Fifteen years of Biomonitoring in Maine: Evolution, Application and Destinations

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ABSTRACT: In 1983, the Maine Department of Environmental Protection undertook a committed effort to incorporate the use of biological information into its water quality management programs. Biological data provides information quality unavailable from traditional physical/chemical data that can integrate the effects on the biological community from a variety of activities and provide a direct measure of the outcome of those effects. A biological monitoring program can be used to direct other water quality programs based on biological response. Maine's biological monitoring program evolved by including new statutory standards specifically directed to describe, in biological terms, goals for the water quality program. Standardized sampling methodology was introduced and numerical criteria have been developed that allow broad and unprecedented use of biological information within the agency's programs. A more extensive discussion of information presented in this paper is found in *Biomonitoring Retrospective: Fifteen Year Summary for Maine Rivers and Streams* (Davies et al 1999) and on the Department's biomonitoring website at: www.state.me.us/dep/blwq/monitoring.htm.

Evolution

All environmental problems have, or have a potential for, a biological consequence. Biological monitoring of river and stream life provides remarkable insight into the functional quality of the environment studied. It can reveal important changes in the composition of biological communities caused by human activities. The condition of the biological assemblages reveals the results of all the physical, chemical, and biological stressors that an aquatic community encounters. Traditional measures of water quality, such as levels of dissolved oxygen or concentrations of toxic contaminants in water, are indirect ways to determine the ecological condition of a waterbody. They allow one to draw inferences concerning expected effects on aquatic life but do not look directly at biological responses in the water and do not account well for interactions when more than one factor is involved. By inventorying the makeup of biological communities and comparing results to those found in impact-free areas, it is possible to determine whether pollution or other habitat altering activities are causing ecological impacts such as the loss of sensitive groups of organisms and the ecological functions they perform. Therefore, environmental program goals can, and should, be written with a biological context (Courtemanch et al. 1989).

Nearly 600 million gallons of wastewater are discharged into Maine's waters every day. The State issues over 350 licenses to industries, businesses, municipalities and schools to regulate the quality of these discharges. Many millions of acres of land are subject to timber harvesting, agricultural use and urban development, causing the release of pollutants such as sediment, nutrients and toxic materials to the State's surface waters. Hundreds of dams interrupt Maine's rivers and streams, altering the natural flow and habitat quality. Also, a legacy of environmental carelessness can be found in the numerous old dumps and hazardous waste sites present across the state. These factors all contribute to concerns for the quality of Maine's waters. The state has numerous programs to address these issues. However, measurement of program success, accountable in biological terms, is an essential requirement needed to direct these programs.

In 1974, the USEPA provided funding for an investigation of the effects of pulp and paper mill waste on the biota of the Penobscot River (Rabeni 1977). This study used standardized sample methods to assess the benthic macroinvertebrates in a 100 km section of the Penobscot River from East Millinocket to Costigan. The study presented a biological description of conditions that ranged from near-natural in quality to severely degraded to partial recovery, and became the rudiment of a future biological monitoring program for the state. The Penobscot River was re-visited in 1981 to investigate whether the $33 million dollars expended for implementation of wastewater treatment since 1974 had resulted in any improvement in biological conditions (Rabeni et al. 1988). This study duplicated all of the data collection and analysis methods of the original work and revealed dramatic improvements throughout the river demonstrating that biological response could be expected and predicted.

By 1983, DEP biologists were sufficiently convinced of the importance and usefulness of biological information that it was resolved to incorporate standards for the condition of aquatic life into a proposed revision of the water quality classification law. Passage of the law, following numerous revisions, negotiations and legislative committee meetings, was accomplished in 1986 (MRSA Title 38 Article 4-A § 464-465, with definitions in § 466). Maine's narrative aquatic life standards are shown in Table 1 (Courtemanch 1995). Concurrent with efforts to pass the new water quality classification law, the Department established standardized data collection protocols (macroinvertebrate sampling using introduced substrates) and, using these methods, began to amass a statewide database (Davies and Tsomides 1997). This statewide monitoring effort marked the beginning of the program in existence today.

By 1989, the Department had amassed a sufficient number of sampling events (144) to embark on development of numerical criteria to support the narrative standards in the statutes. Linear discriminant analysis was chosen as the most promising technique to address both the scientific character, and the regulatory and policy goals, of the new biocriteria program. The final numeric criteria consist of a set of interrelated linear discriminant functions that use 25 quantitative variables to classify unknown samples, by comparing them to narrative characteristics in the statute of four groups: Class AA/A, Class B, Class C and Nonattainment of Any Class. Results are reported in terms of the probability that a sample fits the characteristics of the statutorily assigned class of a waterbody. The use of a probability based approach provides numerous advantages over other biocriteria techniques currently in use (Courtemanch, 1995). Numeric criteria were completed by 1990 and have been used as Department policy since then for all determinations of aquatic life class (Davies et al. 1995).

In 1998, the original numeric criteria model was re-calibrated to include a total of 373 sampling events, significantly improving its robustness. The re-calibration resulted in relatively minor changes to the structure of the original models and enhanced their performance to correctly assess a verification set of samples. The revised model and associated sampling and analytical methods (Davies and Tsomides 1997) are in promulgation as the State of Maine numeric biocriteria regulation (Department Regulations: Chapters 579 and 580). All biomonitoring data collected after January 1, 1999 are analyzed in accordance with the re-calibrated model.

Application

Monitoring and Assessment: Assessment has been the traditional role for biological monitoring, to detect changes in the aquatic community (typically an upstream-downstream comparison) and to relate these changes to activities such as discharges. The aquatic communities of the rivers and streams of Maine are subject to detrimental impacts from various types of activities that can be generally categorized as point sources, non-point sources, in-place (toxic) contamination, spills, habitat and hydrologic modification. The biological monitoring program functions to provide monitoring and assessment data to various programs and initiatives within the Department that are involved in the regulation and management of these activities.

Targeted assessments of the impacts of these activities occur as needed, but in general, the Department follows a five-year, rotating basin assessment schedule. Currently, the Department has the capability to assess 40 to 50 stations per field season. Waterbodies are prioritized for assessment within the targeted basin based on specific concerns about discharge performance or potential enforcement action, re-licensing information needs, concerns about land use practices in the basin. Special investigations may also be required for unique events or documentation of remediation activities. Information about the condition of aquatic life is also useful in the context of numerous other activities and programs throughout the Department including classification, reporting, permitting and licensing, and enforcement (Courtemanch 1995).

Water Quality Classification: Classification information was the first new role designed for biological information when the law was passed. The Department is required to report to the Maine Legislature on the water quality attainment status of the classified waters of the state and to make recommendations for changes to the statutory classification of waters of the state. As established in Maine law, a classification consists of designated uses (such as swimming or habitat for aquatic life), characteristics, and criteria (such as enteric bacteria, dissolved oxygen and aquatic life) which specify levels of water quality necessary to maintain the designated uses. A waterbody must meet all characteristics and criteria to be in attainment of its designated class. When the new classification statute was passed, the use of biological standards for classification determination was considered a primary function.

Results of the analysis of biological data provide a determination of whether or not applicable aquatic life standards (Tables 1) are attained within a sampled stream reach, thus contributing to the determination of overall classification attainment. The statistical protocol for analyzing macroinvertebrate data was developed to yield an objective, easily understandable, pass/fail test of attainment of aquatic life class. The determination is reported as the probability that a sampled site fits the characteristics of its statutorily assigned class. In the state's most recent reclassification legislation, the aquatic life standards and criteria were used for 40% of all new classification re-assignments.

Reporting: The State of Maine 1996 Water Quality Assessment is a report required by Congress under Section 305(b) of the Clean Water Act. It provides a summary of the status of the state's water quality. The biological monitoring program provides data to the 305(b) report to list the aquatic life attainment status of all monitored waters. Biological monitoring data is also used to recommend waterbodies for listing on the state's 303(d) list. This federally required report lists waters that are not attaining applicable water quality standards and that require treatment beyond technology-based controls. Approximately 30% of Maine's listed segments have been listed based on biomonitoring data and application of the biocriteria.

Wastewater Discharge Licensing: Major and minor wastewater discharge licenses are reviewed and reissued every five years. The Department has initiated a watershed-based approach, with licenses due to be issued the year following assessment. Licensing staff consult with department biologists to establish priorities for sampling within the target basin. In cases where aquatic life standards are not attained, biomonitoring staff may work with the licensing staff and the license applicant to establish a plan for remediation of the problem and implementation of an ongoing monitoring plan. Recently, biomonitoring results have been used in the construction of Total Maximum Daily Load (TMDL) determinations (see Destinations below).

Hydroelectric Project Licensing (Section 401 certification): The biomonitoring program has acquired a significant role in the process of certifying and re-licensing hydroelectric power projects. Because Federal Energy Regulatory Commission (FERC) projects are generally licensed for a thirty to fifty year term, and can have substantial environmental and social consequences, they are subject to an exhaustive review process.

When the biomonitoring program was first conceived and new biologically based water quality standards were adopted in the classification system, the scientific basis for those standards was derived from experience the Department had gained from evaluating the effects of point source discharges on aquatic communities. However, the standards were written broadly to provide a basis to address the range of biological response expected to be encountered from different and often complex interactions between human activities and the aquatic community. The advantage and value of biological standards are well expressed when measuring the complex effects of impoundments on our river systems. Using only physical and chemical criteria, waters both within and downstream of impoundments often appear to attain water quality standards, leading to the often-stated assertion that hydropower is a "clean" technology. Measurement of the biological communities associated with impoundments often tells a different story, sometimes revealing severe loss of both the structure and function of the aquatic communities.

Dams affect upstream and downstream aquatic communities differently. Impoundments used for hydroelectric power generation show the most impairment, correlated with the magnitude of flow regulation associated with the facility. Upstream waste discharges and other sources of contamination can compound the effects of water impoundment. Dams reduce water velocities, increase depth, reduce re-aeration potential resulting in reduced dissolved oxygen, reduce light penetration, and promote retention of settleable particles in the upstream impoundment. The settled solids alter the benthic habitat and contribute to oxygen demand. Temperature regimes can be dramatically altered. In effect, the impounded area assumes some of the characteristics of a lake, but typically the water has a much shorter retention time. Thus, the riverine biological community is subjected to quasi-lake conditions for which they are not adapted. Lake-dwelling organisms may also find impoundment conditions unfavorable. The short retention time precludes the development of a planktonic community, the typical food base of lakes.

Conditions below run of river dams may, depending on the specifics of the project operating regime, offer a subsidy to the aquatic community by stabilizing flows and temperatures, and discharging a higher suspended organic matter load than is carried in un-dammed reaches. Typically, under stable downstream flow conditions (such as for projects operated for run-of-river conditions), samples collected within the near-field influence of an upstream dam will exhibit significantly higher numbers of organisms. However, variable or extreme dam release flows, such as peaking-power projects, negatively affect downstream riverine communities when they are unable to adapt to the artificial flow regime and unstable habitat conditions including stranding or dessication due to periodic reduced flows; displacement at high flows; and reduced water quality from the impounded water source

The unprecedented breaching of the Edwards Dam on the Kennebec River on July 1, 1999 afforded a unique opportunity to use biological information to make an important policy decision and to assess recovery of an impounded river. This segment of the Kennebec had never attained even the lowest Class C community standards. FERC denied the renewal of a license for this operating hydroelectric facility due to the environmental harm caused by the dam, including blockage of anadromous fish passage and cumulative impacts to the aquatic community preventing attainment of water quality standards, that outweighed the energy and economic benefits of the dam. Biological monitoring was conducted for years leading up to the decision and in the months following to track predicted recovery. Two months following removal of the Edwards dam, the aquatic community attained Class B quality. While this recovery was expected, the rate of re-colonization of the river by aquatic organisms that had been absent for 160 years was remarkable. Richness doubled and total abundance increased almost ten-fold. Studies on the recovery of the Kennebec will continue to document successional changes in the invertebrate community associated with the removal of the dam.

<u>Surface Water Ambient Toxics Program</u> (SWAT): In 1994, the Legislature identified a need to assess the nature, scope, and severity of toxic contamination in the state's surface waters, and to provide for the assessment of the effects of this contamination on human and ecological health. Maine's SWAT Program was established to fulfill that need. The program uses techniques including fish and shellfish tissue analysis, sediment analysis, and macroinvertebrate biological monitoring to detect and evaluate possible health effects on humans and wildlife.

<u>Enforcement</u>: In any legalist environment, enforcement is a terminal objective of any regulatory function. For a regulation to be enforceable, it must have certain characteristics such as clear and pertinent criteria, standardized methods of information gathering (investigation), predictable and reproducible results (evidence), and unambiguous conclusions. The biological criteria have been

used in enforcement cases because they are designed to possess these traits. In an example of an enforcement action, the biological criteria were used in Maine to identify the impact to a stream caused by nonpoint source discharge from a large egg processing facility. Evidence from biological samples was used to detect the water quality violation, determine where the encroachment was occurring and the probable source, to set a standard for abatement and to fix a damage claim for the activity.

Destinations

Total Maximum Daily Loads: The USEPA has recently accelerated the demand for states to develop and implement TMDLs for waters that are water quality limited. Because Maine has listed a large percentage of these waters based on biological data and because the impacts often involve complex interactions between pollutant sources and habitat conditions, biological monitoring methods are being used throughout the process for detection, listing, source identification, load allocation recommendations and final assessment of compliance.

The first TMDL completed under the USEPA's new guidelines provide an excellent demonstration of the application. A 7 mile segment of the Presumpscot River was affected by the combined effects of an impoundment, regulated river flow, and a pulp and paper mill discharge. The river is classified C, but did not attain aquatic life standards. While factors like oxygen and temperature were implicated, department biologists determined, based on the characteristics of the existing community, that suspended solids (for which the state does not have water quality criteria) was the primary pollutant of concern. By extrapolating data from other rivers with differing suspended solids loads and attainment conditions, the department was able to prescribe a suspended solids load that would provide a community response suitable to attain Class C. A new license with improved TSS limits and biological monitoring requirements, was issued and the TMDL completed for this waterbody.

Non-Point Source Screening: A non-point source screening tool is in development to assist the Division of Watershed Management in assessment and prioritization of its programs. This tool is designed to identify the numerous small waterbodies with non-point source impacts, the source of which are often diverse and multiple in nature. Assessments of waters with a high potential to be impacted by non-point sources are conducted at a regional scale. Information derived from a percent watershed impervious surface database, a Watershed Pollution Potential Index and other observed information provide a regional scale screening. Streams are sampled using a rapid, qualitative method. This screening tool is a modification of North Carolina's standard bioassessment technique (Lenat 1988). A habitat assessment of the stream reach is completed when the samples are collected. Depending on results of the screening, additional monitoring using the quantitative approach may occur

Volunteer use: The public has a natural curiosity about biology of waters which can be used to the benefit of water quality programs. Certain monitoring programs lend themselves well to the use of volunteers if quality of data collected can be assured. Maine's biomonitoring program does not presently incorporate the use of volunteers, however, it is being more widely used outside of the Department (professional environmental consultants, New Brunswick Dept of the Environment) and may have future use within volunteer monitoring programs. The sampling methods were purposely designed to provide reproducible data by individuals that may have limited or variable training and experience. Software is in development that will allow the input of data by anyone to determine water classification attainment. The greatest limitation for use by volunteers will be making correct taxonomic determinations of the sampled organisms.

Geographic Information Systems (GIS): GIS provides analytical and reporting functions that help one draw inferences or conclusions about a given area by recognizing and analyzing the spatial relationships among mapped phenomena. A critical component of a GIS is its ability to produce graphics that convey the results of analyses, helping viewers to understand the results of analyses or simulations of potential events in a spatial context. Future program directions include expanding spatial data analysis and management capabilities. For examples of GIS display of biomonitoring information see Davies et al. (1999).

Aquatic Biodiversity: Maine is presently engaged in documenting the condition of the native aquatic flora and fauna of the state. The state has escaped much of the effects of invading exotic organisms and extensive areas of the state are relatively unaffected by human encroachment or industrialization. The Department's biological monitoring program has revealed that many aquatic communities appear to be intact. This information is being merged with data from other resource agencies to provide a better picture of the natural biological integrity of the state's waters. This affords the opportunity to study and document reference quality communities and to develop water quality programs based on biological criteria that can protect these high quality resources.

Wetland, Lake, Marine waters: The Department is pursuing the use of biological monitoring techniques and criteria development for other waters. Data acquisition has already begun for non-forested freshwater wetlands and lakes. In both instances, invertebrates are being used, however, pilot projects using periphytic diatoms in wetlands (and streams) and planktonic algae in lakes are in progress. Biological monitoring in marine waters is in the early data collection phase for near-coastal, subtidal areas.

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Table 1 Maine's narrative aquatic life and habitat standards for rivers and streams (adapted from Maine Revised Statutes Annotated, Title 38, Sections 464-465)

CLASS	MANAGEMENT	BIOLOGICAL STANDARD
AA	Highest quality water protected for recreation and ecological values. No discharges or impoundments permitted.	Habitat shall be characterized as natural and free flowing. Aquatic life shall be as naturally occurs.
A	High quality water with limited human interference. Discharges limited to non-contact process water or highly treated wastewater of quality equal to or better than the receiving water. Impoundments allowed.	Habitat shall be characterized as natural.. Aquatic life shall be as naturally occurs.
B	Good quality water. Discharge of well treated effluent with ample dilution permitted.	Habitat shall be characterized as unimpaired. Discharges shall not cause adverse impacts to aquatic life. Receiving water shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.
C	Lowest water quality. Maintains the interim goals of the Federal Water Quality Act (fishable/swimmable). Discharge of well treated effluent permitted.	Habitat for fish and other aquatic life. Discharges may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving water and maintain the structure and function of the resident biological community.
Impoundments (Class A, B, C)	Riverine impoundments not classified as Great Ponds and managed for hydropower generation.	Support all species of fish indigenous to those waters and maintain the structure and function of the resident biological community.