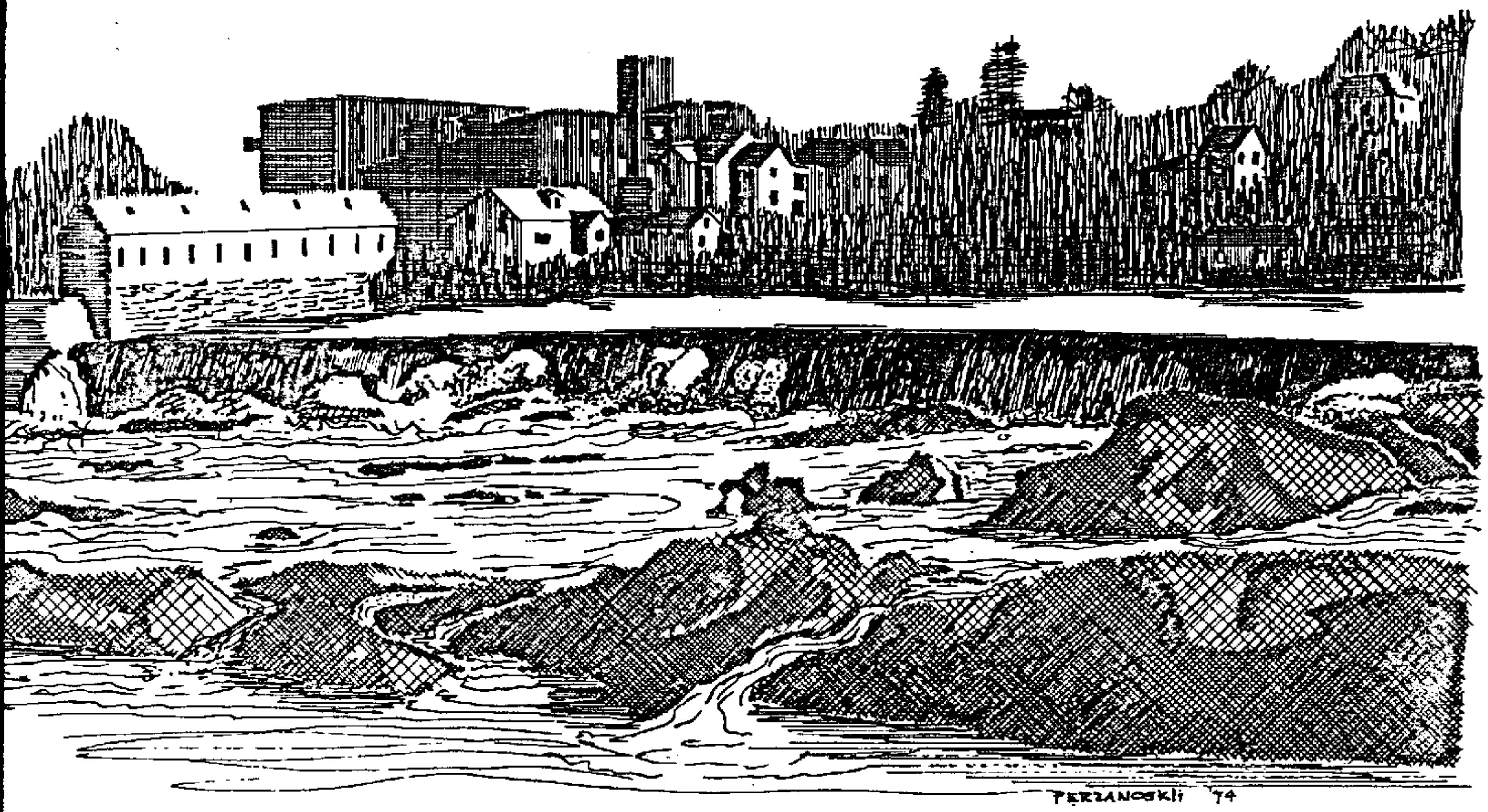
MERRIMACK RIVER



1974

BENTHIC MACROINVERTEBRATE ANALYSIS

department of environmental quality engineering

DIVISION OF WATER POLLUTION CONTROL

thomas c. mcmahon, director

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MERRIMACK RIVER

1974

WATER QUALITY SURVEY

BENTHIC MACROINVERTEBRATE ANALYSIS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MERRIMACK RIVER

The Merrimack River is the second largest river, in terms of flow, in Massachusetts. Beginning in Franklin, New Hampshire, at the confluence of the Pemigewasset and Winnepesaukee Rivers, the Merrimack flows a total of 116 miles to the Atlantic Ocean at Newburyport and Salisbury, draining an area of some 5,000 square miles. The lower 50 miles of the river and approximately 1,200 square miles of the drainage area lie in Massachusetts. Of the 50 miles of river in Massachusetts, the last 22 are tidal (Figure 1).

The Massachusetts portion of the basin has long been a manufacturing center. Historically, the manufacture of textiles, and later paper, played a dominant role in the growth of the three largest cities in the basin, Lowell, Lawrence, and Haverhill. The river, in turn, played a major role in the growth of industry as a source of power. The two dams on the river in Massachusetts, Pawtucket Dam in Lowell and Essex Dam in Lawrence, were built to provide power through canal systems. Another city on the river, Newburyport, also relied on the river as an impetus to growth; the Merrimack estuary provided a somewhat protected harbor for fishing boats from that city.

The industrial growth of the basin carried with it the inevitable byproduct of water pollution. A secondary function of the river in industrial areas was to carry away process and domestic wastes. Due to the large volume of flow in the Merrimack, the river was felt to have an unlimited capacity for carrying liquid wastes. Even in the early twentieth century, when the problems of water pollution were being recognized and pollution abatement facilities were being built in several Massachusetts cities, it was felt that such actions were unnecessary on large rivers like the Merrimack.

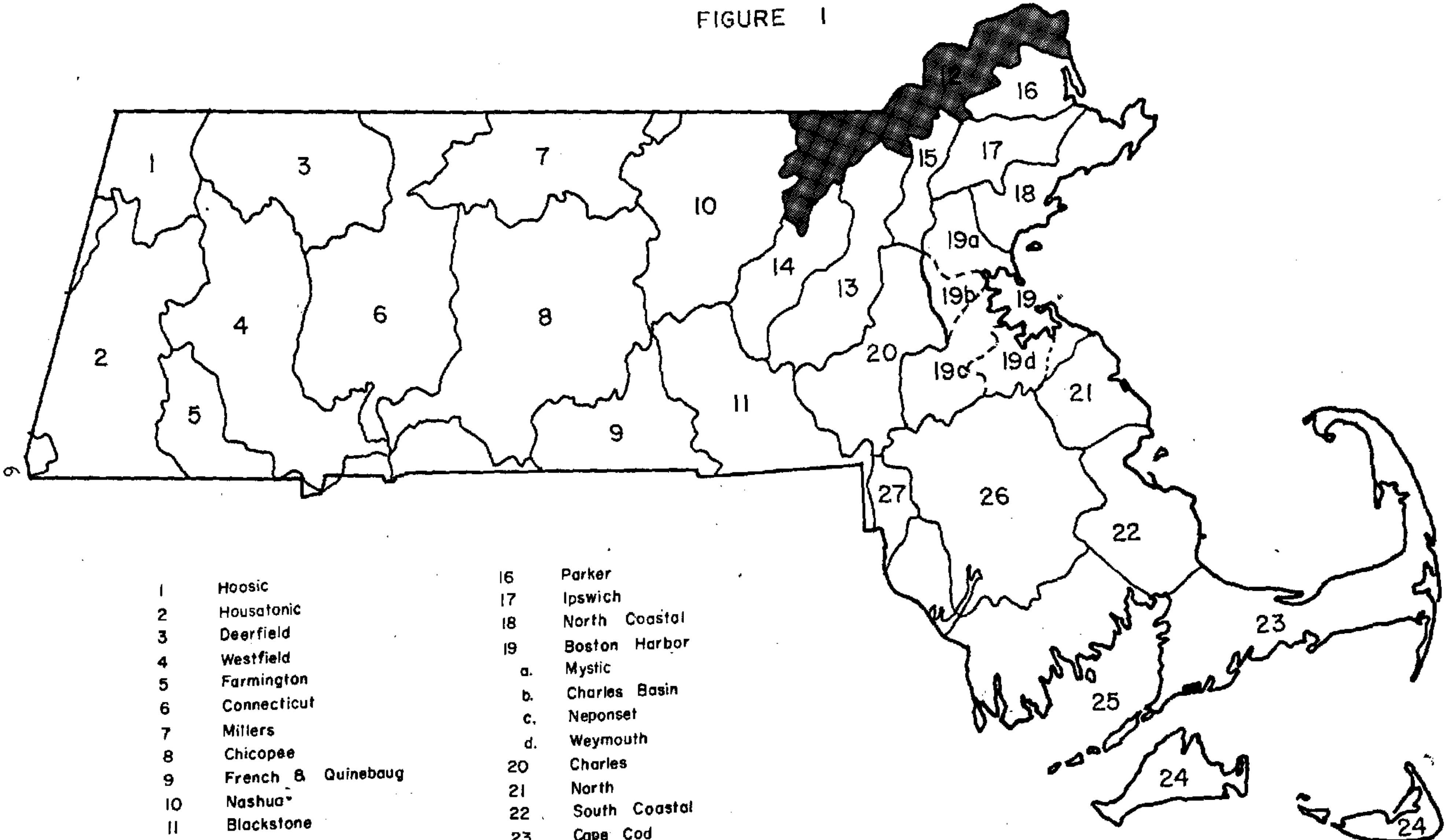
Meanwhile, due to the lack of sufficient groundwater sources, the cities of Lowell and Lawrence came to rely on the river as a source of public water supply. Water treatment plants which were, in their day, the most advanced in the country were built in both cities to treat Merrimack River water. Despite the numerous untreated waste discharges in Massachusetts and upstream in New Hampshire, the river managed until recently to support a variety of uses. A bathing beach in Lowell was used until the 1960's. The shellfish beds in the estuary have gradually been restricted or closed. Sport fishing and boating still take place in the estuary, although the run of anadromous fish today is but a shadow of what it once was.

Although references to the pollution of the Merrimack date back to Thoreau, serious concern over the problem is a fairly recent phenomenon. Several major studies were undertaken during the 1960's by the Federal Water Pollution Control Administration, the Massachusetts Department of Public Health, and Camp, Dresser and McKee Consulting Engineers. These studies led to the requirements for all of the Massachusetts communities on the Merrimack to provide secondary treatment to their wastes. It is somewhat ironic to note that much of the early development of the activated sludge treatment process took place at the Lawrence Experiment Station on the banks of the Merrimack in the 1890's. Seventy years later, that process is the most widely used in sewage treatment plants all over the world, but no such facilities are now operative in Lawrence or its surrounding area.

COMMONWEALTH of MASSACHUSETTS

DRAINAGE BASINS

FIGURE I



1	Hoosic
2	Housatonic
3	Deerfield
4	Westfield
5	Farmington
6	Connecticut
7	Millers
8	Chicopee
9	French & Quinebaug
10	Nashua
11	Blackstone
12	Merrimack
13	Concord & Sudbury
14	Assabet
15	Shawsheen
16	Parker
17	Ipswich
18	North Coastal
19	Boston Harbor
a.	Mystic
b.	Charles Basin
c.	Neponset
d.	Weymouth
20	Charles
21	North
22	South Coastal
23	Cape Cod
24	Islands
25	Buzzards Bay
26	Taunton
27	Ten Mile

INTRODUCTION TO BIOLOGICAL SAMPLING

During the period of June through August 1974, this Division initiated an intensive biological sampling program with the objectives of: 1) providing accurate taxonomic baseline data of macroinvertebrate communities for future comparative evaluation of water quality; 2) providing a useful third parameter in assessing water quality, in addition to the physical-chemical approach; and 3) establishing reliable and consistent methods of both sampling and identifying benthic organisms so that a biological approach to water quality might serve as an accurate and useful indicator.

The study of benthic organisms offers several advantages over a purely physical-chemical water quality sampling methodology. These benthic communities, being for the most part sedentary and incapable of moving great distances by self-locomotion, are a useful tool for detecting environmental perturbations resulting from introduced contaminants. Because of exhibiting a relatively long life span, their characteristics are a function of the past and present, including reaction to infrequently discharged wastes such as toxic substances. Such contaminants could cause macroinvertebrate populations, which are sensitive to stress, to reduce their numbers or biomass which, in turn, could reduce the number of kinds of organisms. Detecting contaminants by periodic chemical sampling would be difficult in this case.

Also, benthic organisms exhibit a relatively long-term retention of contaminants like pesticides, metals, and radioactive materials. Such contaminants may be so infrequently discharged that it becomes difficult to find them in detectable concentrations. Chemical analyses of selected macroinvertebrate fauna could show the presence of these contaminants.

Biological water quality can be expressed both quantitatively and qualitatively. Each has its own requirements, advantages, and limitations. The quantitative approach is essentially an estimation of the numbers or biomass of the various components of the macroinvertebrate community per unit area in all or a portion of the available habitats in the ecosystem being studied (artificial habitats included), and provides information on species composition, species richness, and distribution of individuals within the species.

A quantitative benthic study requires the use of a sampling device that takes a standard unit area or volume of habitat and a measure of precision of the estimates obtained, i.e., replicate sampling in each habitat. This technique provides a measure of productivity and can measure precision of estimates and attach probability statements, thus providing objective comparisons. But most importantly, it enables data of different investigators to be compared.

Unfortunately, no sampling device is at present adequate in taking reliable samples in all habitats. Only selected portions of the environment may be sampled. In addition, the sampling precision is often so low that an indeterminate number of replicates is needed, causing a drain on available time and resources.

The qualitative approach offers an estimate on the richness of species and leads to the determination of the presence or absence of organisms per habitat. In this case, a knowledge of the available habitat types and suitable collecting techniques is needed in order to reach a high level of expertise.

This mode of sampling gives the collector a wide latitude in collecting techniques and leaves all habitats relatively unrestricted for sampling. The processing of qualitative samples is also considerably shorter than that involved in quantitative samples.

Unfortunately, these data also have limitations. The skill of the investigators will differ, so comparison of data is difficult. The drift of organisms into a sample area may bias data and render comparison of data still less useful, and no standing crop or productivity data can be generated from qualitative data.

There are several other variables to be considered in biological sampling that affect both quantitative and qualitative data. The first is the wide seasonal variations that aquatic macroinvertebrates exhibit. This drastically alters the species present, distribution, abundance, and comparison of data taken during different seasons. At some seasons of the year, various stages of organisms shift from aquatic to terrestrial life forms.

Secondly, there are the effects of the abiotic components of the environment such as substrate type, current velocity, and depth. The effects of the physical habitat can very often cause differences that are unrelated to the effects of introduced contaminants. This renders comparisons of unlike habitats with unequal sampling effort useless and misleading.

In the analysis of data, quantitative and qualitative techniques differ greatly. Data from quantitative samples may be used in two instances: 1) to obtain the total standing crop of individuals, or biomass, or both per unit volume or unit area; and 2) to obtain numbers or biomass, or both, of individual taxa per unit area or volume. The presentation of these data may follow a simple tabular form, pictoral line and bar graphs, or histograms. Diversity indices also can measure the environmental quality and the induced stresses on the community structure of benthics. These indices basically contain the two components of species richness and distribution of individuals among the species.

In qualitative data evaluation the analysis can follow either an indicator-organism scheme or a reference station method. In the first method, individual taxa are classified on the basis of their tolerance or intolerance to various levels of contaminants. In the latter method, a comparison of fauna in "clean water" is made with those of a fauna inhabiting an area of stress. This method can show gross to moderate organic contamination on macroinvertebrate populations, but to detect finer changes, a quantitative analysis must be conducted. It is possible to show qualitative data on the presence or absence of tolerant and intolerant taxa and richness of species by employing line and bar graphs, pie diagrams, histograms, or pictoral diagrams.

Organism tolerance to organic wastes can be evaluated by using the following classification which has been set up arbitrarily:

Tolerant: Organisms frequently associated with gross organic contamination and generally capable of thriving under practically anaerobic conditions.

Facultative: Organisms having a wide range of tolerance and frequently associated with moderate levels of organic contamination.

Intolerant: Organisms that are not found associated with even moderate levels of organic contaminants and which are generally intolerant of even moderate reductions in dissolved oxygen.

BIOLOGICAL SAMPLING METHODOLOGY

The methodology this Division has employed in conducting biological sampling has been based heavily upon existing time limits and available resources, i.e., manpower and equipment. A typical sampling routine can best be explained as follows:

1. With the use of a one-square-foot Petersen dredge or a one-square-foot Surber sampler, depending upon depth, flow, and substrate, one set of four hauls is taken. The hauls follow a random transect whereby each bank and two quarter points are dredged.

2. The obtained substrate is placed in a basin and mixed thoroughly into a slurry from which one-quarter of the total sample is sectioned out and retained. The remainder is qualitatively examined and discarded.

3. The retained sample portion is then passed through a standard U.S. No. 30 brass sieve (0.595 mm openings). What remains is placed into a container, fixed, and brought back to the laboratory for analysis.

4. At the same time the dredge samples are taken, all available habitats are sampled by the use of D-nets and by hand. These collected specimens are brought back to the laboratory and incorporated into the taxonomic listing per station. This offers well-rounded baseline data.

5. In the laboratory, the substrate is placed, a portion at a time, into white porcelain pans and the benthics are manually picked and separated according to order.

6. Later identification is made by the use of a 10X-60X stereo-microscope and a 100X-960X (oil immersion) Bausch and Lomb Dynazoom compound scope.

7. Identifications are made to a minimum taxonomic level of genus in most cases and to species if available resources permit. The use of all pertinent keys and reference materials is employed to offer the most accurate identification possible.

8. Benthic samples taken by dredging methods are the only samples treated. All graphics and discussions, unless otherwise stated, apply only to these samples. The habitat data supply important baseline taxonomy but are not recorded per unit area and at times were taken with unequal effort. Therefore, these data are not amenable to quantification.

BIOLOGICAL WATER QUALITY ASSESSMENT OF THE MERRIMACK RIVER

As part of the Division's water quality survey, the Merrimack River was sampled for benthic macroinvertebrates on August 26-27, 1974, at six locations from the Massachusetts-New Hampshire line (mile 49.82) to Haverhill (mile 22.22), where the river is tidally affected.

The Merrimack watercourse at the six stations was characterized by stretches 300 to 400 feet wide, with depths at mid-channel from 6 to 20 feet (see Table 1). Stations MR01, MR03, and MR05 had what appeared to be mid-channel scouring since only solid rock was encountered during the bottom sampling. The banks at these and the other stations were of a clay-silt type mixed with varying amounts of rubble, gravel, and/or sand. At no station was an organic sludge substrate found, although this type was anticipated to occur within the sampled reach since Oldaker (1966) reported black and odorous substances along with "gas-lifted islands of fecal matter and putrid sludges." Pockets of organic deposition may occur, however, and differences of only a few yards between the sampling points of various investigators can cause unlike descriptions of bottom sediments.

Due to the clusters of discharges in the older cities of the basin, it is impossible to determine the impact of individual discharges in this area. Numerous wastes are discharged to canal systems and combined sewers which, in turn, discharge to the river in Lowell, Lawrence, and Haverhill. The discharges in each of these cities have been considered to be a single waste load to the river. These discharges are by far the most complex and severe in the basin. Figure 2 illustrates the relationship of the benthic sampling locations to the discharges into the Merrimack.

For the entire area sampled, that is, from Station MR01 at the Massachusetts-New Hampshire line to Station MR08B off Route 110, Haverhill, chironomids and oligochaetes of primarily tolerant and facultative pollution types dominated the benthic communities. There was no evidence of such "clean water" types as stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). These types may have been excluded by their individual habitat preferences of depth, flow, and substrate and not solely by adverse water chemistry (see Figures 3-7 and Table 2). Out of a total of 3,734 organisms collected at the six sampling sites, only 16 (<1%) were categorized as intolerant to organic pollution (14 chironomids and 2 amnicolid snails). (See Table 3.)

Figures 8 and 9 are a graphic interpretation of the combined effects of the physico-chemical parameters on the benthic macroinvertebrate communities found at the six stations. Each organism was assigned to a pollution tolerance to organic pollution based on the literature and field experience. In Figure 8, the kinds of organisms are grouped by station. "Kinds" is defined as the number of different organisms, regardless of the level to which they were identified, i.e., a family is weighted the same as a species. Figure 9 is based on the total number of organisms by pollution tolerance classification. By moving across and examining the bars of these graphs it is possible to see the dominant tolerance category by station. For example, one can see there were few intolerant kinds collected in the Merrimack, and by distribution, the tolerant organisms were much more abundant than the other two categories. It is possible for a river station

TABLE 1

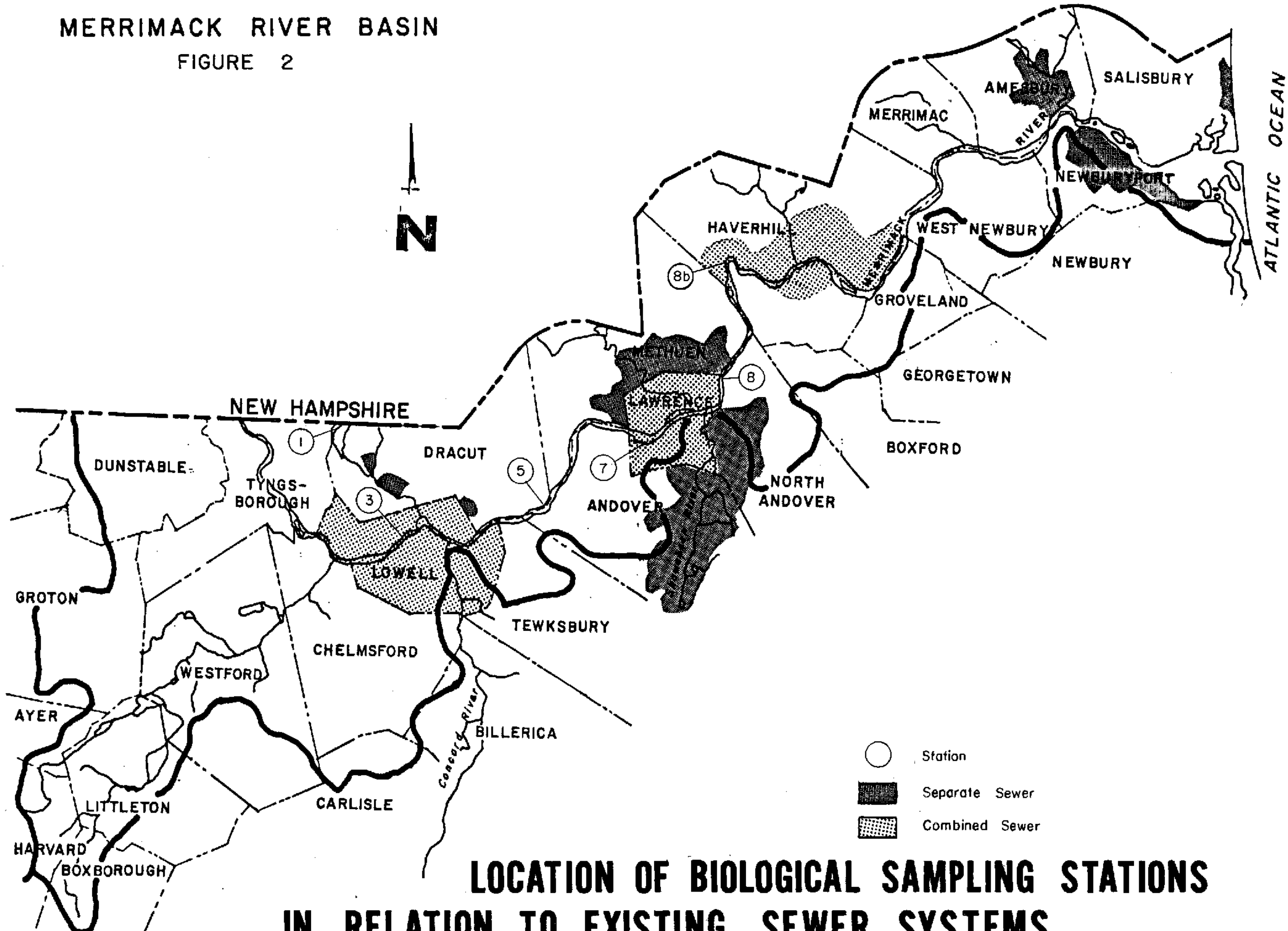
MERRIMACK RIVER BIOLOGICAL STUDY

PHYSICAL CHARACTERISTICS BY STATION

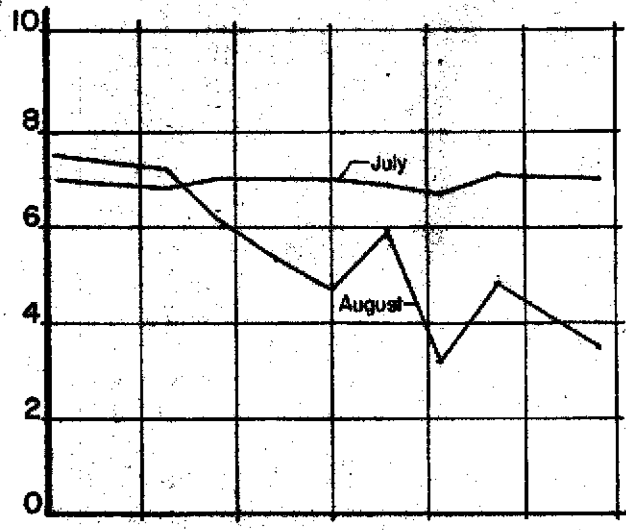
STATION	RIVER MILE	DESCRIPTION	SUBSTRATE TYPE	SAMPLE DEPTH (ft.)
MR01	49.82	Massachusetts-New Hampshire state line	Mid-stream: solid rock Banks: clay-silt-detritus	10 1
MR03	41.00	0.40 miles upstream from Pawtucket Dam	Mid-stream: solid rock Banks: rubble-gravel-clay-silt	12-15 1
MR05	35.00	Power line off Route 110, Dracut	Mid-stream: solid rock Banks: clay-silt	20 1
MR07	29.20	Launch area, Riley Park, Lawrence	Mid-stream: clay-silt-detritus Banks: clay-silt	15 <1
MR08	26.36	Lawrence-Methuen town line	Mid-stream: rubble-gravel-sand Banks: clay-silt-organic matter	6 1
MR08B	22.22	Picnic area off Route 110, Haverhill	Mid-stream: rubble-gravel Banks: gravel-sand-clay-silt	10 1

MERRIMACK RIVER BASIN

FIGURE 2

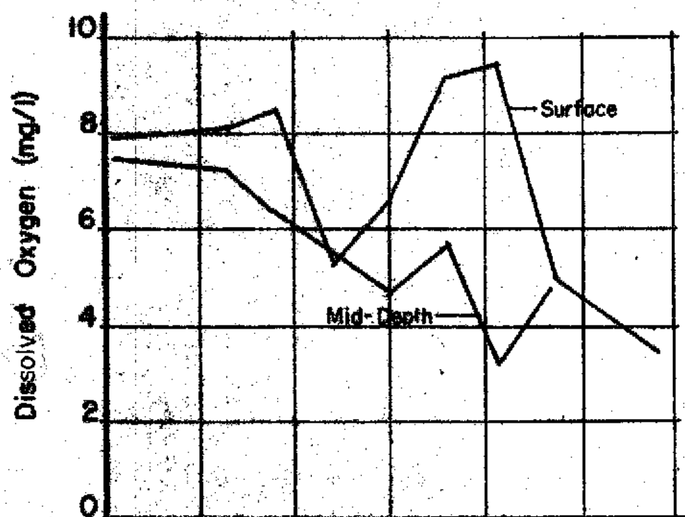


LOCATION OF BIOLOGICAL SAMPLING STATIONS IN RELATION TO EXISTING SEWER SYSTEMS



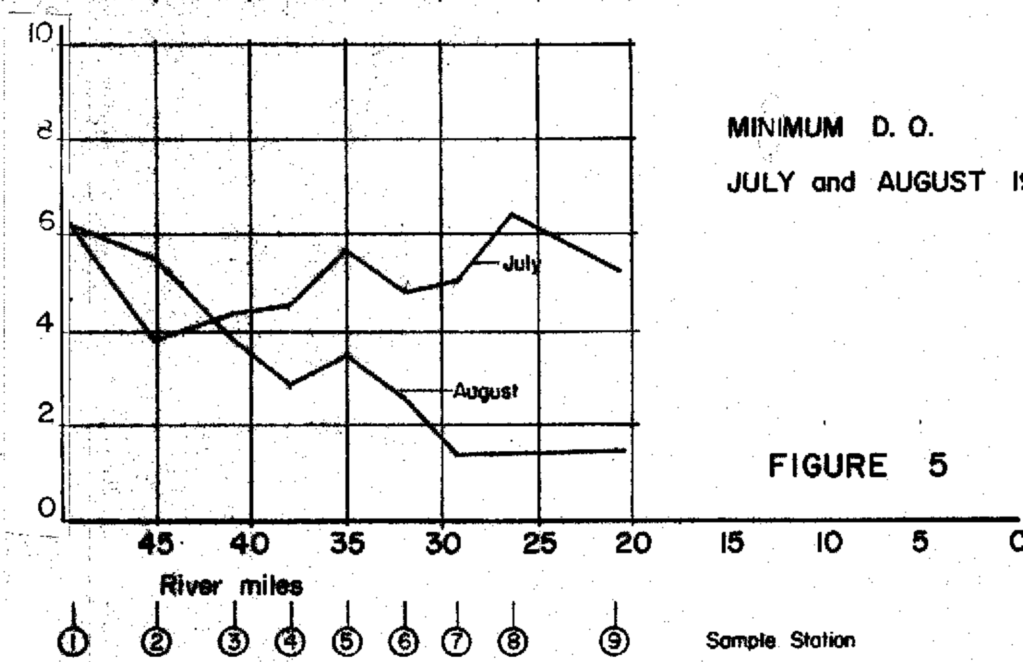
AVERAGE D. O.
JULY and AUGUST 1974

FIGURE 3



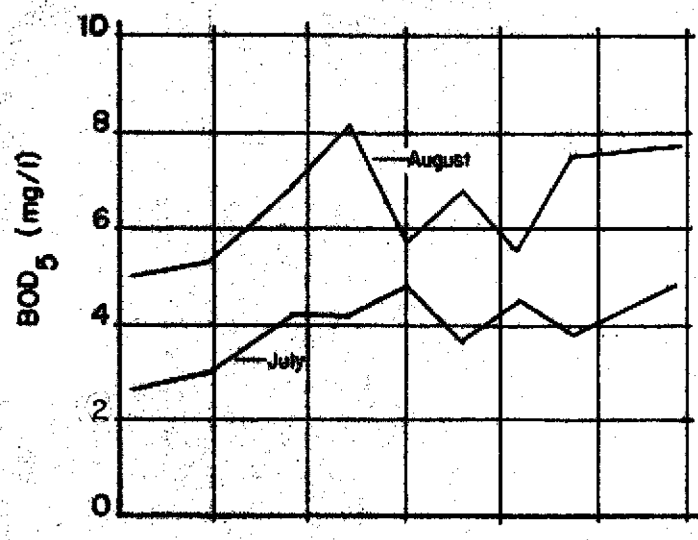
SURFACE and MID-DEPTH D. O.
AUGUST 1974

FIGURE 4



MINIMUM D. O.
JULY and AUGUST 1974

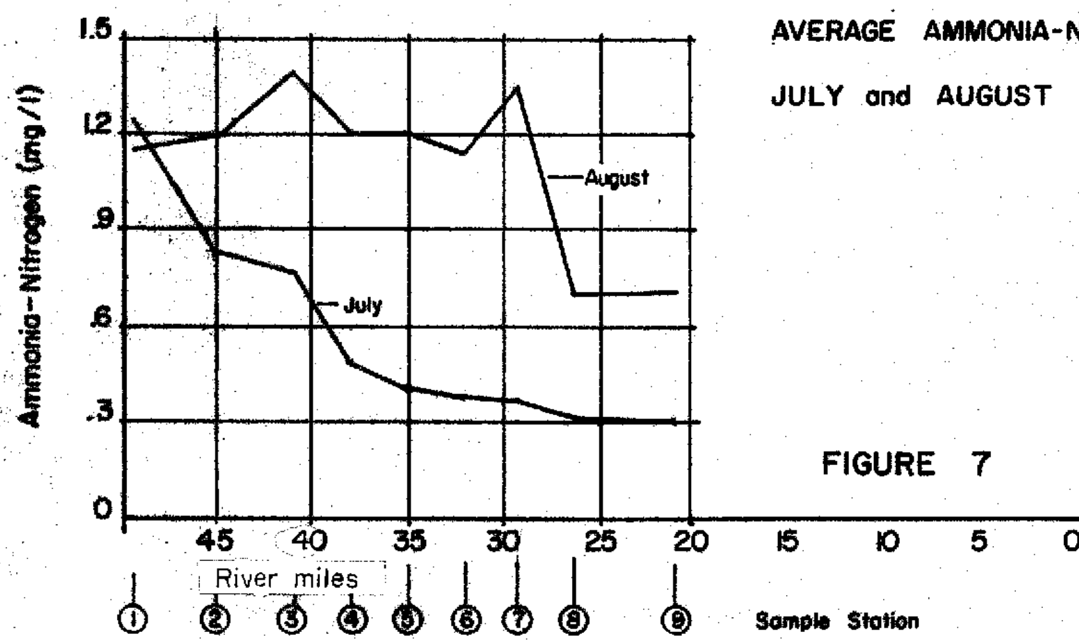
FIGURE 5



AVERAGE 5 DAY BOD

JULY and AUGUST 1974

FIGURE 6



AVERAGE AMMONIA-NITROGEN

JULY and AUGUST 1974

FIGURE 7

TABLE 2

MERRIMACK RIVER 1974 SURVEY

pH DATA

STATION	7/9/74	7/11/74	8/20/74	8/22/74
MR01	7.4	7.7	7.7	7.5
MR02	7.2	7.4	7.6	7.4
MR03	7.0	7.4	7.6	7.4
BB01	7.2	7.3	9.6	7.2
MR04	7.1	7.2	7.7	7.4
MR05	7.2	7.1	7.4	7.3
MR06	7.3	7.2	7.2	7.5
MR07	7.2	7.2	7.1	7.3
SR01	6.9	7.2	7.4	7.3
SR02	7.0	6.9	7.7	7.2
MR08	7.2	6.9	7.1	7.1
MR09	7.2	6.8	7.1	7.2
MR09A	7.1	7.0	7.0	7.3
LR01	7.4	7.1	7.4	7.1
MR10	7.3	7.1	7.4	6.8
MR10A	7.3	7.2	7.2	7.0
MR11	7.1	7.3	6.9	6.8
MR11A	7.3	7.1	7.2	6.9
MR11B	7.0	7.1	7.0	6.8
MR11C	7.2	7.2	7.2	7.0
PW01	7.0	7.2	7.2	6.9
MR12	6.9	7.1	7.1	7.3
MR12A	6.7	7.1	7.4	7.4
MR13	6.6	7.5	7.8	7.6
MR13A	7.5	7.6	7.8	7.7
MR13B	7.5	7.4	7.8	7.7
MR13C	7.6	7.4	7.8	7.6
MR14	7.0	7.6	7.8	7.8
MR14A	7.3	7.7	8.0	7.8
MR15	7.8	7.7	7.8	7.8
MR15A	7.8	---	7.8	7.8
MR17	7.7	8.0	7.9	7.9
MR18	8.0	8.0	8.0	8.0

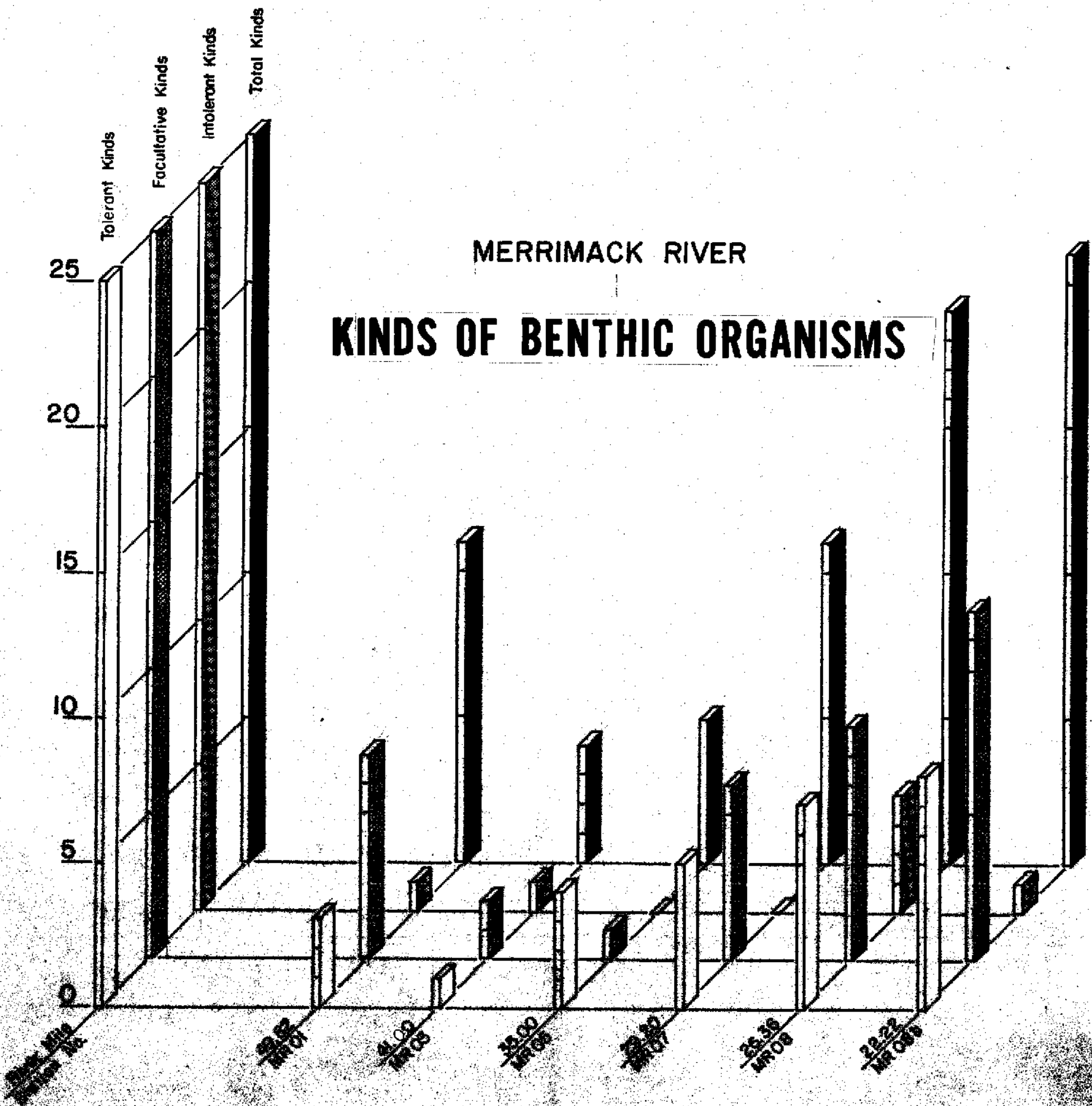

MERRIMACK RIVER
KINDS OF BENTHIC ORGANISMS
Tolerant Kinds
Facultative Kinds
Intolerant Kinds
Total Kinds
25
20
15
10
5
0
25.36
MR 08
22.22

FIGURE 8

MERRIMACK RIVER

DISTRIBUTION OF BENTHIC ORGANISMS

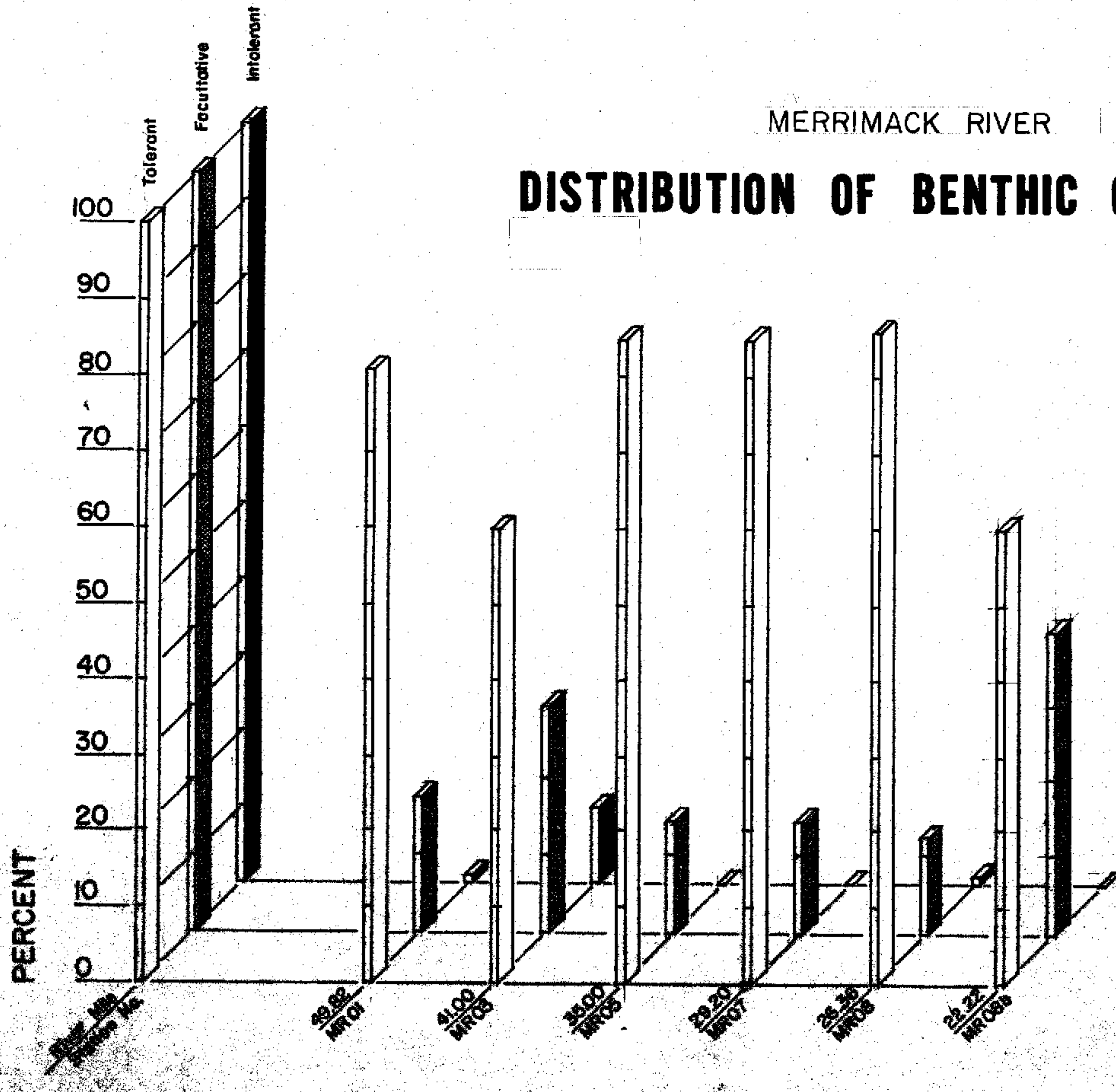


FIGURE 9

to exhibit more organic pollution intolerant kinds but by distribution show a facultative or tolerant dominance in the number of organisms. These graphs are meant to show trends in the benthic response to water quality, not specifics.

The first reach sampled was from the Massachusetts-New Hampshire state line to the Pawtucket Dam in Lowell. This reach included stations MR01 and MR03. Both of these sampling transects had a bedrock substrate at mid-channel causing improper closure and bite of the Petersen dredge. Only the mixed clay-silt banks offered a favorable grab sample; thus, the benthic faunal list is composed to a large degree of bank dwellers. The depths encountered were similar.

The benthic communities at both stations were dominated by tubificid worms of a pollution tolerant type. Station MR01 consisted of 152 individuals, 81% of which fit into an organic pollution tolerant category. Only one intolerant individual, Brillia, a chironomid, was present. Station MR03 consisted of only 10 individuals, 60% of which fit into a pollution tolerant category.

An investigation of the physical and chemical data, in particular D.O., BOD_5, pH, and NH_3, yielded levels indicative of gross organic pollution and suggested a damaged benthic community. The numbers and types of organisms collected bore this assumption out, but the community appeared more than just stressed by organic pollution. The very low numbers and types suggested the possible presence of a toxic material which was severely limiting the benthic fauna. It was initially thought that the ammonia concentration in excess of 1.0 mg/l plus a BOD_5 in excess of 5.0 mg/l was damaging to the fauna, but examination of data on other rivers with similar levels found them to support more sensitive benthic communities (DWPC, Charles River Part A, 1974).

The lack of detritus deposits at MR03 may also be limiting the benthics by reducing the amount of colonizable bottom area. The basically clay-silt substrate is not particularly attractive for the establishment of intolerant clinging and case-building types such as mayflies, stoneflies, and caddisflies. Indeed, these types might never occur under even the most pristine water quality conditions if the substrate, depth, and flow are not favorable.

The second sampling reach extended from the Pawtucket Dam in Lowell to the Lawrence Dam in Lawrence and included stations MR05 and MR07. Station MR05 in Dracut was also subjected to mid-channel scour since only bedrock was located. The banks continued to consist of mainly clay-silt. Immediately upstream of the dam at Station MR07, mid-channel grabs were successfully accomplished. Clay-silt and detritus comprised the major substrate types. In this stretch of the Merrimack, organic sludge deposits were expected, especially behind the dam. No deposits of this type were encountered.

Both stations (MR05 and MR07) exhibited a benthic response of an organic pollution tolerant nature. Over 80% of the benthic organisms were assigned to this category. The water quality conditions at MR05 and MR07 were similar to those in the first stretch, the only notable exception being the D.O. which dropped to a minimum level of 1.4 mg/l at Station MR07. This level was substantially lower than those recorded at the previous stations.

Only 13 organisms of five types were collected at MR05 and 252 individuals of 11 types at MR07. As in the first reach, these numbers seemed quite low and were not thought directly attributable to the organic pollutant levels found. A possible toxic pollutant again appeared to be the cause of the reduction in types and numbers of organisms, although the numbers of Limnodrilus sp. at MR07 indicated a return towards an organically stressed condition. It should be noted that the substrate type in this stretch may not support many of the "clean water" varieties.

The final reach sampled extended from below the Lawrence Dam to a picnic area off Route 110 in Haverhill where the river was tidally affected. Both stations (MR08 and MR08B) in this stretch had rubble-gravel bottoms. The banks consisted of clay-silt which was mixed with organic matter at MR08. Unfortunately, no chemical data were taken at MR08B, but examination of the data from MR08 showed a more intensely organically polluted condition. The ammonia level decreased at MR08 to 0.65 mg/l.

MR08B also yielded two leeches, Glossiphonia complanata and G. heteroclita, both reported in Massachusetts for the first time. Identification was verified by Donald J. Klemm of the Environmental Protection Agency Environmental Monitoring and Support Laboratory. These specimens have been deposited in the Worm Division of the U.S. Natural History Museum, Smithsonian Institution, Washington, D.C.

Although the overall response was one of a continued dominance of pollution tolerant organisms, a marked change in the total number of types occurred at MR08 and MR08B (Table 3). More facultative and intolerant types were present in the forms of chironomids, naidids, and pelecypods (habitat samples). The already established tolerant types were further supplemented by an assemblage of four species of leeches and a large number of midges of the genus Chironomus. The appearance of a large number of pollution tolerant midges (1,056) and oligochaetes (915) of one type at Station MR08 exhibits a damaged condition caused by organics. This condition is also evident at MR08B by examination of the midge and oligochaete populations.

It was not within the realm of this biological assessment to make concrete evaluations of the occurrence of benthic organisms as related to a particular physical or chemical parameter. This assessment was intended not to replace, but to supplement the physico-chemical data. A strict reliance on purely physical and chemical tests can, in some instances, give a misleading impression of conditions which biological observations could easily rectify.

In the upper Merrimack River stations there appeared to be a toxic material present reducing the number of types and individuals. To determine if a toxic material is limiting, complex analytical methods are sometimes involved. Effects such as synergism and antagonism and other complicating factors like temperature, pH, and D.O. make it difficult to predict the overall toxic effect on the river. Even bio-assay methods are not ideal, for they stress conditions under test, not in the stream itself.

TABLE 3

NUMBER AND KINDS OF BENTHIC ORGANISMS BY POLLUTION TOLERANCE

MERRIMACK RIVER - AUGUST 1974

STATION NUMBER	MR01	MR03	MR05	MR07	MR08	MR08B
SENSITIVE ORGANISMS						
Arthropoda						
Insecta						
Neuroptera (dobsonflies, alderflies, spongilla flies)						
Sisyridae (spongilla flies)						
Climacia sp.				*L		
Diptera (true flies)						
Chironomidae (midges)						
Tanypodinae						
Ablabesmyia sp.					1L	
Pentaneurini					8L	
Chironominae						
Tribelos sp.		1L				
Glyptotendipes senilis				*L		
Tanytarsus sp.						2L
Orthocladiinae						
Brilla sp.	1L					
Psectrocladius sp.	*L					
Cricotopus sp.					1L	
Mollusca						
Gastropoda (snails)						
Bulimidae						
Amnicola sp.					*2A	
SUBTOTAL ORGANISMS	1	1	0	0	12	2
SUBTOTAL KINDS	1	1	0	0	4	1

TABLE 3 (Continued)

STATION NUMBER	MR01	MR03	MR05	MR07	MR08	MR08B
FACULTATIVE ORGANISMS						
Nematoda (nematodes)	1A		2A		1A	43A
Annelida						
Oligochaeta (aquatic earthworms)						
Naididae	7A			2A	*151A	306A
Nais communis	2A	*A				
Dero sp.					112A	
Aulophorus sp.	1A				*25A	
Stylaria sp.						1A
Pristina sp.				8A		2A
Allonais sp.					5A	
Arthropoda						
Crustacea						
Isopoda (sow bugs)						
Asellidae						
Asellus communis			*A		*A	
Insecta						
Collembola (springtails)						
Poduridae						
Podura aquatica						*A
Coleoptera (beetles)						
Gyrinidae (whirligigs)						
Dineutus sp.	*A					
Hydraenidae						
Hydraena sp.		1L				
Elmidae (riffle beetles)						
Dubiraphia sp.				1L		1L
Diptera (true flies)						
Ceratopogonidae (biting midges)						
Probezzia sp.	1L			2L		1L
Alluaudomyia sp.					1L	
Chironomidae (midges)						
Tanypodinae						
Procladius sp.	3L			18L		1L

TABLE 3 (Continued)

STATION NUMBER	MR01	MR03	MR05	MR07	MR08	MR08B
FACULTATIVE ORGANISMS (continued)						
Chironominae						
Dicrotendipes sp.						*38L
Xenochironomus sp.					2L	1L
Polypedilum sp.	13L	2L		8L		4L
Paracladopelma sp.						5L
Paralauterborniella sp.						1L
Mollusca						
Gastropoda (snails)						
Planorbidae						
Gyraulus sp.			*A			
Ancylidae (limpets)						
Ferrissia sp.			*A		*2A	
Pelecypoda (clams)						
Unionidae (freshwater mussels)						
Anodonta spp.				*A		*A
A. implicata						*A
A. cataracta					*A	
Elliptio complanata					*A	
SUBTOTAL ORGANISMS	28	3	2	39	299	404
SUBTOTAL KINDS	7	2	1	6	8	12
TOLERANT ORGANISMS						
Annelida						
Oligochaeta (aquatic earthworms)						
Tubificidae			1A		*915A	314A
Limnodrilus sp.	116A	6A		*157A		
L. hoffmeisteri			1A		2A	
Enchytraeidae	2A					
Hirudinea (leeches)						
Glossiphoniidae					*1A	
Helobdella stagnalis		*A	*8A	*A	3A	5A
H. elongata						9A
Glossiphonia heteroclita						1A
G. complanata						1A

TABLE 3 (Continued)

STATION NUMBER	MR01	MR03	MR05	MR07	MR08	MR08B
TOLERANT ORGANISMS (continued)						
Erpobdellidae					*A	
Arthropoda						
Insecta						
Hemiptera (true bugs)						
Saldidae (shore bugs)						
Saldula sp.					*A	
Coleoptera (beetles)						
Dytiscidae (predacious diving beetles)						
Laccophilus sp.					*A	
Diptera (true flies)						
Psychodidae (moth flies)						
Psychoda sp.				34L		
P. alternata					3P,1A	
Chironomidae (midges)						
Chironominae						
Chironomus sp.	*P	1P		19L	*1034L, 19P,2A	230L, 18P
Cryptochironomus sp.	5L			1L		1L
Glyptotendipes sp.		*L,*A	1L	*2L,*P	3L,1P	*20L,7P
G. polytomus				*L		
Mollusca						
Gastropoda (snails)						
Physidae						
Physa sp.					*A	
SUBTOTAL ORGANISMS	123	7	11	213	1984	606
SUBTOTAL KINDS	3	1	4	5	7	8

TABLE 3 (Continued)

STATION NUMBER	MR01	MR03	MR05	MR07	MR08	MR08B
UNIDENTIFIABLE TO TOLERANCE						
Annelida						
Oligochaeta (aquatic earthworms)				6A	4A	54A
Arthropoda						
Insecta						
Coleoptera (beetles)	1L					
Diptera (true flies)						
Chironomidae (midges)	5L	*L		2L,1P	3L,*P,1A	
GRAND TOTAL ORGANISMS	152	11	13	252	2295	1012
GRAND TOTAL KINDS	11	4	5	11	19	21

KEY:

* Denotes organisms taken for baseline data (habitat samples) only. These organisms are not incorporated into the totals.

Stages of development: L = larvae, N = nymphs or naiads, P = pupae, A = adults.

CONCLUSIONS AND RECOMMENDATIONS

1. Benthic macroinvertebrate populations at each station were dominated by pollution tolerant and facultative organisms. Out of a total of 3,734 organisms collected at the six sampling sites, only 16 (<1%) were categorized as intolerant to organic pollution (14 chironomids and 2 anmicolid snails).

2. In the Merrimack River the benthic communities might be limited by factors other than organic pollutants, for example, the type of bottom, speed of current, turbidity, and light penetration.

3. There is a possibility the benthic communities are damaged by a toxic material, thus reducing the number and types of individuals. To determine if a toxic material is limiting, complex analytical methods are sometimes involved. Effects such as synergism, antagonism, and other complicating factors like temperature, pH, and D.O. make it difficult to predict the overall toxic effect on the river. Even bio-assay methods are not ideal, for they assess conditions under test, not in the stream itself.

4. Further studies on the possibility of a toxic material acting in the Merrimack River are recommended. Also, the standard benthic macroinvertebrate sampling program should be continued to better understand the benthic water quality response over an established period of time.

5. This survey will be repeated after water pollution control facilities at Lowell, Lawrence, and Haverhill become operational.

LIST OF BIOLOGICAL REFERENCES

1. American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater. Thirteenth Edition. New York. 874 pp.

2. Beck, W.M. and E.C. Beck. 1966. Chironomidae (Diptera) of Florida, Part I, Pentaneurini: (Tanypodinae). Bull. Fla. St. Mus. Vol. 10, No. 8. pp. 305-379.

3. Borror, Donald J. and Dwight M. DeLong. 1971. An Introduction to the Study of Insects. Third Edition. Holt, Rinehart and Winston, New York. xiii + 812 pp., 653 f.

4. Brown, H.P. 1972. Aquatic Dryopid Beetles (Coleoptera) of the United States. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0370. Identification Manual No. 6. ix + 81 pp., 198 f.

5. Burch, J.B. 1972. Freshwater Sphaeriacean Clams (Mollusca: Pelecypoda) of North America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0367. Identification Manual No. 3. viii + 31 pp., 34 f.

6. -----. 1973. Freshwater Unionacean Clams (Mollusca: Pelecypoda) of North America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-00588. Identification Manual No. 11. xi + 176 pp., 154 f.

7. Burks, B.D. 1953. The Mayflies, or Ephemeroptera of Illinois. Ill. Nat. Hist. Surv. Bull. 26(1): 1-216, 395 f.

8. Brinkhurst, R.O. 1965. Studies of the North American Aquatic Oligochaeta, Part II. In Proc. Acad. Nat. Sci. of Phila. 117(4): 117-172.

9. Brinkhurst, R.O. and B.G.M. Jamieson. 1971. Aquatic Oligochaeta of the World. Univ. of Toronto Press, Toronto, Ontario, Canada. xi+860 pp.

10. Chu, H.F. 1949. How to know the Immature Insects. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 234 pp., 601 f.

11. Eddy, S. and A.C. Hodson. 1950. Taxonomic Keys to the Common Animals of the North Central States. Burgess Pub. Co., Minneapolis, Mn. 161 pp., 765f.

12. Environmental Protection Agency. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. Cornelius I. Weber, ed. EPA Natl. Res. Center, Cincinnati, Ohio. EPA - 670/4-73-001.

13. Ferris, V.R., J.M. Ferris, and J.P. Tjepkema. 1973. Genera of Freshwater Nematodes (Nematoda) of Eastern North America. U.S. EPA Series Biota of Freshwater Ecosystems. Identification Manual No. 10. ix + 38 pp., 14f.

14. Hamilton, A.L., O.A. Saether, and D.R. Oliver. 1969. A Classification of the Nearctic Chironomidae. Fish. Res. Bd. Can. Tech. Rept. 129, 42 pp.

15. Harden, P.H. and C.E. Mickel. 1952. The Stoneflies of Minnesota (Plecoptera). Univ. Minn. Agr. Exp. Sta. Tech. Bull. 201: 1-84.

16. Hilsenoff, W.L. 1970. Key to Genera of Wisconsin Plecoptera (Stonefly) Nymphs, Ephemeroptera (Mayfly) Nymphs, Trichoptera (Caddisfly) Larvae. Res. Rept. No. 67. Wis. Dept. Nat. Res., Madison. 68 pp.

17. -----. 1970. Corixidae (water boatmen) of Wisconsin. Wis. Acad. Nat. Sci., Arts and Letters. Vol. 58: 203-235.

18. Hobbs, Horton H. Jr. 1972. Crayfishes (Astacidae) of North and Middle America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0399. Identification Manual No. 9. x + 173 pp., 115f.

19. Holsinger, John R. 1972. The Freshwater Amphipod Crustaceans (Gammaridae) of North America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0369. Identification Manual No. 5. vii + 89 pp., 32f.

20. Hynes, H.B.N. 1970. The Ecology of Running Waters. Univ. of Toronto Press, Toronto, Ontario, Canada. 555 pp.

21. Jaques, H.E. 1951. How to know the Beetles. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 372 pp., 827 f.

22. Johannsen, O.A. 1934-37. Aquatic Diptera. Entomological Reprint Specialists, Los Angeles, Ca.

23. Keup, Lowell E., W.M. Ingram, and K.M. Mackenthun. 1967. Biology of Water Pollution, A Collection of Selected Papers on Stream Pollution, Wastewater, and Water Treatment. FWPCA, USDI, Cincinnati, Ohio. 290 pp.

24. Klemm, D.J. 1972. Freshwater Leeches (Annelida: Hirudinea) of North America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0391. Identification Manual No. 8. viii + 53 pp., 28f.

25. Mackenthun, Kenneth M. and William Marcus Ingram. 1967. Biological Associated Problems in Freshwater Environments. FWPCA, USDI, Cincinnati, Ohio. x + 285 pp.

26. Mackenthun, K.M. 1969. The Practice of Water Pollution Biology. FWPCA, USDI, Washington, D.C. xi + 281 pp.

27. Mason, William T. Jr. 1968. An Introduction to the Identification of Chironomid Larvae. Division of Water Pollution Surveillance, FWPCA, USDI, Cincinnati, Ohio. 90 pp. (Revised 1973)

28. Needham, J.G. and P.R. Needham. 1962. A Guide to the Study of Freshwater Biology. Holden-Day, Inc., San Francisco. x + 108 pp.

29. Needham, J.G., J.R. Traver, and Yin-Chi Hsu. 1935. The Biology of Mayflies. Comstock Pub. Co., Ithaca, N.Y. xiv + 759 pp., 168 f, 40 pl.

30. Pennak, R.W. 1953. Freshwater Invertebrates of the United States. Ronald Press Co., New York. ix + 769 pp.

31. Roback, S.S. 1957. The Immature Tendipedids of the Philadelphia Area. Acad. Nat. Sci. Philadelphia, Mono. No. 9. 148 pp.

32. Ross, H.H. 1944. The Caddisflies, or Trichoptera, of Illinois. Bull. Nat. Hist. Surv. 23: 326 pp.

33. Usinger, R.L., ed. 1963. Aquatic Insects of California. Univ. of California Press. viii + 508 pp.

34. Ward, H.B., and G.C. Whipple. 1959. Fresh-water Biology. Second Edition. W.T. Edmondson, ed. John Wiley & Sons, Inc. New York. xx + 1248 pp.

35. Williams, W.D. 1972. Freshwater Isopods (Asellidae) of North America. U.S. EPA Series Biota of Freshwater Ecosystems, SN5501-0390. Identification Manual No. 7. ix + 45 pp., 36 f.

ADDITIONAL REFERENCES

1. Oldaker, Warren H. 1966. Report on Pollution of the Merrimack River and Certain Tributaries, Part III - Stream Studies - Biological. USDI. FWPCA. NE Region. Merrimack River Project. Lawrence, Mass. iii + 39 pp. and Appendix.

2. Massachusetts Division of Water Pollution Control. 1974. Merrimack River 1974 Water Quality Survey Data. 86 pp.

3. -----. 1975. Merrimack River Basin Water Quality Management Plan. 100 pp. + Appendix.

4. -----. 1974. Charles River Part A. 112 pp.