4 Federal and State Biomonitoring Programs

Cornelius I. Weber

One of the primary goals of the Federal Water Pollution Control Act (FWPCA), as amended in 1972 and 1977, is to restore and maintain the biological integrity of the nation's waters. Although the *biological* integrity of water is not explicitly defined in the act, frequent mention is made of the protection and propagation of fish, shellfish, and wildlife and the effects of pollutants on the diversity, productivity, and stability of communities of indigenous aquatic organisms. Emphasis is also placed on determining the biological properties (toxicity) of effluents and the effects of effluents on the biota of receiving waters. The definition of biomonitoring in the law is very broad and includes the determination of the effects of pollutants on (all) aquatic life.

The Environmental Protection Agency (EPA) has identified three types of water monitoring: compliance (discharge permit) monitoring, ambient (water quality) monitoring, and intensive surveys. Agency guidance for biomonitoring programs has been issued in two reports, *Model State Water Monitoring Program* (EPA 1975) and *Basic Water Monitoring Program* (EPA 1977).

The responsibility for the ambient monitoring program has been delegated largely to the states, through a federal grant program. The internal EPA monitoring program is carried out through the Regional Surveillance and Analysis Divisions and is limited largely to compliance monitoring and intensive surveys. The EPA also has initiated a limited ambient water monitoring program called the National Water Pollution Surveillance System.

Extensive biomonitoring programs have been, and are now being, carried out by the EPA and other federal, state, and private agencies. The FWPCA places strong emphasis on the restoration and maintenance of the biological integrity of the nation's waters and makes frequent mention of the protection and propagation of the indigenous communities of aquatic organisms. To be effective, biomonitoring programs must include measurements of the toxicity and/or biostimulatory properties of effluents and the effects of effluents on aquatic life in receiving waters (ecosystems). All communities of indigenous aquatic organisms should be sampled, where appropriate, including the plankton, periphyton, macrophyton, macroinvertebrates, and fish.

The properties of communities of aquatic organisms utilized to examine the biological integrity of surface waters and to describe the effects of pollutants on the aquatic organisms in receiving waters are included in the following three basic categories: (1) Standing crop—the numbers and biomass (size, weight, and so on) of organisms present per unit area or volume (population density),

(2) community structure—the kinds (species) of organisms present and their relative abundance, and (3) community metabolism and condition—the rate of physiological processes (such as photosynthesis, respiration, and nitrogen fixation), the bioaccumulation of toxic substances, and the occurrence of pathological conditions.

Where appropriate, representative species are used in controlled laboratory, treatment plant, and field studies of the toxic and/or biostimulatory properties of effluents.

The EPA has prepared guidelines for biomonitoring programs and has published methodology for biological field and laboratory studies in a manual entitled *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents* (Weber 1973a). A national standing committee of senior EPA biologists provides assistance in screening, selecting, and describing available methodology to be incorporated in the manual and in identifying new methodology needs.

Introduction

Objectives of Federal Water Pollution Control Legislation

One of the principal objectives of the 92d Congress in passing the 1972 amendments to the Federal Water Pollution Control Act (FWPCA) (Public Law 92-500) was to restore and maintain the biological integrity of the nation's waters and to achieve, by July 1, 1983, wherever attainable, a quality of water that provides for the protection and propagation of aquatic life. Recognizing the interdependence of human health and welfare and aquatic life, Congress included in this legislation the authorization and/or directives for the U.S. Environmental Protection Agency and the state programs to conduct comprehensive biological monitoring programs. Section 502(15) of the act defined biological monitoring as "the determination of the effects on *aquatic life*, including the accummulation of pollutants in tissue, in receiving water due to the discharge of pollutants (A) by techniques and procedures including sampling of organisms representative of appropriate levels of the food chain appropriate to the volume and the physical, chemical and biological characteristics of the effluent, and (B) at appropriate frequencies and locations." Other sections of this act, and its successor (the Clean Water Act of 1977), refer to measurement of the biological properties of effluents, the effects of toxic and heated effluents on the aquatic life in receiving waters, and the trophic status of recreational lakes.

The development of most of the technical details of the design of the biomonitoring program required to attain the goals of Public Laws 92-500

and 95-217 was left to the EPA. However, the legislation in defining the scope of the program makes frequent use of terminology such as *diversity, stability, and productivity* which relates to specific biomonitoring parameters. The assurance that aquatic life is protected and is propagating, as required by the act, can be achieved only through a coordinated, comprehensive national biomonitoring program that is adequately staffed and includes various federal, state, and local government agencies and private organizations.

Legislative Mandate for Biological Monitoring

The legislative mandate for the collection of biological data by the Environmental Protection Agency and other federal, state, and private agencies is either clearly stated or implied in at least nineteen sections of the federal Pollution Control Act Amendments of 1972 and 1977. Some of the more prominent examples are listed below [see section 502(15) for the definition of biological monitoring]:

Sec. 101 (a) The objective of this Act is to restore and maintain the chemical, physical, and *biological* integrity of the Nation's waters.

(2) it is the national goal that wherever attainable, an interim goal of water quality which *provides for the protection and propagation of fish, shellfish, and wildlife*. . .

Sec. 104 (b) . . . the Administrator is authorized to . . . collect and

(6) disseminate . . . basic data on chemical, physical, and *biological effects* of varying water quality. . .

(d) In carrying out the provisions of this section the Administrator shall develop . . .

(2) Improved methods and procedures to identify and measure the *effects* of pollutants. . .

Sec. 105 (d) In carrying out the provisions of this section, the Administrator shall conduct, on a priority basis, an accelerated effort to develop, refine, and achieve practical application of:

(3) improved methods and procedures to identify and measure the effects of pollutants on the chemical, physical, and *biological integrity* of water, including those pollutants created by new technological developments.

Sec. 106 (e) [Refers to the state monitoring programs which must provide for. . .]

(1) the establishment and operation of appropriate devices, methods, systems, and procedures necessary to monitor,

and to compile and analyze data on (including classification according to *eutrophic condition*), the quality of navigable waters . . . *including biological monitoring*. . . [Also see sec. 305(b).]

Sec. 302(a) Whenever . . .discharges of pollutants . . .would interfere with the attainment or maintenance of that water quality . . . which shall assure . . . the *protection and propagation of a balanced population of shellfish, fish, and wildlife* . . . effluent limitations . . . shall be established. . . .

Sec. 303(d)(1)(b) Each state shall identify those waters or parts thereof within its boundries for which controls on thermal discharges . . . are not stringent enough to *assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife.*

Sec. 304(g) The Administrator shall . . . promulgate guidelines establishing test procedures for the (biological) analysis of pollutants. . . .

(h) The Administrator shall . . . promulgate guidelines for . . . the acquisition of information from owners and operators of point sources of discharges . . . which shall include: (A) (biological) monitoring requirements. . .

Sec. 305(b) Each state shall prepare and submit to the Administrator . . . each year . . . a report which shall include . . . (B) An analysis of the extent to which the navigable waters . . . provide for the *protection and propagation of shellfish, fish and wildlife, and allow* recreational activities in and on the water,
(C) An analysis of the extent to which the elimination of the discharge of pollutants and a level of water quality which provides for the *protection and propagation of a balanced population of shellfish, fish and wildlife* . . . have been or will be achieved.

Sec. 308(a)(3) (A) The Administrator shall require the owner or operator of any point source to. . .
(iii) install, use, and maintain such monitoring equipment or methods . . . including where appropriate, *biological monitoring* methods. . .

Sec. 311 The Administrator shall develop . . . regulations . . . (pertaining to) hazardous substances . . . (which) present an imminent and substantial danger to . . . *fish, shellfish, wildlife*. . . .

Sec. 314(a) Each state shall prepare or establish, and submit to the Administrator for his approval

(1) an identification and classification according to *eutrophic condition* of all publicly owned fresh water lakes in such State. . .

Sec. 316(a) . . . The Administrator may impose an effluent limitation . . . that will assure the *protection and propagation* of a *balanced, indigenous population of shellfish, fish, and wildlife* in and on the body of water (into which the discharge is made)

Sec. 403(c)(1) The Administrator shall . . . promulgate guidelines for the determining of the degradation of the waters of the territorial seas, the contiguous zone, and the oceans, which shall include:

(A) the *effect of disposal of pollutants on* . . . but not limited to *plankton, fish, shellfish, wildlife* . . .

(B) the effect of disposal of pollutants on marine life including the transfer, concentration, and dispersal of pollutants or their byproducts through *biological*, physical, and chemical processes; *changes in marine ecosystem diversity, productivity, and stability; and species and community population* changes. . .

Sec. 502(15) *The term "biological monitoring" shall mean the determination of the effects on aquatic life, including accumulation of pollutants in tissue, in receiving waters due to the discharge of pollutants (A) by techniques and procedures, including sampling of organisms representative of appropriate levels of the food chain appropriate to the volume and the physical, chemical, and biological characteristics of the effluent, and (B) at appropriate frequencies and locations.*

Objectives of a Biomonitoring Program

The threat to human health and welfare posed by the pollution of surface waters has two fundamental aspects: the *direct effects* on human health through contaminated water supplies and food and the *indirect effects* resulting from the impact of pollution on the quantity and quality of aquatic organisms used for human food, the use of water for recreation, the aesthetic quality of the environment, and the integrity of the biosphere (figure 4-1).

The objectives of a biomonitoring program based on Public Law 95-217 are to determine:

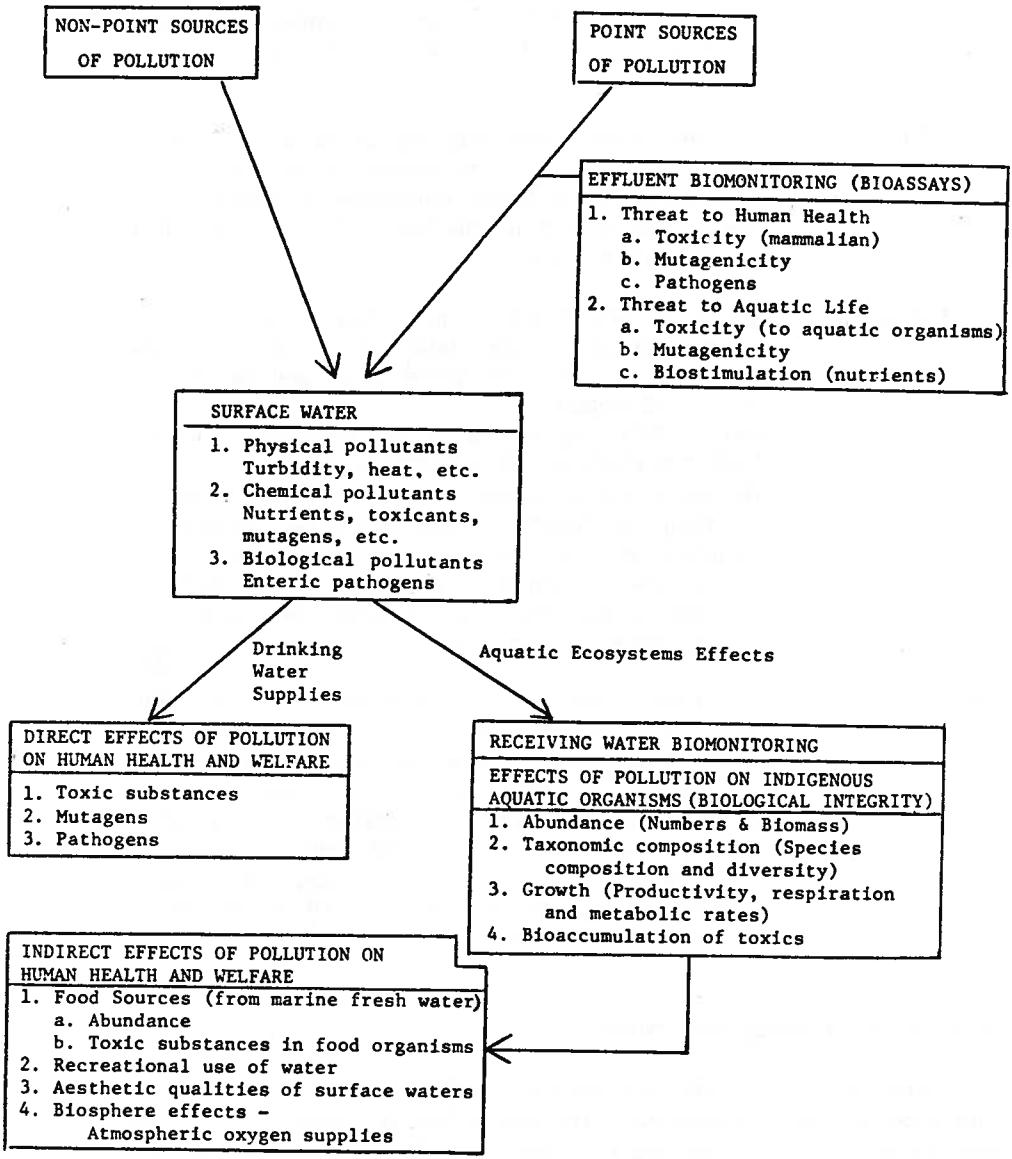


Figure 4-1. Biological Effects of Pollution on Human Health and Aquatic Life

1. If toxic substances and pathogens are being discharged to surface (and ground) waters
2. The dispersion and persistency of pesticides, toxic metals, and other toxicants in water and aquatic life [Sec. 104(1), (2);304(a)(1); 403(c)(1)(A)]
3. If aquatic life has indeed been "protected" and is "propagating" [Sec. 101(a)(2)]
4. Long-term trends in the "diversity, productivity and stability" of communities of indigenous aquatic organisms [Sec. 304(a)(1)]
5. The "trophic status" of surface waters and long-term trends in eutrophication of surface waters [Sec. 106(e)(1); 314(a)]
6. Undesirable effects of nutrients in surface waters [Sec. 104 (h)(A)]
7. If effluent guidelines and permit limitations (NPDES) are adequate to protect aquatic life in receiving waters [Sec. 308(a); 309(a)]
8. The effects of thermal discharges [Sec. 303(d); 316]
9. The effects of spills of oil and other hazardous materials (Sec. 311)
10. The success of the program for the "rehabilitation and environmental repair" of Lake Erie [Sec. 108(d)(1)]
11. The present and projected quality of the waters of the Great Lakes [Sec. 104(f)]
12. The efficacy of domestic waste treatment plants
13. If the goals of the act are being met
14. If program resources are properly allocated

Biological Integrity

From the wording of the various sections of Public Law 95-217 relating to biological monitoring, and especially section 502(15), it is abundantly clear that it was the intent of Congress, in using the terms *biological integrity, aquatic life, plankton, shellfish, fish, and wildlife, ecosystem (population diversity, stability, and productivity)*, and so on to include all communities (types) of aquatic life, freshwater and marine.

The biological integrity of surface waters is related to the following basic questions: Is the water free of hazardous substances? Are the expected kinds of aquatic organisms present in the expected numbers, carrying out life functions at normal rates, free of toxins and pollutant-related disease?

The parameters that must be measured in a biomonitoring program designed to satisfy the requirements of Public Law 95-217 fall into two major groups (see tables 4-1 and 4-2)

1. Biological Properties of Pollutants
   A. Toxicity to human and aquatic life
      (1) Specific pollutants
      (2) Complex (mixed) effluents

Table 4-1
Properties of Indigenous Communities of Aquatic Organisms Used in Determining the Biological Integrity of Surface Waters

	Community					
Parameters	*Phyto plankton*	*Zoo- plankton*	*Peri- phyton*	*Macro- phyton*	*Macro- invert*	*Fish*
Standing Crop						
1. Count	X	X	X	X	X	X
2. Volume	X	X	X		X	
3. Wet weight	X	X	X	X	X	X
4. Dry weight	X	X	X	X	X	
5. Ashfree weight	X	X	X	X	X	
6. DNA content	X					
7. ATP content	X	X	X			
8. Chlorophyll *a* content	X		X	X		
Taxonomic Composition						
1. Species identification	X	X	X	X	X	X
Indicator species	X	X	X	X	X	X
Number of individual species	X	X	X	X	X	X
Total number of species	X	X	X	X	X	X
Diversity index	X	X	X	X	X	X
2. Pigment composition						
Biomass/Chlorophyl *a*	X		X			
Chlorophyl *a*/Chlorophyl *b*	X		X			
Chlorophyl *a*/Chlorophyl *c*	X		X			
Pheophytin content	X		X			
3. Nitrogen (N_2) fixation	X		X			
Metabolic Activity or Condition						
1. *Primary productivity*						
Carbon-14 uptake	X		X	X		
Oxygen evolution	X		X	X		
2. *Respiration rate*						
Plankton dark-bottle O_2 uptake	X					
Electron transport	X					
Benthic respirometer O_2 uptake			X	X	X	
3. *Nitrogen (N_2) fixation*	X		X			
4. *Chemical composition*				X		
Macronutrient content				X		
Enzyme content						
Acetyl choline esterase					X	X
Phosphatase	X			X		
Nitrate reductase	X					
Toxic organics and metals content	X	X	X	X	X	X
5. *Flesh tainting*					X	X
6. *Histopathology*					X	X
7. *Condition factor*						X

Table 4-2
Use of Captive Organisms in Biomonitoring and Toxicity Tests

	Organism					
Type of Test	*Phyto-plankton*	*Zoo-plankton*	*Peri-phyton*	*Macro-phyton*	*Macro-invert*	*Fish*
In Situ Tests						
1. *Bioaccumulation*						
Toxic metals	X	X	X	X	X	X
Pesticides (organics)	X	X	X	X	X	X
Flesh tainting					X	X
2. *Toxicity tests*						
Acute toxicity					X	X
Histopathology					X	X
Histochemistry			X	X	X	X
Choline esterase						X
In-plant Tests (Effluents)						
1. *Bioaccumulation*						
Toxic metals			X	X	X	X
Pesticides (organics)			X	X	X	X
Flesh tainting					X	X
2. *Toxicity tests*						
Acute toxicity	X	X			X	X
Low-level responses (behavioral responses)					X	X
Histopathology					X	X
3. *Biostimulatory tests*						
Algal growth response (AGP)	X		X			
Laboratory Tests						
1. *Bioaccumulation*						
Toxic metals	X	X	X	X	X	X
Pesticides (organics)	X	X	X	X	X	X
Flesh tainting					X	X
2. *Toxicity tests*						
Acute toxicity	X	X			X	X
Chronic toxicity	X	X	X	X	X	X
Histopathology					X	X
Low-level responses (behavioral responses)					X	X
3. *Biostimulatory tests*						
Algal growth response (AGP)	X		X			

B. Mutagenicity
   (1) Carcinogenicity
   (2) Teratogenicity
C. Biostimulatory properties
   (1) Inorganic nutrients (N,P, and so on)
   (2) Degradable organic compounds

2. Properties of Communities of Indigenous Aquatic Organisms
   A. Standing crop—The numbers of and biomass (size, weight) of organisms present.
   B. Community structure—The kinds (and numbers) of species of organisms present (taxonomic composition), including the relative abundance of each kind and overall community structure and stability, and species diversity
   C. Community metabolism and condition—The rate of physiological processes such as photosynthesis (productivity), nitrogen fixation, and respiration; the bioaccumulation of toxic substances; and the occurrence of disease and histopathological conditions, parasitism, and flesh tainting.

This report deals only with programs that determine toxicity and other effects of pollutants on aquatic organisms.

Historical Review of Federal Biomonitoring Programs (Pre-EPA)

The legislative mandates and/or authority for biological monitoring contained in Public Law 95-217 are based on a concept entirely different from the approach taken under section 4(c) of the FWPA of 1956 (Public Law 660) and requires the collection of biological data because of its intrinsic value in determining the biological integrity of surface waters. However, the collection and processing of basic data on aquatic life under Public Law 660 were much more highly coordinated nationally than now under Public Law 95-217.

The biomonitoring program under Public Law 660 consisted of three types of activities: (1) National Water Quality Network (fixed-station, long-term ambient water quality monitoring), (2) Comprehensive River Basin Projects (long-term, intensive basinwide surveys), and (3) Enforcement studies (national laboratory, short-term intensive surveys).

National Water Quality Network (National Water Pollution Surveillance System)

Basic data on the species composition and abundance of aquatic life in the surface waters of the United States were first collected on a nationwide scale within the Federal Water Pollution Control Program by the National Water Quality Network (NWQN), established in 1956 under section 4(c) of Public Law 660 to determine the quality of surface waters used for domestic water supplies. By 1963 this network had grown to approximately 150 stations located

throughout the forty-eight contiguous states and Alaska (figure 4-2a). The biological program was limited to phytoplankton counts and identifications during the first two years of operation, but gradually it expanded until 1963, when it included the collection of data on zooplankton, periphyton, macroinvertebrates, and fish (table 4-3).

The responsibility for the operation of the National Water Quality Network (later named the Water Pollution Surveillance System) was transferred to the regional offices in 1968, and the operation of the system was decentralized. Administration of the laboratory in which the samples were analyzed, now known as the Environmental Monitoring and Support Laboratory (EMSL-Cincinnati), was transferred to the EPA Office of Research and Development.

Comprehensive River Basin Projects

Laboratories located in each of the major river basins in the United States (figure 4-2b) carried out interdisciplinary, long-term, basinwide intensive studies to determine cause-and-effect relationships involving point and nonpoint sources of pollution in the basin. Data were collected on the physical, chemical, and biological integrity of water.

National Field Investigations Center (Cincinnati)

The National Field Investigations Center at Cincinnati was a field arm of the Enforcement Office of the Federal Water Pollution Control Administration Program. This center carried out short-term, intensive chemical and biological studies at a relatively small number of stations designed to provide data suitable for enforcement actions against point sources of pollution. These studies were heavily oriented toward biological effects.

Current Biomonitoring Programs

The EPA water monitoring programs are operated by the regional and research field laboratories, states, and other agencies, under the guidance of the EPA headquarters program offices (figure 4-3). Technical support for the field programs is provided by the various EPA research laboratories. The biomonitoring methods development, standardization, and quality assurance program is carried out at the Environmental Monitoring and Support Laboratory at Cincinnati (figure 4-4). The EPA now recognizes three basic types of monitoring: ambient (long-term) comonitoring. [National Pollution Discharge Elimination System (NPDES) Permit] compliance monitoring, and intensive (short-term)

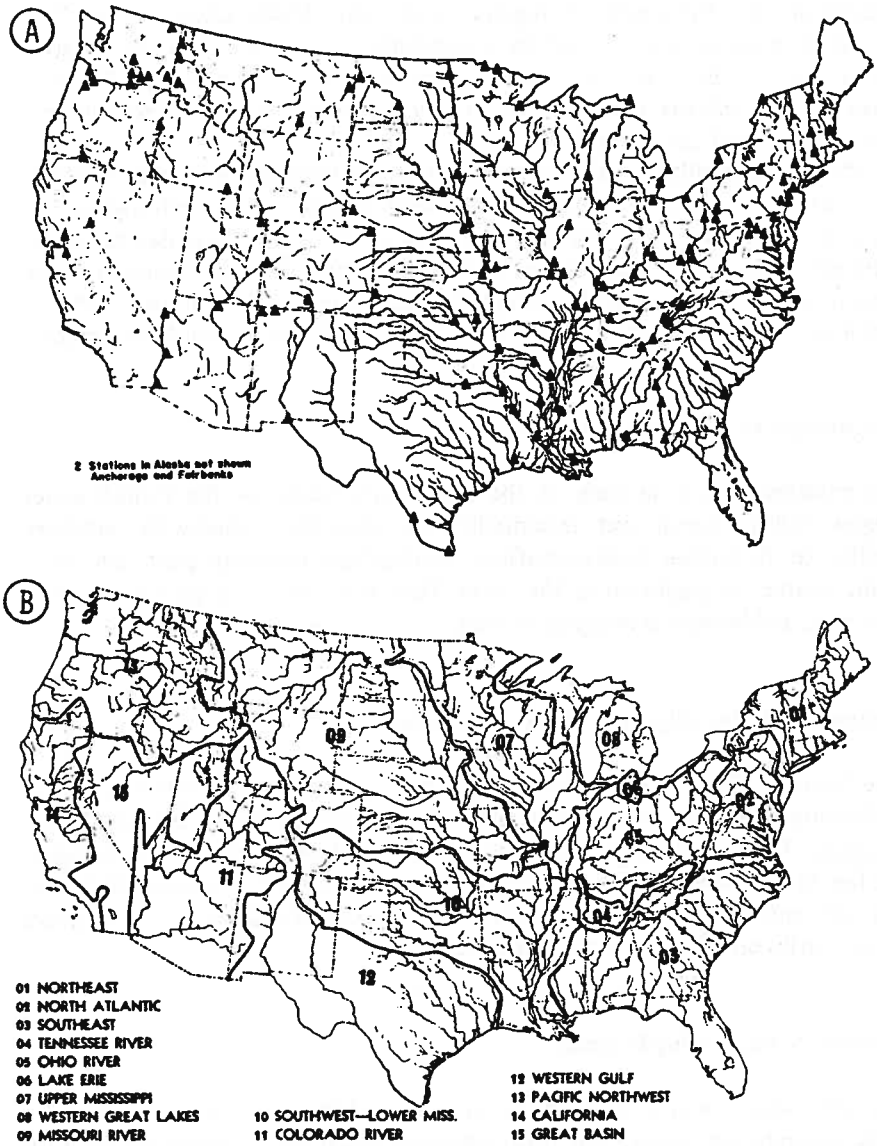


Figure 4-2. (*a*) Sampling Stations, National Water Quality Network (Water Pollution Surveillance System); (*b*) Major River Basins of the United States

Table 4-3
Biomonitoring Data Collected by the National Water Quality Network

Community	*Sampling Period*	*Number of Stations*	*Sampling Method*[a]	*Type of Data*
Phytoplankton	1956-1968	150	3-liter grab	S-R counts (units/ml) and species ID Diatom species, percent composition
Zooplankton	1956-1968	150	3-liter grab	Counts (org/l) and ID to genus
Periphyton	1964-1968	80	Glass slides in floating sampler	Cell density (cells/mm^2) and ID to species Diatom species, percent composition
Macroinvertebrate	1963-1968	40	Multiplates, rock-filled baskets, bottom grab	Counts and ID, organisms/sample or organisms/m^2
Fish	1963-1965	20	Electric shocker	Species composition and biomass

[a]For methods see C.I. Weber, *Methods of Collection and Analysis of Plankton and Periphyton Samples in the Water Pollution Surveillance System*, A&D Report No. 19 (Cincinnati: Department of Health, Education, and Welfare, 1966), and *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents* (Cincinnati: EPA, 1973), EPA-670/4-73-001.

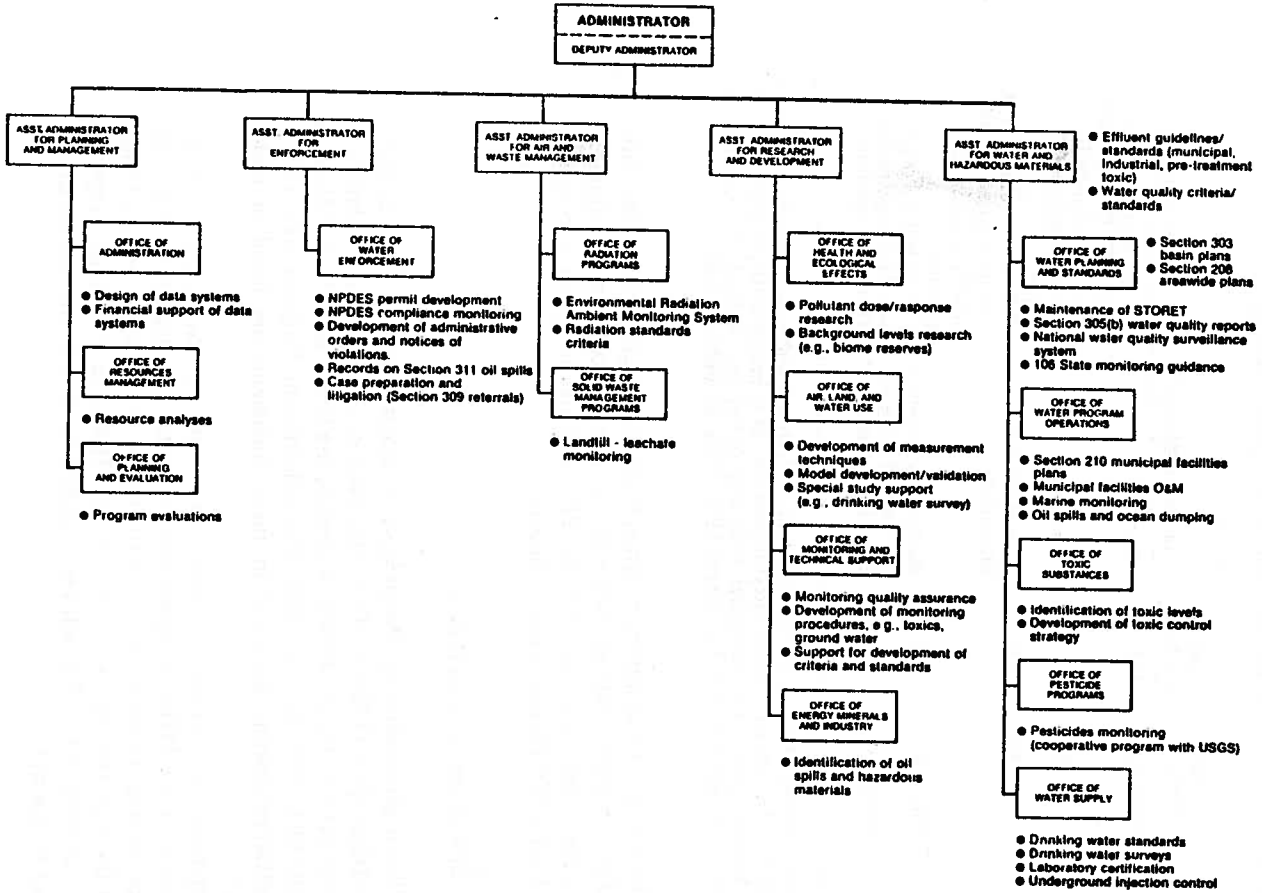
surveys. The ambient biomonitory program is conducted primarily by the states and the U.S. Geological Survey, whereas the compliance biomonitoring and intensive surveys are conducted by the EPA regional programs and by the states which have NPDES permitting authority.

Intramural EPA Biomonitoring Program

National Water Biomonitoring Program. The Monitoring and Data Support Division (MDSD), EPA Office of Water and Hazardous Materials, has developed two different national biomonitoring strategies, the Model State Water Monitoring Program (EPA 1975) and the Basic Water Monitoring Program (EPA 1977). The biological parameters described in these documents are listed in tables 4-4 and 4-5.

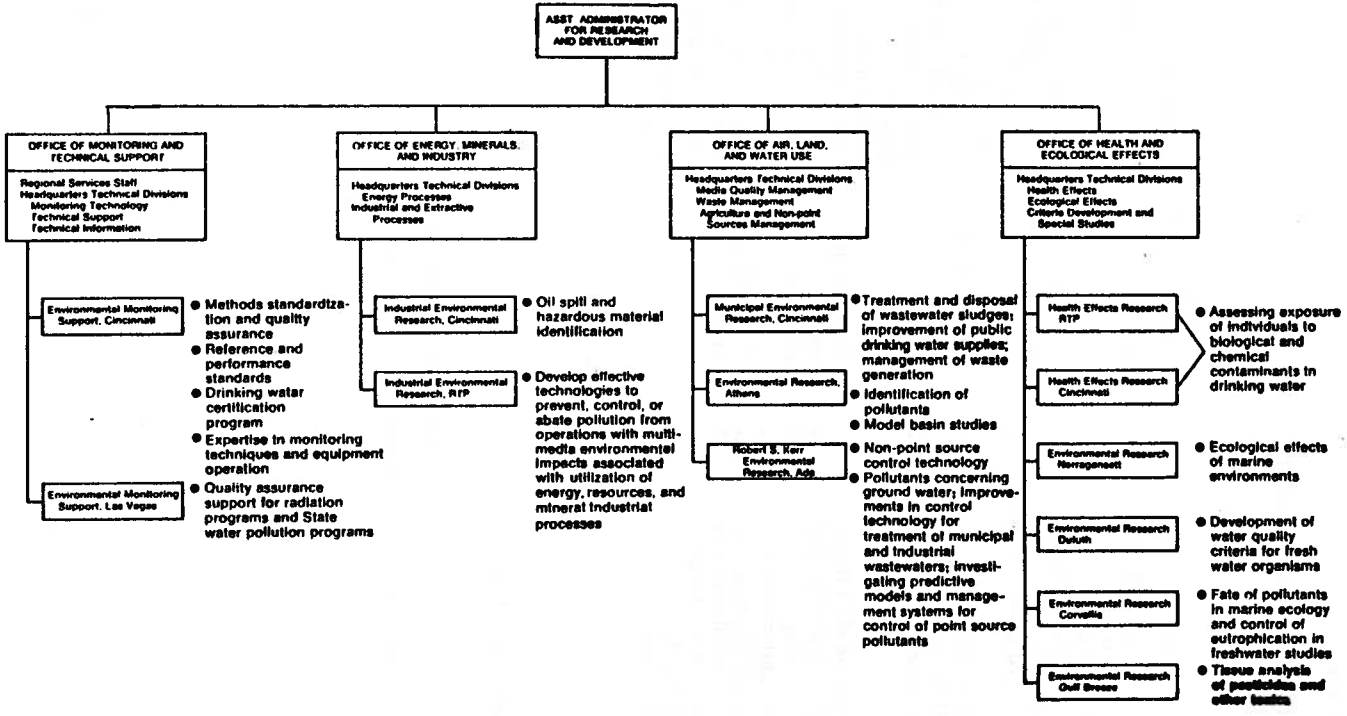
The approaches discussed in these reports are for the optional use by state programs in the MDSD-designed and supported National Water Pollution Surveillance System, operated for the EPA by the states, using section 106(e) funds, and the U.S. Geological Survey (USGS). This network contains approximately 165 stations, 110 of which are operated by USGS, and the remainder are operated by the states.

Regional Programs. The current biomonitoring programs in the EPA regional offices lack coordination at the national level. The size and expertise of the



Source: *Basic Water Monitoring Program* (Washington: Environmental Protection Agency, 1977), EPA 440/9-76-025.

Figure 4-3. Environmental Protection Agency, Water Monitoring Activities



Source: *Basic Water Monitoring Program* (Washington: Environmental Protection Agency, 1977), EPA 440/9-76-025.

Figure 4-4. Water Monitoring Program Support Provided by the EPA Office of Research and Development

Table 4-4
Biological Parameter List, Sampling Frequencies, and Priority for Proposed Biomonitoring Programs

(*a*) Model State Water Monitoring Program

Community	*Parameter*	*Priority*[a]	*Collection and Analysis Mathematics*[b]	*Sampling Frequency*[c]
Plankton	Counts and identification	1	Grab samples	Once each—in spring, summer, and fall
	Chlorophyll *a*	2		
	Biomass as ashfree weight			
Periphyton	Counts and identification	1	Artificial substrates	Minimally once annually during periods of peak periphyton population
	Chlorophyll *a*	2		
	Biomass as ashfree weight	2		
Macrophyton	Areal coverage	2	As circumstances prescribe	Minimally once annually during period of peak macrophyton population density and/or diversity
	Identification	2		
	Biomass as ashfree weight	2		
Macroinvertebrate	Counts and identification	1	Artificial and natural substrates	Once annually during periods of peak macroinvertebrate population density and/or diversity
	Biomass as ashfree weight	2		
	Flesh tainting	2		
	Toxic substances in tissue[d]	2		
Fish	Toxic substances in tissue[d]	1	Electrofishing or netting	Once annually during spawning runs or other times of peak fish population density and/or diversity
	Counts and identification	2		
	Biomass as wet weight	2		
	Condition factor	2		
	Flesh tainting	2		
	Age and growth	2		

(*b*) Basic Water Monitoring Program

	Community of Aquatic Organisms			
	Plankton	*Periphyton*	*Macroinvertebrates*	*Fish/Shellfish*
Parameters				
Counts			X	
Species identification			X	X
Biomass (ashfree weight)		X		
Chlorophyll *a*	X	X		
Toxic substances				X[e]
Habitat Types				
Rivers		X	X	X
Lakes	X	X	X	X
Estuaries	X			X

Table 4-4 continued

	Community of Aquatic Organisms			
	Plankton	*Periphyton*	*Macroinvertebrates*	*Fish/Shellfish*
Sampling Methods				
Sampling season	6/15-9/15	6/15-9/15	6/15-9/15	6/15-9/15
Sampling frequency	Monthly grab	Once annually	Once annually	Once annually
Sampling method		Glass slides	Hester-Dandy	
		Floating	Multiplace	
		Sampler		
Number of replicate samples	3	3	3	

[a]Priority: 1—minimum program; 2—Add as soon as capability can be developed.

[b]See EPA biological methods mannual.

[c]Keyed to dynamics of community.

[d]See *Analysis of Pesticide Residues in Human and Environmental Samples*, CSEPA, Perrine Primate Research Laboratories, Perrine, Fla., 1970, and *Pesticide Analytical Manual* (Washington: Department of Health, Education, and Welfare).

[e]Fish tissue analysis is a specific requirement of the basic ambient monitoring program.

Table 4-5
Biological Parameter Units

Community	*Parameter*	*Units*
Plankton	Counts	Numbers/ml by genus and/or species
	Chlorophyll *a*	mg/m^3
	Biomass (ashfree dry weight)	mg/m^3
Periphyton	Counts	$Numbers/mm^2$
	Chlorophyll *a*	mg/m^2
	Biomass (ashfree weight)	mg/m^2
	Autotrophic index	$\frac{\text{Ashfree weight } (mg/m^2)}{\text{Chlorophyll } a\ (mg/m^2)}$
Macrophyton	Areal coverage	Maps by species and species associations
	Biomass (ashfree weight)	g/m^2
Macroinvertebrate	Counts	Grab—number/m^2 Substrate—number/sampler
	Biomass	g/m^2
	Toxic substances	mg/kg
Fish	Toxic substances	mg/kg
	Counts	Number/unit of effort, expressed as per shocker hour or per 100 ft of a 24-hour net set
	Biomass (wet weight)	Same as counts
	Condition	$K(TL) = \frac{10^5 \times \text{weight in grams}}{L^3\ (\text{length in mm})}$

Source: *Model State Water Monitoring Program* (Washington: Environmental Protection Agency 1975).

biology staff and the scope of the biology programs vary greatly from region to region (table 4-6), depending on the interpretation of the regional administrator and the surveillance and analysis division director, regarding the relative importance of biological data in responding to regional needs and the program guidance provided by EPA headquarters. The regions conduct intensive surveys, industrial and municipal effluent bioassays, sediment oxygen demand measurements, and determine the biological effects of ocean-disposed wastes and heated effluents. They also review Environmental Impact Statements and 316(b) applications. In all but region IV, the biology staff is generally too small to carry out an effective biomonitoring program (table 4-6).

In 1976 the regional programs operated 650 stations, collected approximately 3,600 samples, and had back data on 9,572 stations and 117,157 samples (tables 4-7 and 4-8) (Weber 1976b).

EPA National Enforcement Investigations Center (NEIC) (Denver). A field arm of the Office of Enforcement, the Center has an active biological program and conducts intensive field surveys, effluent bioassays, and other biological studies for regions lacking strong internal biological monitoring programs.

Research Programs. The Large Lakes Research Program is the largest single, current R&D biomonitoring program. This program maintains 200 stations and collects approximately 6,400 samples per year. Data are collected on phytoplankton, zooplankton, and toxic substances in fish tissues. Biological field and laboratory data are also generated by Environmental Monitoring and Support Laboratory (EMSL)-Cincinnati, EMSL-Las Vegas, and the environmental research laboratories at Duluth, Minnesota, Narragansett, Rhode Island, Gulf Breeze, Florida, and Corvallis, Oregon.

Table 4-6
Environmental Protection Agency Regional Biomonitoring Programs

Region	*Approximate Numbers of Biologists*
I	2
II	3
III	3
IV	13
V	3
VI	2
VII	1
VIII	5
IX	1
X	2

Table 4-7
State Programs: Current Rate of Biological Data Acquisition

State[a]	Number of Stations	Number of Samples per Year				
		Plankton	Periphyton	Macroinvertebrates	Fish	Total
Alabama	25			50	18	68
Arkansas	25	133	41	37		211
California	80	370	60	60	150	640
Connecticut	30	200	100	80	30	410
Delaware	10			10		10
District of Columbia	3	36	36	36	36	144
Florida	239	75	63	516	0	654
Idaho	40			480		480
Indiana	200	700	50	15	15	780
Kentucky	50	300	200	250	100	850
Maryland	200			200		200
Michigan	250	611	125	583	450	1,769
Minnesota	40	60	4	30		94
Montana	100		200	200		400
Nevada	4	8	8			16
New Jersey	210	400		230		630
New Mexico	20	50		40		90
New York	80			100		100
North Carolina	128	156	156	208	104	624
Ohio	60			400		400
Pennsylvania	1,800		200	2,400	200	2,800
South Carolina	90	360	90	90	180	720
Tennessee	45	540	540	540	1,080	2,700
Texas	130	145		130		275
Vermont	100	360	24	360	24	768
Virginia	340	1,000		240		1,240
West Virginia	20			27		27
Wisconsin	200	175	70	685	20	950
Total	4,519	5,679	1,967	7,997	2,407	18,050

Source: C.I. Weber, *Feasibility Study for a Centralized Biological Data Management System (BIOSTORET)*. (Cincinnati, Ohio: Environmental Protection Agency 1976).

[a]The absence of any state from this list does not necessarily mean that it lacks a biological monitoring program.

Extramural Environmental Protection Agency Programs

EPA Grantees and Contractors. Agency grantees and contractors collect large amounts of field and laboratory data on aquatic organisms that would be of value to EPA headquarters and regional programs and states if these data were available in a national, computerized, biological data management system.

State Biomonitoring Programs. With the aid of EPA section 106(e) grants, state water pollution control agencies in 1976 maintained approximately 4,500

Table 4-8
State Programs: Back Data from Biomonitoring Programs[a]

State[a]	Number of Stations	Number of Samples				
		Plankton	Periphyton	Macroinvertebrates	Fish	Total
Alabama	25	–	–	45	12	57
Arkansas	130	2,100	–	2,100		4,200
California	400	1,850	–	300	750	2,900
Connecticut	30	250	250	250	60	810
Delaware	30			60		60
Florida	150	40	20	950	–	1,010
Idaho	40	–	–	300	–	300
Maryland	250			200	50	250
Michigan	1,500	1,700	400	4,350	550	7,000
Minnesota	75	400	20	200	50	670
New Jersey	250	850	–	200	–	1,050
New Mexico	50	250	–	250	–	500
New York	425	–	–	875	–	875
North Carolina	128	150	150	200	28	528
Ohio	153	–	–	350	–	350
Pennsylvania	4,650	–	400	7,500	400	8,300
South Carolina	57	515	150	150	150	965
Tennessee	45	540	540	540	1,080	2,700
Texas	230	684	–	961	–	1,645
Vermont	400	850	30	2,000	50	2,930
Virginia	108	–	–	432	–	432
West Virginia	20	36	–	27	–	63
Wisconsin	1,600	400	150	1,400	50	2,000
Total	10,746	10,615	2,110	23,640	3,230	39,595

Source: C.I. Weber, *Feasibility Study for a Centralized Biological Data Management System (BIOSTORET)* (Cincinnati, Ohio: Environmental Protection Agency, 1976).

[a]The absence of any state from this list does not necessarily mean that it lacks a biological monitoring program.

stations and collected about 18,000 biological samples per year. Back data existed for approximately 40,000 biological samples from 11,000 stations. (See tables 4-7 and 4-8). The 1978 state programs are described in table 4-9. The evaluation of the biological data, together with the physical and chemical water quality data, is used by some states to prepare the biennial reports to EPA required under section 305(b), Public Law 95-217. These reports describe the extent to which the navigable waters of the states provide for the protection and propagation of aquatic life. However, current guidelines provided to the states by the EPA for the preparation of the section 305(b) reports do not require mention of biological conditions. As a result, most reports do not include comments on the biological integrity of the state's waters.

Other Organizations

In addition to the work of the EPA, many other federal, interstate, and private agencies are engaged in studies of the effects of pollution on aquatic life. Much of this work is done with pass-through EPA funds and constitutes an extension of its program. It would be to the advantage of the EPA to work more closely with other agencies and to capture their data in a central data processing facility to permit pooling and evaluation of related data, where possible, provide timely access to all data for program planning and evaluation, and reduce or eliminate duplication of effort.

Federal Programs. Other federal programs that have biomonitoring programs include:

1. Tennessee Valley Authority
2. U.S. Department of the Interior
   - U.S. Geological Survey
   - Bureau of Reclamation
   - Bureau of Land Management
   - Office of Biological Services, U.S. Fish and Wildlife Service
3. National Oceanic and Atmospheric Administration (NOAA)
4. U.S. Army Corps of Engineers
5. Nuclear Regulatory Commission
6. Department of Energy

Other programs include state water pollution control agencies, interstate river basin commissions, and area and basin planning commissions (section 208). Available information on the number of stations operated and samples collected by other federal programs is listed in tables 4-10 and 4-11.

Biomonitoring Methods Development, Standardization, and Quality Assurance

Within the EPA, the Aquatic Biology Section, the Environmental Monitoring and Support Laboratory (EMSL) at Cincinnati, has the responsibility for developing, evaluating, and standardizing biomonitoring methods and quality assurance procedures, in support of the regional and state biomonitoring programs.

Program areas include project planning, methods and sample collection and preparation, identification and enumeration of organisms, measurements of biomass and metabolic growth rates, measurements of effluent toxicity, and the bioaccumulation of toxic substances in tissues. The Aquatic Biology Section

Table 4-9
State Biomonitoring Programs, 1978

			Number of Stations					Number per Year	
Region	*State*	*Staff*	*Plankton*	*Periphyton*	*Macro-invertebrates*	*Section 314*	*Toxics in Fish*	*Effluent Bioassay (Static/FT)*	*Intensive Surveys*
I	ME				11	250			
	MA				9				
	VT					x			
II	NJ		Marine	x	x	x			x*
	NY	3			224		224		x
III	DE	1	15		15				
	MD	3	75		244		20	2-3/0	
	PA	10			285		x	10/0	x
	VA	11			120	28	40	12/3-5	
	WV	1 1/2	4	4	22			6/0	
IV	AL	6			26		26	x/0	
	FL	30	76	76	247		247	x	
	GA	4	46	46	46				
	KY	4	7	7	7		7		
	MS	2	16	16	16		16	Plan FT	
	NC	4	256	256	256	x	256		
	SC	6	45	45	45		45	Plan AGP	
	TN	11	21	21	21		21	Plan AGP	
V	IL	8			50				10
	IN	5	Plan	Plan	Plan	x			x
	MI	5	41	41	41			x/x	
	MN	5		20	20			x/x	
	OH	5		40	40				
	WI	4		29			Plan		

VI	AR	4		40		40		40			23	1
	LA	2	Plan	44	Plan	44	Plan	44			44	
	NM	3	Plan	9	Plan	9	Plan	9			7	
	OK	2		22				22			22	
	TX	15		75		75		75	x		13	21
VII	IA	3		36				36				
	KS	3		40				40				
	MO	1						50				
VIII	CO	4	Plan	126	Plan	126	Plan	126				
	MT	2										
	ND	9							x			
	UT	1									x	
IX	(No information)											
X	AK		(Marine)									
	ID					x		x				
	WA					x		x				

"x" indicates some activity, but level is unknown.
Ft = Flow-through
AGP = Algal growth potential test

Table 4-10
Federal Programs: Current Rate of Biological Data Acquisition

		Number of Samples per Year				
	Number of Stations	*Plankton*	*Periphyton*	*Macro-invertebrates*	*Fish*	*Total*
EPA						
Region: I						
II	32	24	–	100	24	148
III	238	440	–	150	90	680
IV	100	400	150	250	50	850
V	100	780	–	520	–	1,300
VI	200	303	91	191	25	610
VII	6	–	–	24	–	24
VIII	15	?	?	?	?	
IX						
X	60	–	360	360	–	720
R&D Corvallis Lab	4	96	–	396	–	492
R&D Grosse Ile Lab	200	4,800	–	400	1,200	6,400
R&D Cincinnati Lab (EMSL)	10	100		100		200
Department of Agriculture						
National Forest Service						
Prineville, OR	40	?	?	?	?	?
Albuquerque, NM	50	40	20	220	–	280
Alamogordo, NM	9	–	–	18	–	18
Durango, CO	12	–	–	–	20	20
Russelville, AK	20	–	–	–	20	20
Provo, UT	40	–	–	500	–	500
Total	1,136	6,983	621	3,229	1,429	12,262

Source: C.I. Weber, *Feasibility Study of a Central Biological Data Processing System* (Cincinnati, Ohio: Environmental Protection Agency, 1976).

is also responsible for developing methods for the storage, retrieval, analysis, and interpretation of biological data and for biological quality assurance.

All communities of aquatic organisms are considered, including the phytoplankton, zooplankton, periphyton, macrophyton, macroinvertebrates, and fish. A biological methods manual was published in 1973, and the second edition is nearing completion (1979). Publications include protocols for the evaluation of biological quality assurance programs, manuals for the identification of aquatic organisms, results of the evaluation and comparison of sampling methods, compilations of data on the pollution tolerance of common aquatic organisms, and methods for measuring effluent toxicity. The specifications for a computerized biological data management system and a coded master list of 11,000 aquatic species also have been published.

Table 4-11
Federal Programs: Back Data from Biomonitoring Programs

	Number of Stations	Number of Samples				
		Plankton	*Periphyton*	*Macroinvertebrates*	*Fish*	*Total*
EPA						
NEIC-Denver	350	150	100	300	200	750
Region I						
II	515	1,020	–	1,500	30	2,550
III	20	520		740	30	1,290
IV	250	2,104	906	1,611	240	4,861
V	4,000	3,000	300	3,700	–	7,000
VI						
VII						
VIII	80	15	15	180	1,000	1,210
IX						
X						
Grosse Ile Lab	345	8,000	400	400	6,200	15,000
Las Vegas Lab	2,400	1,850	–	500	–	2,350
Cincinnati (EMSL)	150	75,000	500	1,000	100	76,600
U.S. Army Corps of Engineers						
Buffalo, N.Y.	100	100	100	100	100	400
U.S. Department of Agriculture						
National Forest Service						
Prineville, OR	40					600
Alamogordo, NM	200	240	40	3,200	–	3,480
Albuquerque, NM	17	–	–	306	–	306
Durango, CO	45	–	–	110	–	110
Russelville, AK	20	–	–	–	–	600
Provo, UT	40	–	–	500	–	500
Total	8,572	91,999	2,361	14,147	7,900	117,607

Source: C.I. Weber, *Feasibility Study for a Centralized Biological Data Management System* (Cincinnati, Ohio: Environmental Protection Agency, 1976).

With the cooperation of the Quality Assurance Branch, EMSL, several biological reference materials have also been prepared. Those now available include:

1. Chlorophyll extract in 90 percent aqueous for the spectrophotometric method (performance evaluation and quality control). The sample contains chlorophylls *a*, *b*, and *c* and pheophytin *a*.
2. Chlorophyll extracts in 90 percent aqueous acetone for fluorometric methods (calibration, performance evaluation, and quality control). Three solutions are available: Two solutions contain purified chlorophyll *a* at different concentrations, and one solution contains a mixture of chlorophyll *a* and pheophytin *a*.

3. Simulated phytoplankton sample for microscope calibration and plankton counting. The sample consists of an aqueous suspension of latex spheres (15,000/ml), varying in size from 4 to 20 μm in diameter.

Additional materials in preparation include the following:

1. Reference toxicants for bioassays: sodium dodecyl sulfate, diquat, and sodium pentachlorophenate
2. ATP samples: four concentrations ranging from 10^{-6} μg/ml to 1 μg/ml
3. Plankton sample for S-R counts and identification
4. Periphyton sample for S-R counts and identification
5. Diatom hyrax mounts, for species proportional counts
6. Diatom reference specimens (hyrax mounts of identified specimens)
7. Macroinvertebrate grab samples for sorting, counting, and identification
8. Macroinvertebrate reference specimens (collections of identified specimens)

Summary and Recommendations

This chapter outlines the federal biological monitoring programs for implementing the objectives of the 1972 and 1977 amendments to the FWPCA.

Legislation provides authorization for the EPA, states, and other federal agencies to conduct comprehensive biological monitoring programs to determine the effects of pollution on recreational water and aquatic life. Current EPA guidelines for preparation of section 305(b) reports by states do not, however, require mention of biological conditions of the state's waters. It is recommended that this oversight be corrected by providing useful instructions and guidelines to states for obtaining information and preparing an annual assessment of the biological integrity of states' water resources.

The current level of staffing of biologists in EPA Regional Offices, Surveillance and Analysis Divisions with biologists is generally inadequate to conduct an optimal biological monitoring program. It is recommended that the staffing levels of the EPA and state biomonitoring programs be raised at least to the "minimum" level recommended in the EPA report entitled *Model State Waters Monitoring Program.*

References

Beck, W.M. 1977. *Environmental Requirements and Pollution Tolerance of* Chironomidae. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA 600/4-77-024.

Harris, T. 1978. *Environmental Requirements and Pollution Tolerance of* Trichoptera. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency.

Hubbard, M.D., and Peters, W.L. 1978. *Environmental Requirements and Pollution Tolerance of* Ephemeroptera. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA 600/4-78-061.

Klemm, D.J. 1979. *Freshwater Leeches* (Annelida: Hirudinea) *of North America.* Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency.

Lewis, P.A. 1974. *Taxonomy and Ecology of* Stenonema *Mayflies* (Heptageniidae; Ephemeroptera). Methods Development and Quality Assurance Laboratory. Cincinnati, Ohio: Environmental Protection Agency.

Lowe, R.L. 1974. *Environmental Requirements and Pollution Tolerance of Freshwater Diatoms.* Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA 670/4-74-005.

Mason, W.T., Jr. 1968. *An Introduction to the Identification of Chironomid Larvae.* Cincinnati, Ohio: Division of Pollution Surveillance, Federal Water Pollution Control Administration, U.S. Department of Interior.

Nacht, L., and Weber, C.I. 1976. *BIO-STORET Final Design Specification.* Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency.

Peltier, W. 1978. *Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms,* 2d ed. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA 600/4-78-012.

Schuster, G.A., and Etnier, D.A. 1978. *A Manual for the Identification of the Caddisfly Genera* Hydropsyche *Pictet and* Symphitopsyche *Ulmer in Eastern and Central North America (Trichoptera: Hydropsychidae).* Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency.

Surdick, R.F., and Gaufin, A.R. 1978. *Environmental Requirements and Pollution Tolerance of* Plecoptera. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA 600/4-78-062.

Environmental Protection Agency. 1974. *Water Quality and Pollutant Source Monitoring.* Monitoring and Data Support Division, Office of Water and Hazardous Materials, Washington. Fed. Reg. 39(168):31500-31505.

_____. 1975. *Model State Water Monitoring Program.* Monitoring and Data Support Division, Office of Water and Hazardous Materials, Washington.

_____. 1977. *Basic Water Monitoring Program.* Monitoring and Data Support Division, Office of Water and Hazardous Materials, Washington, EPA 440/9-76-025.

Weber, C.I. 1966a. *A Guide to the Common Diatoms at Water Pollution Surveillance System Stations.* Cincinnati, Ohio: Division of Pollution Surveillance, Federal Water Pollution Control Administration, U.S. Department of Health, Education and Welfare.

_____. 1966b. *Methods of Collection and Analysis of Plankton and Periphyton Samples in the Water Pollution Surveillance System*. Cincinnati, Ohio: A&D Report No. 19, Division of Pollution Surveillance, Department of Health, Education and Welfare.

_____. 1973a. *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents*. Methods Development and Quality Assurance Laboratory. Cincinnati, Ohio: Environmental Protection Agency, EPA-670/4-73-001.

_____. 1973b. "Biological Monitoring of the Aquatic Environment by the U.S. Environmental Protection Agency." In *Biological Methods for the Assessment of Water Quality*, eds., J. Cairns, Jr., and K.L. Dickson, ASTM Special Publication No. 528. Philadelphia: American Society for Testing and Materials, pp. 46-60.

_____. 1976a. *BIO-STORET Master Species List*. Environmental Monitoring and Support Laboratory. Washington: Environmental Protection Agency. (Second edition in press.)

_____. 1976b. *Feasibility Study for a Central Biological Data Management System (BIO-STORET)*. Environmental Monitoring and Support Laboratory. Cincinnati, Ohio: Environmental Protection Agency.