PREFACE

The major focus of this report is a summary of results from fifteen years of monitoring of rivers and streams with the standard MDEP Biological Monitoring Program sampling and analytical methods. However, other related biological monitoring initiatives are underway in the State, to assess other waterbody types and to refine methods to better address specific categories of biological impact. The opening section of this chapter discusses efforts by the Biological Monitoring Program and the Division of Watershed Management to refine and focus existing biological assessment methods, and to develop new methods, to evaluate impacts of non-point sources on small streams. The remaining three sections examine initiatives that are underway or planned, to apply biological monitoring approaches to other waterbody types, including wetlands, lakes, and near-shore estuarine ecosystems.

Limited biological sampling of the benthic macroinvertebrate community using the multi-habitat screening tool method and the standard rock bags has shown that stations located in urbanized or highly disturbed watersheds are often significantly impacted. Classification attainment of aquatic life and percent watershed imperviousness appear to be related.

Biological Assessments of Nonpoint Source Impacts on Streams

Introduction and Background

Over the last fifteen years water quality monitoring of rivers and streams has focused on those waterbodies impacted by point source discharge, primarily the larger streams and rivers. Recently, biological monitoring has expanded to include streams impacted by nonpoint source (NPS) pollution, through a joint effort of the Biomonitoring program and Division of Watershed Management's Watershed Assessment unit and under the Surface Water Ambient Toxics (SWAT) program which was initiated in 1994. The focus of the nonpoint source effort is the smaller and lower order waterbodies or those waterbodies where nonpoint sources predominate as the cause of water quality threat or impairment.

Nonpoint source pollution is defined as pollution that originates from diffuse sources as opposed to a single discharge. Land use activities due to development (urbanization), agriculture, forestry activities, transportation and mining, as well as atmospheric deposition all may cause nonpoint source pollution. Effects occur due to changes in watershed hydrology in addition to increased concentration of pollutants in the runoff and resultant ecosystem and habitat effects. The specific effects from land use activities are dependent on the types and extent of land use occurring in the watershed. Development associated with urbanization is the greatest threat to water quality, since it accounts for the greatest land use and continues to increase, as opposed to other land uses that may be stable or declining. It is also typically an irreversible type of land use change. As a watershed is cleared and impervious surface area increases, there are resultant hydrological changes. The amount of stormwater runoff increases in direct proportion to the amount of watershed imperviousness and there is a greater amount of the stream flow from surface runoff rather than from base flow or groundwater. The results are higher and more frequent high flow events and lower flow or no flow during dry weather conditions. Higher flows and rate of flow result in an increase in bank erosion and channel scouring. As a result of hydrologic changes, the geometry of the stream changes (becoming wider and shallower) and sediment loading from bank erosion and watershed sources increases. In addition, the concentration of pollutants in the runoff increases. Pollutants of concern include nutrients, bacteria, toxics, suspended materials, and organic loading. Temperature effects may also be present due to both runoff and loss of riparian vegetation.

Thus, aquatic resources may be under stress posed by a multitude of practices within a watershed. Changes in the instream biological community can result from these types of stressors . The biological community provides an ideal response indicator serving as a measure of endpoint response pertinent to water quality goals and it can be used as a measure of Maine's program effectiveness.

Purpose

Biological monitoring and habitat assessment of NPS impacted streams is being used to accelerate Maine's NPS management base program by efficiently identifying waters that are threatened or impaired by NPS pollution and will contribute resource information to facilitate prioritization of water resources. Biological monitoring and habitat assessment techniques also are used as tools to evaluate the effectiveness of pollution control actions that are implemented to restore or improve water quality or stream habitat.

The assessment of NPS impacts on streams uses a three level approach. The first level is a regional screening by river basin using information derived from percent watershed imperviousness and the Watershed Pollution Potential Index (WPPI). This WPPI model relies on the assumption that the relative level of nonpoint impact is a function of watershed disturbance and sensitivity. A watershed disturbance factor is determined from population, road, and land cover data layers and a watershed sensitivity factor developed using soil and slope information. The intent of the level one screening is to provide a ranking of streams based on potential impact of nonpoint source.

Level two assessment is a rapid bioassessment field screening of waterbodies identified by percent watershed imperviousness and the WPPI as being impacted by nonpoint source. This bioassessment screening tool is currently being developed and modified. The intent is to identify streams that have a high likelihood of biological impact as a result of nonpoint source pollution. The Level II biological assessment method under development is a modification of the multi-habitat method developed by Lenat (1988) and Eaton and Lenat (1991). A standardized qualitative collection includes one square meter kick sample, one sweep sample, one leaf-pack sample, and a visual collection. These samples are picked in the field and composited. Two quantitative one square foot kick samples are also taken and picked in the lab . All organisms are identified to genus where possible. In addition to biological monitoring, field assessment includes physical description of the stream and visual assessment of channel, streambank and corridor conditions. A habitat assessment using Barbour and Stribling-Visual Based Habitat Assessment is also completed. (Barbour and Stribling 1991). The screening tool has generally been used to evaluate streams in the fall. Streams identified as having probable impacted reaches are referred to a level three evaluation, described below.

The third level of assessment is the biological monitoring program's Classification Attainment Evaluation which uses rock-filled bags (Fig. 7) to sample the benthic macroinvertebrate community to determine whether or not aquatic life standards are attained in a river or stream reach. The standard protocols to determine classification attainment are described in Part I, Chapter 1 and in Davies and Tsomides (1997).

Priority Waterbodies

Under the Comprehensive Watershed Protection Program (5 MRSA § 3331 (7)), the Maine Land and Water Resources Council is directed to establish a priority waterbody list. The intent of the list is to establish priorities for directing resources to the management of waterbodies based on the degree of threat or impairment to water quality and aquatic habitat that exists due to nonpoint source pollution; the value of the waterbody; the likelihood of successfully restoring or protecting water quality; and the degree of local public support for watershed management. In October 1998, the Maine Land and Water Resources Council approved a list of priority watersheds including 55 river and stream watersheds. This list will be reviewed annually by the Maine Watershed Management Committee and recommendations made to the Council to revise the list. Additional stream monitoring results obtained from the monitoring program may be used as a source of information to the Committee on the degree of threat or impairment to water quality and aquatic habitat.

The priority watersheds list is used to direct resources toward these priority areas. Resources may be technical assistance (i.e. assistance with watershed surveys, management plans) and/or financial assistance to develop a watershed management plan. Along with this, the Nonpoint Source Program administers the grants program that provides assistance for a variety of projects including watershed surveys, management plans, nonpoint source implementation and restoration projects and implementation of management plans.

NPS Biomonitoring Activities

Since 1996, a total of 62 stations on 42 first to fourth order streams have been monitored for nonpoint source impacts or established as reference stations using rock bag substrates. These bags have enabled the program to sample smaller streams while utilizing the quantitative methods established for the standard rock basket or cone samplers. In addition, the multi-habitat screening tool, which is currently being developed, has been used on over one-third of the established 62 stations.

In the past three years, the major sampling efforts have been concentrated in the Presumpscot, Lower Penobscot, and the Lower Androscoggin river basins. These three basins account for 43 of the 62 established NPS stations. Of the 15 stations sampled in the Presumpscot River basin, and the 13 stations established in the Lower Penobscot River basin, 6 stations in each basin are not meeting the standards of their assigned aquatic life classification. Evaluation is not yet complete for the 15 stations sampled on the Lower Androscoggin River basin in 1998. Non-attaining stations in the Presumpscot and Lower Androscoggin basins have been listed on Maine's Section 303(d) Waters (1998) list. Section 303(d) of the Clean Water Act requires the State of Maine to identify waterbody segments that do not attain water quality standards or are imminently threatened, and are not expected to meet state water quality standards even after the implementation of technology-based controls for both point sources and non-point sources of pollution.

Limited biological sampling of the benthic macroinvertebrate community using the multi-habitat screening tool method and the standard rock bags has shown that stations located in urbanized or highly disturbed watersheds are often significantly impacted. Classification attainment of aquatic life and percent watershed imperviousness appear to be related. In general, small streams in urban areas support biological communities low in generic richness and are depleted of pollution-sensitive insects. Typically, the benthic macroinvertebrate communities in these streams consist of highly tolerant non-insect taxa such as leeches, amphipods, worms and mollusks. More sampling is needed in the lower order urban waterbodies, for these aquatic resources have less assimilative capacity and are subjected to a multitude of stressors.

CASE STUDY 1

Urban Nonpoint Source Impacts: Classification Attainment and Percent Watershed Imperviousness

Biological monitoring of the benthic macroinvertebrate community in urbanized watersheds has revealed severe degradation in the lower order streams. Streams with greater than 10% impervious cover appear to be the most affected. These results are comparable to Maxted (1996) where a threshold detrimental effect appeared to exist once the watershed reached 10-15% impervious cover.

Jeff Dennis, of the Division of Watershed Management, has been directing efforts to estimate imperviousness for urbanized watersheds in Maine. As part of a graduate study project by Chandler Morse and Dr. Alexander Huryn, at the University of Maine, the imperviousness of seventeen stream watersheds was measured using detailed analysis of current, large format aerial photos with considerable ground-truthing in residential areas. Three of the streams monitored by MDEP for benthic macroinvertebrates, Long Creek, Kimball Brook, and Trout Brook, were included in this set. The imperviousness for many of the other monitored watersheds was estimated, by Jeff Dennis, using a linear regression of the imperviousness of seventeen watersheds, with the density of urban land use for those watersheds indicated by the watershed land cover extractions developed for the Watershed Pollution Potential Index (WPPI). The algorithm derived by that regression was used to predict the imperviousness of the Little River, Royal River, Pleasant River, Frost Gully, Collyer Brook, Cold Spring Brook, Johnson Brook, Clark Brook, Farm Brook, Tannery Brook, and Beaver Dam Brook watersheds. Since the urban land cover classification of the LANDSAT image was only valid for western Maine, the remaining streams in the Bangor, Exeter, and T5R9 NWP were roughly estimated from 7.5 minute USGS Quadrangles.

Biological information from 27 streams was evaluated in relation to watershed imperviousness. Nineteen streams were sampled using rock bag artificial substrates and the benthic macroinvertebrate data were run through the Biological Monitoring Program's linear discriminant models to predict aquatic life attainment. The other 8 streams were sampled using the multi-habitat method. Best Professional Judgement (BPJ) was used to assign aquatic life classification attainment for multi-habitat samples. Eight of the eleven streams with estimated imperviousness of 10% or greater did not meet the State minimum aquatic life standards while the other three streams only met the Class C aquatic life standards. All streams with estimated imperviousness of less than 3% met the Class A aquatic life standards (Table 6). Further work must be done on these streams with highly disturbed watersheds, for it is clear that the habitat degradation and the resulting hydrological changes, as well as an increase in pollutants to the waterbody are causing significant loss of sensitive taxa and a change in the resident biological community causing loss of structure and function.

Table 6 Relationship between watershed imperviousness and aquatic life classification determinations from biomonitoring of some urban streams in Maine

Stream	Town	% Impervious	Class	Model	BPJ
Stinking Brook	T5R9 NWP	<3	A	x	
Footman Stream	Exeter	<3	A	x	
Babel Brook	T5R9 NWP	<3	A	x	
Ashworth Brook	T5R9 NWP	<3	A	x	
Allen Stream	Exeter	<3	A	x	
French Stream	Exeter	<3	C	x	
Little River	Gorham	5	A	x	
Royal River	New Gloucester	5	B	x	
Pleasant River	Windham	7	A	x	
Frost Gully (above)	Freeport	7	A	x	
Collyer Brook (above)	Gray	7	A	x	
Kimball Brook	S. Portland	7	NA	x	
Cold Spring Brook	Gorham	8	B		x
Johnson Brook	Gorham	9	B		x
Frost Gully (below)	Freeport	9	B	x	
Collyer Brook (below)	Gray	9	B	x	
Meadow Brook	Bangor	10	NA	x	
Clark Brook	Westbrook	11	NA		x
Farm Brook	Gorham	12	C		x
Tannery Brook	Gorham	13	C		x
Trout Brook	S. Portland	13	NA	x	
Beaver Dam Brook	Westbrook	13	NA		x
Concord Gully	Freeport	14	C		x
"Valley Ave." Stream	Bangor	15	NA	x	
Long Creek	S. Portland	17	NA		x
"Pushaw" Stream	Bangor	20	NA	x	
"Ohio" Stream	Bangor	30	NA	x	

Biological Standards

A =aquatic life as naturally occurs
B = only non-detrimental changes in community composition allowed
C = change in community composition but structure and function maintained
NA = non-attainment, impaired, structure or function not maintained

CASE STUDY 2

***Urban Non-point Source Impacts: Capisic Brook above and below urban Portland, Maine*.**

Capisic Brook is a small first and second order stream which originates in a spring or wetland near Westbrook College in Portland. The control site, Station 256, is in a relatively undisturbed wooded area in the Evergreen Cemetary, in Portland, and is the upstream-most available sampling area. Reconnaissance upstream of the cemetary was impossible as it originates in a dense industrial/commercial area and is largely culverted or filled. The existence or extent of inputs of urban toxic substances to the control is unknown. From the cemetary the brook continues through an area of dense residential and industrial development and is subject to culverting and diversion throughout its length. The aesthetic appearance of the brook, as well as several key water quality parameters change dramatically between the control and the urbanized locations (Table 7). In particular, water temperature, conductivity, total phosphorus, and total dissolved solids reflect the impacts of industrialization and urbanization. Day-time dissolved oxygen is much higher at the downstream site due to greatly increased algal and macrophyte biomass, caused by nutrient enrichment. Although not measured, it can be assumed that there is a diurnal drop in dissolved oxygen overnight, due to algal respiration.

The upstream site, Sta. 256 meets Class C aquatic life standards. The benthic community is low in pollution-sensitive taxa from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) but they have been replaced by relatively sensitive organisms in the order Diptera. The Hilsenhoff Biotic Index is a measure of the contribution of pollution insensitive taxa to community make-up. The higher the value the more the biological community is considered to be affected by organic pollution. Figure 10 reveals the loss of sensitive organisms that has occurred from the upstream (Sta. 256) to the downstream location (Sta. 257). Figure 11 illustrates that while both sites have a low percentage of EPT, the percentage of pollution-tolerant non-insects in the community increases from 6% at the upstream site to 87% at the downstream site. These very tolerant non-insect organisms include worms, leeches, and amphipods. A combination of causes had probably contributed to the dramatic change in community composition. Non-point source runoff from residential and industrial areas, temperature elevation due to increased impervious surfaces and reduction in canopy cover, combined sewer overflows, and possible groundwater contamination along the urban setting of the stream are probably the major causes of impact. More sampling of these small urban streams is needed to elucidate the reasons for observed changes in community structure.

Figure 10 Box plots showing values of the Hilsenhoff Biotic Index for Capisic Brook above and below urbanized areas in Portland, Maine. Values are compared to the distribution of all values for all sampling events within a given class in the Maine DEP Biological Monitoring Program database.
(N=490 $N_{(A)}$=115 $N_{(B)}$=162 $N_{(C)}$=123 $N_{(Non\text{-}Attainment)}$=90)

Sta. 256 ***(511)***= above Portland Sta. 257 ***(512)***= below Portland

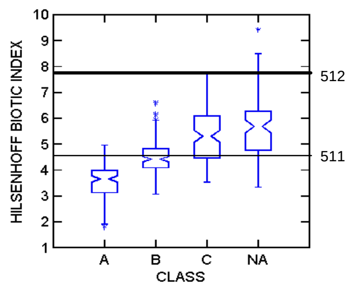
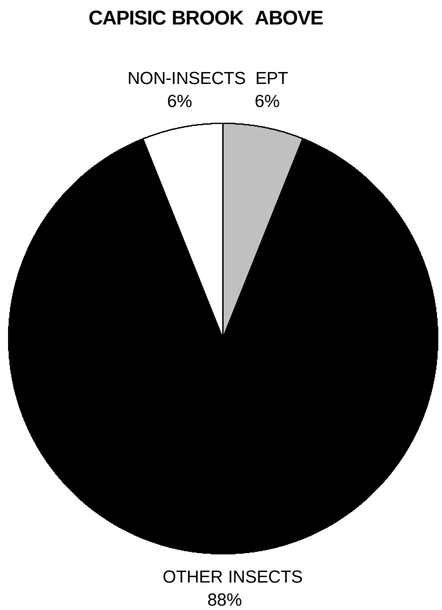


Figure 11 Comparison of differences in community structure in Capisic Brook above and below urbanized areas in Portland, Maine.



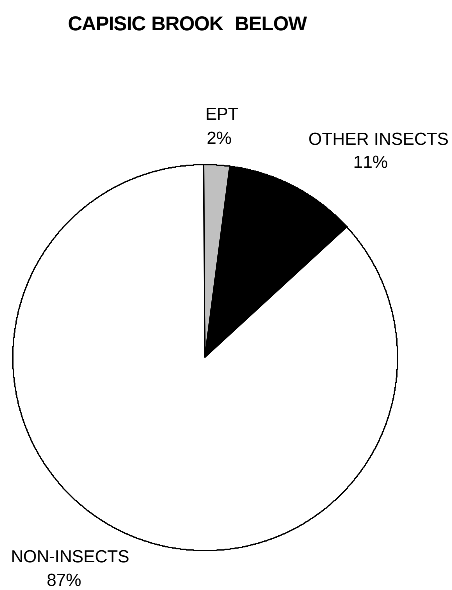


Table 7. Values for water chemistry parameters in Capisic Brook above and below Portland, Maine

Parameter	**Capisic Brook above Portland** August 24,1995	**Capisic Brook below Portland** August 24,1995
Temperature	14.5 C	**23 C**
Dissolved Oxygen	9.5 ppm	**14.6 ppm**
Conductivity	73 mmhos	**341 mmhos**
	ppm	**ppm**
Cadmium	ND .0003	ND .0003
Lead	ND .002	ND .002
Zinc	0.002	0.004
Total Phosphorus	0.022	**0.043**
Ammonia Nitrogen	NR	NR
Total Kjeldahl Nitrogen	K.1	0.4
Nitrate+ Nitrite-N	0.22	0.18
Total Dissolved Solids	46	**169**
Suspended Solids	2.5	1.6
Dissolved Organic Carbon	11	6
Gasoline	ND	ND
MTBE	ND	ND

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Biological assessment provides a direct, objective measure of wetland condition and can be used to evaluate impacts from human activities.

Biological Assessment of Freshwater Wetlands

Introduction and Background

In 1997, the Biological Assessment of Wetlands Workgroup (BAWWG) was established, to improve methods and programs to assess the biological integrity of wetlands. The group consists of wetland scientists from Federal and State agencies and universities, and is coordinated by the EPA Headquarters Office of Wetlands, Oceans and Watersheds in partnership with the EPA Office of Science and Technology, in Washington, D.C. Ongoing BAWWG topics include development of assessment methods, study design, data analysis techniques and wetland classification. BAWWG also provides a forum for peer review and collaborative projects. In 1998, a New England workgroup (NEBAWWG) was formed under the guidance of EPA New England in Boston to develop a regional wetland biomonitoring network, to sponsor and oversee regional state pilot projects, and to coordinate with and complement efforts of other biomonitoring groups. Maine DEP staff actively participate on both the EPA Headquarters and New England BAWWG workgroups.

The Need for Wetland Bioassessment

Until recently, State agencies in Maine have relied largely on functional assessments to evaluate wetlands for regulatory and planning purposes. This approach involves identifying wetland functions and values that are likely to exist based on maps, field indicators and best professional judgement. Wetland "functions" are characteristics or processes that are presumed to exist independent of their value to human society, such as flood storage, nutrient cycling, sediment and toxicant retention, groundwater recharge or discharge and wildlife habitat. Wetland "values" to society are also evaluated during this process, which may include recreation potential, educational value, historical significance and scenic/aesthetic quality. Two functional assessment methods commonly used in Maine are the "New Hampshire Method" (Ammann and Stone 1991), and the U.S. Army Corps of Engineers "Highway Methodology" (US Army Corps of Engineers 1995).

The New Hampshire Method was designed to provide basic information about wetland functions and values for planning, education and inventory purposes. It is useful for comparing a number of wetlands within a local study area, generally a town or watershed, but is not recommended for assessing individual wetlands, for impact analysis, or in legal proceedings. In the New Hampshire Method, 14 "functional values" are numerically scored from 0 to 1.0, then weighted based on wetland size. The method is open-ended, since functional values may be added or removed from the evaluation process. The Highway Methodology is a qualitative, descriptive approach designed to characterize wetlands for the Federal wetland permitting process. Evaluators use best professional judgement to determine which of 13 functions and values are exhibited, listing applicable "considerations and qualifiers" that serve as criteria for this determination. Functions and values are designated as "principal" if they comprise an important physical component of the wetland ecosystem, or are of special value to society. Similar to the New Hampshire Method, functions, values and supporting criteria used in a Highway Methodology assessment may be modified.

Functional assessment methods such as these are important tools for wetland planning and management, however they do not directly measure the ecological health of wetlands or the effects of human activities on wetland biota. Moreover, since functional assessment criteria are flexible and incorporate human value judgements, results are subjective and often highly variable depending on the evaluator and focus of the assessment. For many purposes, supplemental methods that employ a more rigorous scientific approach are needed. Biological assessment provides a direct, objective measure of wetland condition and can be used to evaluate impacts from human activities. The following are potential applications of wetland bioassessment that are not adequately addressed through functional assessment methods:

- Detecting ecological impairment for screening-level inventories, site-specific impact assessments and long-term trend analysis;
- Diagnosing physical, chemical and biological stressors, including toxics, nutrient enrichment, non-point source pollution, hydrologic changes, and introduced species;
- Evaluating the effectiveness of wetland protection activities;
- Developing performance standards for restoration and mitigation projects;
- Identifying ecological linkages among wetlands and other water bodies to refine water quality modeling;
- Developing and supporting wetland biocriteria and water quality standards; and

- Tracking wetland condition for the Maine Water Quality Assessment Report to Congress required under Section 305(b) of the Clean Water Act.

Wetland Biological Assessment Pilot Project

The Maine Department of Environmental Protection (MDEP) is currently developing methods to evaluate the biological integrity of freshwater wetlands. With support from EPA, the Biomonitoring Program has undertaken a pilot study in the Casco Bay watershed to develop biological sampling protocols, and to identify potential indicators (metrics) of wetland condition. The following are major objectives of the pilot project:

1. To develop biological sampling protocols for non-tidal wetlands

2. To measure wetland attributes across a gradient of human disturbance in a pilot watershed

3. To identify candidate metrics/indicators of biological integrity on a watershed basis

The pilot study area is located in southern Maine where development pressure and threats to wetlands are high, and therefore provides a good location to examine the effects of human activities. The Casco Bay watershed encompasses a wide range of wetland types and potential sources of wetland impact. The pilot project has focused on non-tidal wetlands having permanently or semi-permanently flooded water regimes. The project is designed to compliment other planning and assessment efforts in the watershed to produce a more comprehensive understanding of wetland ecosystems. Existing spatial data for this region were enhanced by the ongoing Casco Bay Estuary Project, and are much more complete than in other portions of the State. The availability of a well-developed Geographic Information System (GIS) has greatly aided the selection of wetlands for the biological assessment pilot study. A landscape-level wetland prioritization project for the watershed is also currently in progress. This effort is being led by the Maine State Planning Office, and will produce valuable wetland characterization data that may provide a means to focus future assessment activities.

<u>Methods</u>

Initial field work for the bioassessment pilot project began in August 1998. Wetlands were targeted on a watershed basis using existing GIS data, professional knowledge and field surveys to encompass a range of human disturbance, including potential reference (minimally-disturbed) sites. Study sites were confined to non-tidal wetlands having permanently or semi-permanently flooded water regimes.

During the first season, MDEP staff collected macroinvertebrates from 20 wetland sites (General Map 2). Two different sampling approaches were tested. The first was designed to produce a quantitative sample. In this method, a stovepipe sampler was used to enclose 3 replicate sample plots to restrict the movement of organisms. Water, vegetation and surface sediments were then agitated, and a standard volume of water was removed into a sieve bucket. Vegetation and detritus contained in the samples were retained. Samples were preserved in the field for later sorting and taxonomic analysis.

A qualitative, multihabitat sampling approach was also tested, with the goal of developing a screening level assessment tool. A D-frame net was used to sample all inundated microhabitats within the immediate vicinity of each site, including emergent vegetation, aquatic macrophyte beds, pools and channels. Organisms were “picked” or sorted from detritus in the field. One to several organisms representing each different taxon found were placed into a vial of alcohol until no “new” taxa were observed.

Algae and diatoms were sampled as part of a collaborative project undertaken by Dr. R. Jan Stevenson of Michigan State University. This project is supported through an EPA Headquarters Cooperative Agreement. Water samples for quantitative phytoplankton analysis were collected, in addition to qualitative sediment, epiphyte, macroalgae and multihabitat samples. In the multihabitat method, water, sediment, plant material, soil and woody debris from various microhabitats were composited and preserved in the field.

Physical/chemical parameters analyzed in water samples include nutrients, chlorophyll *a*, anions and cations, dissolved organic carbon, true color, alkalinity, pH, and acid neutralizing capacity. Sediments were analyzed for a suite of metals, total organic carbon and percent moisture. Habitat descriptions, dominant plant species, water temperature, dissolved oxygen and conductivity were recorded in the field.

Data from 1998 are currently being analyzed to identify wetland attributes that show predictable changes in response to human activities such as development. These attributes will later be tested on a broader geographic scale for potential use as biological metrics. During the summer of 1999, DEP collected additional wetland samples in the Casco Bay watershed and continued to refine protocols for macroinvertebrates and algae.

It is anticipated that the methods developed during the pilot project will support the creation of a statewide wetland bioassessment program consistent with the objectives of the Clean Water Act. Such a program would include development of biological criteria to assess and track the ecological health of wetlands, and to evaluate impacts from human activities. This information may then be applied to pollution control efforts, planning, restoration and reporting.

Regulatory Context

Wetlands are regulated by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency under Section 404 of the Clean Water Act, which pertains to dredge and fill activities, and also by the State of Maine under the Natural Resources Protection Act (NRPA). In 1995, changes were made to the state and federal regulatory programs in Maine to improve consistency and to streamline the permitting process. Applicants may now submit a single application form to MDEP to obtain both state and federal permits. In Maine's unorganized territories, which comprise approximately 52% of the State, the Maine Land Use Regulation Commission (LURC) is responsible for wetland regulation. MDEP and LURC technically have dual jurisdiction over wetlands in unorganized areas, however legislation has been introduced to shift responsibility entirely to LURC. Unlike other portions of the State where all wetlands are regulated, regulation in LURC jurisdiction is generally restricted to wetlands that appear on the National Wetlands Inventory maps and are at least 15,000 square feet in size.

In addition, Section 401 of the Clean Water Act requires applicants to obtain a certification or waiver from the appropriate state water pollution control agency for federally permitted or licensed activities that may result in a discharge to waters of the United States, including wetlands. The state agency may review the proposed project with respect to state water quality standards, and may grant or deny certification. States may also place conditions on water quality certification, or may waive their certification authority. In Maine, Section 401 certification is issued by MDEP concurrently with wetland alteration permits approved under the NRPA, although the State currently has no wetland-specific water quality standards. MDEP also evaluates potential wetland impacts during the review process for hydropower and National Pollutant Discharge Elimination System (NPDES) license applications. Since existing standards for surface waters do not reflect the range of natural conditions exhibited by wetlands, they are not adequate as a basis for water quality certification and licensing decisions. The development of wetland biocriteria would enhance the Department's ability to assess project impacts.

The current approach to wetland regulation differs from that used for other waters in that permitted activities such as draining and filling often result in significant ecological impairment or physical loss of the protected resource. For projects impacting large wetland areas or for those affecting wetlands of special significance, compensation for lost wetland functions is generally required. This may include restoration of previously altered wetlands, enhancement of existing functions and values, creation of new wetlands, or preservation of wetlands and/or adjacent upland sites that may be threatened by development. In 1997, the Maine Legislature authorized MDEP to implement wetland mitigation banking and to develop a compensation fee program in conjunction with the State Planning Office, subject to federal approval. Under this legislation, developers may obtain credits for compensation projects to offset future wetland impacts of up to 25 acres per year, or may pay a fee in lieu of compensation. The resulting fund will enable the State to undertake large scale compensation projects and target high priority sites on a watershed basis, however the quality of these projects will hinge on improved understanding of wetland ecology and development of better tools to monitor success. An excellent opportunity exists to apply biological monitoring in developing project goals and performance standards, and to refine restoration techniques and best management practices.

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Maine is home to almost 6000 lakes and ponds most of which became part of the landscape by glacial activity some 12,000 years ago. Fish wiers dating back 7000 years indicate that our lakes have been an integral part of the regional economy for a lot longer than most of us are aware.

Biological Assessment of Lakes

Introduction and Background

Maine is home to almost 6000 lakes and ponds most of which became part of the landscape by glacial activity some 12,000 years ago. Fish wiers dating back 7000 years indicate that our lakes have been an integral part of the regional economy for a lot longer than most of us are aware. Over the past century, Maine's lakes have provided a wide range of economic and recreational opportunities to residents and non-residents alike. Recent studies reveal that millions of dollars are received from our lake related tourist economy annually.

Maine's lakes tend to be quite diverse with no two lake ecosystems quite alike. They vary in size, depth, biota, position in the landscape and water quality. Maine's lake management program tends to focus on trophic aspects of water quality. The trophic status of a lake can be directly related to nutrient levels in the water column. Sources of nutrients include point source discharges, non-point sources and previously accumulated nutrients in lake sediments. Fortunately there are very few (4) known point source discharges to Maine lakes, and internal recycling of accumulated nutrients occurs in a low percentage of lakes (<5%). Thus, management of nutrient inputs is primarily a matter of management of non-point sources and stormwater runoff.

Legislative Considerations

The Maine Legislature has declared that it is the State's objective to restore and maintain the chemical, physical and biological integrity of the State's waters and to preserve certain pristine waters. To manage this objective in lakes, they have provided in the classification system (Table 8) that all Maine lakes are classified as Great Ponds-A (GPA) (Title 38 Section 465-A).

Table 8. The classification of Maine lakes, Title 38 Section 465-A

*1. **Class GPA waters**. Class GPA shall be the sole classification of great ponds and natural ponds and lakes less than 10 acres in size.*
A. Class GPA waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection, recreation in and on the water, fishing, industrial process and cooling water supply, hydroelectric power generation and navigation and as habitat for fish and other aquatic life. The habitat shall be characterized as natural.
B. Class GPA waters shall be described by their trophic state based on measures of the chlorophyll "a" content, Secchi disk transparency, total phosphorus content and other appropriate criteria. Class GPA waters shall have a stable or decreasing trophic state, subject only to natural fluctuations and shall be free of culturally induced algal blooms which impair their use and enjoyment. The number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 29 per 100 milliliters or an instantaneous level of 194 per 100 milliliters
C. There may be no new direct discharge of pollutants into Class GPA waters. Aquatic pesticide treatments or chemical treatments for the purpose of restoring water quality approved by the department are exempt from the no discharge provision. Discharges into these waters licensed prior to January 1, 1986, are allowed to continue only until practical alternatives exist. No materials may be placed on or removed from the shores or banks of a Class GPA water body in such a manner that materials may fall or be washed into the water or that contaminated drainage therefrom may flow or leach into those waters, except as permitted pursuant to section 480-C. No change of land use in the watershed of a Class GPA water body may, by itself or in combination with other activities, cause water quality degradation that would impair the characteristics and designated uses of downstream GPA waters or cause an increase in the trophic state of those GPA waters.

The attainment of the trophic aspects of the GPA classification has been accomplished with the evaluation of the specific parameters listed in paragraph B in addition to a few others (dissolved oxygen, color, specific conductance, and alkalinity). These results are evaluated from a statewide perspective. One drawback to this approach is the appearance that assume all lakes have the potential of attaining the same optimum water quality. Other aspects of the GPA class have been evaluated on a limited basis. For example, Paragraph A under Title 38 Section 465-A, ends with the condition that 'the habitat be characterized as natural'. Currently, lakes that have wide water level fluctuations due to hydropower drawdowns are determined as violating this aspect of GPA because of the impact to natural communities in the littoral zone.

Bioassessment Opportunities

In reality, it is likely that not only size and depth influence water quality, but also location in the landscape or 'ecoregion'. So there is a need to better establish 'best possible' or reference conditions for lake types in various regions of the state. This approach would allow a more realistic evaluation of the degree to which the water quality has departed from historical conditions. This '
approach has been implemented in a number of other northern lake states with some success and is a commonly encountered element of establishing reference conditions for the development of stream biocriteria. Another approach that may prove viable is to compare a lake to its condition 100-150 years ago. This can be done using paleolimnological techniques that compare surface sedimented diatom assemblages to assemblages found deeper in lake sediments.

There are other habitat considerations that could be incorporated into our assessment strategy. For example, recent literature suggests that the trophic condition of lake water is closely linked with the biological community. The assessment of both components could be used to more precisely evaluate attainment of GPA standards. Knowledge of the biological community structure may also reveal biological approaches to lake restoration strategies applicable in situations when GPA standards are not being met.

Bioassessment Pilot Project

Because opportunities exist to incorporate a bioassessment approach into Maine's management of lakes, the DEP chose to take advantage of an opportunity offered by EPA to test their Draft Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document (U.S. EPA, 1998c). The test, conducted on historical lake data, focused on lake classification, selection of reference lakes and the evaluation of potential metrics for water column plankton communities (phytoplankton and zooplankton). The dataset used in this pilot test for the lake classification and reference lake selection portion, had a reasonable amount of data from which to draw preliminary conclusions about how Maine lakes behave regionally. The biological dataset was limited in the total number and distribution of lakes across Maine's landscape. However, a number of biological metrics did appear to hold promise for evaluating trophic conditions.

Lake Classification Results. The classification effort focused on 451 lakes which had complete datasets. Cluster analysis was utilized on a combination of morphometric and chemical variables summarized in Table 9. These selected variables have adequate geographical and lake-type coverage and should have some basis, at least in theory, for either influencing lake biology or measuring biological conditions. The ecoregion approach suggested in the EPA guidance resulted in 3 'modified' ecoregions, based on Omernik (1987), each having two lake classes. Surface area and the depth variables were primarily responsible for the clustering. Three concerns were evident from this portion of the pilot test: 1) how to handle outlier lakes (i.e., very large lakes), 2) how to incorporate additional lakes as data becomes available, and 3) the inherent bias of selection of those monitored lakes that are represented in the datasets.

Table 9 Summary of variables used for the trial lake classification analysis and reference lake selection.

Morphological/Physical	Chemical	Trophic
Surface Area	Apparent Color	Grand Mean - Secchi Transparency
Maximum Depth	Alkalinity*	TSI calculated from Secchi Transparency.*
Mean Depth	Specific Conductance*	Grand Mean - Chlorophyll *a**
Drainage Area*		Grand Mean - of Secchi Transparency . having 5 months of data/year
Flushing Rate**		*
Elevation		
Watershed Disturbance Ranking		
* indicates a small amount of missing data		
** lakes with flushing rates > 50 times per year were excluded from the analysis		

Selection of Reference Lakes. Each of the lakes in the dataset was assigned a development ranking derived from GIS 1990 Census Data. Rankings from a subset of these lakes were found to be similar to rankings derived from the examination of United States Geological Service (U.S.G.S.) topographic maps. Lakes having low development rankings were screened by professionals to eliminate lakes impacted by activities unrelated to population. Box and whisker plots were used to compare trophic status of reference lakes to non-reference lakes in each lake class. These comparisons often showed little separation between reference and non-reference lakes. This may be partially explained by the disproportionate number of reference and non-reference lakes. The technique used to choose reference lakes may need refinement but appears to be compatible with the guidance emphasis on using readily available information.

Biological Parameters. Maine examined metrics from phytoplankton and zooplankton data to evaluate their potential utility. Forty-six phytoplankton metrics were examined. Thirteen metrics showing potential utility were reduced to the four listed in Table 10, after the elimination of redundant metrics.

Table 10 Four suitable phytoplankton metrics.
Total cell volume
Percent volume Cyanophyta
Percent volume Chrysophyta
Ratio of Cyanophyta volume to Desmid volume

Seven out of nineteen zooplankton metrics showed potential utility in screening for trophic increases. Metrics with inherent redundancy were eliminated. Cumulative distribution plots for reference sites and non-reference sites were utilized to determine potential scoring levels for two metrics: total abundance and the ratio of cladocera to copepods (Table 11).

Table 11 Scoring for two viable zooplankton metrics.

Metric	**Metric Levels**	**Score**
Total Abundance	<7,500	5
	7,500-28,750	3
	>28,750	1
Ratio of Cladocera to Copepods	<0.5	5
	0.5-2.25	3
	>2.25	1

Current Bioassessment Development

The pilot project was valuable in elucidating what data were needed to continue developing statewide lake bioassessment techniques. It was recognized that there is enormous potential for the development of biological metrics to assess biological assemblages from numerous lake or lake watershed habitats. However, since Maine lake management targets water column trophic state, it was decided initially to continue the focus on water column primary producers and their consumers (phytoplankton and zooplankton). In particular, better characterization of lakes is needed to designate *reference lakes* or *lakes having minimum* disturbance in terms of both their biological and chemical composition.

Since 1996, biological samples have been collected from approximately 300 lakes in addition to an expanded list of chemical and physical parameters. In 1996, 100 candidate reference lakes were visited; 200 lakes that can serve as test lakes were visited in 1997 and 1998. Chemical parameters include cations, anions, ANC, pH, DOC, specific conductance, apparent color, alkalinity, total phosphorus, and chlorophyll_*a*. The biological samples consisted of phytoplankton, zooplankton and surface sedimented diatoms.

Phytoplankton samples were obtained from the epilimnion using a minimum of 3 integrated tube samples (cores) and were preserved in Lugol's solution in opaque, 60 ml. Nalgene bottles. Zooplankton samples were obtained with an 80-micron Wisconsin net. Depending on the depth of the lake, either 3 or 5 tows were obtained from one meter above the sediment to the water surface. Samples were anesthetized using one half of an Alka Seltzer table for approximately 225 ml. of sample. Samples were preserved in sugared formalin in 250 ml. clear Nalgene bottles. Surface sedimented diatoms were obtained using a Hongvie type sediment corer. The top centimeter of sediment from two cores was collected using a turkey baster and stored in a labeled whirlpac.

The highest priority is to better characterize reference conditions in regions of the state that are receiving the highest pressure from non point sources. Zooplankton samples from 100 reference lakes have species analysis completed and another 50 test lakes are currently being analyzed. Due to the expense of surface sedimented diatom analysis, 80 of the reference samples and 20 test samples are currently being analyzed. Phytoplankton identifications from this latter set of lakes will be made as soon as arrangements are made with the analyst. It is anticipated that analysis of this data will begin in autumn of 1999. If the results are favorable and funds become available, it is anticipated that the remaining samples will be evaluated. Short sediment cores may be obtained from a few reference lakes and a few test lakes during the winter of early 2000 from which to evaluate a paleolimnological approach.

Future Considerations

Over the next few years, Maine will be analyzing this biological data and further developing bioassessment techniques. Maine will also be exploring the usefulness of a regional or 'ecoregion' approach to lake management. EPA is currently attempting to establish nutrient criteria for lakes in the northeast and it is likely that their effort will also have some effect on how Maine manages its lake resources or a subset thereof. Regardless, the incorporation of additional assessment techniques will provide varying levels of assessment intensity for use at both state and local levels.

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The Marine Environmental Monitoring Program uses the framework of Maine's Water Classification Program to make general assessments of the biological community as well as site specific assessments for permitting, licensing, or enforcement.

The Marine and Estuarine Biological Community

Introduction and Background

Forty three percent of Maine's population lives in the coastal region. This population pollutes directly and indirectly by driving vehicles, heating houses and businesses, generating sewage, disturbing soils, spilling oil and hazardous chemicals, applying pesticides and fertilizers and paving surfaces. Regulated discharges from industries, businesses, and municipalities, contaminants released from old industrial sites, underground tanks and dumps, and air pollutants from the eastern seaboard and the Midwest add to this pollutant mix. Stormwater picks up pollutants from the land and delivers them to coastal waters. On the ocean side, oil spills, dredging, discharges from boats, direct deposition of air pollutants, some seafood harvesting activities, and old underwater dumps and sawdust deposits can impact the marine and estuarine waters. Also, there are hundreds of alterations to coastal wetlands that are permitted each year through the Maine's Natural Resources Protection Act (38 MRSA, Sections 480-A to 480-Z) or Permit by Rule (38 MRSA, Section 480-H & 341-D) that have the potential to impact coastal habitat quality.

The Marine Environmental Monitoring Program (MEMP)

Marine monitoring within the Maine Department of Environmental Protection (MDEP) began informally in 1986 as a collaborative project with the Maine Audubon Society, the Department of Marine Resources and the University of Maine. The program set a course beginning with clarifying chemical processes within the near coastal system, to understanding near coastal physical habitats, to understanding the biological resources and ultimately concluding at an ecological level.

When the Marine Environmental Monitoring Program (MEMP) was formally established by the Legislature in 1988, chemical contamination was identified as its priority. Because toxic contaminants, especially metals and halogenated hydrocarbons, can cause more persistent environmental problems than nutrient enrichment, the first years of the program were devoted to addressing toxics. Furthermore, in the 1980s the MDEP already had evidence of toxic contamination in areas such as Boothbay Harbor, Blue Hill, and Portland Harbor. Nutrient enrichment and eutrophication were not yet a known concern on the coast of Maine.

In the 1990s, however, concern over nutrient enrichment and its consequent hypoxia and nuisance algal blooms prompted the program to begin assessing this potential problem. For both toxic contamination and nutrient enrichment, the intent was to first document the severity and extent of the problem. In order to interpret the results, the MEMP had to describe patterns of natural variability.

It soon became obvious, that information on natural variability was the most useful and therefore important data that the MEMP was gathering. The near coastal environment is much more complex than inland waters because it includes variables that affect the chemistry, habitat and thus the biology of these areas. These range from natural phenomena such as tides, salinity gradients, and multidirectional currents, to human disturbances such as commercial dragging, boating activity, dredging and filling and direct and indirect impacts from removing (i.e., harvesting) selected species from the biological community.

Separating human disturbances from natural forces is a challenge. Developing biological criteria amidst this uncertainty is premature. Rather, the MEMP has emphasized understanding natural variability. This approach has worked well for reviewing specific projects and conducting ecological impact assessments. The MEMP uses the framework of Maine’s Water Classification Program to make general assessments of the biological community as well as site specific assessments for permitting, licensing, or enforcement.

Marine Biological Assessment

Maine's revised Water Classification law (38 MRSA, Section 465-B) of 1986 has explicit narrative aquatic life standards for the classification and protection of aquatic life in estuarine and marine waters (Table 12). This aquatic life language is almost identical to the wording for the aquatic life standards for rivers and streams 38 MRSA, Section 464 (Table 1). Like freshwater, the diversity of invertebrate life (e.g., animals without backbones such as clams, snails, lobsters, and worms) in marine and estuarine waters indicates how suitable a waterbody is for the support of aquatic life. Although freshwater and marine biological communities are very different, their response to pollutants is somewhat similar.

Table 12 Maine's Water Quality Classification System for Marine and Estuarine Waters

CLASS	MANAGEMENT	BIOLOGICAL STANDARD
SA	High quality water with limited human interference. Discharges limited to noncontact process water or highly treated wastewater equal to or better than the receiving water.	Habitat natural. Aquatic life as naturally occurs.
SB	Good quality water. Discharge of well-treated effluent with ample dilution permitted.	Habitat unimpaired. Ambient water quality sufficient to support life stages of all indigenous aquatic species. Only non-detrimental changes in community composition allowed.
SC	Lowest water quality. Maintains the interim goals of the Federal Water Quality Act (fishable/swimmable). Discharge of well treated effluent permitted.	Ambient water quality sufficient to support life stages of all indigenous fish species. Change in community composition may occur but structure and function of the community must be maintained.

A major problem in developing marine and estuarine biological standards is the lack of a reference or natural condition. Physical disturbance of the ocean floor by activities such as dragging nets or dredges disrupts the biological community. Unlike in freshwater, it is legal to practice this type of disruptive activity. Much of the bottom of Maine's coastal waters has been dragged for scallops, mussels, or fish. In some areas, the harvest of important predators or grazers (e.g., sea urchins) has resulted in major changes in the natural biological community. Also, salinity, water temperature, sediment composition, currents, depth, tides, and the presence of rockweed, kelp or eelgrass are some of the natural factors that must be considered when making a biological assessment. Toxic contaminants and dredging of harbors for navigation further complicates the evaluation.

Still, it is possible to make biological assessments using best professional judgement based on:

- site visits and sampling;
- examination of quantitative data sets from various places in Maine;
- species records from Maine;
- studies on disturbance and recovery of biological communities; and
- information on species distributions, sensitivities, life histories, seasonality, and feeding types.

Applications of Marine Biological Assessments in Maine

Salmon Pen Aquaculture Monitoring

In 1991, Maine enacted an Aquaculture Monitoring Program (12 MSRA, Section 6077). This law made the Department of Marine Resources (DMR) responsible for establishing and maintaining a comprehensive information base pertaining to all aspects of the siting, development and operation of finfish aquaculture facilities within the State. The law states that information on the geo-physical site characteristics, including currents and bathymetry; benthic habitat characteristics and effects, including changes in community structure and function; water column effects, including water chemistry and plankton; feeding and production data sufficient to estimate effluent loading; smolt and broodstock introduction and transfer data; and disease incidence and use of chemical therapeutics must be collected. The salmon industry pays DMR a fee of one cent per pound of whole fish harvested to fund the monitoring program (12 MSRA, Section 6078). This is the only State program that requires semi-annual, standardized assessments of the biological community for the purposes of siting and management.

The MEMP reviews the monitoring results and makes recommendations to DMR. The biological assessment includes a video survey and analysis of benthic invertebrates from cores taken under and around the salmon pens. Conditions such as hyperdominance, excessive build-up organic material, or *Beggiatoa* mats are considered to be unacceptable impacts to the biological environment. If these conditions occur, the owner of the salmon pens are asked or required to take mitigation measures to correct the problem.

Functional Assessments for Maine's Resources Protection Act (NRPA) Permitting

A two-year project to provide functional assessment guidelines for NRPA permitting is complete. Alison Ward, a NOAA Coastal Fellow has been working with the MEMP and produced a report entitled Maine's Coastal Habitats: Types, Values, and their Assessment in the fall of 1999. This report includes sections on the coastal geology of Maine, the functions and values of intertidal and subtidal habitats, case histories, and intertidal assessment guidelines.

Functional assessment guidelines are adapted to specific proposed activities (e.g., dredging, lobster pounds, piers) within a coastal wetland. The guidelines, designed for use by professional consultants, include a survey checklist, methods for benthic sampling and analysis, habitat mapping and photography guidelines, a semi-quantitative field card, and a comprehensive list of biological, geological, physical, chemical, commercial, recreational, and educational considerations for the marine environment. The checklist requests information about the applicant and the site; the type, nature and extent of the proposed activity; detailed descriptions of the geology and biology; historical information; impact assessment; recommendations; and potential restoration sites. The benthic sampling protocol specifically outlines the number of samples required, the sampling technique, and the analysis procedure for each habitat type. The considerations are a comprehensive list of questions that address the functions and values of marine systems as well as addressing potential impacts that may be caused by alteration of the natural environment.

At present, the functional assessments that are submitted to the MDEP range from extremely qualitative surveys to quantitative sampling. Most are not of a quality that allows for a reasonable assessment of the data. There is a great need to standardize the assessment methodology practices and educate the MDEP permitters, consultants and regional biologists about all the marine and estuarine habitat functions and values, survey techniques and habitat distributions in Maine.

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