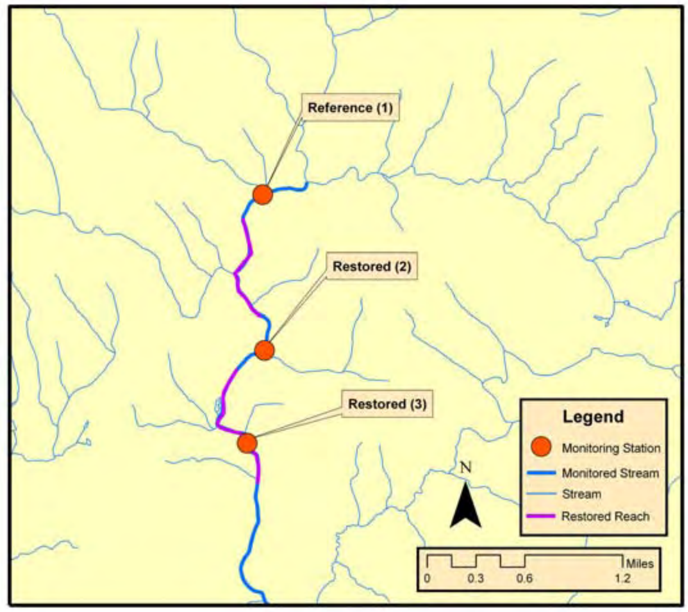

Figure 15. Location of macroinvertebrate monitoring stations for the East Prong of the Roaring River in Stone Mountain State Park.

Table 3a. Summary statistics from the upstream reference reach at Stone Mountain State Park (1998-2008).

	Station 1, upstream reference								
Metric/Survey year	**98**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**
Total Taxa Richness	73	61	73	73	69	77	57	61	56
EPT Taxa Richness	39	37	37	41	42	39	32	35	30
EPT abundance	165	173	202	215	182	208	150	156	181
DIC (%)	-	-	-	-	-	-	-	-	-
# of Indicator Species	31	23	26	28	24	30	25	22	21

Table 3b. Summary statistics from Stations 2 and 3 at Stone Mountain State Park (1998-2008).

	Station 2, below active restoration									Station 3, within lower restoration reach								
Metric/Survey year	**98**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**98**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**
Years after Constr	PreC	1	2	3	4	5	6	7	8	PreC	1	2	3	4	5	6	7	8
Total Taxa Richness	75	67	75	88	59	72	65	63	61	66	61	73	79	68	70	59	51	66
EPT Taxa Richness	38	36	35	41	32	37	33	31	30	36	28	32	40	38	39	28	31	31
EPT abundance	170	154	183	219	157	194	174	128	121	194	109	126	180	174	176	152	128	123
DIC (%)*	73%	64%	54%	65%	62%	62%	78%	57%	58%	93%	36%	32%	61%	69%	52%	50%	43%	63%
# of Indicator Species	20	14	15	21	17	25	24	20	20	19	8	11	18	17	23	15	20	23

*Only abundant taxa were used in this analysis

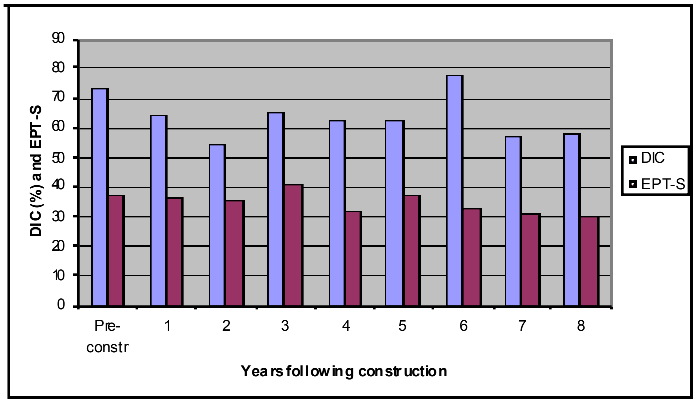

Figure 16. Dominant in Common (%) and EPT taxa richness from Station 2, below the active restoration reach of the East Prong of the Roaring River, Stone Mt State Park.

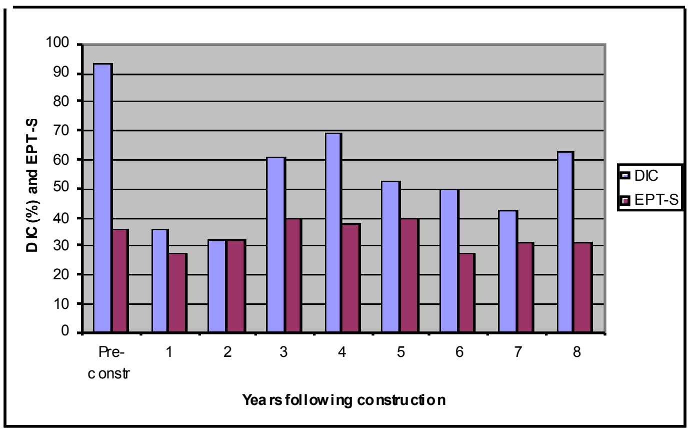

Figure 17. Dominant in Common (%) and EPT taxa richness from Station 3, within the lower restored reach of the East Prong of the Roaring River, Stone Mt State Park.

Biological data from this project indicate that restoration at the lower reach was not successful, given the 8-year monitoring period. As noted above, the maintenance activities may have re-introduced some instability. Or perhaps a monitoring period longer than eight years is needed to show recovery. It is also important to note that perhaps because the stream was relatively healthy and stable to begin with, it may not have been an appropriate candidate for the level of restoration that was conducted, and that less invasive work or spot repairs on severely eroding banks may have been all that was necessary.

Conclusions

Water quality managers and restoration scientists agree that the practice of stream restoration is in its infancy. Stream restoration in North Carolina as a mitigation tool has been used for only about 10 years. Managers and scientists also agree that there is a lack of data describing biological responses to restoration. As a result, biological criteria have not been incorporated into regulatory policies for mitigation (Palmer 2008, Palmer et al. 2005 and Lave et al. 2008). Biological data are infrequently collected as part of monitoring protocols, and long-term information has not been collected or is very rare in the literature (Tullos et al. 2009).

The information summarized in this article represents benthic macroinvertebrate responses to stream restoration up to eight years following construction. These data illustrate how benthic macroinvertebrate communities can be used to determine project effectiveness and/or success. Data from the project at Jumping Run Creek clearly illustrate that despite the lack of apparent success within the restoration reach due to the construction of numerous large cross vanes, downstream water quality improved. Perhaps regulatory agencies need to consider mitigation credits for the demonstration of improved water quality below restoration projects in addition to within these projects.

Biological condition improved and effectiveness criteria were obtained at the restoration project at UT Lyle Creek. This one project demonstrates that the biological fauna can recover from restoration activities and that the fauna are an effective monitoring tool.

There are a number of stream restoration projects, such as Stone Mountain State Park, where the biological fauna have not yet recovered, even after eight years following construction. In many instances, a five-year monitoring plan is insufficient to document recovery, which may take much longer. Also, regulation of stream restoration activities needs to include specific language noting when stream restoration is not an appropriate option. In some cases, diverse, stable streams are selected for restoration inappropriately and the construction process may impact stream health. Pre-construction evaluation of stream health and potential for success are essential not only for project selection but also for attainment of restoration goals.

Effectiveness criteria, such as those proposed by NC DWQ (NCDENR 2002), or significant improvements in taxa richness or biocriteria downstream of a restoration project, are examples of how these data are useful and can be incorporated by regulatory agencies. Finally, restoration scientists should actively participate in re-defining stream mitigation policy by incorporating and encouraging the use of biological criteria.

For More Information

Dave Penrose
NCSU Water Quality Group
email: dave_penrose@ncsu.edu
Director, Watershed Science
email: dave_penrose@ncwatersheds.com
http://ncwatersheds.com/

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-02. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Berner, L. and M.L. Pescador. 1988. The Mayflies of Florida. University Presses of Florida.

Cummins, K. W. and M. J. Klug. 1979. Feeding Ecology of Stream Invertebrates. *Ann. Rev. Entomol*. 10:147-172.

Gibson, George R., (editor). 1996. Biological Criteria: Technical Guidance for Streams and Small Rivers. EPA 822-B-96-001, U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Hocutt, C. H. 1975. Assessment of a Stressed Macroinvertebrate Community. *Water Resour. Bull*. 11(4):820-835.

Klemm, D. J., P. A. Lewis, F. Fulk and J. M. Lazorchak. 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. EPA/600/4-90-030.

Kolkwitz, R. & Marsson, K. (1909) Ökologie der tierischen Saprobien. Beiträge zur Lehre von des biologischen Gewasserbeurteilung. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, 126-152.

Lave, R., M. M. Robertson and M. W. Doyle. 2008. Why You Should Pay Attention to Stream Mitigation Banking. *Ecol. Restoration* 26(4):287-289.

Lenat, D.R. 1988. Water Quality Assessment of Streams using a Qualitative Collection Method for Benthic Macroinvertebrates. *J. N. Am. Benthol. Soc.*7:222-233.

Merritt, R. W. and K. W. Cummins (eds.). 1984. An Introduction to the Aquatic Insects of North America. 2nd edition. Kendall/Hunt Publishers. Dubuque, Iowa.

Minshall, G.W., K.W. Cummins, R.C. Peterson, C.E. Cushing, D.A. Burns, J.R. Sedell and R.L. Vannote. 1985. Developments in Stream Ecosystem Theory. *Can. J. Fish. Aquatic Sci*. 42:1045-1055.

North Carolina Department of Environment, Health and Natural Resources (NCDEHNR). 1997. Standard Operating Procedures for Biological Monitoring. Division of Water Quality. Water Quality Section. Biological Assessment Group. 52pp.

North Carolina Department of Environment and Natural Resources (NCDENR). 2002. Ecological Functions of Restored Stream Systems: Benthic Macroinvertebrates. Final Report for EPA Wetland Program Development Grant (#CD984487-98).

Palmer, M. 2008. Reforming Watershed Restoration: Science in Need of Application and Applications in Need of Science. *Estuaries and Coasts*. DOI 10.007/s 12237-008-9129-5.

Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad Shah, J., Galat, D.J., Gloss, S., Goodwin, P., Hart, D.H., Hassett, B., Jenkinson, R., Kondolf, G.M., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, L., Srivastava, P. & Sudduth, E. (2005) Standards for ecologically successful river restoration. *J. Appl. Ecol*, 42:208-217.

Palmer, M.A., R.F. Ambrose and R.L. Poff. 1997. Ecological theory and community restoration ecology. *Restoration Ecol.* 5(4):291-300.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross and R. M. Hughes. 1989. Rapid Bioassessment Protocols For Use In Streams And Rivers. EPA/444/4-89-001.

Poff, L.N., J.D. Olden, N.K.M. Vieira, D.S. Finn, M.P. Simmons and B.C. Kondratieff. 2006. Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. *J. N. Am. Benthol. Soc*. 25(4):730-755.

Resh, V.H. and J.D. Unzicker. 1975. Water Quality and Aquatic Organisms: The Importance of Species Identification. *J. Water Poll. Cont. Fed.*47:9-19.

Shackleford, B. 1988. Rapid Bioassessment of Lotic Macroinvertebrate Communities: Biocriteria Development. Arkansas Department of Pollution Control and Ecology. Little Rock, Arkansas. 45pp.

Tullos, D. D., D. L. Penrose, G D. Jennings and W. G. Cope. 2009. Analysis of Functional Traits in Reconfigured Channels A: Implications for the Bioassessment and Disturbance of River Restoration. *J. N. Am. Benthol. Soc*. 28(1):80-92.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The River Continuum Concept. *Can. J. Fish. Aquatic Sci.* 37:130-137.

Wallace, B.J. and J.R. Webster. 1996. The Role of Macroinvertebrates in Stream Ecosystem Function. *Ann. Rev. Entomol*. 41:115-139.

Yount, J.D. and G.J. Niemi. 1990. Recovery of Lotic Communities and Ecosystems from Disturbance – A Narrative Review of Case Studies. *Environ. Manage*. 14(5)547-569.

■

INFORMATION

EPA Announces Funding Recipients for Providing Technical Assistance to Livestock Operators

The U.S. Environmental Protection Agency announced the names of recipients of $8 million in federal funding for providing technical assistance to livestock operators, including animal feeding operations, for the prevention of water discharges and reduction of air emissions. The CLEANEAST Program, directed by RTI International of Research Triangle Park, NC, is responsible for the 27 states east of the Mississippi River. Environmental Resources Coalition (ERC) of Jefferson City, MO is directing the CLEANmp-West Program that is responsible for the western states.

The funding recipients will provide livestock operations with two types of technical assistance at no-cost to the operator: (1) comprehensive assessments of water and air quality environmental challenges and recommendations for strategies to mitigate these challenges; and (2) development or review of the facility's nutrient management plan, which specifies the amount of manure that can be applied to crops to minimize the potential for runoff to water bodies. Although the technical assistance will be available to any livestock operation in the United States, special emphasis is being placed on facilities that are in impaired watersheds.

More information is available:

- For livestock operations in the eastern U.S. at http://livestock.rti.org or by calling 866-881-1191.
- For livestock operations west of the Mississippi River at http://www.erc-env.org/CLEANMP.htm or by calling 800-897-1163.

New EPA Educational Stormwater Video

The U.S. Environmental Protection Agency and the U.S. Botanic Garden produced a 9-minute on-line video, *Reduce Runoff: Slow It Down, Spread It Out, Soak It In*, that highlights green techniques such as rain gardens, green roofs and rain barrels to help manage stormwater runoff.

The film showcases green techniques that are being used in urban areas to reduce the effects of stormwater runoff on the quality of downstream receiving waters. The goal is to mimic the natural way water moves through an area before development by using design techniques that infiltrate, evaporate, and reuse runoff close to its source.

The techniques are innovative stormwater management practices that manage urban stormwater runoff at its source, and are very effective at reducing the volume of stormwater runoff and capturing harmful pollutants. Using vegetated areas that capture runoff also improves air quality, mitigates the effects of urban heat islands and reduces a community's overall carbon footprint.

The video highlights green techniques on display in 2008 at the U.S. Botanic Garden's *One Planet – Ours!* Exhibit and at the U.S. EPA in Washington, D.C., including recently completed cisterns.

The video is available online at http://www.epa.gov/nps/lid.

New Quality Growth Report Released from Southeast Watershed Forum

As pressure from development, drought and climate change threaten the natural resources, water availability and quality of life in the Southeast, many communities and organizations have found solutions for managing growth while conserving their green infrastructure. To showcase some of these case studies, the Southeast Watershed Forum announces the release of its newest special report, *Building Sustainable Communities: Quality Growth Strategies in the Southeast.* The report also includes training and on-line resources for individuals, organizations and communities.

A limited number of hard copies of *Building Sustainable Communities* are available for free by calling 615-627-1310 or kd@southeastwaterforum.org.

Electronic copies are available on the Forum's website: http://www.southeastwaterforum.org/news/newsletters.asp

New EPA Website for Watershed Managers

The U.S. Environmental Protection Agency recently posted a new website called *Watershed Central* to help watershed organizations and others find key information they need to manage watersheds. *Watershed Central* helps users find environmental data, watershed models, nearby local organizations, and guidance documents. *Watershed Central* also contains links to watershed technical resources and funding, mapping applications, and includes a *Watershed Central Wiki* that users may use to collaborate. EPA's new site is located at http://www.epa.gov/watershedcentral.

■

MEETINGS

Call for Abstracts

2009 AWRA Annual Water Resources Conference: November 9-12, 2009, Seattle, WA. Abstracts due May 22, 2009. Visit conference website at http://www.awra.org/meetings/Seattle2009/index.html.

Meeting Announcements — 2009

May

2009 IECA Southeast Chapter Muddy Water Blues: Providing Innovative Solutions to Complex Regulations: May 11-13, 2009, Asheville, NC. Visit conference website at http://guest.cvent.com/i.aspx?5S,P1,26F47356-B188-4DC0-BF3E-DBA4756ED083

Fifth National Conference on Nonpoint Source and Stormwater Outreach: Achieving Results with Tight Budgets: May 11-14, 2009, Portland, OR. Visit conference website at http://www.epa.gov/nps/outreach2009

20th Annual Nonpoint Source Pollution Conference: May 18-20, 2009, Portland, ME. Visit conference website at http://www.neiwpcc.org/npsconference

June

AWRA 2009 Summer Specialty Conference: Adaptive Management of Water Resources II: June 29-July 1, 2009, Snowbird, Utah. Visit conference website at http://www.awra.org/meetings/SnowBird2009/

July

Soil & Water Conservation Society 2009 Annual Conference: Delivering Conservation, Today and Tomorrow: July 11-15, Dearborn, MI. Visit conference website at http://www.swcs.org/en/conferences/2009_annual_conference/call_for_papers/

NCER 2009: 3rd National Conference on Ecosystem Restoration: The Spirit of Cooperation: July 20-24, 2009, Los Angeles, CA. Visit conference website at http://www.conference.ifas.ufl.edu/NCER2009

August

StormCon '09: The North American Surface Water Quality Conference & Exposition, August 16 - 20, 2009, Anaheim, CA. Visit conference website at http://www.StormCon.com

September

17th National Nonpoint Source Monitoring Workshop: Reducing Nutrients and Documenting Results: September 14-17, 2009, New Orleans, LA. See Highlight on Page 15.

December

2009 NWEC: Northwest Environmental Conference and Tradeshow: December 7-8, 2009, Portland, Oregon. Visit conference website at http://www.nwec.org/2009/

■

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA). Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

The NCSU Water Quality Group publications list and order form can be downloaded at http://www.ncsu.edu/waterquality/issues/pub_order.html

17th National Nonpoint Source Monitoring Workshop:

Reducing Nutrients and Documenting Results

Sept. 14-17, 2009 – New Orleans, Louisiana
http://www.tetratech-ffx.com/nps_monitoring/

The Annual Nonpoint Source (NPS) Monitoring Workshop is an important forum for sharing information and improving communication about controlling and monitoring NPS pollution issues and projects. The focus of the 17th National Workshop is on nutrients and lessons learned that can be factored into State Nutrient Reduction Strategies.

Specific topics of interest highlighted at the 17th annual workshop will include:

- Stream and Wetland Restoration Practices for Nutrient Management
- Controlled Drainage Practices for Agricultural Nutrient Management
- Innovative Agricultural Nutrient Conservation and Management Practices
- Nutrient TMDL and Watershed Action Plan Implementation
- Bio-Assessment Tools & Methodology for Nutrients
- Monitoring Landscape Changes Associated with Nutrient Management
- Manure Management
- Evaluating the Effectiveness of Environmental Management Systems
- Coastal NPS Efforts
- Managing Nutrients from Urban NPS and Stormwater
- Interpreting Nutrient Monitoring Data
- Monitoring Behavioral Changes Associated with Nutrient Management Practices

Hotel & Logistics Queries Contact Person
Elsa Mittelholtz, Tetra Tech, Inc.
elsa.mittelholtz@tetratech.com
703.385.6000, ext. 160
fax 703.385.6007

Workshop Queries Contact Person
Thomas E. Davenport, USEPA
davenport.thomas@epa.gov

NCSU Water Quality Group
Department of Biological and Agricultural Engineering
North Carolina Cooperative Extension Service
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637

NONPROFIT ORG.
U.S. POSTAGE
PAID
RALEIGH, NC
PERMIT No. 2353

NC STATE UNIVERSITY

NCSU Water Quality Group
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637
Telephone: (919) 515-3723
Fax: (919) 515-7448
Website: http://www.ncsu.edu/waterquality/

Personnel

Jean Spooner
Robert O. Evans
Kristopher Bass
Michael R. Burchell II
Jon Calabria
Carter Cone
Barbara A. Doll
Garry L. Grabow
Karen R. Hall
William F. Hunt
Gregory D. Jennings
Bonnie Kurth
Daniel E. Line
Jan Patterson
Dave Penrose
Catherine S. Smith
Laura Lombardo Szpir