Wisconsin's Natural Community Stratified Random Wadeable Stream Monitoring Program 2010-2013

Since the passage of the Clean Water Act (CWA) in 1972, the U.S. Congress, American public, and other interested parties have asked the U.S. Environmental Protection Agency (USEPA) to describe the water quality condition of U.S. waterbodies. These requests have included seemingly simple questions:

- *Is there a water quality problem?*
- *How extensive is the problem?*
- *Which environmental stressors affect the quality of the nation's streams and rivers, and which are most likely to be detrimental?*

To answer these questions, USEPA, other federal agencies, states, and tribes have decided to collaboratively use probabilistic surveys as the primary tool in a project called the Wadeable Streams Assessment (USEPA 2006, 841-B-06-002).

Designing a State-wide Assessment

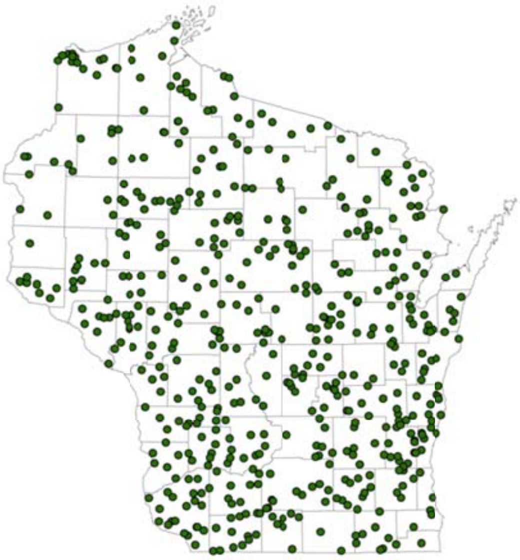
In 2003, 2008 and 2013 WI DNR took part in three statistically valid surveys of the Nation's rivers and streams led by the USEPA: the Wadeable Stream Assessment (WSA, 2003) and the National Rivers and Streams Assessment (NRSA, 2008 and 2013). The sampling designs for The National surveys were a probability-based network that provided statistically-valid estimates of conditions for the population of rivers and streams across the United States with a known confidence. In 2010-2013 the Wisconsin DNR began a similar monitoring program to assess the condition of wadeable streams across the State using a probabilistic design called the Natural Community Stratified Monitoring program (NCSR). The Wisconsin project design included monitoring at ~550 sites over four years that was spatially stratified to cover the entire stream, geographic and land use types found throughout the State (Fig 1). By using a probabilistic design the State was able to use the results to determine the condition of Wisconsin's wadeable streams in a statistically valid manor. The results of this analysis provide a clear assessment of the physical, chemical & biological quality of wadeable, perennial streams across the State.

Why Wadeable Streams?

Wadeable streams provide valuable benefits to Wisconsin residents including fishing, swimming and aesthetics a well as vital habitat to aquatic and terrestrial to semi-terrestrial wildlife (such as reptiles and waterfowl). In Wisconsin there are nearly 45,000 miles of wadeable streams, a number that

Did you know?

Approximately 90% of stream and river miles in the United States are small, wadeable streams. Wisconsin alone has ~45,000 miles a perennial wadeable streams.



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could potentially double if including intermittent and ephemeral streams. Most of the State's (and Nation's) waterways are smaller wadeable stream and river systems that form an intimate linkage between the land and water. Thus, activities performed on land are reflected in local water quality and that water is carried to all parts of the State through the dense linkages of streams to rivers to larger downstream waterbodies.

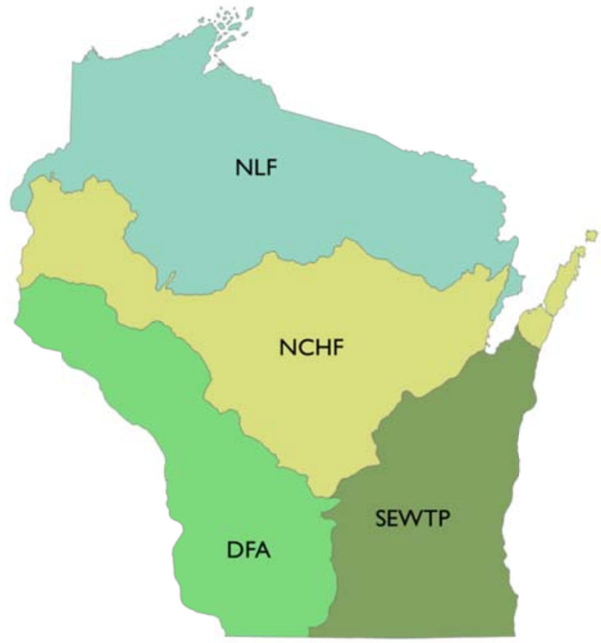
How Were Sampling Sites Chosen?

Wisconsin's sampling locations were selected using a probabilistic survey design. These probabilistic survey designs are used in a number of disciplines (i.e. election polls) when a population of interest is too large or too cost expensive to sample all components (such as Wisconsin's 45,000 stream miles). To select sites for the survey all of Wisconsin's wadeable streams were included in a sample population and stratified based on geographic location and stream type. Geographic location was defined as Level 3 Omernik Ecoregions that generally divide the State into four equal areas (Fig 2). Stream types were defined as Wisconsin's Natural Community classification system which classifies streams based on size (flow) and temperature (http://dnr.wi.gov/topic/rivers/naturalcommunities.html, Sites were selected using a spatially balanced stratified random sampling technique where each site was assigned a probability of being selected based on the population size of the respective strata. This ensures that the full range of stream attributes have a chance of being selected (sites were not biased towards one region of the State or towards really small streams which are more numerous than bigger rivers). This unbiased site selection with known probabilities allows for extrapolation of results to the entire population and ensures that assessment results represent the condition of streams throughout the State.

Field Sampling

Selected sites were sampled by field crews from 2010 to 2013 using WI DNR standard operating procedures (SOPs, http://intranet.dnr.state.wi.us/int/water/monitoring/guidance.htm). Water quality samples for specific conductivity, dissolved oxygen, pH, total suspended solids, nitrogen-series and total phosphorus were taken once during summer baseflow conditions. Water chemistry samples were sent to the Wisconsin State Laboratory of Hygiene for analysis. Quantitative physical habitat and fish assemblage surveys were conducted once during the summer index period. Macroinvertebrate assemblage samples were collected and identified in the field during the fall index period and identified at the UW Steven Point Aquatic Biomonitoring Laboratory.

Water Quality Assessments



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Wisconsin applies different data requirements and assessment methods to determine if a certain water quality pollutant is exceeding acceptable levels that are protective of stream uses (http://dnr.wi.gov/topic/SurfaceWater/assessments.html). For most constituents this requires more than one summer sample as was collected for the NCSR monitoring program. Therefore, results presented in the NCSR analysis as in "Poor" condition represent one water quality sample exceeding the threshold for a specific pollutant but does not specifically equate to an impaired water because of minimum data requirements necessary for attainment decisions.

For the NCSR analysis thresholds to determine if a stressor was in "Good" or "Poor" condition was determined by one of three methods 1) Applying the threshold found in Wisconsin's water quality standards 2) Applying the categorical rating developed as guidelines for biologic and habitat indices, or 3) applying the 90th percentile of reference site conditions (see Table 1).

Chemical and Physical Stressors

A) Phosphorus and Nitrogen

Phosphorus and nitrogen, commonly referred to as "nutrients", are naturally occurring elements that are necessary for all life. The concentrations of nutrients in aquatic ecosystems have been increased over time by a variety of human land uses and sources that lead to a condition called eutrophication. This is a state where excess nutrients lead to increased productivity that often causes algal blooms and low dissolved oxygen concentrations that are harmful to sensitive aquatic life and impair recreational opportunities. Wisconsin has a water quality standard (WQS) for total phosphorus in wadeable streams at 0.075 mg/l. There is currently no WQS for nitrogen.

B) Total Suspended Solids

Total Suspended Solids (TSS) is a measure of the weight of solids that are suspended in water. High concentrations of TSS can lead to high rates of sedimentation in streams and alter benthic habitat, as well as indicate general pollution. Native geology, soils, and stream geomorphology can all account for natural variation in background TSS concentrations in a stream.

Parameter	Threshold Source
Total Phosphorus	WI WQS
Conductivity, Dissolved Oxygen	Reference Site 90th Percentile
pH	WI WQS
Nitrogen & TSS	Reference Site 90th Percentile
Qualitative Habitat	Categorical Rating
Macroinvertebrate IBI	Categorical Rating
Fish IBI	Categorical Rating

C) Conductivity

Conductivity is the ability of water to pass an electrical current and is used as a surrogate for the concentration of inorganic dissolved ions in the water (such as chloride, sulfate, and sodium, among others). Conductivity naturally varies based on the geology, soils and weathering rates of the surrounding watershed. Conductivity can be increased in through urban and agricultural land uses. Conductivity itself can impair the osmoregulation of organisms with gills and other semipermeable membranes or be used a surrogate for pollution from specific land uses (i.e. septic tanks).

D) Dissolved Oxygen

Dissolved oxygen (DO) is the amount of gaseous oxygen that is dissolved in water and available to aquatic organisms. DO varies within streams based on time of day (production and respiration cycles), water temperature and physical reaeration (riffles). Eutrophication can cause DO to have larger diurnal swings with and nighttime low dissolved oxygen can be detrimental, or lethal to aquatic organisms.

E) pH

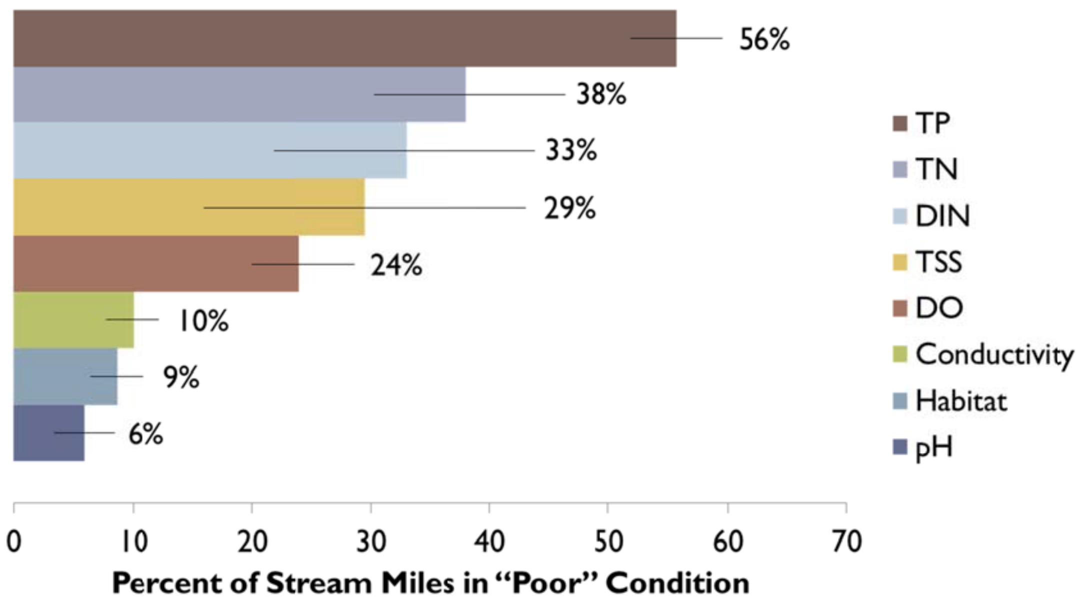
pH is the measure of hydrogen ions present in stream water. pH can control the biologic availability, solubility and speciation of chemicals in water. Even moderately acidic water may irritate the gills of aquatic fish and insects or reduce the hatching success of fish eggs.

F) Qualitative Habitat

Qualitative habitat is a metric that aggregates several factors of stream physical characteristics and develops a rating. In general the habitat rating indicates the amount of good habitat such as hiding, resting and foraging areas, for stream fishes.

Ranking Stressors – Extent

Stressors can be ranked based on how prevalent they are in the environment. Stressors that are widespread and commonly exceed thresholds developed to protect water quality would have a greater extent. Among all streams in Wisconsin total phosphorus (TP) is the most prevalent stressor of those considered in this study. 56% percent of all streams in the State, by length, are in “Poor” condition for TP concentrations (“Poor” threshold sources are defined in Table 1). Total nitrogen (TN), dissolved inorganic nitrogen (DIN) and total suspended solids (TSS) are the next most prevalent stressors ranking at 38%, 33% and 29% of streams in Poor condition, respectively. In order of decreasing prevalence, dissolved oxygen (DO, conductivity, physical habitat and pH are the least prevalent stressors in Wisconsin's streams (Fig 3).



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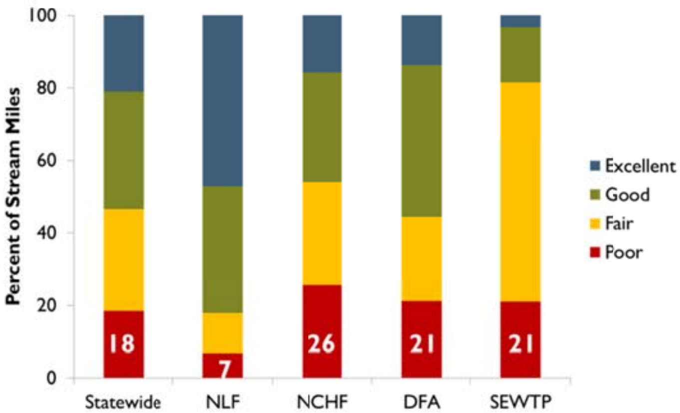
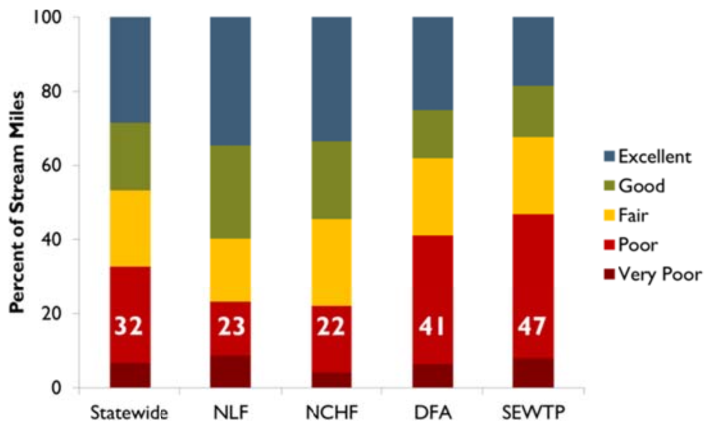
Indicators of Biological Stress

Water resource managers often evaluate the health of a stream system by examining the biologic communities that reside in the streams. Measuring biological assemblages, such as macroinvertebrates and fish, has the direct advantage in that it integrates the cumulative effects of multiple stressors over long periods of time (weeks to years) on a waterbody. This allows a direct examination of how stressors are affecting the condition of a stream ecosystem by how the biologic communities are responding. The WI DNR currently assesses biologic stream health using both macroinvertebrate and fish assemblages by using an Index of Biotic Integrity (IBI) that provides an overall score for stream health.

Why sample bugs and fish?

As aquatic macroinvertebrates and fish spend the majority of their life in aquatic environments, they are capable of integrating the combined effects of stressors over time, providing a measure of the past and present conditions (Karr and Dudley, 1981).





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Condition of Biologic Assemblages

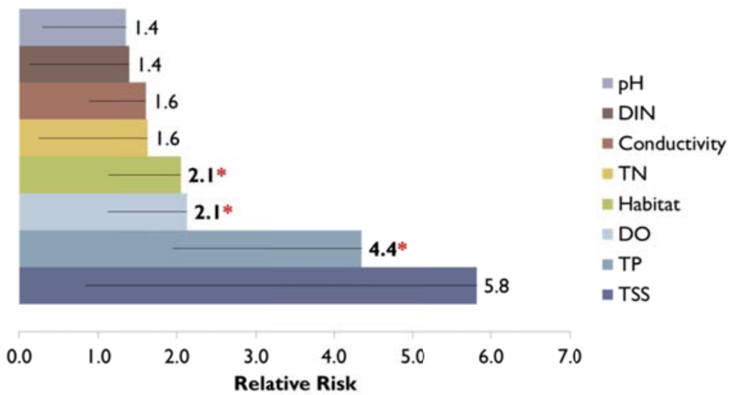
Biologic assemblages (macroinvertebrates and fish) were assed using the appropriate IBI for the assemblage and stream type (i.e. natural community). Although different IBIs may be applied based on the stream type the raw score is always translated into a categorical rating that can be compared among all IBIs.

For macroinvertebrate IBI we found that 18% of streams, by length, are in "Poor" condition. Comparing the spatial distribution we found that he percent Poor was lowest in the Northern Lakes and Forests (NLF) Ecoregion (7%) and was higher in the other Ecoregions. The NLF is the northern most Ecoregion in Wisconsin and is generally the least populated and most "pristine" so the spatial differences agree with expectations (Fig 4A).

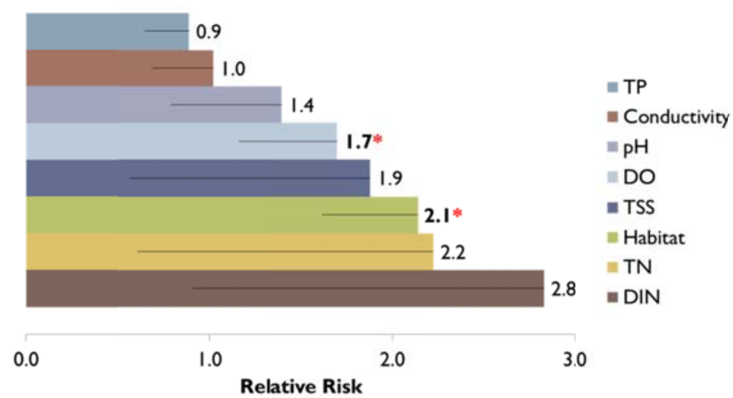
Fish assemblage condition is estimated to be in "Poor" or "Very Poor" condition at 32% of streams Statewide. Again there is a spatial difference where the northern most Ecoregions, NLF and North Central hardwood Forests (NCHF) have a lower percentage of "Poor" streams than the southern Ecoregions (Fig 4B).

Ranking Stressors - Severity

Stressors can be ranked on their prevalence, or how widespread they are but that doesn't capture the severity of a stressor. In other words, a stressor may not be very common but where it is found it may be very detrimental to biologic communities. In this report stressor severity is assessed using a measure called Relative Risk. Relative Risk (RR) measures the increased probability that a biologic assemblage will be in "Poor" condition if the stressor is also in "Poor" condition. This risk assessment method is commonly used in the medical community and produces and easy to interpret result. A RR of three (3) to Fish IBI condition would be interpreted as: if stressor A is in "Poor" condition at a particular stream than the fish assemblage would have a 3x greater probability of also being in "Poor" condition.



The most severe stressor to macroinvertebrate condition total suspended solids (TSS) with a 5.8x greater chance of macroinvertebrates being in "Poor" condition. The next most severe stressors were total phosphorus (TP), dissolved oxygen (DO) and physical habitat with a RR of 4.4, 2.1 and 2.1, respectively. Although TSS had the highest RR it was not considered statistically significant in this study. TSS and nitrogen samples were only taken at a subset of sites and the low sample size likely led to a higher error and confidence interval (Fig 5A).



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The most severe stressor to fish condition was found to be dissolved inorganic nitrogen (DIN) and total nitrogen (TN) with a 2.8 and 2.2 greater chance of macroinvertebrates being in "Poor" condition, respectively. The next most severe stressors were physical habitat, total suspended solids (TSS) and dissolved oxygen (DO) with a RR of 2.1, 1.9 and 1.7, respectively. Again, although TSS and nitrogen had higher RR scores it was not considered statistically significant in this study likely because of low sample size (Fig 5B).

Next Steps

- The 2010-2013 NCSR monitoring will be finalized in early 2015 when all macroinvertebrate taxonomic results are analyzed and reported. Current analysis included ~ 80% of all of the macroinvertebrate samples collected
- Total nitrogen, dissolved inorganic nitrogen and total suspended solids will be collected at every NCSR monitoring location in order to increase sample size and confidence in analyses for future iterations.
- The NCSR monitoring program will continue with monitoring 50 sites per year and the results will be analyzed and reported every two years (100 total sites) to track trends.

References and Further Reading

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Wisconsin DNR Water Quality Monitoring and Assessment

http://dnr.wi.gov/topic/surfacewater/monitoring.html