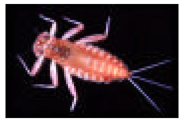

PREFACE

Passage of the revised Water Classification law (38 MRSA, Section 464) in 1986 by the Maine State Legislature established Maine as the first state in the nation to statutorily adopt explicit narrative aquatic life standards for each water classification for the protection of aquatic life (Tables 1 and 2). The federal government has since recognized the valuable contribution of biological information to water quality management programs and has recommended that all states initiate the development of narrative aquatic life standards. (U.S. EPA, 1990; US EPA 1998a; USEPA, 1998b).

The purpose of this document is to present results of fifteen years of biological monitoring efforts on rivers and streams by the Maine DEP Biological Monitoring Program and to summarize biological assessment activities under development by the State, for other water body types such as lakes, wetlands and estuaries (Part I Ch. 2 *Related Biological Monitoring Activities and Programs*, p. 25) . The results presented here are based on the original, 1990 biological criteria linear discriminant model. The report provides the results of statewide biomonitoring activities, in text, maps and tables, organized by major river basin. This report also highlights and details information on status and trends by examining case studies for locations of special interest. A presentation of the current status and trends for overall water quality in Maine may be found in the 1996 "State of Maine Water Quality Assessment", (305b) report (MDEP 1996a).

“Nearly 600 million gallons of wastewater are discharged into Maine’s waters every day…..Biological monitoring of river and stream life provides remarkable insight into the functional quality of the environment studied.”

Introduction and Background

Program Synopsis: Development of Biological Criteria

The Maine Department of Environmental Protection Biological Monitoring Program began a standardized program of sampling stream invertebrate communities in 1983. This statewide monitoring effort marked the beginning of the program in existence today. Numeric criteria, to assess attainment of the State's narrative aquatic life standards, were derived from a set of 144 samples of baseline biomonitoring data. The analytical approach used multivariate statistical analysis (linear discriminant analysis) and professional biologist expert judgement to identify variables that best predict attainment of aquatic life classification. Numeric criteria were completed by 1990 and have been used as Department policy, since then, for all official determinations of aquatic life class attainment, for issuance of 401 Water Quality Certification, for state and federal reporting and for problem identification. See, *Data Collection and Analysis*, p. 20 Davies et al, 1995, and Davies and Tsomides, 1997 for a more complete discussion of the analytical approach.

In 1998 the original numeric criteria model was re-calibrated to include a total of 373 sampling events, significantly improving its flexibility and robustness. The re-calibration resulted in relatively minor changes to the structure of the original model, involving simplification of the structure of two of the sub-models, the elimination of two poorly performing variables, and changes in model coefficients to account for the new data. The Department proposes that the revised model and established sampling and analytical methods (Davies and Tsomides 1997) be promulgated as the State of Maine numeric biocriteria regulation. All biomonitoring data collected after January 1, 1999 will be analyzed in accordance with the new, re-calibrated model.

Biological Information to Assess Environmental Quality

Currently, 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. In addition, tens of 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 and groundwater. 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.

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. It asks the question: "Is this aquatic community showing evidence of harm?" The condition of the biological assemblages reveals the results of all the physical, chemical, and biological stressors that an aquatic community encounters. The approach relies on the great diversity of invertebrate life (animals without backbones such as clams, snails, crayfish, leeches and especially, immature aquatic insects) in rivers, streams and wetlands, to determine how suitable a waterbody is for the support of aquatic life. Different types of invertebrate life demonstrate widely differing tolerances to pollution (Figs. 1-5).

Fig. 1: **Immature mayfly nymph**

Fig. 2: **Freshwater Unionids**

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 stream and do not account for interactions when more than one factor is involved. By inventorying the makeup of invertebrate communities and comparing results to those found in pollution-free areas, it is possible to determine whether or not pollution is causing ecological impacts such as the loss of sensitive groups of organisms and the ecological functions they perform (Courtemanch, Davies and Laverty 1989).

The Department's Biological Monitoring Program provides water quality information for a wide array of programs and initiatives including:

- general, long-term ambient monitoring and trend assessment;
- evaluation of water quality classification attainment;
- evaluation of impacts downstream of discharges;
- evaluation of the effects of management activities
- evaluation of the effects of non-point source impacts;
- evaluation of impacts from diffuse toxic contamination through the Surface Water Ambient Toxics Program (MDEP 1993);
- evaluation of the impacts of hydropower activities in fulfillment of requirements for the Clean Water Act SEC. 401 water quality certification process.

In addition, the Program is refining methods and criteria to better assess aquatic biological impacts of poor land use practices on stream and wetland systems, discussed in Part I, Chapter 2.

As of the end of the 1998 field season, a total of 362 biological monitoring stations have been established throughout the State, on 139 different rivers and streams (General Map 1). Many of these stations have been sampled more than once and a few stations have been sampled annually for up to 14 years. Over the years the Biological Monitoring Program has documented numerous examples of dramatic recovery of the biotic community after the implementation of new treatment technologies (Case Study 4). It has also revealed important biological effects that would have gone undetected with traditional chemical monitoring methods (Case Studies 1,3 and 7).

This report contains case studies highlighting the effectiveness and importance of the efforts by industry, municipalities and the State to improve treatment and restore affected aquatic resources (Case Studies 4,6 and 11). Examples include the restoration of the Piscataquis River, downstream of Guilford, from a severely degraded and neglected resource in the early 1980’s to a high quality river, exhibiting Class A biological characteristics in some downstream reaches today. The dramatic, positive biological response was the result of construction of the Guilford sewage treatment plant in 1988 (Part II, Basin Chapter 2).

The restoration of Cooks Brook, site of serious cadmium contamination from a metal finishing plant in the early 1980's, is another success story. Sources of groundwater contamination have been removed, transforming Cooks Brook from a stream essentially devoid of aquatic life to a high quality stream supporting brook trout today (Part II Basin Chapter 9).

More discouraging are the several cases of long-standing aquatic life impacts caused by known sources that are poorly responsive to corrective actions (Case Study 5, E. Branch of the Sebasticook River), and the situations where habitat and flow alterations have had obvious detrimental impacts on the biota (see *Hydroelectric Project Re-licensing*, p. 15, and *Biological Effects of Hydropower Impoundment*, p. 16, in this Chapter, and Case Study 11). Biological monitoring provides a wealth of information on the overall success of the State's water quality management efforts, in terms that are imminently meaningful to the tremendous diversity of life that makes up our State's natural heritage.

Fig. 3: Stonefly nymph

Fig. 4: Chironomid midge larvae

Milestone Experiences:

Department biologists have relied on biological assessment of stream benthic macroinvertebrates since the early 1970's, when the value of this approach was first being recognized and evaluated nationally. Early biomonitoring studies included examination of the downstream effects of chlorination below municipal sewage treatment plants (Courtemanch 1977) and several studies on the effects of pesticides used during the spruce budworm outbreak in Maine timberlands in the 1970's (Courtemanch and Gibbs 1980; Gibbs et al, 1984). These and other studies were important in redirecting specific state policies such as better regulation of chlorination, and established the value of biological information in environmental decision-making.

In 1974, the US EPA 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 rock-filled basket introduced substrates to sample benthic macroinvertebrates in a 100 km section of the Penobscot River from East Millinocket to Costigan. Three of the eleven sampled stations were severely degraded, as evidenced by the dominance of pollution tolerant organisms including sludge worms and chironomid midges (Fig. 4), as described in Case Study 4.

The Penobscot River was re-visited in 1981 to investigate whether the $33 million dollars expended for implementation of secondary wastewater treatment, at area pulp and paper mills, since 1974, had resulted in any improvement in biological conditions (Davies 1987; Rabeni et al 1988). This study, funded by the US EPA, duplicated all of the data collection and analysis methods of Rabeni 1977 and uncovered dramatic improvements at the most severely affected stations from 1974.

Secondary treatment technology instituted at the paper mills, succeeded in decreasing the discharge of total suspended solids and biochemical oxygen demand by 80%. Biomonitoring results demonstrated the environmental benefits gained by the improvements in wastewater treatment. In contrast to conditions prior to implementation of secondary treatment, even the stations in closest proximity to the mills had viable populations of pollution sensitive organisms such as mayflies and stoneflies (Figs. 1and 3).

By 1984, DEP biologists were sufficiently convinced of the importance and usefulness of biological information that they resolved to incorporate explicit 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). Maine's narrative aquatic life standards and supporting definitions are shown in Table 1 and described in several peer-reviewed publications (Courtemanch and Davies 1988; Courtemanch 1989; Courtemanch et al 1989; Davies et al 1991; Courtemanch 1995). Concurrent with efforts to pass the new water quality classification law, the Biomonitoring Program established standardized data collection protocols (rock-filled baskets, rock-filled riffle bags and rock-filled cones (Figs. 6,7,8 and 9) and, using these methods, began to amass a statewide, baseline database.

By 1989, a sufficient number of sampling events existed to embark on the development of numeric criteria to support the narrative standards in the law. With the statistical expertise of insect ecologist, Dr. Francis Drummond, at the University of Maine, numerous exploratory multivariate statistical analyses were applied including cluster analysis, correspondence analysis (DeCorAna), two-way indicator species analysis (TWINSPAN) and linear discriminant analysis. The Department, in January of 1990 also convened a technical advisory committee of non-agency scientists to provide peer review and oversight of the biocriteria development process. Individuals chosen had a demonstrated understanding of the technical challenges inherent in the development of numeric criteria and the use of the benthic macroinvertebrate community in water quality assessment. Participants were also selected to provide broad representation from various interest groups and stakeholders, including the pulp and paper industry, independent consulting biologists, environmental advocacy groups, academia and other state natural resource agencies. At the outset it was made clear that the role of the group was technical oversight of the numeric criteria development process. Participants were requested, as far as possible, to refrain from advocacy or debate that did not contribute to the scientific and technical quality of the ultimate biocriteria product. The Technical Advisory Committee was active for about 2 1/2 years and was instrumental to the success of the final product.

Linear discriminant analysis was chosen as the most promising technique to address both the scientific goals 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 characteristics of the four groups defined by the baseline data. Results are reported in terms of the probability that a sampled station fits the characteristics of its legally assigned class. The original linear discriminant model was completed in 1992 and has served as the Biomonitoring Program's draft numeric criteria since that time. As noted in the Introduction, the model was recalibrated with an additional 229 sampling events in 1998. The upgraded model will go to rulemaking in the spring of 2000.

Fig. 5: Nets of caddisfly larvae

Table 1 Maine's narrative aquatic life and habitat standards for rivers and streams

CLASS	MANAGEMENT	BIOLOGICAL STANDARD
AA	High quality water for recreation and ecological interests. 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 noncontact 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	Riverine impoundments 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.

Table 2 Definitions of terms used in Maine's Water Classification law**.**

1. **Aquatic life.** "aquatic life" means any plants or animals that live at least part of their life cycle in fresh water.

2. **As naturally occurs.** "As naturally occurs" means conditions with essentially the same physical, chemical and biological characteristics as found in situations with similar habitats, free of measurable effects of human activity.

3. **<u>Community function</u>.** "Community function" means mechanisms of uptake storage and transfer of life-sustaining materials available to a biological community which
determine the efficiency of use and the amount of export of the materials from the community.

4. **<u>Community structure</u>.** "Community structure" means the organization of a biological community based on numbers of individuals within different taxonomic groups and the proportion each taxonomic group represents of the total community.

5. **<u>Indigenous.</u>** "Indigenous" means supported in a reach of water or known to have been supported according to historical records compiled by State and Federal agencies or published in scientific literature.

6. **<u>Natural.</u>** "Natural" means living in or as if in, a state of nature not measurably affected by human activity.

7. **<u>Resident biological community</u>.** "Resident biological community" means aquatic life expected to exist in a habitat, which is free from the influence of the discharge of any pollutant. This shall be established by accepted biomonitoring techniques.

8. **<u>Unimpaired</u>.** "Unimpaired" means without a diminished capacity to support aquatic life.

9. **<u>Without detrimental changes in the resident biological community</u>.** "Without detrimental changes in the resident biological community" means no significant loss of species or excessive dominance by any species or group of species attributable to human activity.

COST ESTIMATES AND RESOURCE REQUIREMENTS

The current Biological Monitoring Program for rivers, streams and wetlands is operated on a budget of $200,000 to $235,000 per year. This figure includes staffing (3 professional biologist full-time equivalents, and 1 summer intern), overhead, contractual services and equipment. This figure represents about 2% of the State's total expenditure, of about 10 million dollars per year, for water resource management. Chris Yoder, manager of the Ohio Environmental Protection Agency Biological Monitoring Program, has recommended that to be maximally effective, funding for biological monitoring activities should amount to between 5 and 15% of the cost of a state's overall surface water quality management budget. Ohio EPA's exceptional biological monitoring program has about 12 full time equivalent staff for rivers and streams and is operated on a budget representing about 9% of total expenditures for Ohio water resource management. Maine's Biological Monitoring Program was staffed with 1.25 full-time equivalent biologists for the first five years. In 1988 a second full-time biologist was hired for the rivers and streams program and a third biologist was added for development of wetland bioassessment methods in 1997. Part-time summer intern assistance has been available for most field seasons. Appendix 4 provides a description of the functional roles of the MDEP Biological Monitoring Program staff and synoptic biographical information. Activities directed to development of bioassessment approaches for lakes and estuaries are performed by staff in the Department's Lakes Program and the Marine Program, respectively.

Numeric Aquatic Life Criteria Development and Program Implementation Costs:
Total staff resources expended, by the Department, to develop narrative and numeric aquatic life criteria was 13.5 full-time equivalents at a total cost of about $600,000, expended over about seven years. Federal grants targeted to water quality planning and standards allowed the Program to contract significant work products, including programming of database management software and multivariate statistical analysis. Contractual services costs for criteria development total approximately $57,000 over the same time period. These services include sample taxonomic work-up, software development and statistical analysis.

Annual Monitoring and Program Maintenance Costs:
The river and stream Biomonitoring Program is currently maintained with two full-time equivalent professional staff and 0.25 full-time equivalent summer intern staff. Collaboration with the Division of Watershed Management provides some additional staffing support. A third river and stream biologist will be added to the staff in 2000. Equipment expenses average $500 to $800 per year. Sample sorting and taxonomic work-up costs about $30,000 for 50 river and stream stations (three samples per station), and an additional $5,000-6,000 for 20 wetland stations. Taxonomic work-up is currently contracted to freshwater invertebrate taxonomist, Michael Winnell, of Petoskey Michigan and to Rhonda Mendel and Bruce Grantham of LOTIC, Inc. in Unity, Maine. Mr. Winnell has identified about 80% of samples over the past 12 years. Quality assurance activities have confirmed the precision and accuracy of the taxonomic services used in the Program. The high level of skill and professionalism of these taxonomists ensures the consistency and accuracy of the taxonomic record in the Biological Monitoring Program database.

USE AND APPLICATIONS

Water Quality Classification

The Department is required to report to the Maine State Legislature on the water quality attainment status of the classified waters of the State and to make recommendations for changes to the legal classification of waters of the State. As established in Maine statute, a classification consists of designated uses (such as swimming or habitat for aquatic life) and criteria (such as for bacteria, dissolved oxygen and aquatic life) which specify levels of water quality necessary to maintain the designated uses. A waterbody must meet the criteria of all three standards to be in attainment of its designated class.

Results of the analysis of biological data provide a determination of whether or not applicable aquatic life standards (Tables 1 and 2) 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. For a complete description of the development of numeric aquatic life criteria (the statistical model) supporting this law refer to Davies et al 1995.

Information about the condition of aquatic life is also useful in the context of numerous other activities and programs throughout the Department including monitoring and assessment; reporting; permitting, licensing and enforcement (Courtemanch 1995).

Monitoring and Assessment

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, habitat and hydrologic modification. The Biological Monitoring Program functions to provide monitoring and assessment data to various programs and initiatives, within the Department of Environmental Protection, that are involved in the regulation of these activities. Table 4 presents the relative magnitude of potential impacts to surface water quality in the state.

Table 4. Relative magnitude of potential human impacts to inland waters of Maine

Total State Area=19.8 million acres

Point Sources	**Daily Discharge Volume**
Pulp and paper	350 million gallons/day (MGD)
Publicly owned sewage treatment works (POTW)	190 MGD *(Note: may include significant industrial wastes)*
Combined sewer overflows	8.2 MGD avg. (more than 3 billion gallons total annual volume)
Food processors	4 MGD
Textiles	3 MGD
Non-Point Sources	**Areal Extent**
Timber Harvesting	
commercial timberland	16.9 million acres or 85% of State
acres harvested in 1996	473,000 acres or 2.4%
Agriculture	1.3 million acres or 7% of State
Urbanization	300 site location of development permits per year
In-place (toxic) Contamination	**Number**
Number of water supplies contaminated by leaking petroleum storage tanks	280 (approximate)
Known uncontrolled hazardous waste sites	40-50 (approximate)
Habitat and Hydrologic Modification	**Number of Permits**
Hydroelectric power	104 FERC-licensed storage and generating dams
Water level control	679 licensed dams to regulate water levels
Stream alterations	414 permits for stream alteration or crossing issued by DEP in 1996

Targeted assessments of the impacts of these activities occur as needed, but in general, the Department follows a five-year, rotating basin assessment schedule (Table 5). Currently, the Biomonitoring Unit and non-point source assessment program have 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 discharger performance or potential enforcement action, re-licensing information needs, concerns about land use practices in the basin, and specific requests from interested stakeholders. Since 1994 the Surface Water and Ambient Toxics program has provided a legislative mandate, funded at approximately ½ million dollars per year, to support a major assessment initiative to identify impacts of toxic substances on Maine's waters, as described below.

Table 5. Every five year rotating basin assessment schedule

Major Basins	Assessment Schedule
Androscoggin	1998; 2003
Kennebec and Mid-Coast	1997; 2002
Penobscot, St. Croix and Downeast Coast	1996; 2001
Piscataqua, Saco and Southern Coast	1995; 2000
St. John; Presumpscot	1994; 1999

Surface Water Ambient Toxics Program (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 Surface Water Ambient Toxics Monitoring Program was established to fulfill that need. A five year work plan was developed jointly by Department staff and an independent Technical Advisory Group established by the Legislature to comprehensively monitor the State's rivers, lakes and coastal waters (MDEP, 1993a,b). Results from the first two years have been reported to the Legislature (MDEP, 1996b; 1997).

The program uses techniques including fish and shellfish tissue analysis, sediment analysis, and biomonitoring to evaluate possible health effects on humans and wildlife. The Biomonitoring component measures direct toxic effects on aquatic communities using methods developed by the Biomonitoring Program.

Reporting

The *State of Maine 1996 Water Quality Assessment* is a report required by Congress under Section 305(b) of the Federal Water Pollution Control 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. Biomonitoring 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 due to aquatic life concerns.

Permitting, Licensing and Compliance Activities

The Biomonitoring Program provides technical review and assistance for Department permitting activities including issuance of wastewater discharge licenses, issuance of 401 Water Quality certificates for hydroelectric project relicensing, technical review of active or potential enforcement cases and management of sites contaminated by hazardous substances. The program also reviews projects referred for evaluation of violations of land-use regulations.

Wastewater Discharge Licensing:

Major and minor wastewater discharge licenses are reviewed and reissued at least every five years. The Department has initiated a watershed-based approach, following the rotation shown in Table 5, with licenses due to be issued the year following assessment.

The Biomonitoring Unit consults with licensing staff in order to establish priorities for sampling within the target basin and provides results of assessment activities. In cases where aquatic life standards are not attained, Biomonitoring staff may work with the licensing staff and the discharger to establish a plan for remediation of the problem and an ongoing monitoring plan (See Case Study 11: Biocriteria as a TMDL modeling endpoint, Presumpscot River).

Hydroelectric Project Licensing:

The Biomonitoring Program plays a significant role in the process of certifying and re-licensing hydroelectric power projects by submitting formal requests for necessary studies, reviewing study plans and results, and evaluating whether or not aquatic life standards can be attained under any proposed changes to the operating regime. Maine's waters are constrained by over 1500 dams with 783 currently licensed by the state or federal government for the purposes of water level control or hydroelectric power generation. Of these, the Federal Energy Regulatory Commission (FERC) has jurisdiction to license 104 dams for hydroelectric power generation or for storage capacity. An additional 31 dams generate power but are exempt from FERC licensing for various reasons. The balance of the flow regulation dams must be registered with the Department but are not subject to extensive environmental review. Because FERC projects are generally licensed for a thirty to fifty year term, and they may have substantial environmental and social consequences, they are subject to an exhaustive review process.

From start to finish, re-licensing activities often span three to five years. Two field seasons of on-site data collection are customary for average projects. Additional years of assessment may be required for problematic projects. The MDEP Bureau of Land and Water Quality is required to certify whether or not a project, due for re-licensing, will meet water quality standards under the proposed operating regime. The Department’s water quality engineering staff focuses on attainment of dissolved oxygen standards under existing and proposed operations as well as minimum flow issues downstream of the dam. The Department’s biological staff evaluates attainment of aquatic life standards. MDEP technical staff rely on several existing policy guidance’s when making minimum flow recommendations. These include:

- the aquatic base flow policy (ABF) of 0.5 cfs per square mile of drainage area from the U.S. Fish and Wildlife Service (Larsen 1981);
- an adaptation of an MDEP "zone of passage" regulation (MDEP Water Quality Regulation Chapter 581) recommending that 75% of the cross-sectional area remain wetted (3/4 wetted policy); and
- a U.S. FWS policy recommending that the ratio of maximum generation flow to base flow be not greater than 10 to 1 (Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986).

Project specific minimum flow recommendations generally are the greater of the two flows determined for ABF and the ¾ wetted policy. ABF is generally considered to be protective of fishery and other aquatic life requirements while the ¾ wetted policy considers habitat quantity.

Benton Falls Dam, Sebasticook River, Benton , Maine

BIOLOGICAL EFFECTS OF HYDROPOWER IMPOUNDMENT

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 MDEP had gained from evaluating the effects of point source discharges on aquatic communities. However, the standards were written robustly, to provide a broad 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 standards, waters both within and downstream of impoundments often appear to attain water quality standards in the majority of situations, 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, as described in the following section.

Dams, in general, affect upstream and downstream benthic macroinvertebrate communities differently. Impoundments used for hydroelectric power generation show the most impairment, correlated with the amount of flow regulation associated with the facility. Upstream waste discharges and other sources of contamination can compound the effects of water impoundment. Dams on rivers 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 are also dramatically altered, with the degree of the alteration determined by specifics of the shape of the impoundment and the operating regime of the hydro-electric project. In effect, the ponded area assumes some of the characteristics of a lake, but typically the ponded water volume has a much shorter retention time, as compared to a natural lake. Thus the riverine biological community is subjected to quasi-lake conditions for which they are not adapted. Lake-dwelling organisms generally, also find run-of-river impoundment conditions unfavorable. The short retention time precludes the possibility of the development of a planktonic community, the typical food base of lakes. High flow volumes in spring and fall, experienced by the river are also reflected in riverine impoundments, frequently causing scouring of accumulated organic matter on the substrate, and partially restoring the riverine, mineral-based substrate. This constitutes a periodic disturbance of benthic habitat for typical lake-dwelling organisms, resulting in lower production. Biological assessment of impounded benthic communities reveals that the detrimental effects of these unnatural conditions usually results in severe loss of both community structure and function. This is detected in biological metrics as reduced sample abundance and richness, increased Hilsenhoff Biotic Index values (due to loss of sensitive taxa), increased relative Diptera abundance, increased numbers of non-insects and reductions in filter feeding groups. These findings are indicative of the intolerance of lotic-adapted communities to the effects of reduced water velocities and indicate a shift in community function toward a food base of settled organic matter.

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 and are dominated by filter-feeding invertebrates such as Hydropsychid caddisflies. However, variable or extreme dam release flows, such as those occurring at peaking-power projects, negatively affect downstream riverine communities when they are unable to adapt to the artificial flow regime and unstable habitat conditions. Predominant effects include disturbance of expected production of filter-feeding organisms (Hydropsychid caddisflies; black flies, etc.); stranding or dessication due to periodic reduced flows; displacement at high flows; and reduced water quality from the impounded water source

Operation of peaking hydro-electric projects may cause a change in the discharge volume by orders of magnitude within a twenty-four hour cycle. In store and release projects the effect may be spread out over a seasonal or annual time scale but still results in an unstable habitat, poorly synchronized to natural life-history demands of native riverine organisms. Nehring and Anderson consider a peak flow of about five times a good aquatic base flow to be acceptable for salmonid survival and production. High to low flow ratios greater than 10 have been found to result in detrimental impacts to fishery resources (Nehring and Anderson 1982, 1983). Comparable results have been observed downstream of Maine peaking projects, with detrimental effects documented when the daily maximum ratio is greater than 10 to 1.

Since 1986, several changes have occurred to account for some of the observed biological effects of these impounded waters. The sampling protocol allows for a 56 day colonization period in the impounded waters, recognizing that colonization may be retarded in these slower, deeper waters. Biological monitoring is only used in impoundments with hard bottom, eroded substrates applicable to the models' design (Davies et al 1995; Davies and Tsomides 1997). The Legislature also modified the biological standards to require, as a minimum, that waters behind riverine impoundments only have to meet the biological standards of Class C (maintain structure and function, protect indigenous fish species) regardless of the statutory water classification they are assigned, and that downstream waters below certain specified generation stations only need to meet the Class C standards. While these changes ruled out some of the non-attainment findings, a number of impounded waters still do not attain the revised standards, pointing out the profound effects that these impoundments have on the resident aquatic communities (*see Table 3*). This has led the MDEP to require changes in the operating regimes of these facilities as part of water quality certification for re-licensing. Recommendations have included changes in the base flows maintained to provide adequate aquatic habitat, limitations on maximum flows to prevent excessive flow alteration, ramping of flows to prevent washout of organisms, and discharge from selected depths in the impoundment. In some cases, reductions in wasteloads to the impoundment are also required to attain minimum aquatic life standards. See Case Study 11 *Biocriteria as a TMDL*

Modeling Endpoint Presumpscot River, for a further discussion of how biological criteria can be used to assess water quality conditions and can be directly used to make recommendations for problem abatement.

The unprecedented breaching of the Edwards Dam on the Kennebec River in Augusta, Maine on July 1, 1999 came about because, for the first time ever, the U.S. Federal Energy Regulatory Commission (FERC) denied the renewal of a license for an operating hydroelectric dam. The FERC ruled that environmental harm caused by the dam, including blockage of anadromous fish passage and detrimental impacts to benthic communities, far outweighed the energy and economic benefits of the dam. The Biomonitoring Program is participating in a two year National Science Foundation grant, with Dr. James Thorp of Clarkson University, to study the effects of dam removal on productivity and energy pathways in the former impoundment, as well as to study resulting changes in benthic community structure. Field observations of samples collected in the former impoundment, within two months following removal of the Edwards dam, already have confirmed the expected but still stunning re-colonization of the river by aquatic organisms that have been absent for 160 years. Information from this study will contribute to the Department's knowledge base and decision-making ability when faced with future proposals to pursue a dam removal option for other projects.

Table 3. Waters not attaining biological standards affected by hydropower impoundments.

Basin	**Segment**	**Statutory Class**	**Recommended changes**
St. John	Squa Pan Stream	A	Minimum/maximum flows, lower water classification
Kennebec	Moxie Stream	AA	Minimum flows
	Dead R below Flagstaff L.	AA	Minimum/maximum flows
	Kennebec R at Bingham	A	Minimum/maximum flows
	Norridgewock impoundment	B	To be determined
	Edwards impoundment	C	Dam removal, raise water classification
	Cobbossee Stream	B	Minimum flows
Androscoggin	Jay impoundment	C	Minimum flows, wasteload reductions
	Otis impoundment	C	Minimum flows, wasteload reductions
	Livermore impoundment	C	Minimum flows, wasteload reductions

Basin	Segment	Statutory Class	Recommended changes
Presumpscot	Cumberland Hills impoundment	B	To be determined
	Smelt Hill impoundment	C	Minimum flows, wasteload reductions, dam removal
Saco	Saco River below West Buxton	A	Minimum flows
	Saco River below Skelton	A	Minimum flows
Salmon Falls	Salmon Falls River	B	Run-of-river flows, wasteload reductions, lower water classification

DATA COLLECTION AND ANALYSIS

Benthic macroinvertebrate data for streams and rivers are collected at two levels of rigor, using two collection protocols. The primary protocol is termed Classification Attainment Evaluation and involves a highly standardized, quantitative methodology. The second is the Non-Point Source Screening Tool, which is rapid and largely qualitative.

Classification Attainment Evaluation

Data Collection Methods

The Biological Monitoring Program uses standardized rock-filled wire baskets, mesh bags or cones (Figures 6, 7 and 8) to sample the benthic macroinvertebrate community to determine whether or not aquatic life standards are attained in a river or stream reach. The three sampling devices have been designed to cover the full range of water depths encountered in the flowing waters of the state. Rock-filled mesh bags are used in small streams and allow standardized sampling access to sites as little as 5 cm in depth. They can be flattened to fit the contours of the stream bed and have been shown to yield results indistinguishable from the standard rock basket method, when deployed in the same location. Rock-filled baskets are used for the majority of wadeable sites in the state. They are described in USEPA 1973 and have been widely applied across the country. The Program's remote-retrievable rock-filled cone sampler provides an extension of the State's standardized sampling unit to non-wadeable rivers (Courtemanch 1984). The device is retrieved by boat using a weighted, funnel-shaped closing apparatus that is dropped down a line to settle over the cone (Figs. 8-9). The base of the cone is fitted with Nytex mesh to prevent loss of organisms on retrieval. The cone device has been shown to provide comparable results to the rock-basket methods, as well. All sampler types are customarily placed on the stream bottom for four weeks, though a eight week colonization period is sometimes used in impoundments. These samplers provide a fresh, standardized habitat of stream cobble, and resident and drifting organisms readily colonize them. The sampling season is restricted to July through September to assess the community during times of maximal stress due to high temperatures, low dissolved oxygen concentrations and low flows.

On retrieval, biologists collect and preserve all accumulated material from the samplers and identify the sample of organisms to the lowest level possible (usually genus or species). Davies and Tsomides (1997) provide a detailed account of field methods used by the Biological Monitoring Program.

The Department has collected aquatic life samples from upstream and downstream of all major licensed wastewater discharges in the state, from waters downstream of hydroelectric facilities, and from a number of non-point source impacted waters. The database also includes a large number of relatively undisturbed and unpolluted waterbodies. These sampling locations represent a wide range of water quality conditions in Maine. Samples taken from upstream of a source of pollution establish expected biological conditions in the absence of the pollution source. The pollution-impacted locations are selected to represent the presumed "worst-case" conditions, after mixing, and recovery zones of the rivers and streams sampled.

Fig. 6. Rock-filled baskets

Fig. 7. Rock-filled riffle bag for sampling streams less than 10 cm deep

Figs. 8-9. **Remote-retrievable rock-filled cone and retrieval funnel for sampling non-wadeable rivers**

Data Analysis Methods:

Experience examining changes in the makeup of benthic macroinvertebrate communities, across a range of water quality conditions, convinced Department biologists that these changes are predictable and quantifiable. The specific language describing the aquatic life characteristics of the four water quality classes (AA, A, B, C), in the Water Classification law, is an outgrowth of this experience (Table 1). The law actually contains only three separate, allowable aquatic life standards because the narrative standard, “as naturally occurs”, applies to both Class AA and Class A. Communities with very poor aquatic life characteristics comprise a fourth observable aquatic life group that represents non-attainment of minimum standards. These four *a priori* groups served as the basis for developing the predictive models (linear discriminant functions) currently in use by the Biomonitoring Program.

Extensive multivariate statistical analysis of statewide biomonitoring data confirmed that the four groups observed by the biologists and described in the narrative standards are, in fact, statistically distinct groups. Statistical analysis directed the selection of the 25 most significant variables contributing to group definition. A list of the variables used in the models appears in Appendix 1 and a complete account of the development of the linear discriminant functions may be found in Davies et al (1995).

Quality Assurance:

Much attention has been given to data quality assurance and quality control including:

- minimum qualifications for field and laboratory personnel;
- standardized, documented field collection procedures, performed under the direct supervision of a senior biologist;
- whole sample work-up, with a standardized level of effort for all field collections and sub-sampling procedures; (Courtemanch 1996)
- supervised sample sorting in the laboratory, with a proportion re-sorted by another person to determine sorting efficiency;

- consistent taxonomic work-up (over 80 percent of samples identified by the same taxonomist), with identifications to species whenever possible.

Data quality is assured by rigorous data entry and data editing protocols during transfer of raw data to the computerized database management system. Taxonomic records are entered using a bar code reader to ensure accurate transfer of taxonomic codes. All data is proofed by an MDEP senior biologist prior to final acceptance into the permanent database.

A relational database (FOXPRO) stores the taxonomic code table and all sampling event data, computes analytical variables, and computes and reports results of the linear discriminant models. An example report of the data output produced by the Biomonitoring Program, termed the Aquatic Life Classification Attainment Report, is provided in Appendix 2. Plans are underway to migrate data management and reporting functions to a more current database system such as Oracle and to manage data in combination with an integrated spatial data analysis platform in ArcInfo.

Non-Point Source Screening Tool:

Data Collection Methods

The non-point source screening tool has been developed as a cooperative effort between two divisions of the Bureau of Land and Water Quality: the Division of Environmental Assessment and the Division of Watershed Management. This tool is designed, primarily, to discover and prioritize non-point source impacts. A more complete discussion of the approach, and case studies, are presented in Part I Chapter 2.

Assessments for waters with a high potential to be impacted by non-point sources are conducted at a regional or statewide scale. Initially, waters at high risk of impact are listed. Information derived from percent watershed impervious surfaces and the Watershed Pollution Potential Index (WPPI) method will provide a regional scale screening tool (see Part I Ch. 2 *Biological Assessment of Non-point Source Impacts*). Anecdotal observations of stream and watershed conditions reported or collected by DEP, other state or federal agencies, or the general public, is another important source of information to identify waters of high potential risk.

Streams from this list, which are identified as high risk, are sampled using a rapid, qualitative method. This screening tool is a modification of North Carolina's standard bioassessment technique (Lenat 1988). It is comprised of a 1 meter square kick, a one minute sweep (bank area), a leaf pack sample, and a collection made by visual inspection. These samples are sorted in the field for all the different types of organisms (Richness). They are preserved and identified in the lab to the lowest level possible. In addition, 2 one square foot kick samples (1 minute each) are taken and all organisms are preserved and identified in the lab. A habitat assessment of the stream reach is completed when the samples are collected.

Data Analysis Methods:
The biological information is reviewed and stations of concern are referred for evaluation by the standard, more rigorous protocol termed Classification Attainment Evaluation, which requires quantitative data for use in the multivariate statistical model.

Note: The non-point source screening tool is relatively new (first used in Spring of 1996) and the selected method or methods may be modified, depending on the specific type of non-point source impact, the degree of resolution a specific method may offer, and for what purpose the biological information is being collected.

Geographic Information System
A Geographic Information System (GIS) is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e., data identified according to their locations. A GIS makes it possible to link or integrate information that is difficult to associate through any other means. It can use combinations of mapped variables to build and analyze new variables.

With a GIS one can "point" at a location, object, or area on the screen and retrieve recorded information about it from off-screen files. This type of analytical function in a GIS helps one to 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 on the screen or on paper that convey the results of analyses, helping viewers to understand the results of analyses or simulations of potential events. Each basin described in this report contains such a mapped graphic (Basin Maps Section) . The Biological Monitoring Program has mapped 362 sampling stations in ArcView 3.0 with links to data from 525 sampling events. ArcView shape files have been created for each 8 digit United States Geological Survey Hydrologic Unit Code river basin, with some basins combined for presentation purposes. Additional GIS data coverages used in this report include major dams, municipal and industrial discharges, town polygons, 100k hydrography and legal classifications of rivers and streams. A description of data sources for coverages used in this report precedes the Basin Maps on p. 160. As noted above, future Program directions include expanding spatial data analysis and management capabilities by creating real-time linkages between the relational and the spatial databases.