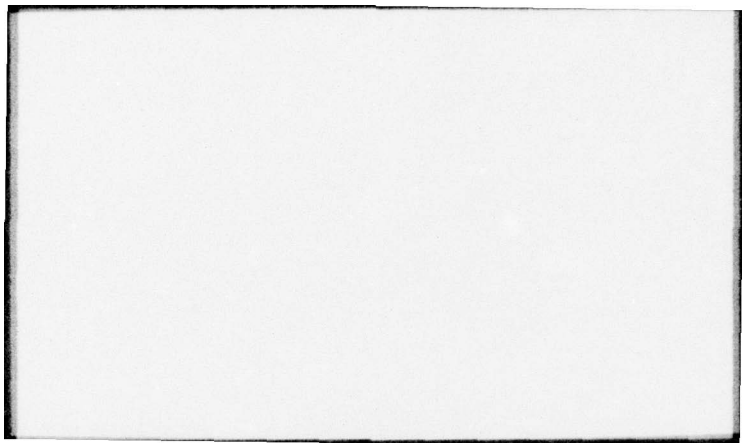
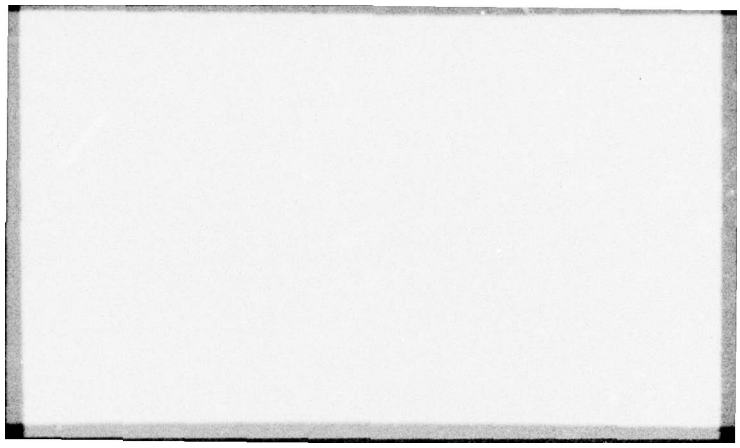
AD-A033 547 BATTELLE COLUMBUS LABS OHIO F/G 6/3
AQUATIC LIFE STUDIES AT BADGER ARMY AMMUNITION PLANT, VOLUME I.(U)
AUG 76 J M STILWELL, D C COOPER, M A EISCHEN DAMD17-74-C-4123
UNCLASSIFIED NL

1 OF 3
ADA033547





(12)

FINAL PHASE II REPORT
(VOLUME I)

on

AQUATIC LIFE FIELD STUDIES AT BADGER ARMY AMMUNITION PLANT

to

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND

D D C
DEC 21 1976
C

by

J. M. Stilwell, D. C. Cooper, M. A. Eischen, M. C. Matthews, B. E. Sherwood, and T. B. Stanford

December 10, 1976

Supported by

U.S. Army Medical Research and Development Command
Washington, D.C.

Contract No. DAMD 17-74-C-4123

Project Officer
J. Gareth Pearson

Unlimited Distribution

Approved for public release
Distribution Unlimited

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
(9) Final rept May-Dec 75 on Phase 2,	
4. TITLE (and Subtitle) Final Phase II Report (6) Aquatic Life Field Studies at Badger Army Ammunition Plant • Volume I.	5. TYPE OF REPORT & PERIOD COVERED Phase II Report May-December, 1975 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) J. M. Stilwell, D. C. Cooper, M. A. Eischen, M. C. Matthews, B. E. Sherwood, and T. B. Stanford	8. CONTRACT OR GRANT NUMBER(s) (15) DAMD 17-74-C-4123
9. PERFORMING ORGANIZATION NAME AND ADDRESS Battelle Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (11) 31 Aug 76
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Medical Research and Development Command, Washington, D.C. 20314	12. REPORT DATE August 31, 1976 13. NUMBER OF PAGES 100 (12) 102p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Munitions, Waste Products, Pollution, Benthic Macroinvertebrates, Periphyton, Phytoplankton

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See following Executive Summary

407 080

bpg

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

EXECUTIVE SUMMARY

The United States Army Medical Research and Development Command has been supporting research in order to recommend environmental quality standards for the munitions industry. Phase I preliminary studies were completed in 1974, and Phase II investigations were begun in the spring of 1975. Two surveys were originally placed at the Badger Army Ammunition Plant (BAAP), however, cessation of production resulted in the cancellation of the second survey.

The objectives of the Phase II studies at BAAP were to collect replicated quantitative data describing the specific nature of effluent effects on receiving systems and to determine the relationship between observed effects and the amount of primary munitions constituents in the effluents.

Areas investigated included water quality, sediment chemistry, munitions constitutent concentrations, periphyton community and the benthic macroinvertebrate community. Periphyton and invertebrates were selected for study because of the relative ease of sampling and analysis of this group as well as their usefulness as indicators of environmental quality. A variety of parameters were calculated for both groups of organisms studied. Standing crop, species diversity, and colonization rates were obtained for both algae and invertebrates. Additionally, chlorophyll *a* and biomass were calculated from algal samples.

Sampling stations were selected in effluent receiving systems and control areas near the BAAP. Water and sediment samples were collected at all biological sampling stations. Periphyton was collected with artificial substrates (glass slides) at all stations. Phytoplankton was also collected with appropriate sampling gear. Benthic macroinvertebrates were collected from both artificial substrates (multiple-plate samplers) and natural substrates (Ponar dredge). Replicate samples were collected in all cases to provide statistically valid data.

Field investigations were conducted at BAAP from late April to early June, 1975, with intensive sampling occurring during a one-week period from May 18 to May 24.

Two primary munitions compounds were investigated in the Phase II program--nitrocellulose and nitroglycerine. The ecological responses to these two compounds were quite different and were dealt with separately.

Nitrocellulose

Nitrocellulose manufacturing wastes at BAAP were discharged through a nonoperating industrial treatment plant (ITP) to a small stream. The waste stream emptied into Grueber's Bay after passing through a series of three settling ponds. Sampling stations were established in the ITP stream, the first settling lake, Grueber's Bay and Weigand's Bay. Weigand's Bay was used as a control due to its proximity to the plant and similar morphology.

The water quality of the aquatic systems receiving nitrocellulose manufacturing wastes sampled in the area of the BAAP show somewhat degraded conditions existing in the ITP stream and the first settling lake. High concentrations of NO_3/NO_2, sulfate and chloride, have been recorded in these waters. Conditions in Grueber's Bay approached background levels (Weigand's Bay) with the exception of slightly elevated sulfate concentrations. Nitrocellulose was detected in the waters of these systems in concentrations from <1.0 to 12.1 ppm.

Sediment samples from the three receiving systems were high in volatile solids, COD, and nutrients. Analysis for nitrocellulose confirmed the presence of this compound in the sediments of these areas. Concentrates in the sediments ranged from 17.8-296.0 ppm.

A review of the algae data, both periphyton and phytoplankton, collected from BAAP receiving systems indicates an environmental perturbance existing in both the ITP stream and the settling lake (SL-1). Standing crops, diversity, chlorophyll *a* and biomass were all low at these two stations. The inhibiting factor was not clear, but did not appear to be nitrocellulose.

In Grueber's Bay at the highest NC concentrations, no overall toxic effects were observed in the algal community. More species of

algae were recorded from Grueber's Bay than the control bay. A shift in dominant species was noted between the two bays. The overall results of algal sampling indicate no negative effect on the periphytic or planktonic algae in Grueber's Bay caused by the manufacturing waste discharge.

The benthic macroinvertebrate data collected during Phase II also indicate an environmental perturbance existing in the ITP stream and the first settling lake. Very few organisms were collected in either of these areas. The stress condition existing in the ITP stream and settling lake appears to be caused by poor water quality as organisms were unable to colonize either the natural or artificial substrates in these areas. This would seem to eliminate nitrocellulose as the cause of the environmental perturbance in these two areas--as it is essentially insoluble in water. A possible explanation might be periodic, excessive chlorination of the sanitary waste discharged to this system.

The situation in Grueber's Bay is even more complex. Water quality parameters monitored in this bay are similar to those found in the control Weigand's Bay, which is considered to have good-to-excellent water quality for this area of Wisconsin. However, a reduction in numbers of individuals, number of species, and $\overline{H}$ was noticed in the bottom sediments of GBT-1. This is clearly a problem involving substrate quality rather than water quality as artificial substrate samplers were colonized by large numbers of a variety of invertebrates and supported communities similar to those found in samples from Weigand's Bay. High concentrations of volatile solids, COD and nutrients, could lead to periodic oxygen depletions and an anoerobic condition in the sediments.

Environmental stress was experienced by both algal and invertebrate communities inhabiting on-site aquatic systems; the cause was believed to be something other than nitrocellulose. Algae inhabiting Grueber's Bay demonstrated no effect due to waste discharge. Macroinvertebrates living in and on natural substrates near the head of Grueber's Bay were experiencing some environmental stress. The cause of this was again believed to be something other than dissolved nitrocellulose. Possible anaerobic conditions or physical habitat alterations due to nitrocellulose manufacturing wastewater discharge may account for the observed effects.

Nitroglycerine

Two ponds located on-site received waste products from the manufacture of nitroglycerine (NG pond) and rocket paste (RP pond). Water and sediment samples were collected and analyzed for a variety of parameters including nitroglycerine concentration in the NG pond and nitroglycerine and nitrocellulose in the RP pond.

The two ponds receiving nitroglycerine manufacturing wastes were found to have moderately hard water. The nitroglycerine pond also had high dissolved solids concentrations and low pH values. The rocket paste pond was characterized by low oxygen content, leading to an anaerobic condition in the sediments. Mean concentrations of nitroglycerine in the water of the nitroglycerine pond and rocket paste pond were 7.4 mg/ℓ and $<$ 1.83 mg/ℓ, respectively.

The sediments of the nitroglycerine pond approach expected background conditions with the exception of nitroglycerine concentrations of 37.5 mg/ℓ. Conditions in the rocket paste pond sediments were somewhat worse with high COD and TKN values contributing to the anaerobic bottom sediments. Nitroglycerine values here were lower - $<$ 2.2 mg/ℓ in all samples.

Examination of the phytoplankton and periphyton populations found in these ponds revealed an extremely depauperate algal community. Very few species were identified and many of those present are considered highly tolerant.

No benthic macroinvertebrates were collected from the bottom sediments or on artificial substrates in either of these two ponds. Water and sediment quality analyses and a review of the biological communities existing in the nitroglycerine and rocket paste ponds elicit very poor environmental quality in these two systems.

Algae and macroinvertebrate communities were adversely impacted at nitroglycerine concentrations of $\approx$3.0 ppm. Therefore, "no effect" levels of NG concentration lie well below 3.0 ppm for both groups studied. Effluent standards would necessarily have to be adapted to each particular receiving system.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Background	1
Purpose	2
Scope	2
PHASE II RESEARCH STRATEGY	4
Sampling Protocol	4
Facility Description	4
Location and Description of Sampling Sites	5
Sampling Schedule	5
Sampling and Analytical Methods	9
Water Sample Methodology	9
Sediment Sample Methodology	10
Munitions Constituent Analyses	11
Algae	14
Benthic Macroinvertebrates	20
Data Management and Interpretation	21
Analysis of Variance (ANOVA)	21
Cluster Analysis	24
RESULTS OF INVESTIGATIONS IN EFFLUENT RECEIVING SYSTEMS	26
Nitrocellulose Receiving Systems	26
Water Quality	26
Sediment Chemistry	28
Munitions Constituent Analysis (Nitrocellulose)	30
Periphyton	32
Phytoplankton	41
Benthic Macroinvertebrates	45
Nitroglycerine Receiving System	61
Water Quality	61
Sediment Chemistry	64
Munitions Constituent Analysis (Nitroglycerine)	67
Algae	69
Benthic Macroinvertebrates	74
ASSOCIATION OF MUNITIONS EFFLUENTS WITH ECOLOGICAL RESPONSE	76
Nitrocellulose	76
Algae	76
Benthic Macroinvertebrates	78
Nitroglycerine	79
Algae	79
Benthic Macroinvertebrates	82

TABLE OF CONTENTS
(Continued)

Page

CONCLUSIONS RELATIVE TO ENVIRONMENTAL QUALITY STANDARDS 84
Nitrocellulose 84
Correlation Between Nitrocellulose Levels and Ecological Responses 84
Stream Versus Effluent Considerations 85
Nitroglycerine 85
Correlation Between Nitroglycerine Levels and Ecological Responses 85
Stream Versus Effluent Considerations 86

REFERENCES 87

APPENDIX A

WATER CHEMISTRY DATA A-1

APPENDIX B

SEDIMENT CHEMISTRY DATA B-1

APPENDIX C

PERIPHYTON AND PHYTOPLANKTON DATA C-1

APPENDIX D

BENTHIC MACROINVERTEBRATE DATA D-1

LIST OF TABLES

		Page
Table 1.	BAAP Station Legend.	7
Table 2.	Numbers of Samples of Different Aquatic Parameters Attempted, Collected, and Analyzed from Sample Stations at BAAP, Spring, 1975	8
Table 3.	Summary of Water Quality Investigations From Weigand's and Grueber's Bays, ITP Stream and The Settling Lake	27
Table 4.	Summary of Sediment Characteristics For Weigand's and Grueber's Bays and The Settling Lake	29
Table 5.	Mean Nitrocellulose Concentrations at Selected BAAP Sampling Stations	31
Table 6.	Summary of Analyses of the Data From Phytoplankton and Artificial Substrate Samples From Weigand's and Grueber's Bays, the ITP Stream, and the Settling Lake . . .	34
Table 7.	Duncan's Mean Separation Test Results Corresponding to ANOVA's of the Data From Phytoplankton and Artificial Substrate Samples From Weigand's and Grueber's Bays	36
Table 8.	Results of Chlorophyll a and Ash-Free Dry Weight Biomass/Analyses and Autotrophic Index (AI) From Nitrovellulose Receiving and Reference Systems	38
Table 9.	Benthic Macroinvertebrate Species Composition of Natural Substrates at BAAP	46
Table 10.	Species Composition of Artificial Substrates in Waters Surrounding the BAAP	49
Table 11.	Summary of Analyses of the Benthic-Macroinvertebrate Data From Natural and Artificial Substrate Samplers at Weigand's and Grueber's Bays, the ITP Stream, and the Settling Lake	53
Table 12.	ANOVA's on Benthic Macroinvertebrate Collections From BAAP Transects	55
Table 13.	Summary of Water Quality Investigations From Nitroglycerine and Rocket Paste Ponds	65
Table 14.	Summary of Sediment Characteristics From Nitroglycerine and Rocket Paste Ponds	66
Table 15.	Results of Analyses for Nitroglycerine and Nitrocellulose in the Water and Sediments of the Rocket Paste Pond	68
Table 16.	Summary of Analyses Data From Phytoplankton and Artificial Substrate Samples From the Nitroglycerine Pond	72
Table 17.	Summary of Analyses of Data From Phytoplankton and Artificial Substrate Samples From the Rocket Paste Pond	75

LIST OF FIGURES

		Page
Figure 1.	Phase II Sampling Stations At Badger Army Ammunition Plant, Baraboo, Wisconsin	6
Figure 2.	Artificial Substrate Periphyton Sampler (Diatometer)	16
Figure 3.	Artificial Substrate Incubation Rack and Diatometer (Lentic Conditions)	17
Figure 4.	Artificial Substrate Periphyton Dendogram of Substations From Weigand's and Grueber's Bays	40
Figure 5.	Species-Area Curves of Phytoplankton Data From Weigand's and Grueber's Bays, Transects 1 and 2	43
Figure 6.	Phytoplankton Dendogram of Substations From Weigand's and Grueber's Bays	44
Figure 7.	Artificial Substrate Dendogram of Benthic Macroinvertebrate Substations From Weigand's and Grueber's Bays	58
Figure 8.	Natural Substrate Dendogram of Benthic Macroinvertebrate Substations From Weigand's and Grueber's Bays	60
Figure 9.	Benthic Macroinvertebrate Colonization Rate of Artificial Substrates in the BAAP Settling Lake	62
Figure 10.	Benthic Macroinvertebrate Colonization Rate of Artificial Substrates in Weigand's and Grueber's Bays	63
Figure 11.	Species-Area Curve of the Phytoplankton Community of the Nitroglycerine Pond	71
Figure 12.	Species-Area Curve of the Phytoplankton Community of the Rocket Paste Pond	73
Figure 13.	Ranges of Algal Species Diversity Versus Ranges of Nitrocellulose Concentration in Weigand's and Grueber's Bays	77
Figure 14.	Ranges of the Number of Natural Substrate Benthic Macroinvertebrates Species Versus Ranges of Nitrocellulose Concentration in the Sediments of Weigand's and Grueber's Bays	80
Figure 15.	Ranges of Numbers of Algal Species Versus Ranges of Nitroglycerine Concentration	81
Figure 16.	Number of Natural Substrate Benthic Macroinvertebrates Species Versus Range of Nitroglycerine Concentrations in Sediments Rocket Paste and Nitroglycerine Ponds	83

INTRODUCTION

Background

The United States Army Medical Research and Development Command (USAMRDC) has been supporting a major research effort whose ultimate objective is to develop suggested environmental quality standards for the munitions industry. Accordingly, USAMRDC is conducting and underwriting numerous research projects relating to the effects of numerous munitions compounds and effluents on aquatic and terrestrial organisms. These efforts include field studies to provide data supplementary to laboratory studies and to augment the interpretability of laboratory data. Battelle's Columbus Laboratories (BCL) is one of several contractors which have been engaged in field studies at various munitions plants in support of this objective.

BCL conducted Phase I screening studies at three munitions plants during 1974 to determine if there were observable effects of munitions waste discharges on bottom invertebrates and attached algae in effluent receiving systems, and to determine if there was any indication of bioaccumulation of munitions compounds by aquatic organisms. The three facilities at which Phase I investigations were conducted were:

Badger Army Ammunition Plant (BAAP) (production of nitrocellulose, nitroglycerine, and rocket paste)

Joliet Army Ammunition Plant (JAAP) (production of TNT, loading and packing of Compound B)

Lake City Army Ammunition Plant (LCAAP) (production of primer compounds)

The results of Phase I investigations are described and discussed in Cooper et al.(1975). Observed effects of effluent discharges were suggested at BAAP, definite at JAAP, and indeterminate at LCAAP; there were no definite indications of bioaccumulation of munitions compounds by organisms in any of the effluent receiving systems investigated.

Purpose

Under Contract No. DAMD 17-74-C-4123 with USAMRDC, BCL has been conducting Phase II followon investigations at two of the three munitions plants studied during Phase I - BAAP and JAAP. Phase II investigations at BAAP were originally planned to cover two survey periods, one in the spring of 1975 and one in the late summer-early fall of 1975. However, cessation of production operations at BAAP resulted in the cancellation of the second survey period.

The objectives of Phase II investigations have been to collect and analyze replicated quantitative information relative to the specific nature of effluent effects on receiving systems, and to determine the relationship(s) between observed effects and the amount of primary munitions constituents in the effluents. This report describes and discusses Phase II investigations at BAAP.

Scope

The scope of Phase II investigations at BAAP was predicated on the results of Phase I investigations and ensuing discussions with USAMRDC. Elements of Phase II investigations included:

- Replicate sampling and analysis of water and sediment from all sampling locations
- Replicate sampling and analysis of benthic macroinvertebrates from all sampling locations
- Replicate sampling and analysis of diatoms and filamentous algae from all sampling locations
- Replicate sampling and analysis of phytoplankton from selected sampling locations
- Analysis and interpretation of all resultant data relative to effluent effects and the association of primary munitions constituents (nitrocellulose, nitroglycerine) with these effects.

Selected water samples were analyzed for conductivity, dissolved oxygen, temperature, pH, total solids, dissolved solids, suspended solids, alkalinity, hardness, chloride, sulfate, nitrate, nitrite, ammonia, Kjeldahl nitrogen, total phosphorus, COD, TOC, nitrocellulose, and nitroglycerine.

Selected sediment samples were analyzed for total solids, volatile solids, nitrate, nitrite, Kjeldahl nitrogen, total phosphorus, COD, nitrocellulose, and nitroglycerine.

Benthic macroinvertebrate samples from both natural and artificial substrates were analyzed for number of species, number of individuals of each species, species diversity, and colonization rates of artificial substrates.

Periphyton samples were analyzed for number of species, number of individuals of each species, species diversity, colonization rates on artificial substrates, chlorophyll a, organic biomass and autotrophic index. Phytoplankton samples were analyzed for number of species, number of individuals of each species, and species diversity.

Discussion of the Phase II research strategy sample analysis and interpretation of results obtained is presented in Volume I of this report. Much of the raw data and calculated data, which provide support for Volume I is contained in the Appendices (Volume II).

PHASE II RESEARCH STRATEGY

The Phase II research strategy was predicated upon results obtained during Phase I investigations (Cooper et al., 1975) and interaction with USAMRDC. The main emphasis was placed on the development and conduct of a research protocol which would determine the nature and extent of effects of nitrocellulose and nitroglycerine production effluents on diatoms, filamentous algae, and benthic macroinvertebrates in the effluent receiving systems.

Sampling Protocol

The Phase II sampling protocol emphasized acquisition of replicate and quantitative information from sampling locations similar to those employed in Phase I. Primary emphasis was placed on acquiring information relative to the nitrocellulose receiving system; secondary emphasis was placed on acquiring information relative to the nitroglycerine receiving system.

Facility Description

Badger Army Ammunition Plant (BAAP) is a government-owned contractor-operated installation located in south central Wisconsin about 10 miles south of Baraboo, Wisconsin. Operated by Olin Corporation, its primary mission has been the manufacture of nitrocellulose and nitroglycerine and the production of rocket paste (a mixture of nitrocellulose and nitroglycerine). The plant facilities occupy about 8,000 acres of gently rolling, partially wooded terrain, portions of which are leased out for agricultural cultivation and livestock grazing.

An industrial waste treatment plant for contending with wastes associated with nitrocellulose manufacturing has been constructed, but has not been operated to date. The only functional mechanism for effluent waste control has been a series of three settling lakes which have been periodically dredged as the need arose. Historically, the settling lakes discharged into Grueber's Bay, an embayment of Lake Wisconsin, an impounded reach of the Wisconsin River.

BAAP went into a standby status on instructions from Armament Command (ARMCOM) in the spring of 1975; all production of nitrocellulose, nitroglycerine, and rocket paste was halted in May of 1975. These instances occurred immediately prior to the initiation of Phase II sampling efforts at BAAP. Since it was expected that substantial amounts of nitrocellulose and nitroglycerine might be present in the sediments at various sampling locations, Phase II sampling was continued as originally proposed, in spite of the absence of continually flowing effluent outfalls.

Location and Description of Sampling Sites

Phase II sampling stations at BAAP are identified on a map of the BAAP area in Figure 1. A physical description of each of these stations is presented in Table 1. Each transect in Grueber's Bay and in Weigand's Bay, used for reference purposes, consisted of three substations located perpendicular to the longitudinal axis.

Sampling Schedule

Phase II sampling was confined to the spring of 1975 due to the cessation of munitions production at BAAP. Field investigations were conducted from late April to early June, with intensive sampling occurring during a one week period from May 18 to May 24. Since a portion of the investigations concerned the relative differences in colonization rates of diatoms, filamentous algae, and benthic macroinvertebrates on artificial substrates at different stations, selected artificial substrate samplers were picked up at weekly intervals throughout the April-June sampling period.

Table 2 presents a matrix of sample stations and aquatic parameters measured describing numbers of samples attempted, collected, and analyzed. Extra samples were collected in almost every case in the event additional data were necessary to clarify or confirm a particular area of investigation.

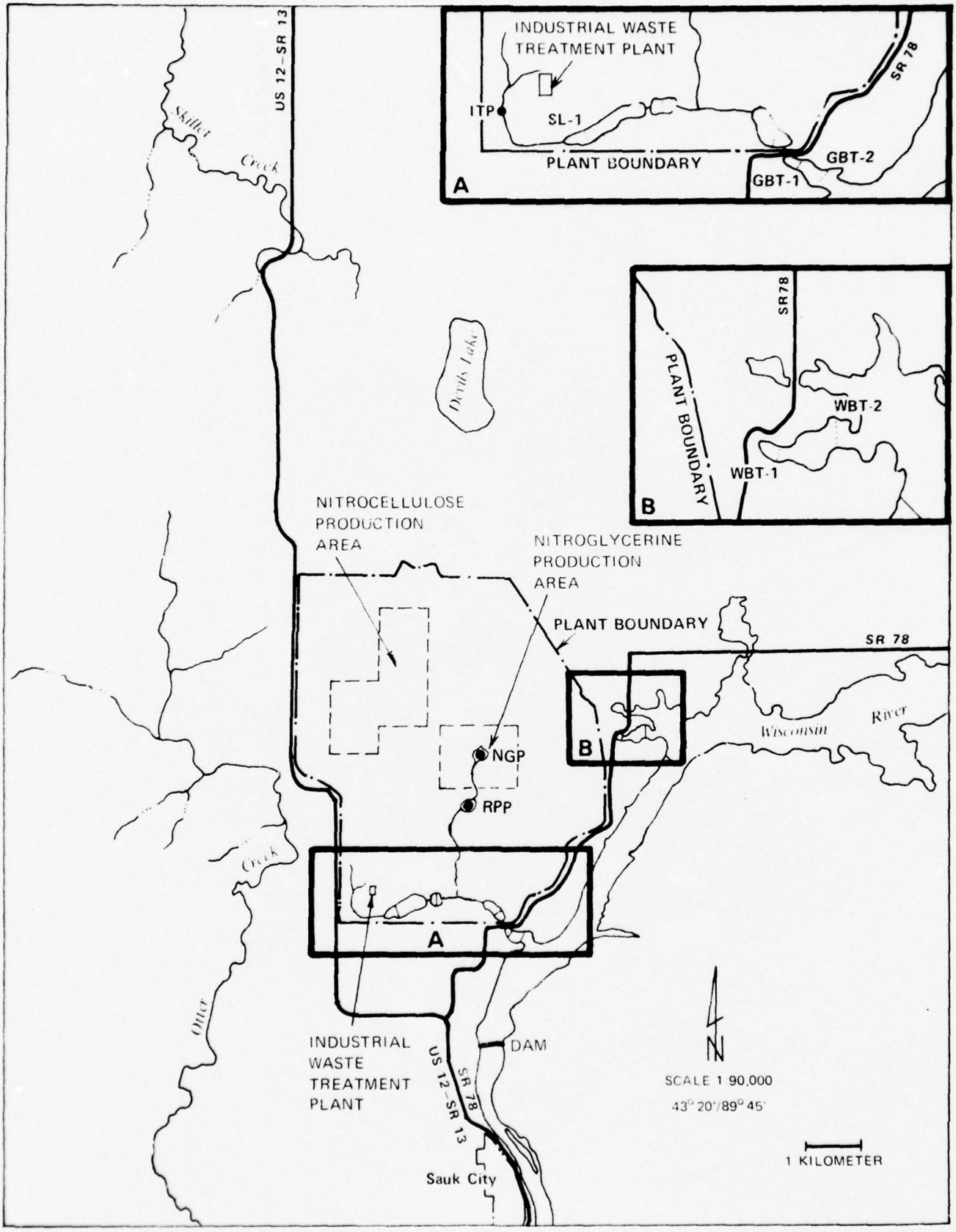


FIGURE 1. PHASE II SAMPLING STATIONS AT BADGER ARMY AMMUNITION PLANT (BAAP), BARABOO, WISCONSIN

TABLE 1. BAAP STATION LEGEND

Plant/Station #	Description of Station
ITP	industrial waste treatment plant outfall stream; stream - 3-5 m wide with riffle and pool; riffle - 7.5-15 cm deep; pool - 30-45 cm deep; sand, gravel, pebble substrate, clear water, brown attached algae
SL-1	head of 25 acre settling lake (3 substations); ≅ 100 m wide; substation 1 - 1 m deep; substation 2 - 1.7 m deep; substation 3 - 1 m deep; substrate (same for all substations) - firmly compacted fine silt, sand, clay
RPP	rocket paste discharge pond - 1.3-1.5 m deep; substrate - very firm; surrounded by trees, heavy leaf litter; turbid water
NGP	nitroglycerine discharge pond - 2 m deep; substrate - clay, firm compaction; partial canopy; water pea green in color; cattle watering site
WBT-1	transect (3 substations) across head of Weigand's Bay; 75 m wide; substrate - silt, fine sand with detritus present, soft compaction; tree lined; partial canopy; substation 1 - 1.3 m deep, substation 2 - 1 m deep, substation 3 - 1 m deep
WBT-2	transect (3 substations) across mid-Weigand's Bay; substations 2 and 3 - soft black silty substrate, no detritus, 6 m deep; substation 1 - mostly sandy substrate, much detritus composed of leaves and sticks, 2 m deep
GBT-1	transect (3 substations) across head of Grueber's Bay; 150 m wide; 0.6 m deep; black silty substrate with some detritus; soft to very soft compaction; trees on north shore, pasture on south shore - almost open canopy
GBT-2	transect (3 substations) across mid-Grueber's Bay; substation 1 - 4 m deep; substations 2 and 3 - 4.3 m deep; substations 1 and 2 - soft black silty clay substrate with small amount of detritus; substation 3 - substrate varied between black silty material with soft compaction to hard clay

TABLE 2. NUMBERS OF SAMPLES OF DIFFERENT AQUATIC
ANALYZED FROM SAMPLE STATIONS AT BAAP,

	Chemical Characterization				Munitions Constituents				Periphyt		
	Water		Sediment		Water		Sediment		Artificial Substrates		
	Collected	Analyzed	Collected	Analyzed	Collected	Analyzed	Collected	Analyzed	Attempted	Collected	Analyzed	A
Station												
WBT-1-1	5	2	3	1	5	0	3	0	9	9	5	
WBT-1-2	5	2	3	1	5	0	3	0	9	9	5	
WBT-1-3	5	2	3	1	5	0	3	0	9	9	5	
WBT-2-1	5	2	3	0	5	0	3	0	9	9	5	
WBT-2-2	5	2	3	0	5	0	3	0	9	2	1	
WBT-2-3	5	2	3	0	5	0	3	0	9	9	5	
GBT-1-1	5	2	3	1	5	4	3	2	9	9	5	
GBT-1-2	5	2	3	2	5	2	3	3	9	9	5	
GBT-1-3	5	2	3	1	5	1	3	3	9	9	5	
GBT-2-1	5	2	3	1	5	2	3	3	9	9	5	
GBT-2-2	5	2	3	0	5	3	3	3	9	9	5	
GBT-2-3	5	2	3	0	5	1	3	3	9	7	4	
ITP-0	7	5	N.A.[a]	N.A.	7	4	N.A.	N.A.	N.A.	N.A.	N.A.	
ITP	5	1	3	0	5	3	3	3	9	9	5	
SL-1	5	2	3	0	5	2	3	3	9	9	5	
SL-2	5	2	3	2	5	3	3	3	9	9	5	
SL-3	5	2	3	0	5	1	3	1	9	9	5	
NG-0	6	1	N.A.	N.A.	6	4	N.A.	N.A.	N.A.	N.A.	N.A.	
NGP	5	5	3	2	5	5	3	3	9	9	5	
RP-0	6	1	N.A.	N.A.	6	3	N.A.	N.A.	N.A.	N.A.	N.A.	
RPP	5	4	3	2	5	4	3	3	9	9	5	

(a) N.A. = Not applicable.
(b) Natural substrate periphyton sample

IFFERENT AQUATIC PARAMETERS ATTEMPTED, COLLECTED, AND
ATIONS AT BAAP, SPRING, 1975

Periphyton				Phytoplankton			Benthic Macroinvertebrates					
bstrates		Chlorophyll a					Natural Substrates			Artificial Substrates		
ted Analyzed	Attempted	Collected	Analyzed	Attempted	Collected	Analyzed	Attempted	Collected	Analyzed	Attempted	Collected	Analyze
5	1	1	1	5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
				5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	7	5
1	1	0	0	5	5	3	5	5	5	9	9	9
5	1	1	1									
				5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
5	1	1	1									
				5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
5	1	1	1	5	5	3	5	5	5	9	9	7
4	1	1	1									
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
5	1	1	1	5	5	3(b)	5	5	5	9	9	9
				5	5	3	5	5	5	9	9	9
5	1	1	1	5	5	3	5	5	5	9	9	9
5	1	1	0	5	5	3	5	5	5	9	9	9
5	1	0	0									
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
5	1	1	1	5	5	3	5	5	5	9	9	9
N.A.	N.A.	N.A.	N.A.	N.A..	N.A..	N.A..	N.A..	N.A..	N.A..	N.A.	N.A.	N.A.
5	1	1	1	5	5	3	5	5	5	9	9	9

Sampling and Analytical Methods

Water Sample Methodology

Each of the five water samples collected at each sampling location at BAAP was analyzed on-site for conductivity, dissolved oxygen, temperature and pH by means of appropriate portable probes and electrodes (Martek Water Quality Analyzer). Laboratory analyses of selected samples returned to Battelle included total solids, dissolved solids, suspended solids, alkalinity, hardness, chloride, sulfate, nitrate, nitrite, ammonia, Kjeldahl nitrogen, total phosphorus, chemical oxygen demand (COD) and total organic carbon (TOC).

Chloride concentrations were determined by colorimetric titration using an Aminco- Cotlove Chloride Titrator. Ammonia was determined using an Orion ion-selective electrode.

All forms of phosphorus in each sample were converted to phosphate and the total phosphorus then determined according to the recent EPA published methods (1973).

Sulfate analyses were made by titration using the barium perchlorate procedure originally developed by Fritz and Freeland (1954).

Chemical oxygen demand was determined in accord with the EPA published methods. For the determination of total organic carbon (TOC), an aliquot of each water sample was acidified with hydrochloric acid and purged with nitrogen to remove CO_2. The sample was then injected into a Beckman TOC Analyzer where it was combusted under oxygen atmosphere at 900 C to yield CO_2 which was quantified with an IR detector.

All remaining analyses were conducted according to the APHS standard methods described by Taras, et al. (1971). The values for hardness and alkalinity are expressed as equivalents of calcium carbonate. The hardness determination is actually a measure of both calcium and magnesium, that is, total hardness, and the alkalinity values are based on a titration with sulfuric acid. A few samples were acidic upon collection. The alkalinity values in those instances represent the equivalents of calcium carbonate that would be required for neutralization. These samples are designated in the water quality tables in the Results section of this report.

Time differentials between collection and analysis varied due to the large number of samples to be analyzed and staged collection periods. During the interim, all samples were kept under constant refrigeration (4 C) in the dark. Further, three separate sample bottles were used for collection at each station and chemical preservatives were added to two of them. The sample collected for nitrogen and phosphorus analyses was placed in 200 ml polyethylene bottles, preserved with 10 mg of mercuric chloride, and refrigerated. The sample collected for COD analysis was placed in a 100 ml polyethylene bottle, preserved with 0.2 ml of concentrated sulfuric acid, and refrigerated. The sample collected for all other analyses was placed in a 500 ml polyethylene bottle and refrigerated with no chemical preservatives.

Sediment Sample Methodology

Each of the three sediment samples collected at each sampling location at BAAP were submitted to Battelle for laboratory analysis of total solids, volatile solids, nitrate, nitrite, Kjeldahl nitrogen, total phosphorus, and chemical oxygen demand.

The phosphorus analysis involved fusing the sediment sample with Na_2CO_3 followed by quantification of total phosphorus according to the APHS standard methods (Taras, et al., 1971). All remaining analyses were performed according to the APHS standard methods also, except COD which was analyzed by the published EPA method (1973).

Time differentials between collection and analysis varied due to the large number of samples and staged collection periods. During the interim, all samples were kept under constant refrigeration (4 C) in the dark. Further, two sample bottles were used for sediment collection at each station with chemical preservation of one. The sample to be used for analysis of nitrogen, phosphorus and COD parameters was collected in a 200 ml polyethylene bottle, preserved with 0.5 ml of concentrated sulfuric acid, and refrigerated. The sediment to be analyzed for total solids and volatile solids was collected in a 250 ml glass bottle and refrigerated with no chemical preservatives.

Munitions Constituent Analyses

The purpose of this study was to develop a methodology suitable for the accurate determinations of low levels of constituent munitions in the waste water stream effluent and sediment samples collected at BAAP in conjunction with the biological sampling and assay. The munitions selected for analysis at BAAP were nitrocellulose (NC) and nitroglycerine (NC).

Both of the munitions selected for study show some sensitivity to photolytic as well as chemical and thermal degradation. Hence, all samples were collected in amber bottles, shipped in wet ice-filled coolers, and stored at 4 C prior to analysis. The sample sizes collected were 500 ml for water and approximately 250 ml (300-400 gms) for sediment. No preservatives or inhibitors were added to these water and sediment samples.

All solvents used in this study were distilled-in-glass analytical grade obtained from Burdick and Jackson Laboratories, Muskegon, Michigan. All chromatographic analyses were performed on a varian 1700 Aerograph equipped with a $Sc^{3}H$ electron capture detector and an Infotronics Model CRS-204 digital integrator and a Hewlett-Packard Automatic Sampler 7670A.

All standard solutions of the munitions studied were prepared from authentic samples obtained during Phase I and II of this study from Dr. B. E. Hackley, Edgewood Arsenal, Aberdeen Proving Ground, Maryland.

Nitrocellulose. The determination of nitrocellulose in water samples in this study was patterned after the colorimetric method employed by Bolletter and described by Rosenblatt, et al (1973). The Bolletter procedure utilizes the base hydrolysis of nitrocellulose to produce nitrite ion, followed by the diazotiziation of sulfanilic acid and coupling with a primary aromatic amine to generate a red azo dye, which may be quantitated spectrophotometrically.

$$C_6H_7O_2(ONO_2)_3 \xrightarrow[OH]{} NO_2$$

$$NO_2^- + HSO_3\text{-}\text{Ø}\text{-}NH_2 \longrightarrow HSO_3\text{-}\text{Ø}\text{-}N_2^+ \xrightarrow{NH_2\text{-}\text{ØØ}} HSO_3\text{-}\text{Ø}\text{-}N_2\text{-}\text{ØØ}NH_2 \quad .$$

$$(\text{red}, \lambda_{max} = 525\ m\mu)$$

Since nitrocellulose is essentially insoluble in water, 100 ml aliquots of each water sample were suction-filtered through acetone resistant 1.0 μ Millipore Filter Discs (No. NRWP02500), thereby collecting all NC particles greater than 1.0 μ in size. The filter disc was then rinsed with 20 cc acetone in a 50 ml beaker and analyzed as follows:

(1) The acetone extract was treated with 1.0 ml of 1.0 N NaOH

(2) The mixture was then allowed to evaporate in the 50 ml beaker to near dryness under a stream of argon gas

(3) At this point, 5.0 ml of a colorimetric reagent was added which was prepared from 4.0 gm citric acid, 0.6 gm mn $SO_4.H_2O$, 0.2 gm sulfanilic acid and 0.13 gm α-naphthylamine hydrochloride in 60 ml distilled water and 1.0 ml of 1.0 N HCl. This reagent solution was prepared fresh daily as trace contamination from exposure to the atmosphere quickly darkened the solution after about 1 day.

(4) Each sample was then diluted to 25.0 ml, 50.0 ml, or 100.0 ml depending upon the intensity of the color developed, and allowed to stand for 30 minutes to insure complete color development before spectrophotometric measurement of the red dye produced (λ_{max} = 525 mμ). A quick study indicated that the color remained stable for several hours, however, all readings were taken within 1 hour of color development.

Sediment samples (20 gm aliquots) were mixed with 5.0 gm activated charcoal, and dried with 2-3 times their weight of Na_2SO_4 (anhydrous powder) for 3-4 hours. Extraction with ethyl acetate in a Soxhlet extraction was conducted for 20-22 hours. The extracts were then adjusted in volume to 250 ml and 1 ml aliquots were withdrawn, diluted to 10 ml with acetone in a 50 ml beaker, and subjected to the Bolleter method of analysis as outlined above.

Spectrophotometric readings (the percent transmittance of each sample) were determined on a Spectronic 505 using a reference blank prepared from a 10 ml acetone for water samples or 1 ml ethyl acetate + 10 ml acetone for sediment samples, and worked up according to the procedure outlined above. The concentration of NC in each sample was determined from standard curves derived for a concentration range of 1-10 ppm. The visible dection limit was 0.5 ppm, however, inconsistent readings with concentrations less than 1.0 ppm were observed and accurate determinations could not be reported below this value, using this analytical method.

Nitroglycerine. Molecules of relatively low molecular weight, and possessing the ability to accept electrons, are systems amenable to gas chromatographic analysis using electron capture detection. This technique is extremely sensitive to trace amounts of the electron-accepting species and provides for their detection and quantitation in the presence of large amounts of otherwise interfering materials which do not activate the detector. Nitroglycerine is such a species by virture of the electron capture characteristics caused by the presence of multiple-NO_2 functionality. Similar characteristics, although more pronounced, are exhibited by such nitroaromatic systems as the nitrotoluenes.

The solubility of NG in water is significant, equalling 1.8 g/l at 20 C. The hydrolysis of nitric esters at various values has been reported (Urbanski, 1965). Although the products of the hydrolysis of NG are ultimately organic acids and aldehydes, there is some indication that in the presence of other oxidizable materials, the initial alcohol is formed (i.e. glycerine, and likely mono- and dinitroglycerine). The partially nitrated glycerines have explosive and pysiological properties similar to those of nitroglycerine (Urbanski, 1965).

The procedure developed in this study for the determination of NG involved the extraction of 100 ml aliquots of each water sample with three 50 ml portions of CH_2Cl_2. Sediment samples were dried with 2-3 times their weight anhydrous Na_2SO_4, and extracted with ethyl acetate overnight in a Soxhlet extractor. The extracts were spiked with known amounts of 2,4 -DNT as an

internal standard (not otherwise present in these samples), reduced in volume to 2.0 ml and analyzed via electron capture gas chromatogrphy. The concentration of NG in each sample was determined from the peak area ratios of NG to that of the internal standard, and the ratios obtained from prepared mixtures of known amounts of NG and 2,4-DNT.

Gas chromatographic conditions were patterned in part after Trowell (1970) consisting of a 6 ft x 2 mm glass column packed with 3 percent OV-17/3 percent QF-1 on Gas Chrom Q, a column temperature of 125 C (isothermal), an injector temperature of 160 C, and a detector temperature of 200 C, using an N_2 carrier gas flow = 30 ml/min.

The reliability of the analytical method was validated (for water samples) by subjecting known amounts of authentic NG to the procedure described above and comparing the results with those obtained from unprocessed standard mixtures of authentic NG and internal standard to determine the efficiency of recovery. As might be expected, this efficiency appears to fall for samples of low concentrations.

	% Recovered
1.0 ppm	103
0.1 ppm	28

The minimum amount detectable using the methodology developed in this study was 0.01 ppm NG in water samples and 0.05 ppm in sediment samples. However, because of fluctuations in the peak area ratios determined from repeated injection of samples with low concentrations, and the limited extractions of NG at low concentration values are not reported any lower than 0.6 ppm NG in water samples and 1.5 ppm in sediment samples.

Algae

Sampling. Five replicate samples of the phytoplankton communities of the settling lake, the nitroglycerine and rocket paste ponds, and each transect substation of Weigand's and Grueber's Bays were collected during the main survey period, May 19-23, 1975. Subsurface samples were taken with a 2-liter Van Dorn water sampler and filtered through a Wildco 20-mesh plankton

bucket. Organisms were rinsed into collection bottles and preserved in 6:3:1 solution of water, alcohol, and formaldehyde.

Artificial substrate periphyton samplers (diatometers) were set out at each sampling station on May 6, 1975. Each sampler consisted of a vertically oriented 15-unit slide rack maintained at constant water depth of 10 cm by floats which also served as wing guards to prevent fouling and scouring (Figure 2). The samplers were attached by nylon rope to the float on the invertebrate artificial substrate sampler rack (Figure 3). Samplers were incubated in situ for a period of three weeks. Slides were removed from the samplers at one-week intervals; 2 slides the first week, 5 the second, 2 the third. The collection of the 5 slides occurred during the main survey period. All slides for periphyton analysis were placed in individual sample bottles and preserved with 6:3:1. Six slides were also collected during the main survey period for chlorophyll a and biomass analyses. These slides were placed in a single bottle, immediately wrapped in foil and packed in ice to prevent further photosynthetic activity. Samples were then placed in a freezer within 4 hours of collection and remained frozen until analyses were performed.

The attached algal community (periphyton) was sampled from natural substrate found in the ITP stream. A known area (3.14 cm^2) was etched on cobble-sized rocks (5 replicates), scraped with a knife, funneled into a sample bottle and preserved with algal preservative (6:3:1).

Analysis. Quantitative procedures were utilized in the analysis of all algae samples. All samples were adjusted to a constant volume to normalize resultant data.

Diatoms in the samples were analyzed according to the following procedure:

- Fifteen ml of sample were removed with a pipette from each sample bottle and treated with 30 percent H_2O_2 and $K_2Cr_2O_7$ to dissolve extraneous organic matter (including non-diatomaceous algae)

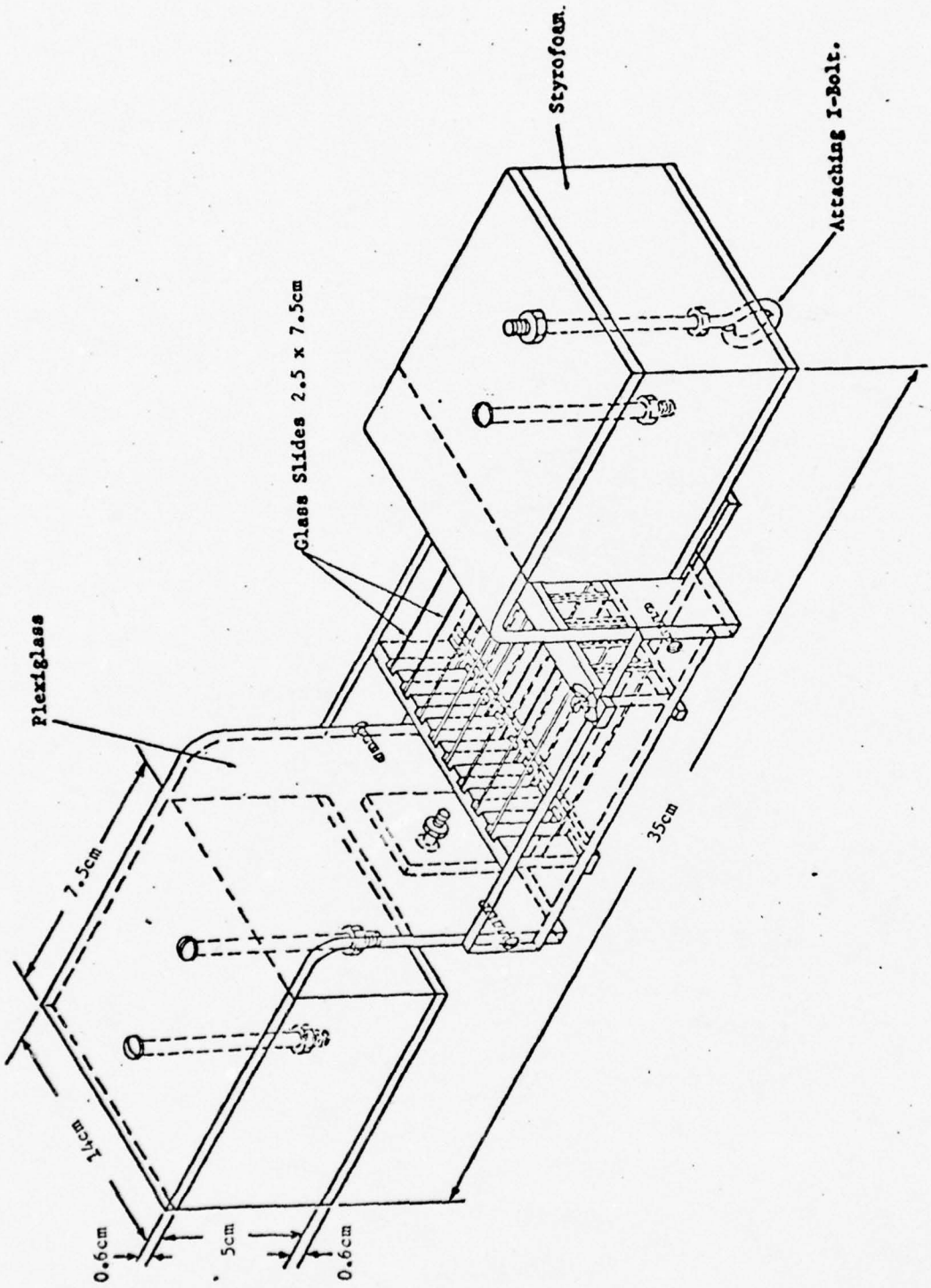


FIGURE 2. ARTIFICIAL SUBSTRATE PERIPHYTON SAMPLER (DIATOMETER)

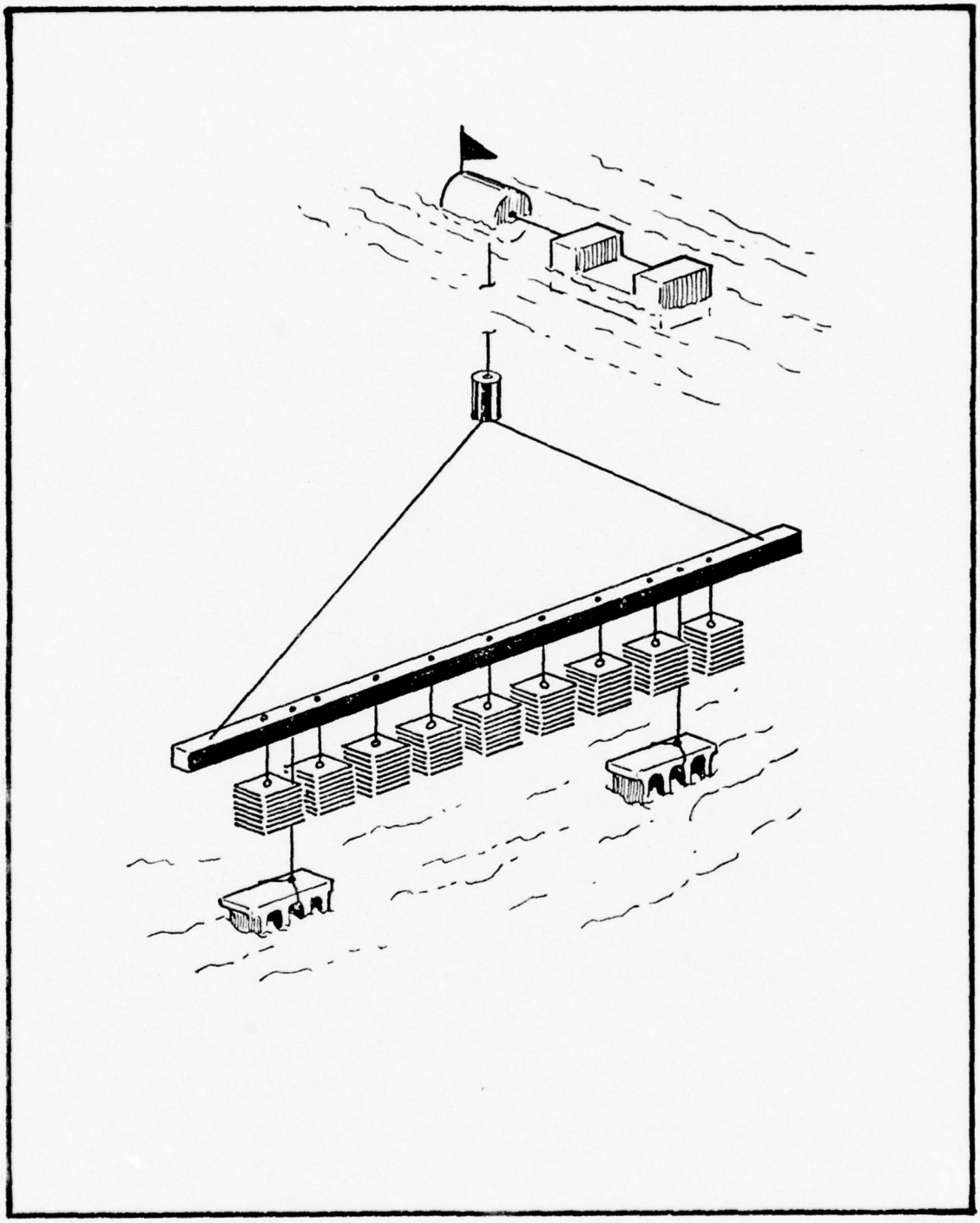


FIGURE 3. ARTIFICIAL SUBSTRATE INCUBATION RACK AND DIATOMETER (LENTIC CONDITIONS)

- Residue was washed with tap water; the supernatant liquid was decanted 3-5 times at 3-hour intervals until the sample cleared
- Ten drops (0.5 ml) of sample were placed on a cover slip; water was evaporated from the cover slips on a slide warmer; cover slips were then placed on a hot plate for a minimum of 2 hours to combust any organic material which may have remained in the diatom frustules
- Cover slips were fixed to slides using Hyrax mounting medium
- Diatoms on each slide were identified to species under oil immersion with the aid of appropriate taxonomic keys (Hustedt; 1930; Patrick and Reimer, 1966)
- Counts were made and recorded for 40 microscope fields (averaging approximately 200 cells; in the case of sparsely populated samples, the entire slide was often counted)

For non-diatomaceous algae, a sepearate procedure was used:

- One-tenth ml of sample was transferred by pipette into a Palmer counting cell
- Whole-organism counts of 40 Whipple-grid fields were made using a compound microscope at 400 X and appropriate keys enabling identification to the lowest practical taxon of non-diatom forms (Prescott, 1962; Smith, 1950; Taft and Taft, 1971).

Chlorophyll a Analysis. Chlorolphyll extraction procedures following Weber (1973) were conducted in near darkness to prevent further photodegradation. Only a small indirect light was used. Reagent grade acetone was diluted by filling a 100-ml graduated cylinder with 90 ml of acetone and adding sufficient distilled water to bring the resultant mixture to 100 ml. Surgical gloves were used to hold the thawed slides while the organic accumulation from each of the six slides from one site were scraped into the same evaporating dish. The slides and field sample bottle were rinsed with 88

percent acetone, and the scrapings were poured into a 60 ml glass vial. The evaporating dish was also rinsed with 88 percent acetone and poured into the glass vial, which was topped off with 88 percent acetone. The algal cells were disrupted for 5 minutes using a Sonifier Cell Disrupter (Model W185 by Heat Systems - Ultrasonics, Inc.) and allowed to steep for 24 hours at 4 C to facilitate further phytopigment extraction.

Chlorophyll a analysis was made of the combined extracts from the scrapings of the six replicate slides. Ten, twenty, or thirty ml of extract, depending on clarity of the sample, were transferred to a centrifuge tube. Eighty-eight percent acetone was added to the centrifuge tube (more acetone was used for darker samples) to make a total of 30 ml. Samples were centrifuged at 1,600 rpms at 4 C for 15 minutes. The optical density of 3 ml of supernatant was measured at 663, 645, and 630 nanometers (nm) in a Model B Spectrophotometer (Beckman Instruments, Inc.), using an 88 percent acetone blank for standardization. Corrections for turbidity were made by determining OD 750 and subtracting these values from OD 663, OD 645, and OD 630. The contents of the centrifuge tube were thoroughly mixed and returned to the original sample bottle. The centrifuge tube was rinsed with 88 percent acetone, and this was also added to the sample bottle. Chlorophyll a concentrations were calculated using the following formulas:

$$C_a = 11.64\ OD_{663} - 2.16\ OD_{645} + 0.10\ OD_{630}$$

where C_a is the chlorophyll a concentration in mg/l. This was converted to area of substrate (mgChla/m^2) by:

$$\text{mg Chla}/m^2 = \frac{C_a\text{(mg/l)} \times \text{volume of extract (l)}}{\text{area of substrate (m2)}}$$

Determination of Ash-free Dry Weight. Ash-free dry weight was determined following the methods described by Weber (1973). Contents of the 60 ml vial and centrifuge tube used in chlorophyll a analysis of each sample were poured into an evaporating dish, which had been previously washed with concentrated hydrochloric acid, burned in a muffle furnace at 550 C, allowed to cool in a dessicator for 1 hour, and weighed on an analytical balance. The dish with the combined extracts from the six scrapings

was dried in an oven at 105 C for a minimum of 24 hours, placed in a dessicator to cool for 1 hour, and then weighed on an analytical balance. The dried samples were ashed in a muffle furnace at 550 C for 1 hour, allowed to cool, rewetted with approximately 2 ml of distilled water to replace water of hydration lost when the sample was ashed, dried again in a drying oven at 105 C for 24 hours, cooled in a dessicator for 1 hour, and finally weighed on an analytical balance. Ash-free dry weight was determined using the following formula:

$$g/sample = g\ dry - g\ ash\ wt.$$

This was converted from g/mm^2 to mg/m^2 (the sample weight was divided by six to give the weight of one slide) by the formula:

$$mg/m^2 = \frac{g/sample \times 1000}{(6)\ (0.003871)}$$

where 0.003871 is the area in m^2 of one slide.

Once the biomass of the algae was determined, the autotrophic index was computed using the formula:

$$\text{autotrophic index} = \frac{\text{ash-free wt } (mg/m^2)}{\text{chlorophyll } \underline{a}\ (mg/m^2)} \quad .$$

Benthic Macroinvertebrates

Sampling. Benthic macroinvertebrates inhabiting natural substrates were sampled at BAAP during May 19-23, 1975, with a Petite Ponar grab sampler (6" x 6") at all stations and transects with the exception of the ITP stream. Here, samples were collected from riffle areas in this stream with a Surber sampler. Five replicate samples were taken at each station. Samples were then quickly screened to remove silt, placed in plastic bottles, stained with Rose Bengal, and preserved 24 hours later in 60 percent ethanol.

Multiple-plate artificial substrate samplers (Hester and Dendy, 1962) were employed at all sampling stations to collect benthic macroinvertebrates. Nine samplers were suspended approximately 0.3 meter above the bottom substrate from an incubation rack as pictured in Figure 3. (This rack was not used in the

ITP stream; 9 samplers were suspended between stakes pounded into the substrate.) The incubation racks were set in place at each on-site sampling station on April 29, 1975, and in Grueber's and Weigand's Bays on April 30, 1975. These artifical substrates were then retrieved after 3-, 4-, and 5-week incubation periods. Two samplers were removed after 3 weeks, five samplers were retrieved during the main survey period and the two remaining one week later.

The samplers were collected by slowly raising the whole incubation rack to within a few centimeters of the surface. The appropriate samplers were cut from the rack with a knife and the rack was lowered back into position. The sampler was immediately placed in a 1-qt container and sealed. The samplers were completely disassembled and washed thoroughly into a 30-mesh screen at the BAAP laboratory. All the organisms removed from each sampler were placed in individual bottles, preserved in 5 percent formalin and returned to BCL for identification.

Analysis. Bottom grab samples from lotic environments at BAAP were washed in the BCL laboratory to remove the remaining silt and excess Rose Bengal from the sample. Organisms were hand-picked in the lab from unsorted Surber samples. Artificial substrate samples were washed in the lab to remove the preservative. All samples were then placed in glass petri dishes for identification and enumeration.

Benthic macroinvertebrates were identified with the aid of stereoscopic and/or compound microscopes. Identification to the lowest practical taxon was made utilizing taxonomic keys (Eddy and Hodson, 1961; Edmonson, 1959; Heard and Burch, 1966; Mason, 1968; Pennak, 1953; Peterson, 1960; Usinger, 1971; Walter and Burch, 1957; Johannsen, 1933; Ross, 1944; Frison, 1935; Burks, 1953). Midge larvae were mounted on slides and identified under a compound microscope (400X) according to procedures presented by Mason (1968).

Data Management and Interpretation

Analysis of Variance (ANOVA)

One-way analyses of variance were performed on benthic macroinvertebrate and algae sample data to test for significant locational differences in the following three measures of community structure: (1) population density or standing crop (expressed as numbers of organisms per sampling unit), (2) numbers of species per sampling unit, and (3) Shannon diversity index ($\bar{H}$). Artificial

and natural substrate data were always analyzed separately; further, the data from the artificial substrates were analyzed separately for each of the three different sampling weeks.

In the analyses of variance, each replicate sample was treated as the basic data unit from which the 3 community structure variables (number of individuals, number of species, and Shannon index) were computed. Using all replicates obtained from each sampling site, data from related sites within a larger area were pooled together so as to maximize the possibility of detecting a significant difference between that area and another. Data from substations within the bay transects were pooled so as to maximize the possibility of detecting significant differences among the four major areas represented by the transects. For each community structure variable, four transect means (for WBT-1, WBT-2, GBT-1, and GBT-2) were calculated. The transect means were then tested simultaneously in the same analysis of variance for differences among themselves.

The analyses of variance were performed on Battelle's CDC 6400 computer system, using the SPSS Statistical programs (Nie, et al; 1975). An F-test having a significance level of 0.90 or greater was chosen as the criterion for deciding whether technical areas warranted emphasized attention. The simplest method for presenting the results of the ANOVA is to display the significance level of the F-test, and the group means accompanied by the line segments generated from a Duncan's Mean Separation Test.

The Duncan's Mean Separation Test (Duncan, 1955) is a necessary follow-up to an ANOVA whenever three or more means are demonstrated by the ANOVA to be significantly different, because it determines for any possible pair of means whether or not one of them is significantly higher or lower than the other. The Mean Separation Test arranges the means in increasing order from top to bottom, and the line segments which determine the similarities and differences among them are drawn vertically to the immediate right of the means. If any two means are connected by a line segment, they are similar; but if none of the line segments connects both of them, the two means are shown to be significantly different, with the higher of the two means being significantly higher than the lower one.

The Mean Separation Test is relevant only if the preceding ANOVA testing for differences among means is significant at a level of 0.90 or greater. If the ANOVA is not significant, the Mean Separation Test is redundant because it merely connects all the group means together with one line segment, restating that they are similar.

It must be noted in general that in order for group means to be proven significantly different by an ANOVA, the values within each group must be consistent enough so that within-group variability is reasonably small. Large within-group variability may produce differences among means that are only the result of a few extreme fluctuations within some particular groups, rather than consistently occurring values. This nonuniformity, or heterogeneity, of group variances may cause an F-ratio to be not significant even though the magnitude of the differences among the group mean may appear to be quite large.

To check for such an occurrence, the hypothesis of homogeniety of group variances was tested using the F-max statistic to see whether the data fulfilled this assumption required by the ANOVA. The F-max statistic is the ratio of the largest to the smallest within-group variance. For numbers of species and diversity indices, this hypothesis was accepted, but for raw numbers of individuals it was often rejected. The numbers of individuals were transformed by logarithms and retested; the transformation succeeded in producing homogeneous variances, so these log-data were used in the ANOVA's. It must be noted, however, that the means of raw numbers are presented in the tabled results so that they may be more easily interpretable.

For macroinvertebrate numbers of individuals, there were two cases (natural substrate data, and artificial substrate data during Week 3), in which the homogeneity of variance criterion was not satisfied even after the log transformation was performed. However, in both cases, the large values of the F-max statistic were caused by one of the group variances being unusually small in comparison to all the others. (None of the variances were large enough to indicate skewness in the data.) This situation apparently did not decrease the power of the F-test in the ANOVA because significant differences were detected at levels greater than .999, so for these reasons the results of the ANOVA's were considered valid.

Cluster Analysis

In order to measure the degree of similarity between sampling sites with respect to species assemblages, similarity coefficients were computed among all possible pairs of sites for benthic invertebrates and algae data. The term "species assemblage" will be used to jointly refer to two characteristics of a biological population-species composition, and the abundance of organisms within each of those species present.

Separate similarity coefficient matrices were computed for artificial and natural substrate data. The similarity coefficient used was the Pinkham and Pearson measure of similarity (Pinkham and Pearson, 1974) and is defined as

$$S_{ab} = \frac{1}{k} \sum_{i=1}^{k} \frac{\min (X_{ia}, X_{ib})}{\max (X_{ia}, X_{ib})} \quad .$$

In this expression S_{ab} = Similarity between sites a and b, k = the number of species found at one or both sites, X_{ia} = number of individuals of species i at site a, and X_{ib} = number of individuals of species i at site b. The values used for the X's were obtained by pooling together the individuals of species i over all the replicates within each sampling site for artificial substrates, all replicates over all incubation periods were pooled. Mutual absences of species, that is, values of i where both Xia and Xib were zero, were ignored, since the long species lists involved could cause a pair of sampling sites with no species in common, to have a high similarity coefficient simply by having a large number of mutually absent species.

The value of S_{ab} can range from a minimum of 0 to a maximum of one. S_{ab} = 0 where sites a and b have no species in common; S_{ab} = 1 when a and b have exactly the same species present, and each of these species has the same density at site a as it does at site b. This is such a stringent requirement that it is very rarely achieved in actual field data. As a consequence, all the S_{ab} values calculated were rather low even for closely located pairs of sites. However, much information can be gained from studying the relative magnitudes of these coefficients.

The calculated similarity matrices were used in a computer program (Anderberg, 1973) which performed cluster analyses to link the sampling sites into a hierarchical "tree" structure, which is displayed in the form of a dendogram. The clustering algorithm used was the unweighted pair-group method which maximizes the average similarity index between the merged pairs of groups (Kaesler and Cairns, 1972).

Similarity coefficients provide a way of comparing and contrasting sampling sites which is different from that provided by analyses of variance. Two sites could be demonstrated by an ANOVA and a Mean Separation Test to be similar on the bases of numbers of individuals, numbers of species, and species diversity; yet, it is still conceivable that these two sites could have completely different species compositions from one another. On the other hand, a similarity coefficient directly measures the degree of overlap in species composition and species dominance between two sites because its computation utilizes information about the simultaneous occurrences of various species.

RESULTS OF INVESTIGATIONS IN EFFLUENT RECEIVING SYSTEMS

Nitrocellulose Receiving Systems

Water Quality

Table 2 is a summary of the analyses from the late May water sampling effort. The data utilized to compose the summary table are included in Appendix A, Table 1. The sample sites are described in an annotated legend (see Table 1) and located on Figure 1. The table also includes selected water quality criteria referred to in the following discussion of water quality (Battelle Columbus Laboratories, 1975a, 1975b; Eckenfelder, 1970; National Science Foundation, 1973). Applicable USGS determinations of regional water quality ranges from stations within the Wisconsin River Basin (area considered - upper 10,000 square miles, time - 1963-1970) are also summarized and included as further reference (U.S. Department of the Interior, 1963-1970).

Weigand's Bay data compare well with selected regional quality determinations and are considered reflective of good to excellent water quality conditions. The slightly higher pH ranges from the BCL sampling effort (in comparison to USGS data - dominately stream stations) are probably consistent with expected regional daylight nonstream values.

The Badger industrial waste treatment plant discharge (ITP-O) and stream (ITP) can be characterized as "weak" (not highly degraded relative to industrial wastes) and variant with a median total dissolved solids concentration of about 190 mg/ℓ. This dissolved solids (DS) concentration is only twice this area's expected low background (see control values for Weigand's Bay, Table 3). Temporal use of hypochlorite detergents and associated increased chloride concentrations are believed to be dominantly responsible for this higher dissolved solids concentration. A single high COD concentration of 134 mg/ℓ and corresponding TOC increase to 40 mg/ℓ was also reported for the industrial collection plant discharge on May 19, 1975 (Table 3).

TABLE 3. SUMMARY OF WATER QUALITY INVESTIGATIONS FROM WEIGAND'S AND GRUEBER'S BAYS, ITP STREAM AND THE SETTLING LAKE

		Field Measurements				Laboratory Measurements (mg/l)													Number of Samples Considered	
		pH	Conductivity	Temperature °C	Dissolved Oxygen	Alkalinity	Total Hardness	Suspended Solids	Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Total Kjeldahl Nitrogen	Ammonium	Nitrite	Nitrate	Phosphate	Sulfate	Chloride	Laboratory	Field
Selected water quality criteria		6-9	900	-	>5	-	-	<80	<500	<40	<12	1.0	<0.02	-	<1.5	<0.1	<250	<250		
	Total min.	6.7	108	0	-	31	40	-	66	-	-	-	0	0	0.06	0.04	4.4	0.5		250
	May-June mode	-	150	-	-	45	60	-	100	-	-	-	-	-	1	-	12	3		54
	Total max.	8.6	348	27	-	258	273	-	284	-	-	-	1	0.05	11	1.7	19	16		250
Weigand's Bay Transect #1	MIN	9.2	139	20.4	4.6	44	53	12	88	35	11	1.1	<0.05	<0.02	<0.3	<0.02	12	5	6	15
	MAX	9.6	158	25.7	9.6	48	60	38	112	44	13.2	1.6	<0.30	0.05	0.5	0.09	17	6		
Weigand's Bay Transect #2	MIN	9.4	133	19.9	5.3	42	54	<5	94	38	10.9	0.8	<0.05	0.02	<0.3	<0.02	14	5	6	15
	MAX	9.6	155	24.7	10.8	44	58	18	122	44	14.0	1.9	<0.30	0.03	0.5	0.23	14	5		
Grueber's Bay Transect #1	MIN	8.8	144	22.3	3.6	39	57	22	90	38	13.4	1.0	0.13	0.02	0.3	<0.02	16	5	6	15
	MAX	9.7	161	27.1	10.4	61	68	300	126	166	21.3	7.2	0.53	0.02	0.3	0.41	20	6		
Grueber's Bay Transect #2	MIN	9.2	129	20.2	5.0	34	52	12	98	34	12.7	1.0	<0.05	0.02	<0.3	0.2	11	5	6	15
	MAX	9.6	134	26.1	11.2	46	56	20	116	50	14.0	2.2	0.40	0.03	0.3	0.2	16	5		
Industrial treatment plant discharge 5/21/75 composite	MIN	7.-	192	12.7	6.7	55	71	10	160	26	11.0	0.6	0.05	0.04	2.0	0.72	40	11	4	5
	MAX	8.9	274	17.0	7.7	60	111	20	426	134	40.0	1.5	0.23	0.22	8.0	0.10	64	158	composite	
	$\bar{x}$	-	-	-	-	70	119	8	302	71	9.0	1.1	0.30	0.49	13.0	<0.02	80	62		
Stream below Industrial treatment plant	MIN	8.1	229	14.6	6.6	68	115	<5	472	30	7.6	0.8	0.40	0.30	7.0	<0.02	57	170	1	5
	MAX	8.5	288	17.5	7.7															
Settling Lake	MIN	9.3	642	23.6	6.2	26	190	14	462	27	8.1	0.3	0.05	0.83	13.0	<0.02	138	24	6	15
	MAX	10.1	716	27.9	10.8	130	203	16	488	38	11.0	0.9	0.30	0.86	90.0	0.02	141	35		

Samples taken to reflect conditions in a shallow pond downstream of the industrial collection plant output and a smaller sewage treatment plant discharge (SL 1, 2, 3), show increases in NO_3/NO_2 and sulfate concentrations (Table 3). The NO_3/NO_2 concentrations were extremely high [> 100 mg/ℓ NO_3/NO_2 considered dangerous to livestock (National Science Foundation, 1973)] with values generally ranging from 6-90 mg/ℓ. Reported residual chlorine discharge concentrations for the period [ranging from 0.28 to 0.99 mg/ℓ (R. Thiede, personal communication)] from the Badger sewage treatment plant should be considered higher than desirable levels for protection of aquatic life (National Science Foundation, 1973).

Sulfate concentrations in the settling lake were about 140 mg/ℓ or about twice the ITP stream discharge concentrations and an order of magnitude greater than background concentrations. It is probable that nonpoint source surface transport contributes to these higher concentrations.

The nearest Grueber's Bay (Wisconsin River) transect continues to show only slightly higher sulfate concentrations. Sampling disturbance of highly flocculent bottom sediments is believed responsible for the elevated suspended solids concentrations (Table 3). With respect to other (Table 3 summarized) constituent concentrations and/or other Grueber's Bay sample locations, the water quality differences are considered insignificant upon comparison with background determinations at Weigand's Bay. It should be noted that nitrocellulose production was inactive prior to sampling.

Sediment Chemistry

Table 4 summarizes the analyses of sediment samples collected in late May, 1975. The complete data set utilized to compose the summary table is included in Appendix B, Table 1. The sample locations are shown on Figure 1 and an annotated legend, providing field descriptions of the sample sites, is included in Table 1. Table 4 also includes as reference reported sediment classification "schemata" available from the U.S. EPA and the Corps of Engineers (Corps of Engineers, 1970; Boyd, et al., 1972; Reimers, et al., 1975).

As shown in the table, the analyses of Weigand's Bay sediments indicate the samples are well within the recommended limits for volatile solids and chemical oxygen demand. However, sediment nutrients, as represented by the total Kjeldahl nitrogen (TKN) and phosphate concentrations, appear to be slightly higher than desirable levels.

TABLE 4. SUMMARY OF SEDIMENT CHARACTERISTICS FOR WEIGAND'S AND GRUEBER'S BAYS AND THE SETTLING LAKE

		Total Solids	Total Volatile Solids	Chemical Oxygen Demand	Total Kjeldahl Nitrogen	Nitrate	Nitrite	Phosphate	Number of Samples
		(values in percent dry weight)				(values in ppm dry weight)			
Objectionable[a] Sediment Characteristics			>6.0	>5.0	>0.10				
Polluted Sediments	"light"[b]		<5	<4.0				<300[c]	
	"heavy"		>8	>12.0				>900	
Weigand's Bay	Min	46.6	1.70	3.05	0.13	1	<0.1	600	3
	Max	53.6	2.40	3.96	0.19	1	0.1	920	
Grueber's Bay	Min	8.0	2.98	2.64	0.84	2	1.0	1,720	5
	Max	12.8	5.33	5.88	1.40	31	4.2	11,000	
Settling Lake	5/19/75	30.2	5.73	5.42	0.65	13	2.0	4,800	
	5/22/75	19.2	9.44	8.55	0.697	650	0.6	1,050	2

(a) U.S. EPA - selected bulk analysis allowable sediment constituents (National Science Foundation, 1973).
(b) Corps of Engineers - selected bulk analysis classification of polluted sediments (Corps of Engineers, 1970).
(c) Originally reported as P.

The settling lake sediments (Table 4) are regarded as highly polluted in regard to volatile solids, COD, and nutrients. Grueber's Bay sediments are also polluted. As shown in Table 4, Grueber's Bay sediments tend to be high in volatile solids, total Kjeldahl nitrogen, and chemical oxygen demand. Phosphate concentrations also range to an order of magnitude higher than the reference stations in Weigand's Bay. The temporal resuspension of these sediments due to wind mixing periodically results in depletion of oxygen in the surface waters of Grueber's Bay in contrast with Weigand's Bay (compare TKN, COD in Table 4). The sediment associated nutrients in Grueber's Bay are also higher.

Munitions Constituent Analysis (Nitrocellulose)

The concentrations of nitrocellulose (NC) in the individual water and sediment stations examined at BAAP are listed in full in Appendices A and B. However, a rough summary of these values is given in Table 5. Average concentrations of NC in the settling lake water stations appear to be consistently less than 2 ppm, while GBT-1 stations maintain somewhat higher NC levels (5-13 ppm), which rapidly fall off at GBT-2 to consistently low values of < 3 ppm. Some daily fluctuations were detected with occasional high concentrations in ITP effluent being reflected in downstream stations.

Nitrocellulose is practically water insoluble and exists as very fine particles in these water samples. Turbulence and the fact that NC fines are present in the sediment beneath the water station being sampled are important considerations in the evaluation of these data. Hence, the somewhat elevated values found in GBT-1 water stations may result from the resuspension of NC fines from the sediment beneath. The ITP stream is also influenced by turbulent flow which maintains the particles in suspension and generates high water concentrations. As a result of this behavior, an interpretation of water sample data in terms of the environmental fate of NC wastes must be done with reference to NC levels detected in the corresponding sediment samples.

Product-moment correlation coefficients (Pearson's r) were computed between nitrocellulose levels in the water and each water quality parameter. Values from all available water samples taken at all stations were used,

TABLE 5. MEAN NITROCELLULOSE CONCENTRATIONS AT SELECTED BAAP SAMPLING STATIONS

	Water (ppm)	[Range]	Sediments (ppm)	[Range]
ITP-O	4.4	[< 1.0-14.0]	-	-
ITP Stream	5.1	[< 1.0-7.6]	62	[27.5-131.9]
SL-1	1.5	[< 1.0-3.5]	116	[28.8-296.0]
GBT 1-1	12.1	[4.5-20.0]	120	[110.5-130.0]
GBT 1-2	7.5	[4.0-10.9]	106	[73.2-164.4]
GBT 1-3	12.0	[12.0]	130	[63.4-195.0]
GBT-Mean	10.7		119	
GBT 2-1	1.2	[< 1.0-1.3]	60	[31.5-97.5]
GBT 2-2	1.4	[< 1.0-2.3]	41	[29.0-51.6]
GBT 2-3	< 1.0	[< 1.0]	33	[17.8-43.7]
GBT 2-Mean	< 1.2		45	

except for those taken at the outfalls; these were excluded from the calculations since the combinations of values there did not represent stable conditions.

Nitrocellulose levels were found to have significant positive correlations with the following water quality parameters:

alkalinity ($r = .64$), suspended solids ($r = .61$), COD ($r = .58$), and TOC ($r = .70$).

These r values were each calculated from 16 points, and were all significant at the .95 level or greater. No significant negative correlations were found.

Correlation coefficients between nitroglycerine levels and water quality levels could not be computed because of the small number of samples analyzed for nitroglycerine.

Concentration of NC in the sediment samples examined were generally at least 5-10 times greater than that found in the corresponding water samples, presumably a result of the settling out and build-up of NC particles in the stream and lake bottoms. This build-up may not be uniform throughout a particular location and, in fact, NC pellets were actually observed at some of the stations. Hence, wide fluctuations in NC content were detected at some stations, particularly in the settling lakes. Consistently high concentrations at the first transect of Grueber's Bay indicate an important source of NC to the corresponding water stations due to turbulence as discussed above. Concentrations are greatly reduced in the sediments at GBT-2. Here, depth restricts resuspension of the particles into the water column as nitrocellulose becomes almost undetectable. From the data obtained, the variations in average sediment and water NC concentrations indicate a general migration and settling-out of munitions discharges from the ITP stream to the head of Grueber's Bay (GBT-1) where some build-up of NC in the sediment occurs.

Periphyton

Artificial substrate periphyton was analyzed to facilitate comparisons between Weigand's and Grueber's Bays, which appeared to have similar periphyton communities.

Species Composition. Grueber's Bay samples from transects 1 and 2 contained 109 different periphyton species compared to 83 species identified in Weigand's Bay samples. Sixty-eight species were common to both bays. Samples from GBT-1 contained 95 different species compared to 65, 67, and 55 in GBT-2, WBT-1, and WBT-2, respectively. The 7 most common genera were Scenedesmus, Melosira, Synedra, Fragilaria, Diatoma, Nitzschia, and Gomphonema. All species commonly found in Weigand's Bay were also in Grueber's Bay. Scenedesmus is often associated with waters of high nutrient content (Palmer, 1969). This indicator organism was present in both bays and was most important at GBT-1. The concentrations of ammonium and phosphates were higher at GBT-1 than at the other three transects (Table 3), contributing to the greater importance of Scenedesmus at GBT-1. Synedra and Fragilaria were the dominant genera in Weigand's, but both genera were also abundant in Grueber's Bay.

The fact that all species prevalent in the reference system were also common in the receiving system suggests that both Weigand's and Grueber's Bays are suitable for the development of a diverse periphyton community.

Species compositions and standing crops (number of individuals/cm^2) of artificial substrate periphyton are presented in Appendix C, Tables 1-18. The species composition data is summarized in Appendix C, Table 19.

Community Structure. Community structures in Weigand's and Grueber's Bays were compared in reference to several parameters including standing crop, species diversity ($\bar{H}$), number of species, and colonization rates. A summary of periphyton and phytoplankton data from Weigand's and Grueber's Bays is presented in Table 6. Means were calculated for standing crop, species diversity, and number of species for each of the four bay transects. After three weeks of incubation, the mean standing crop and mean number of species were 50 percent greater at GBT-1 than at the reference transects. The mean species diversity was also higher at GBT-1. The higher standing crop at GBT-1 was due to greater numbers of Scenedesmus spp. As mentioned earlier, the increase in Scenedesmus spp., a chlorophycean, at GBT-1 was probably a result of greater nutrient content. The increase in Scenedesmus numbers caused a shift in percent abundance of chlorophycean species from 11 percent at WBT-1 to 43 percent at GBT-1. This shift corresponds with a decrease in diatom (Chrysophyta) percent abundance from 85 percent at WBT-1 to 48 percent at GBT-1. These percentages were calculated from data presented in Appendix C, Tables 1-12. The above changes in relative abundance of algal groups was probably due to morphometric differences in the two bays rather than to the presence of effluent compounds in the receiving systems. The shallow conditions at Grueber's Bay allowed for more movement of nutrients from the bottom into the photosynthetic zone, resulting in an increase in chlorophycean species and overall standing crop at GBT-1.

Analyses of variance (ANOVA) were performed on periphyton and phytoplankton data to clarify significant differences in community structure parameters of Weigand's and Grueber's Bays. Numbers of individuals, number of species, and the Shannon Index ($\bar{H}$) were the parameters considered in the ANOVA analysis. Results of analyses of variance performed on artificial substrate data are presented in Table 7. One transect mean was produced by combining all replicates in all substations within each transect. Separate transect means were calculated for phytoplankton data and the three

TABLE 6. SUMMARY OF ANALYSES OF THE DATA FROM PHYTOPLANKTON AND ARTIFICIAL SUBSTRATE SAMPLES FROM WEIGAND'S AND GRUEBER'S BAYS, THE ITP STREAM, AND THE SETTLING LAKE

Station	Mean (NC) ppm	Phytoplankton				Artificial Substrate Periphyton											
						Second Week				Third Week				Fourth Week			
		Mean No. of Individuals Per liter x 10^6	Mean No. of Species	Mean Diversity Index	Total No. Of Species	Mean No. of Individuals Per cm^2 x 10^5	Mean No. of Species	Mean Diversity Index	Total No. Of Species	Mean No. of Individuals Per cm^2 x 10^5	Mean No. of Species	Mean Diversity Index	Total No. Of Species	Mean No. of Individuals Per cm^2 x 10^5	Mean No. of Species	Mean Diversity Index	Total No. Of Species
WBT 1-1	0.0	2.8	12.7	1.72	23	0.6	12.0	1.50	12	3.2	21.7	2.57	33	4.6	18.0	1.71	18
WBT 1-2	0.0	3.1	11.7	1.59	21	0.4	14.0	1.64	14	3.2	18.0	2.31	30	3.1	20.0	2.03	20
WBT 1-3	0.0	3.3	15.3	1.84	32	1.1	14.0	1.52	14	2.4	20.0	2.33	35	7.1	19.0	1.33	19
WBT 1-m	0.0	3.1	13.2	1.72	25	0.7	13.3	1.55	13	2.9	19.9	2.40	33	4.9	19.0	1.69	19
GBT 1-1	12.5	1.7	14.7	2.10	29	1.1	21.0	1.82	21	3.9	30.7	2.86	50	7.3	36.0	2.87	36
GBT 1-2	7.5	1.4	10.7	1.93	19	1.1	26.0	2.41	26	5.4	32.3	2.94	54	4.9	29.0	2.86	29
GBT 1-3	12.0	1.4	11.0	1.84	22	1.3	23.0	1.96	23	4.9	29.0	2.85	47	6.2	31.0	2.78	31
GBT 1-m	10.7	1.5	12.1	1.96	23	1.2	23.3	2.06	23	4.7	30.7	2.88	50	6.1	32.0	2.84	32
WBT 2-1	0.0	4.0	9.3	1.12	16	0.8	17.0	1.84	17	3.7	19.0	2.42	29	1.3	14.0	2.38	14
WBT 2-2	0.0	2.4	9.0	1.57	15	0.4	11.0	1.36	11	-	-	-	-	-	-	-	-
WBT 2-3	0.0	2.7	10.3	1.43	18	0.7	12.0	1.85	12	3.0	17.7	2.36	26	5.7	35.0	2.97	35
ITP	4.8	8.7	23.7	1.65	41*	0.06	7.0	0.70	7	0.4	19.3	0.87	31	1.8	19.0	2.13	19
WBT 2-m	0.0	3.0	9.5	1.37	16	0.6	13.3	1.68	13	3.3	18.4	2.39	28	3.5	24.5	2.68	25
GBT 2-1	1.2	0.9	9.7	1.84	18	0.5	15.0	2.11	15	1.9	17.7	2.48	28	3.7	19.0	2.24	19
GBT 2-2	1.4	1.1	9.3	1.94	15	0.4	19.0	2.07	19	4.5	22.7	2.61	33	5.2	30.0	2.93	30
GBT 2-3	1.0	1.5	11.7	1.95	22	0.6	15.0	1.92	15	3.8	22.7	2.56	37	4.5			
GBT 2-m	1.2	1.2	10.2	1.91	18	0.5	16.3	2.03	16	3.4	21.0	2.55	33	4.5	24.5	2.59	25
SL-1	0.7	0.5	13.6	1.07	44	0.4	5.0	0.32	11	1.0	13.9	1.16	41	10.9	12.0	1.27	19

* natural periphyton samples

different weeks of artificial substrate data. The three parameters mentioned above were analyzed for significant differences. In Table 7, one Duncan's Mean Separation Test is presented by each pair of adjacent columns with the significance level of the corresponding ANOVA listed below the second column in the pair. For the Mean Separation Test, the four transect means are listed in increasing order from top to bottom; mean separation lines are drawn to the immediate right of the means. The differences and similarities of the means are illustrated by the mean separation lines - two means connected by a line segment are similar, two means not connected are significantly different.

The artificial substrate standing crop and number of species were consistently greater in GBT-1 than in WBT-1, and these two parameters were significantly different for GBT-1 compared to the reference transect after two and three weeks of incubation (Table 7). Standing crop and number of species results for GBT-2 and WBT-2 were similar through all three weeks of the sampling period. As mentioned earlier, morphometric differences probably account for the larger standing crop and greater number of species at GBT-1 compared with WBT-1. These same two parameters were similar at GBT-2 and WBT-2, because the morphometry was also similar at these deeper transects.

The species diversities of both Grueber's Bay transects were significantly greater than the corresponding reference transects after two and three weeks of incubation. The species diversity at WBT-1 remained significantly lower than at GBT-1 after the fourth week of incubation (Table 7). These lower species diversities at the reference transects resulted from large numbers of Fragilaria spp. and Synedra spp. The above results for the parameters analyzed do not suggest any adverse effect on the periphyton community of Grueber's Bay.

Both natural and artificial substrate periphyton samples were collected from the ITP stream; the results are listed in Appendix C, Tables 38 and 16, respectively. The natural substrate results for mean species diversity were similar to the artificial substrate species diversity after four weeks of incubation (Table 6); these results were comparable to the two bays. The mean standing crop for the natural substrate samples was

TABLE 7. DUNCAN'S MEAN SEPARATION TEST RESULTS CORRESPONDING TO ANOVA'S OF THE DATA FROM PHYTOPLANKTON AND ARTIFICIAL SUBSTRATE SAMPLES FROM WEIGAND'S AND GRUEBER'S BAYS

	Phytoplankton						Artificial Substrates, Week 2					
	Site	No. of indiv.x10^6	Site	No. of species	Site	Diversity index	Site	No. of indiv.x10^4	Site	No. of species	Site	Diversity index
Transect means plus Duncan's Mean Separation Test	GBT-2	1.1	WBT-2	9.5	WBT-2	1.36	GBT-2	5.1	WBT-1	13.3	WBT-1	1.55
	GBT-1	1.4	GBT-2	10.2	WBT-1	1.71	WBT-2	6.3	WBT-2	13.3	WBT-2	1.68
	WBT-2	3.0	GBT-1	12.1	GBT-2	1.90	WBT-1	7.1	GBT-2	16.3	GBT-2	2.03
	WBT-1	3.0	WBT-1	13.2	GBT-1	1.95	GBT-1	11.5	GBT-1	23.3	GBT-1	2.06
Signif. level of F-test from ANOVA		>0.999		0.995		>0.999		0.97		0.995		0.95

	Artificial Substrates, Week 3						Artificial Substrates, Week 4					
	Site	No. of indiv.x10^5	Site	No. of species	Site	Diversity index	Site	No. of indiv.x10^5	Site	No. of species	Site	Diversity index
Transect means plus Duncan's Mean Separation Test	WBT-1	2.9	WBT-2	18.3	WBT-2	2.39	WBT-2	3.5	WBT-1	19.0	WBT-1	1.68
	WBT-2	3.3	WBT-1	19.8	WBT-1	2.40	GBT-2	4.5	WBT-2	24.5	GBT-2	2.58
	GBT-2	3.4	GBT-2	21.0	GBT-2	2.55	WBT-1	4.9	GBT-2	24.5	WBT-2	2.67
	GBT-1	4.7	GBT-1	30.6	GBT-1	2.88	GBT-1	6.1	GBT-1	32.0	GBT-1	2.83
Signif. level of F-test from ANOVA		0.99		>0.999		>0.999		(not signif.)		(not signif.)		0.98

greater than that for the artificial substrates and the two bays because one natural substrate sample contained a large number of unicellular flagellates. After two and three weeks of incubation, the ITP artificial substrates were much lower in standing crop and species diversity than either the ITP natural substrates or the artificial substrate bay samples.

Chlorophyll *a*, Ash-free Biomass, Autotrophic Index. Chlorophyll *a*, ash-free dry weight biomass, and autotrophic indices (AI) were determined after three weeks of incubation (Table 8). Chlorophyll *a* and ash-free biomass provide useful estimates of standing crop (Wetzel, 1963; Wright, 1959). The autotrophic index is the relationship between biomass (ash-free dry weight) and chlorophyll *a* expressed as a ratio. Weber and McFarland (1969) stated that AI figures greater than 100 may be due to organic pollution. The chlorophyll *a* and ash-free biomass were both greater in GBT-1 than at WBT-1. These results reflect the trends observed in the parameters previously discussed. The autotrophic indices were similar in both bays, ranging from 102 to 207 for Weigand's Bay and from 120 to 206 for Grueber's Bay. The large accumulation of periphyton on artificial substrate slides at the time of chlorophyll analysis probably lowered the chlorophyll data relative to biomass results, consequently raising the AI values over 100, and not necessarily indicating organic pollution. These results further support the premise that the effluent in Grueber's Bay does not adversely effect the periphyton and may actually enhance growth due to nutrient input.

Colonization. The rate of colonization was determined by comparing the results from the three different weeks of the sampling period (Table 6). The three sampling weeks represent two, three, and four weeks of incubation. The number of species and species diversity increased from the second to the third week, but these two parameters remained constant the fourth week. This pattern was observed in both bays and in SL-1, indicating that colonization

TABLE 8. RESULTS OF CHLOROPHYLL *a* AND ASH-FREE DRY WEIGHT BIOMASS/ANALYSES AND AUTOTROPHIC INDEX (AI) FROM NITROCELLULOSE RECEIVING AND REFERENCE SYSTEMS (3-WEEK INCUBATION PERIOD)

	[NC] ppm	Chlorophyll *a* mg/m^2	Ash-Free Biomass mg/m^2	Autotrophic Index
WBT 1-1	0.0	10.3	1,636	159
WBT 1-2	0.0	11.4	2,067	181
WBT 1-3	0.0	17.3	1,774	102
WBT 1-$\bar{m}$	0.0	13.0	1,826	147
GBT 1-1	12.5	28.9	5,933	205
GBT 1-2	7.5	37.1	7,048	190
GBT 1-3	12.0	35.2	5,735	163
GBT 1-$\bar{m}$	10.7	33.7	6,238	186
WBT 2-1	0.0	10.8	2,244	207
WBT 2-2	0.0	-	-	-
WBT 2-3	0.0	15.4	1,761	114
WBT 2-$\bar{m}$	0.0	13.1	2,003	161
GBT 2-1	1.2	9.7	2,006	206
GBT 2-2	1.4	12.3	1,912	156
GBT 2-3	< 1.0	17.0	2,041	120
GBT 2-$\bar{m}$	1.2	13.0	1,986	161
ITP	4.8	0.12	323	2,784
SL-1	0.7	0.65	362	582

was virtually complete by the third week of sampling. The similar colonization rates observed at Grueber's and Weigand's Bays suggest that this function is not effected by the effluent in Grueber's Bay.

Cluster Analysis. Figure 4 shows a dendogram constructed from similarity coefficients computed from artificial substrate periphyton samples taken at Weigand's and Grueber's Bays. The most important sequences of steps that took place in the formation of the tree were: (1) all three substations from GBT-1 formed a cluster by themselves at a level of association of 0.30, (2) all the substations from all the three remaining transects - GBT-2, WBT-1, and WBT-2 - formed a cluster together at level 0.22. Within this large cluster there were smaller groupings in which the various substations from GBT-2, WBT-1, and WBT-2 mixed together more or less randomly, (3) the cluster for GBT-1 joined the cluster for the reamining transects at level 0.18. After these three major steps, one substation WBT-2, joined the final cluster at the low end of the tree. This substation was very dissimilar from all the others because the calculation of its species assemblage was based on laboratory analysis of only one replicate since the diatometer was lost after the first sampling week. It can be eliminated from consideration for this reason.

From these trends certain conclusions can be made about the periphyton species assemblages at the four transects. GBT-1 shows a strong internal similarity in its species assemblages among substations. None of the remaining three transects posses this degree of internal similarity due to the random order in which their substations mixed together; that is, they cannot be distinguished from each other on the basis of species assemblages. However, these three transects show more similarities among themselves than with GBT-1.

To summarize, the cluster analysis demonstrates a major difference between the periphyton species assemblages found at GBT-1 and those found at all other transects. This observation agrees with the results of the ANOVA's performed on two community structure variables, numbers of individuals, and numbers of species from artificial substrate samples taken during each of sampling weeks two and three (Table 7). In these ANOVA's the Duncan's Mean Separation Test grouped the three transects GBT-2, WBT-1, and WBT-2 together; GBT-1 was placed in a group by itself significantly different from (and higher than) all the others.

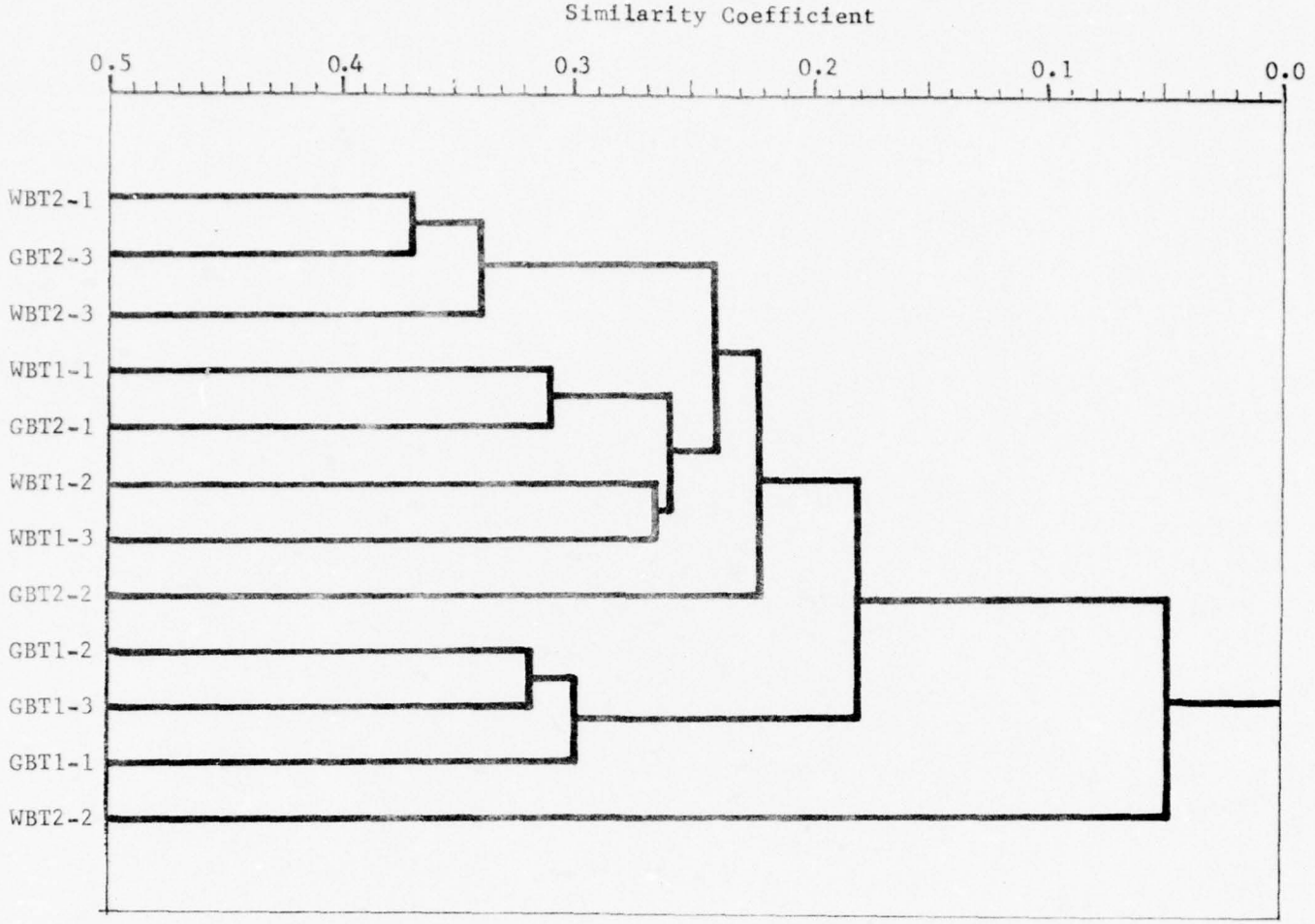


FIGURE 4. ARTIFICIAL SUBSTRATE PERIPHYTON DENDOGRAM OF SUBSTATIONS FROM WEIGAND'S AND GRUEBER'S BAYS

Phytoplankton

Phytoplankton samples were analyzed to provide another basis for comparison between the reference and receiving systems. Phytoplankton results did not suggest any large differences between Weigand's and Grueber's Bays.

Species Composition. Phytoplankton species compositions were very similar between the two bays. Grueber's Bay and Weigand's Bay contained 52 and 46 different phytoplankton species, respectively, with 29 species common to both. Melosira spp. and Asterionella formosa were important taxa in both bays. All of the commonly occurring species in Weigand's Bay were also found in Grueber's Bay. The similarity in species composition between the receiving and reference systems suggests little if any effect of the effluent discharges on the planktonic algae.

The species composition and standing crop results for phytoplankton are listed in Appendix C, Tables 20-34. Species distribution is summarized in Appendix C, Table 37.

Community Structure. Standing crop, number of species, and species diversity were analyzed for comparison between the two bays. Phytoplankton data are summarized in Table 6, with means listed for the three parameters. Analyses of variance were performed on the phytoplankton data to assist in determining significant differences between the reference and receiving systems (Table 7).

The phytoplankton standing crop at Weigand's Bay was double the amount at Grueber's Bay. This difference was significant at a level greater than 0.999. Species diversity results were the opposite, with GBT-1 and GBT-2 significantly greater than the corresponding reference transects. The reason for these differences was the greater abundance of Melosira spp. in Weigand's Bay. The large Melosira spp. numbers raised the standing crop and lowered the species diversity at Weigand's Bay relative to the same parameters at Grueber's Bay. The mean number of phytoplankton species ranged from 9.0 to 15.3 in Weigand's Bay and from 9.3 to 14.7 in Grueber's Bay with the lower number of species found in transect 2 of each bay. The number of species at GBT-1 and WBT-1 were similar to each other but significantly greater than both GBT-2 and WBT-2. This difference probably

resulted from the shallowness of the transects-1 compared to the deeper transects-2. The above results considering together the three parameters suggest no apparent adverse effect on the phytoplankton community of Grueber's Bay caused by the effluent influx.

Species-area curves were drawn for the four transects in Weigand's and Grueber's Bays (Figure 5). Comparisons of the curves for the two bays reveal a greater number of species present at GBT-1 than at WBT-1. As illustrated by the species-area curves, GBT-2 and WBT-2 were almost equivalent in numbers of species. The shapes of the curves, flattening gradually with increased volume examined, indicate that a sufficient number of samples were analyzed. The species-area curves suggest no adverse effect in Grueber's Bay. In fact, the receiving system contained more total species than the reference system.

Cluster Analysis. Figure 6 shows a dendogram constructed from similarity coefficients computed from phytoplankton samples taken at Weigand's and Grueber's Bays. The main sequences of steps that formed the tree were: (1) all three substations from WBT-1 clustered together by themselves at a level of association of 0.34, (2) all three substations from WBT-2 clustered together by themselves at a level of 0.25, (3) the cluster for WBT-1 joined the cluster for WBT-2 at a level of 0.24, (4) all the substations from the two Grueber's Bay transects GBT-1 and GBT-2 formed a cluster at a level of 0.23. Within this larger cluster, there were smaller groupings in which the various substations from GBT-1 and GBT-2 mixed together randomly. (5) The cluster for WBT-1 and WBT-2 joined the cluster for GBT-1 and GBT-2 at a level of 0.20.

The main conclusions concerning phytoplankton assemblages at the two bays which can be drawn from this dendogram are the following. WBT-1 possesses a strong degree of internal similarity among its substations as does WBT-2 to a lesser extent. WBT-1 and WBT-2 are more similar to each other than they are to GBT-1 and GBT-2. The two Grueber's Bay transects show more similarities to each other than they show internal similarities; that is, they cannot be distinguished from each other on the basis of species assemblages.

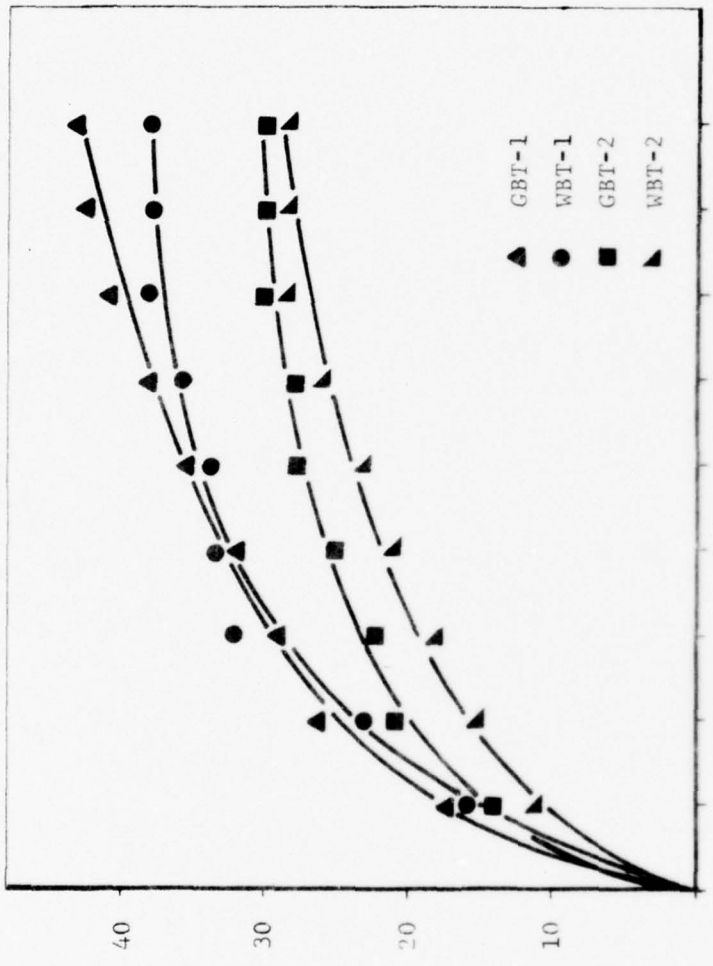


FIGURE 5. SPECIES-AREA CURVES OF PHYTOPLANKTON DATA FROM WIEGAND'S AND GRUEBER'S BAYS, TRANSECTS 1 AND 2

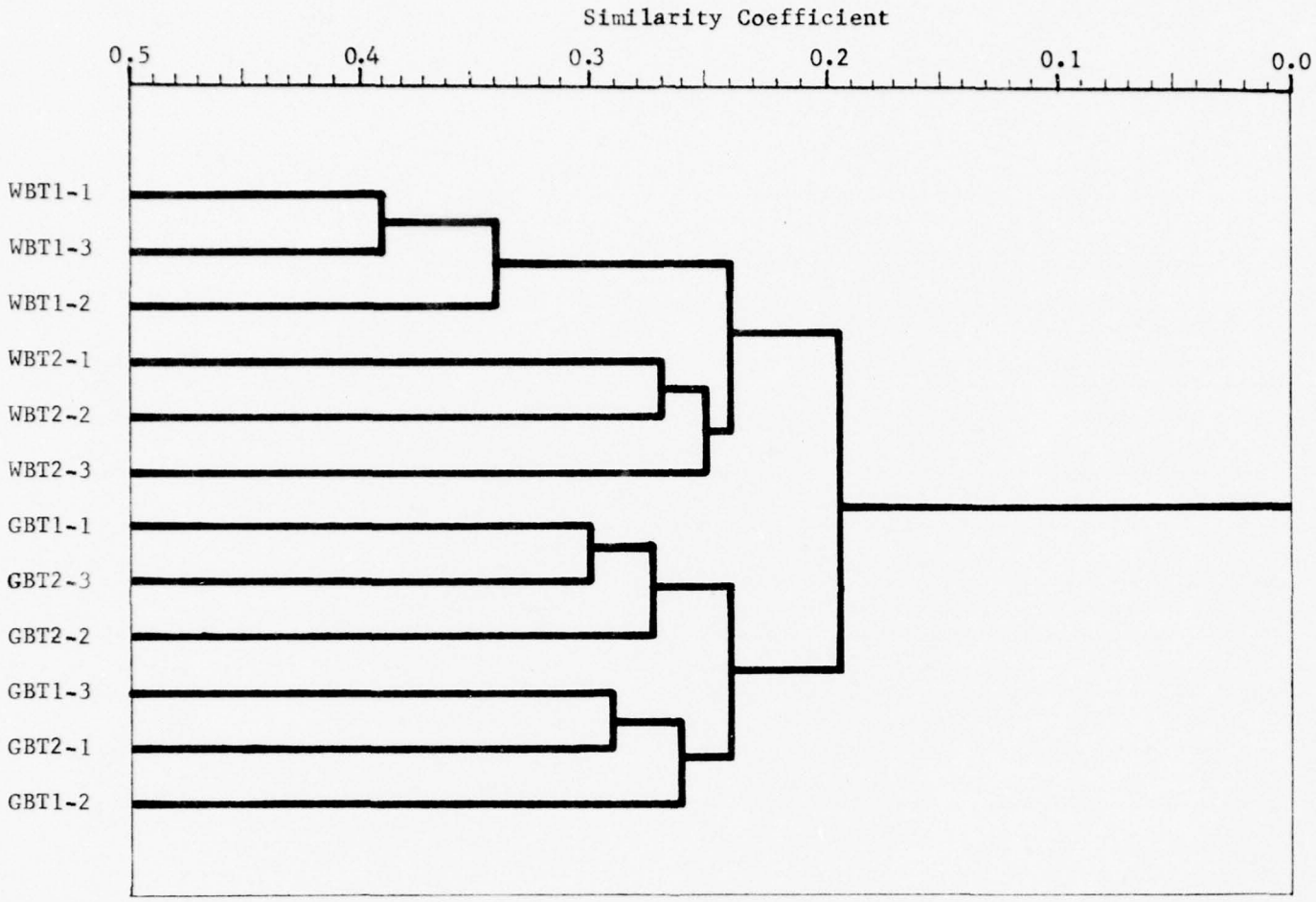


FIGURE 6. PHYTOPLANKTON DENDOGRAM OF SUBSTATIONS FROM WEIGAND'S AND GRUEBER'S BAYS

In summary, the phytoplankton assemblages are chiefly differentiated between the two bays. To a somewhat lesser extent, within Weigand's Bay the species assemblages are differentiated by transect position (inner or outer). These results agree with the results of the ANOVA performed on the total number of individuals obtained from phytoplankton samples (Table 7). For this community structure variable, the Duncan's Mean Separation Test grouped the two Grueber's Bay transects together into one group and the two Weigand's Bay transects together into a second, significantly different group.

Benthic Macroinvertebrates

Species Composition. A summary of the benthic species collected from natural and artificial substrates is found in Tables 9 and 10, respectively. The most striking observation from these species lists is the small number of organisms found in the ITP stream. Species present included one midge, two beetles, oligochaetes, and a lepidopteran (possibly terrestrial). All these were collected from the natural substrate with a Surber sampler. This number of species is much lower than one would expect to find in comparable streams in this area of Wisconsin (Cooper et al, 1974). No invertebrates were collected on the artificial substrate samplers placed above the substrate. The failure of organisms to colonize this section of stream may be due to the excessive chlorination of the sanitary waste effluent which is discharged to this stream immediately upstream from the sampling station.

The settling lake invertebrate community was composed primarily of midge fly larvae. A total of eight species of midge were collected, two from the natural substrate and six from artificial substrates. One species of snail, Physa sp., was the only other invertebrate collected from the natural substrate. Artificial substrates were colonized by one damselfly, Enallagma sp., one beetle larvae, Berosus sp., a waterboatman of the family Corixidae and aquatic earthworms. This number of species is within the range (6-15 species) expected in farm ponds of central Wisconsin (S. Richman, personal communication).

TABLE 9. BENTHIC MACROINVERTEBRATE SPECIES COMPOSITION OF NATURAL SUBSTRATES AT BAAP

	WBT-1	GBT-1	WBT-2	GBT-2	ITP	Settling Lake
Diptera						
Chironomidae						
Tanypus sp.	X	X				
Procladius sp.	X	X	X	X		
Pentaneura sp.	X		X	X		
Chironomus (*Chironomus*) sp.	X		X	X		
Chironomus (*Cryptochironomus*) *abortivus*	X					
Chironomus (*Cryptochironomus*) sp.	X	X	X	X		
Chironomus (*Dicrotendipes*) sp.	X					X
Chironomus (*Endochironomus*) sp.	X	X		X		
Chironomus (*Tribelos*) sp.	X					
Glyptotendipes sp.	X	X	X	X		
Pseudochironomus sp.			X			
Polypedilum sp.	X		X	X		
Paralauterborniella sp.		X		X		
Tanytarsus sp.	X		X	X		
Prodiamesa sp.			X			
Orthocladius sp.	X				X	
Unidentified midges	X	X	X	X		
Ceratopogonidae						
Palpomyia sp.	X	X		X		X
Ephemeroptera						
Ephemeridae						
Hexagenia sp.	X		X			
Baetidae						
Caenis sp.	X	X		X		
Baetisca sp.		X				
Odonata						
Coenagrionidae						
Ischnura sp.	X	X				

TABLE 9. (Continued)

	WBT-1	GBT-1	WBT-2	GBT-2	ITP	Settling Lake
Trichoptera						
Leptoceridae						
Oecetis sp.	X					
sp.				X		
Coleoptera						
Dytiscidae						
Hydaticus sp.					X	
sp.					X	
Hydrophilidae						
Berosus sp.		X				
Elmidae						
Dubiraphia sp.	X					
Limnius sp.	X					
Lepidoptera						
Pyralidae						
sp.					X	
Gastropoda						
Physidae						
Physa sp.						X
Planorbidae						
Helisoma sp.	X	X	X			
Pelecypoda						
Sphaeriidae						
Sphaerium sp.	X		X	X		
Unionidae						
sp.	X		X			

TABLE 9. (Continued)

	WBT-1	GBT-1	WBT-2	GBT-2	ITP	Settling Lake
Bryozoa						
Lophopodidae						
Pectinatella magnifica			X			
Cristatellidae						
Cristatella sp.	X					
Oligochaeta						
sp.	X	X		X	X	
Hirundinea						
sp.	X					
Ostracoda						
sp.		X				
Isopoda						
Asellidae						
Lirceus sp.	X					
Asellus sp.	X		X			
Amphipoda						
Talitridae						
Hyalella azteca	X	X	X	X		

TABLE 10. SPECIES COMPOSITION OF ARTIFICIAL SUBSTRATES IN WATERS SURROUNDING THE BAAP

	WBT-1	GBT-1	WBT-2	GBT-2	ITP	Settling Lake
Diptera						
Chironomidae						
Pentaneura sp.	X	X	X	X		
Chironomus (Chironomus) sp.		X				X
Chironomus (Einfeldia) sp.			X			
Chironomus (Cryptochironomus) abortivus		X	X	X		
Chironomus (Dicrotendipes) sp.	X	X	X	X		
Chironomus (Endochironomus) sp.	X	X	X	X		X
Chironomus (Tribelos) sp.	X		X	X		
Glyptotendipes sp.	X	X	X	X		X
Polypedilum sp.		X		X		
Tanytarsus sp.		X	X	X		X
Phaenopsectra sp.				X		
Psectrocladius sp.	X	X	X			
Cricotopus sp.	X	X	X	X		
Midge pupae	X	X	X	X		
Unidentified midges		X	X	X		X
Ceratopogonidae						
Palpomyia sp.	X	X	X			
Probezzia sp.	X	X	X	X		
Alluajdomyia sp.	X	X		X		
Ephemeroptera						
Heptageniidae						
Stenonema sp.	X		X	X		
Baetidae						
Leptophlebia sp.	X		X	X		
Ephemerella sp.	X	X				
Caenis sp.	X	X	X	X		
Baetisca sp.	X	X	X	X		
Odonata						
Coenagrionidae						
Coenagrion sp.		X				
Ischnura sp.	X	X	X	X		
Enallagma sp.		X	X	X		X
Trichoptera						
Hydroptilidae						
Agraylea sp.		X	X	X		
Orthotrichia sp.		X		X		
sp.	X	X	X	X		
Phryganiidae						
Phryganea sp.	X					
Leptoceridae						
Leptocella sp.		X				
Oecetis sp.	X	X		X		
sp.	X	X	X	X		
Limnephilidae						
Pycnopsyche sp.	X	X				
sp.				X		
Coleoptera						
Dytiscidae						
Hydroporus sp.	X					
sp.		X				
Gyrinidae						
Dineutus sp.	X					
Hydrophilidae						
Berosus sp.						X
Elmidae						
Stenelmis sp.	X	X				
Hemiptera						
Corixidae						
sp.						X
(eggs)						X
Pleidae						
Plea striola	X	X				
Plecoptera						
Perlodidae						
Isoperla sp.	X	X	X	X		
Gastropoda						
Physidae						
Physa sp.	X	X				

TABLE 10. (Continued

	WBT-1	GBT-1	WBT-2	GBT-2	ITP	Settling Lake
Planorbidae						
Helisoma sp.	X	X		X		
Gyraulus sp.	X	X				
Ancylidae						
Ferrissia sp.		X				
Turbellaria						
Planariidae						
Dugesia sp.	X	X		X		
Nematoda						
sp.	X	X	X	X		
Bryozoa						
Plumatellidae						
Plumatella repens	X	X				
Lophopodidae						
Pectinatella magnifica	X	X	X			
Lophopodella carteri		X				
Lophopodella sp.		X		X		
Oligichaeta						
sp.	X	X	X	X		X
Hirundinea						
sp.	X	X				
Ostracoda						
sp.		X		X		
Isopoda						
Asellidae						
Lirceus sp.		X	X	X		
Asellus sp.		X				
Amphipoda						
Talitridae						
Hyalella azteca	X	X	X	X		
Gammaridae						
Gammarus sp.	X	X	X	X		
Crangonyx sp.				X		
Stygobromus sp.	X	X	X	X		
Hydracarina						
sp.	X	X	X	X		
Hydroida						
Hydridae						
Hydra sp.	X	X	X	X		
Total No. of Species	42	53	34	41	0	11

Species lists for Grueber's and Weigand's Bays are presented separately by transect (Tables 9 and 10). Water depth, light penetration, and other physical-chemical abiotic factors differ greatly between transects 1 and 2 in both bays. Thus, the biological communities are also somewhat different. Therefore, comparisons of invertebrate species will be made only between morphologically similar transects; that is, GBT-1 compared with WBT-1 and GBT-2 compared with WBT-2.

The macroinvertebrate communities in these two bays are comprised of a variety of insect larvae and nymphs, including midges, mayflies, stoneflies, damselflies, caddisflies, beetles, and bugs. Other invertebrates found include snails, clams, flatworms, bryozoa, oligochaetes, isopods, amphipods, water mites, and hydra.

In general the species compositions of the invertebrate communities in these two bays are quite similar. The number of species in both bays tends to decrease at the deeper transects 2 on both natural and artificial substrates. However, in collections from the bottom sediments (natural substrate) in GBT-1 only 16 species were collected compared to 31 species from WBT-1. In addition to clams, elmidae beetles, caddisflies, and burrowing mayflies (Hexagenia sp., in particular), seven species of midge larvae found in Weigand's Bay were not collected in Grueber's Bay. However, of these invertebrates found in the sediment of Weigand's Bay and not in Grueber's the following species were able to colonize artificial substrates suspended in Grueber's Bay during the 5-week incubation period: Pentaneura sp., Chironomus (Chironomus) sp., C. (Cryptochironomus) abortivus, C. (Dicrotendipes) sp., Polypedilum sp., Tanytarsus sp., Oecetis sp., Lirceus sp., Asellus sp., a species of leech, and a species of water mite. (The burrowing mayfly, Hexagenia sp., was not found on the suspended samplers in Grueber's Bay. This organism is a substrate burrower and would not be expected to colonize a suspended artificial substrate.) The occurrence of these organisms on artificial substrates in Grueber's Bay, coupled with the fact that, in many cases, greater numbers of organisms colonized Grueber's Bay samplers than Weigand's, indicate that water quality in Grueber's Bay is not adversely affecting the benthic community, but that the sediments in Grueber's Bay in the area of the BAAP discharge have been rendered inhospitable to certain benthic macroinvertebrates.

The tabular results of benthic macroinvertebrate sampling at BAAP are presented in Appendix D, Tables 1 through 29. A complete listing of species and numbers of organisms collected in each dredge sample is presented in Appendix D, Tables 1 through 13. The same data for each artificial substrate sample appears in Appendix D, Tables 15 through 29. Surber sampler data from the ITP stream are found in Appendix D, Table 14.

Community Structure. The benthic macroinvertebrate community structure including standing crop, species diversity and colonization rate reveals some stress conditions existing in the ITP stream and the first settling lake. Communities in Weigand's and Grueber's Bays appear to be diverse, stable, and quite similar with one possible exception which will be discussed later.

A summary of benthic invertebrate data is presented in Table 11. The table includes the mean values for number of organisms and species per square meter, species diversity, and total number of species per station for both natural and artificial substrate samples. Means for artificial substrate data are presented for each sampling week during the incubation period. Additionally, transect means have been computed for Weigand's Bay, Grueber's Bay, and the settling lake.

A review of the data (Table 11) from the ITP stream shows a depauperate benthic community inhabiting this stream. Low standing crops, number of species, and diversity all indicate a severely stressed condition existing in this area of the ITP stream due possibly to excessive chlorination of the sanitary waste effluent and/or the discharge of cleaning solutions in the industrial effluent.

The perturbance seen in the ITP stream is also observed in the settling lake. Benthic macroinvertebrate standing crops, number of species per square meter, and diversity are very low on both the natural and artificial substrates in this pond (Table 11). This failure of invertebrates to colonize artificial substrates suspended in the water column would indicate that the source of the perturbance is either dissolved or suspended in the water and not exclusively a substrate quality condition.

TABLE 11. SUMMARY OF ANALYSES OF THE BENTHIC-MACROINVERTEBRATE DATA FROM NATURAL AND ARTIFICIAL SUBSTRATE SAMPLERS AT WEIGAND'S AND GRUEBER'S BAYS, THE ITP STREAM, AND THE SETTLING LAKE

	MEAN (NC) ppm (WATER)	MEAN (NC) ppm (Sediment)	Natural Substrates				Artificial Substrates											
							Week 3				Week 4				Week 5			
			Mean Number of Individuals	Mean Number of Species	Mean Species Diversity	Total Number of Species	Mean Number of Individuals	Mean Number of Species	Species Diversity	Total Number of Species	Mean Number of Individuals	Mean Number of Species	Species Diversity	Total Number of Species	Mean Number of Individuals	Mean Number of Species	Species Diversity	Total Number of Species
WBT 1-1	0.0	0.0	151.20	11.40	2.08	20	214.50	8.00	1.59	13	351.67	12.33	1.30	22	181.00	14.50	1.80	21
WBT 1-2	0.0	0.0	118.14	10.00	1.91	19	234.50	12.00	1.64	15	294.00	14.00	1.37	21	410.00	17.00	2.08	23
WBT 1-3	0.0	0.0	255.20	13.20	2.10	24	1615.50	12.50	1.04	19	1036.67	13.33	1.10	21	580.00	19.00	1.96	24
WBT 1-MEAN	0.0	0.0	174.93	11.53	2.03	21	688.16	10.83	1.42	15.66	560.78	13.22	1.25	21.33	390.33	16.83	1.94	22.66
GBT 1-1	12.5	120.25	30.40	3.00	0.92	7	119.50	8.50	1.27	12	86.33	18.33	2.21	25	168.50	15.50	1.77	24
GBT 1-2	7.5	106.13	39.20	3.20	1.05	5	645.00	11.50	0.66	19	450.00	17.00	1.61	24	357.00	19.50	1.80	26
GBT 1-3	12.0	129.66	54.40	4.20	1.08	15	243.50	11.00	0.97	16	243.00	17.67	1.76	25	304.50	19.00	1.92	26
GBT 1-MEAN	10.66	118.68	41.33	3.46	1.01	9	336.0	10.33	0.96	15.66	259.77	17.66	1.85	24.66	276.66	18.00	1.83	25.33
WBT 2-1	0.0	0.0	37.60	4.20	1.15	15	16.00	6.50	1.53	11	39.00	12.33	2.06	20	303.00	12.50	0.64	16
WBT 2-2	0.0	0.0	0.80	0.20	0.00	1	21.50	6.50	1.52	8	24.67	9.67	1.97	15				
WBT 2-3(a)	0.0	0.0	3.20	0.60	0.00	2	13.50	5.50	1.48	8	17.00	9.20	2.05	22	266.00	6.00	0.76	8
WBT 2-MEAN	0.0	0.0	13.86	1.66	0.38	6	17.00	6.16	1.50	9	26.89	10.40	2.03	19	284.5	9.25	0.70	12
GBT 2-1	1.2	60.2	4.80	0.80	0.11	3	62.50	12.00	1.85	18	38.33	11.67	1.86	20	1419.50	12.00	0.15	16
GBT 2-2	1.4	41.46	18.40	1.80	0.39	5	52.00	9.50	1.38	15	39.67	7.33	1.46	14	630.50	13.00	0.47	17
GBT 2-3	<1.0	33.00	69.60	6.20	1.50	15	56.50	8.50	1.37	13	57.75	8.75	1.67	14	207.50	14.00	0.94	20
GBT 2-MEAN	<1.2	44.88	30.92	2.93	0.66	7.66	57.00	10.00	1.53	15.33	42.25	9.25	1.66	16	725.5	13.00	0.51	14.33
ITP			1.80	1.60	0.42	5	0	0	0	0	0	0	0	0	0	0	0	0
SL 1-1			0.80	0.20	0	1	0	0	0	0	0.80	0.40	0	0	4	1.5	0.487	3
SL 1-2			2.40	0.60	0.14	3	0.05	0.05	0	1	0.20	0.20	0	1	3.50	2.50	0.74	5
SL 1-3			0	0	0	0	1	1	0	1	1.60	0.40	0	2	11.50	4.5	1.57	9
SL MEAN			1.06	0.26	0.046	1.33	0.35	0.35	0	0.66	0186	0.34	0	1	6.33	2.83	0.93	5.66

(a) 5 reps

The benthic community inhabiting the head of Grueber's Bay in the area of the BAAP discharge indicates an environmental perturbance in the natural substrate and not in the water. Samples from natural substrates (Table 11) at GBT-1 had lower standing crops, number of species, and species diversity than collections from WBT-1. However, artificial substrate samples from these areas did not differ significantly in the parameters measured. (A complete statistical analysis of data from Weigand's Bay and Grueber's Bay is presented later in this section.) These data would indicate the perturbance observed in the ITP stream and settling lake does, in fact, extend into the head of Grueber's Bay where a cumulative effect on the bottom substrates is manifested. The presence of high concentrations of volatile solids, TKN, and COD in the sediments of Grueber's Bay periodically result in oxygen depletion of the surface water and render the substrate anaerobic - a condition many invertebrates cannot tolerate.

Analysis of Variance. Table 12 presents the results of analyses of variance performed on benthos data to test for differences between the four bay transects WBT-1, WBT-2, GBT-1, and GBT-2. All replicates in all sub-stations within each transect were pooled to produce one transect mean; however, artificial and natural substrate data were analyzed separately as were the three different sampling weeks for artificial substrate data. The variables analyzed for significant differences were total number of individuals, total number of species, and Shannon index ($\bar{H}$). In Table 12 each pair of adjacent columns presents the results of one Duncan's Mean Separation Test which accompanied the corresponding ANOVA, the significance level of which is stated below the second column in the pair. For the Mean Separation Test the four transect means are presented in increasing order from top to bottom and the mean separation lines which determine the differences and similarities of the means are drawn vertically to the immediate right of those means. If any line segment connects two means, those two means are similar, whereas they are significantly different if no line segment connects both of them.

All ANOVA's except one were found to be significantly different at a level greater than 0.95.

For the natural substrate data the Mean Separation Test for all three variables analyzed produced very similar results. WBT-2 had the lowest mean number of individuals, mean number of species, and mean diversity index.

TABLE 12. ANOVA'S ON BENTHIC MACROINVERTEBRATE COLLECTIONS FROM BAAP TRANSECTS

	Natural Substrates						Artificial Substrates, Week 3					
	Site	Number of Individuals	Site	Number of Species	Site	Diversity Index	Site	Number of Individuals	Site	Number of Species	Site	Diversity Index
Site means in increasing order and Duncan's Mean Separation	WBT-2	13.8	WBT-2	1.6	WBT-2	0.38	WBT-2	17.0	WBT-2	6.1	GBT-1	0.96
	GBT-2	30.9	GBT-2	2.9	GBT-2	0.66	GBT-2	57.0	GBT-2	10.0	WBT-1	1.42
	GBT-1	41.3	GBT-1	3.4	GBT-1	1.01	GBT-1	336.0	GBT-1	10.3	WBT-2	1.50
	WBT-1	174.9	WBT-1	11.5	WBT-1	2.03	WBT-1	688.0	WBT-1	10.8	GBT-2	1.53
Significance level of F-test		>0.999		>0.999		>0.999		0.98		0.995		0.98

	Artificial Substrates, Week 4						Artificial Substrates, Week 5					
	Site	Number of Individuals	Site	Number of Species	Site	Diversity Index	Site	Number of Individuals	Site	Number of Species	Site	Diversity Index
	WBT-2	25.0	GBT-2	9.2	WBT-1	1.25	GBT-1	276.6	WBT-2	9.2	GBT-2	0.51
	GBT-2	46.5	WBT-2	10.1	GBT-2	1.66	WBT-2	284.5	GBT-2	13.0	WBT-2	0.70
	GBT-1	259.7	WBT-1	13.2	GBT-1	1.85	WBT-1	390.3	WBT-1	16.8	GBT-1	1.83
	WBT-1	560.7	GBT-1	17.6	WBT-2	2.03	GBT-2	752.5	GBT-1	18.0	WBT-1	1.94
		>0.999		>0.999		>0.999		(not signif. different)		0.999		>0.999

This was due partially to substrate variation in this area of Weigand's Bay. The bottom was often firm sand which seldom contains large numbers of organisms and is also more difficult to sample. GBT-2 had the second lowest mean of these three variables; GBT-1 had the second highest, and WBT-1 had the highest. For each of these variables, WBT-2 and GBT-2 were shown to be similar to each other, both with the lowest means. Also for each of these variables WBT-1 had a significantly higher mean than all three other transects. In general, for natural substrates, WBT-2 and GBT-2 are quite comparable, both having low population densities and low diversities; GBT-1 is intermediate, but more comparable to WBT-2 and GBT-2 than to WBT-1. WBT-1 appears to have a far more developed benthic community than all the other three transects in terms of both density and diversity.

For the artificial substrates the results are more complex. For week three, WBT-1 and GBT-1 had the highest mean number of individuals and highest number of species, but they had the lowest diversities. For week four, these two transects again had the highest number of individuals and highest number of individuals and highest number of species, but WBT-1 had the lowest diversity. By week five, GBT-2 had the highest mean number of individuals (though not significantly different), but it also had the lowest diversity.

In general, when numbers of individuals are high at any particular transect, but the diversity is low, one or a few species are increasing in number and are strongly dominating the community. This was, in fact, happening at different transects at different sampling weeks. However, it is notable that for all three weeks, WBT-1 and GBT-1 had the highest mean number of species.

During weeks three and four, WBT-1 and GBT-1 had large population densities due to the fair-to-large numbers of C. (Endochironomus) sp., Glyptotendipes sp., and Hyalella azteca. By week five, however, C. (Endochironomus) decreased at both these transects and Glyptotendipes decreased at GBT-1 while remaining high at WBT-1. Also during week five, oligochaetes showed an increase in numbers at WBT-1 and GBT-1. WBT-2 and GBT-2 did not prove to have a noticeable predominance in any species of midges during any of the three weeks.

These population trends account for the high population sizes and low diversities at WBT-1 and GBT-1 during weeks three and four. The decreasing peak of midges at WBT-1 seems to explain the increase in diversity at this

transect by week five. However, the large population size and low diversity at GBT-2 during week five is due not to midges, but to a drastic increase in numbers of hydras, especially at substation 1. This increase in numbers of hydras also occurred to a lesser extent at WBT-2 during week five, lowering diversity indices.

Cluster Analysis. Figure 7 shows a dendogram performed on similarity coefficients computed from artificial substrate benthic macroinvertebrates samples taken at Weigand's and Grueber's Bays. The most important sequences of steps that took place in the formation of the tree were: (1) all three substations from WBT-1 formed a cluster by themselves at a level of association of 0.33, (2) all three substations from GBT-1 formed a cluster by themselves at a level of association of 0.30, (3) the cluster for WBT-1 and the cluster for GBT-1 merged together at a level of 0.28, (4) all the substations from both of the outer transects, GBT-2 and WBT-2, formed a cluster together at level 0.22. Within this large cluster, there were smaller groupings in which various substations from WBT-2 and GBT-2 mixed together more or less randomly, and (5) the cluster containing WBT-1 and GBT-1 finally merged with the one containing WBT-2 and GBT-2 at a level of only 0.15.

From these overall trends some conclusions can be made about the macroinvertebrate species assemblages (species compositions and abundance of organisms within species) at the four transects. WBT-1 and GBT-1 each show strong internal similarities in species assemblages, in the sense that within the same transect the species compositions remain similar from one substation to another. However, the overall similarity of the two transects, WBT-1 and GBT-1, to one another is almost as great as the internal similarities that each one possesses; further, they are much more similar to one another than they are to the two outer transects, WBT-2 and GBT-2. The two outer transects show more similarity to one another than they show internal similarities, so they cannot be clearly distinguished from one another on the basis of species assemblages.

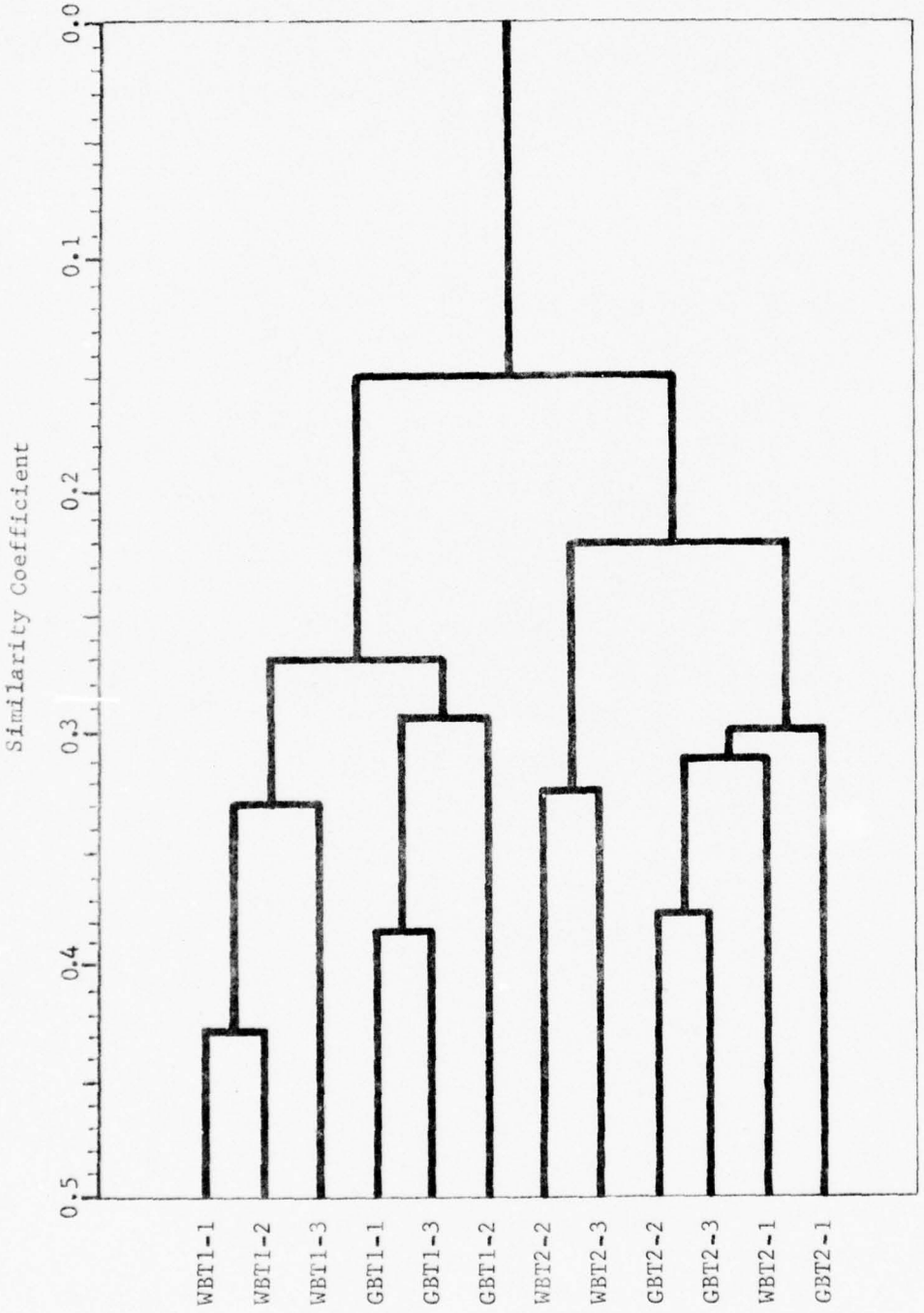


FIGURE 7. ARTIFICIAL SUBSTRATE DENDOGRAM OF BENTHIC MACROINVERTEBRATE SUBSTATIONS FROM WEIGAND'S AND GRUEBER'S BAYS

In summary, the macroinvertebrate species assemblages sampled from artificial substrates in the two bays are chiefly differentiated by transect position (inner or outer). A moderate difference between the two bays also exists, but this is demonstrated only by species assemblages found in the two inner transects. These results agree with the results of the ANOVA's performed on two community structure variables, numbers of individuals, and numbers of species from artificial substrate samples taken during the intensive sampling week (Table 12). For these two variables, the Duncan's Mean Separation Test grouped the two outer transects, WBT-2 and GBT-2, together, whereas the two inner transects were separated into distinct groups, different from the outer transects and also different from each other.

Figure 8 shows a dendogram performed on similarity coefficients computed from natural substrate benthos samples taken at Weigand's and Grueber's Bays. All three substations from Weigand's Bay transect 1 clustered together by themselves at a level of association of 0.21, and all three substations from Grueber's Bay transect 1 clustered together by themselves at a level of 0.18. Beyond these portions of the tree, however, the patterns are not as clear as in the corresponding dendogram for artificial substrate data (Figure 7). Here, the substations from the outer transects, WBT-2 and GBT-2, do not follow any logical sequence of steps in grouping with each other or in grouping with the inner transect clusters. Even the inner transects do not seem to exhibit much internal similarity because the highest similarity coefficient represented, which corresponds to the merge between WBT 1-1 and WBT 1-2, is only 0.35 (as compared to 0.43 for the artificial substrate dendogram).

The dendogram for natural substrate samples has a less clearly-defined structure than does the one for artificial substrates. This means that the transects are not very well differentiated with respect to species assemblage as reflected in the natural substrate samples. This could be due to the sparseness and patchiness of the invertebrate community normally inhabiting the natural substrates, thereby creating more variability between samples than that found in the more controlled aritifical substrates.

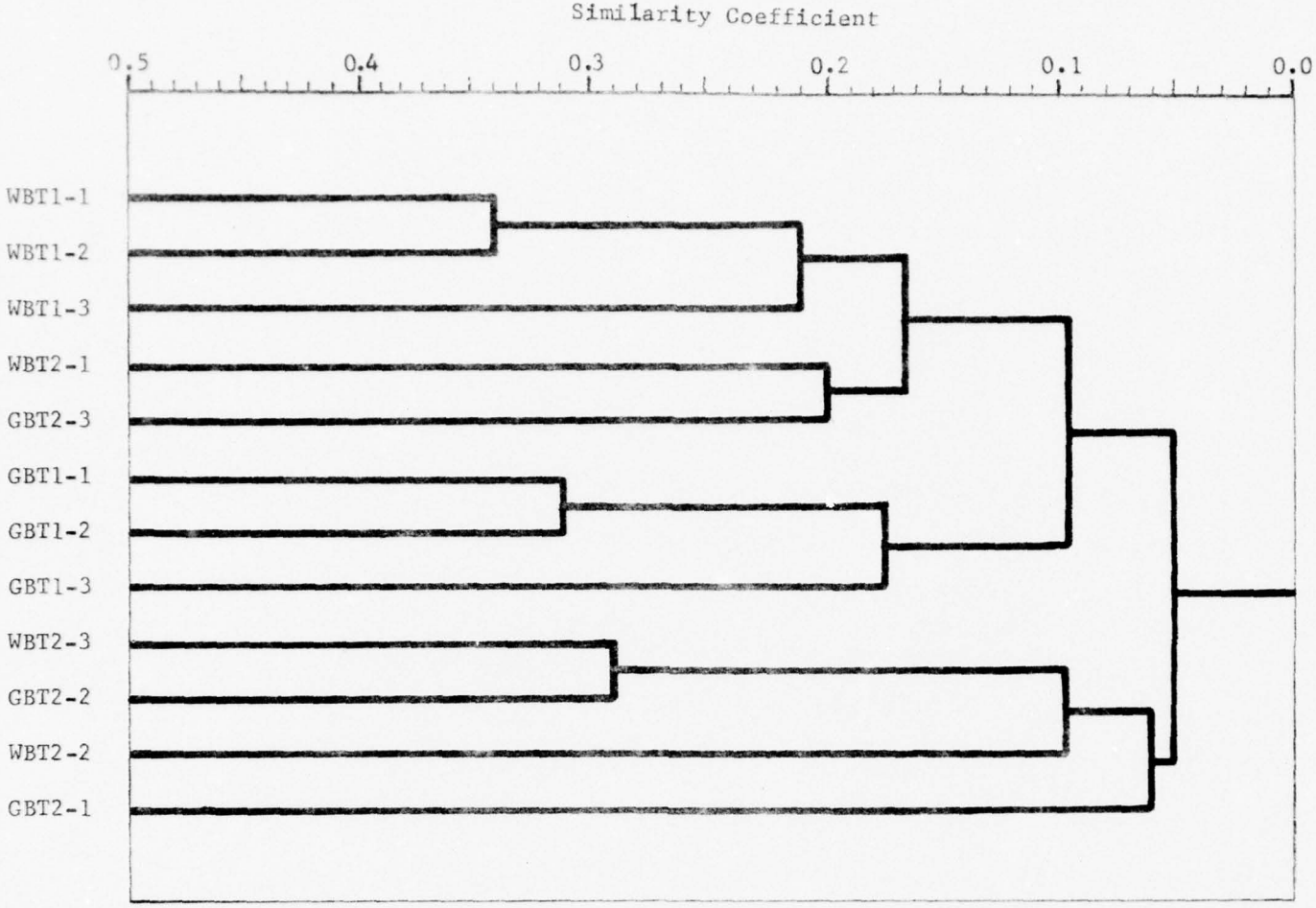


FIGURE 8. NATURAL SUBSTRATE DENDOGRAM OF BENTHIC MACROINVERTEBRATE SUBSTATIONS FROM WEIGAND'S AND GRUEBER'S BAYS

Colonization. A review of the artificial substrate sample data for number of individuals and species over the three weeks of incubation gives an indication of colonization rate. Figure 9 presents the rate of colonization observed in the settling lake (no colonization of artificial substrates occurred in the ITP stream). The rate of increase in number of individuals and number of species is extremely slow compared to the rates observed in Grueber's and Weigand's Bays (Figure 10). At three weeks incubation no organisms had colonized these samplers, while several hundred individuals of many species were collected on the bay samplers.

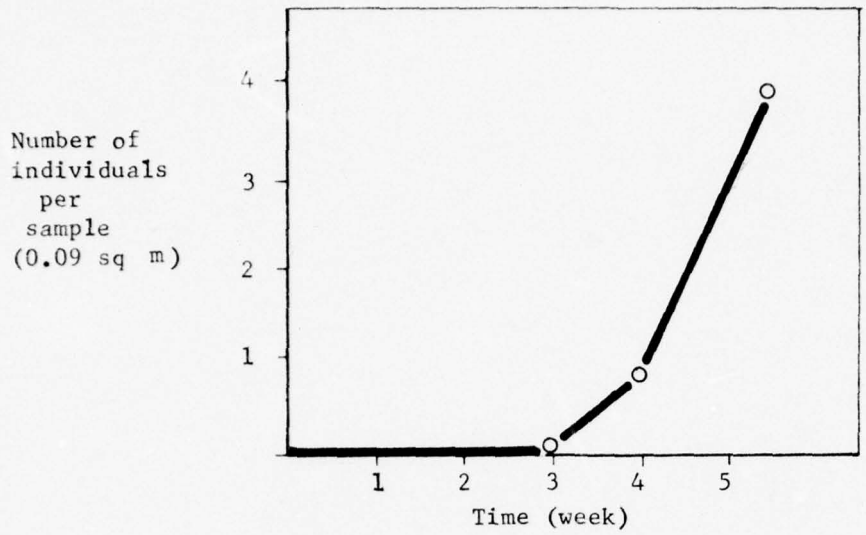
Figure 10 graphically portrays the rates observed for both transects in Weigand's and Grueber's Bays. Figure 10, A and B, presents the data from the inner (shallower) transect from both bays. It appears from this figure that a maximum community density had been reached by the third week and began to decline during the fourth and fifth weeks of incubation. The number of species increased during this time.

Samplers in the outer (deeper) transects were colonized at a slower rate and had not begun to decline at the fifth week of incubation. The increase in number of species with time was slower at this deeper transect but continued to increase as observed at the shallower transect.

Nitroglycerine Receiving Systems

Water Quality

Analyses of samples from the nitroglycernine production area showed the water to be moderately hard with values generally 2 to 3 the regionally expected soft-water background (Table 13). Analyses of the samples (DS and conductivity) from the nitroglycerine pond also indicated a dissolved constituent concentration on the order of 5 to 6 times expected background. As indicated by the data, sulfates ($\sim$ 130 mg/ℓ) and chlorides ($\sim$ 50 mg/ℓ) account for much of this higher dissolved solids concentration. Although sulfates are an order of magnitude greater than background, they are judged to be well below problem concentrations. Nitrate/nitrite concentrations are two orders of magnitude higher than expected background concentrations and should be considered marginally of concern. The nitroglycerine pond effluent is highly acid with a pH concentration ranging from 3.0 to 3.5.



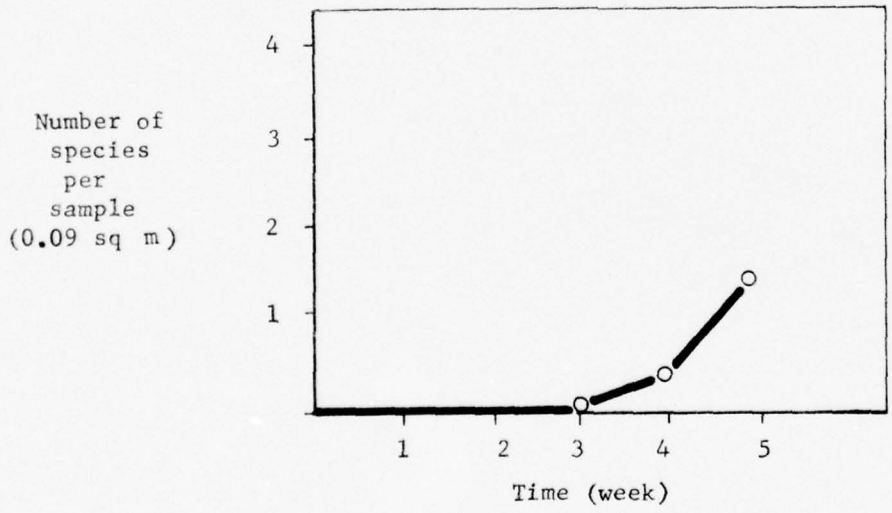


FIGURE 9. BENTHIC MACROINVERTEBRATE COLONIZATION RATE OF ARTIFICIAL SUBSTRATES IN THE BAAP SETTLING LAKE

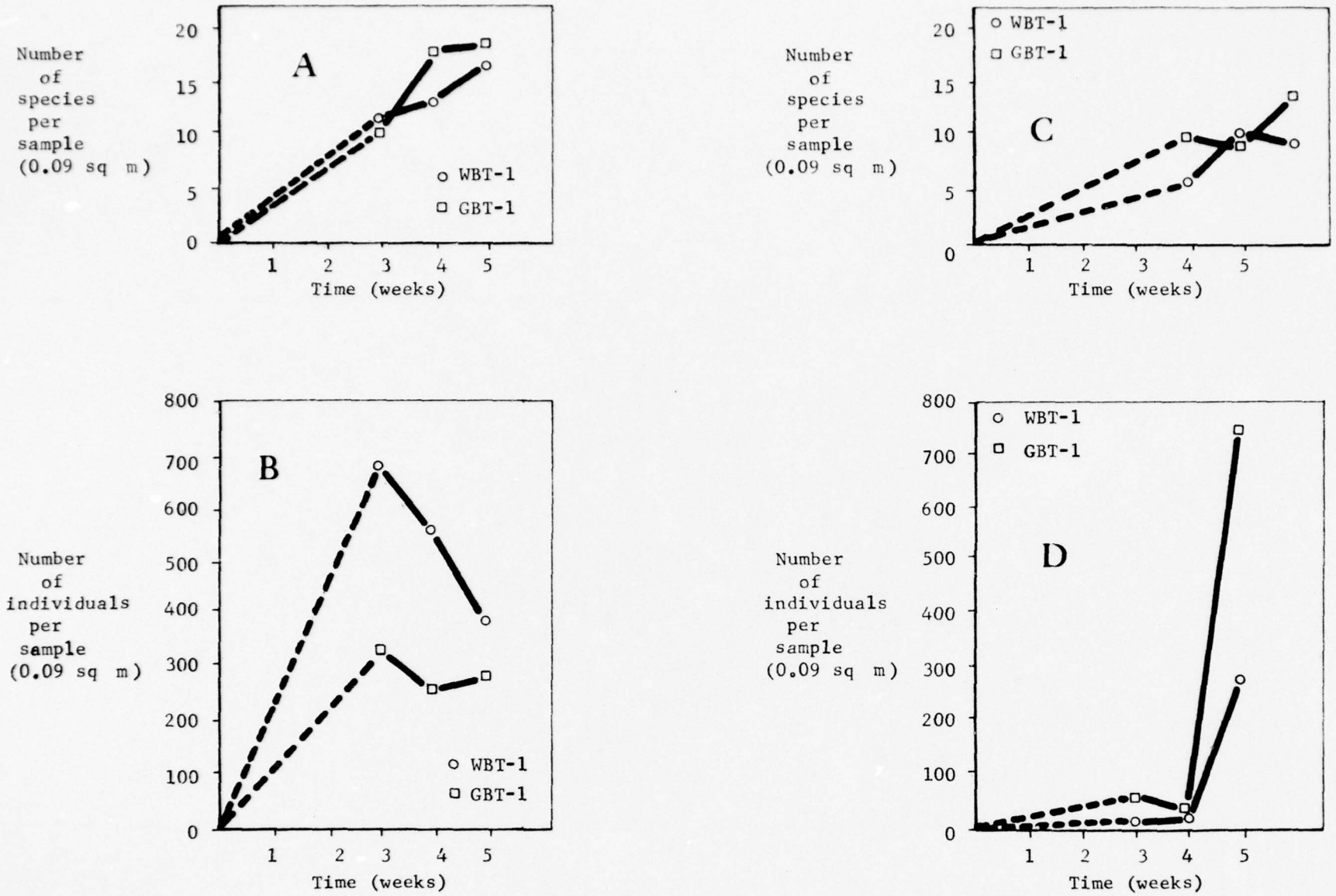


FIGURE 10. BENTHIC MACROINVERTEBRATE COLONIZATION RATE OF ARTIFICIAL SUBSTRATES IN WEIGAND'S AND GRUEBER'S BAYS

Rocket paste manufacturing discharges also influence water quality conditions (Table 13). Extremely low dissolved oxygen (DO) concentrations were reflected by the field measurements. Even at the lower temperatures found at the rocket paste discharge, DO concentrations are slightly depressed with oxygen saturations generally less than 75 percent of equilibrium.

The DO concentrations in the pond downstream from this discharge are low with 4 out of 5 values less than 5 mg/ℓ and a single low determination for May 27, 1975 of 1.3 mg/ℓ. Earlier investigations (Cooper et al, 1974) have noted the strongly anaerobic conditions of this pond's sediment as evidenced by evolution of H_2S. Although the oxygen-demanding substance(s) are not immediately obvious from review of the complete laboratory analyses (in Appendix A, Table 1) the reported COD (chemical oxygen demand) value (~ 120 mg/ℓ, 3 times background) is indicative of their presence and the associated oxygen-demanding reactions.

Sediment Chemistry

Summary Table 14 presents analyses of sediment samples taken from the nitroglycerine pond which indicate that the sediments are within desirable limits for volatile solids and chemical oxygen demand. Nutrients as represented by the total Kjeldahl nitrogen and phosphate concentrations can be considered slightly high with respect to both background determinations (Weigand's Bay) and the sediment classification "schema" shown in Table 3 (Corps of Engineers, 1970; National Science Foundation, 1973).

Sediments from the rocket paste pond had a moderately high COD and very high TKN. The downstream transport of sediments from this pond could severely deplete receiving waterbody oxygen concentrations. One of the total Kjeldahl nitrogen determinations is an order of magnitude greater than EPA's classifications of objectionable sediment concentrations. The wide range in results of sediment analysis (Appendix B, Table 1) in this pond from May 19 to May 22 must be due to spatial variations rather than temporal effects. The production of nitroglycerine and rocket paste had stopped prior to the sampling conducted by Battelle's Columbus Laboratories.

TABLE 13. SUMMARY OF WATER QUALITY INVESTIGATIONS FROM NITROGLYCERINE AND ROCKET PASTE PONDS

		Field Measurements				Laboratory Measurements (mg/l)													Number of Samples Considered	
		pH	Conductivity	Temperature °C	Dissolved Oxygen	Alkalinity	Total Hardness	Suspended Solids	Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Total Kjeldahl Nitrogen	Ammonium	Nitrite	Nitrate	Phosphate	Sulfate	Chloride	Laboratory	Field
Selected water quality criteria		6-9	<900	-	>5	-	-	<80	<500	<40	<12	<1.0	<0.02	-	1.5	<0.1	<250	<250		
Wisconsin River Basin - USGS	Total min.	6.7	108	0	-	31	40	-	66	-	-	-	0	0	0.06	0.04	4.4	0.5		250
	May-June mode	-	150	-	-	45	50	-	100	-	-	-	-	-	1	-	12	3		54
	Total max.	8.6	568	27	-	258	273	-	284	-	-	-	1	0.05	11	1.7	19	16		250
Nitroglycerine discharge 5/23/75 composite	MIN	6.8	238	9.3	8.5	31	110	15	262	28	6.3	0.8	<0.30	0.09	3.0	<0.02	38	36	1	5
	MAX	10.3	418	10.2	11.8															
Nitroglycerine Pond effluent	MIN	3.1	661	20.8	10.1	-	148	<5	596	30	12.7	0.6	0.30	0.11	20.0	0.02	133	55	1	5
	MAX	3.5	1268	22.6	14.4															
Rocket Paste discharge 5/22/75 composite	MIN	6.7	193	11.6	6.8	32	86	<5	190	121	37.7	0.9	<0.30	0.37	20.0	0.02	44	13	1	5
	MAX	10.1	394	16.2	9.1															
Rocket past pond effluent	MIN	7.1	238	19.8	1.3	42	93	<5	195	89	30.0	0.2	<0.30	0.09	7.0	0.02	44	15	mean of 2	5
	MAX	7.4	279	25.1	6.4			10		116	44.0	1.3	0.11	0.20	14.0					

TABLE 14. SUMMARY OF SEDIMENT CHARACTERISTICS FROM NITROGLYCERINE AND ROCKET PASTE PONDS

		Total Solids	Total Volatile Solids	Chemical Oxygen Demand	Total Kjeldahl Nitrogen	Nitrate	Nitrite	Phosphate	Number of Samples
		(values in percent dry weight)				(values in ppm dry weight)			
Objectionable[a] Sediment Characteristics			>6.0	>5.0	>0.10				
Polluted Sediments	"light"[b]		<5	<4.0				<300[c]	
	"heavy"		>8	>12.0				>900	
Nitroglycerine Pond	5/19/75	49.7	2.48	1.83	0.2	1,550	1.0	1,300	
	5/22/75	42.8	1.88	1.92	0.157	1,570	0.4	1,300	2
Rocket Paste Pond	5/19/75	6.25	4.07	7.40	1.43	510	19.0	2,800	
	5/22/75	0.70	0.30	6.32	0.223	60	8.1	50	2

(a) U.S. EPA - selected bulk analysis allowable sediment constituents (National Science Foundation, 1973).
(b) Corps of Engineers - selected bulk analysis classification of polluted sediments (Corps of Engineers, 1970).
(c) Originally reported as P.

Munitions Constituent Analysis (Nitroglycerine)

Concentrations of nitroglycerine (NG) and nitrocellulose (NC) were measured in the water and sediments of the holding pond receiving nitroglycerine manufacturing wastes. Concentrations in the industrial effluent were also measured. A summary of NG and NC concentrations found in the individual samples can be found in Table 15. A mean value of 7.4 ppm was calculated for the NG concentration in the nitroglycerine pond water with a range from 4.8-9.0 ppm. The sediments were found to have a mean concentration of 37.5 ppm nitroglycerine ranging from 31.8 to 43.0 ppm. The industrial effluent contained a < 1.73 ppm mean concentration of nitroglycerine at the time of biological sampling. This low value was probably due to a reduction and eventual halt in nitroglycerine production prior to the time of sampling.

The results of analyses measuring nitrocellulose and nitroglycerine concentrations in the water and sediments of the rocket paste pond are presented in Table 15. Effluent concentrations are also given. Detailed sample analysis data for both ponds are presented in Appendices A and B. Nitroglycerine levels in the pond water and sediments were considerably lower in the rocket paste pond than in the nitroglycerine pond. Values for water and sediment were < 1.83 ppm and < 1.73 ppm, respectively, with little variability among subsamples. A 24-hour effluent composite sample had a value of 6.3 ppm nitroglycerine.

Values for nitrocellulose concentration were quite low in both the water and sediment of the rocket paste pond, much lower than the values found in the waters and sediments of Grueber's Bay, the ITP stream, and the settling lake. Mean concentrations of nitrocellulose in the water and sediment were found to be < 1.2 ppm and 1.27 ppm, respectively.

Correlation coefficients between NG levels and water quality parameters could rot be computed because of the small number of samples analyzed for nitroglycerine.

TABLE 15. RESULTS OF ANALYSES FOR NITROGLYCERINE AND NITROCELLULOSE IN THE WATER AND SEDIMENTS OF THE ROCKET PASTE POND

	Nitroglycerine (ppm)				Nitrocellulose (ppm)			
	Water	(Range)	Sediment	(Range)	Water	(Range)	Sediment	(Range)
Nitroglycerine Production Effluent	7.4	(4.8-9.0)	-	-	-	-	-	-
Nitroglycerine Pond	1.3	(< 0.6-3.4)	37.5	(31.8-43.0)	-	-	-	-
Rocket Paste Effluent	4.35	(3.9-4.8)	-	-	-	-	-	-
Rocket Paste Effluent (Composite)	6.3	(6.3)	-	-	2.7	(2.7)	-	-
Rocket Paste Pond	< 1.83	(< 0.6-3.9)	< 1.73	(< 1.5-2.2)	< 1.2	(< 1.0-1.4)	< 1.27	(< 0.1-3.6)

Algae

Species Composition. A total of 18 algal species colonized artificial substrates in the nitroglycerine pond (Appendix C, Table 17). Dominating the flora was a coccoid Myxophycean (blue-green) species, a group which is indicative of a polluted situation (Palmer, 1969). In a pond naturally dominated by blue-greens, several species should occur; only two were found in the nitroglycerine pond. Species found are summarized in Appendix C, Table 19.

Analysis of phytoplankton samples from the pond showed two blue-green species comprising 18 percent of the standing crop (Appendix C, Table 35). Forty-seven percent of the number of individuals counted were of the genus Scenedesmus (S. dimorphus and S. quadricauda). This genus has been classified as exceedingly tolerant, particularly the species S. quadricauda (Palmer, 1969). Analysis of the phytoplankton population resulted in only six species. The relative over-abundance of only a few species and the generally depauperate flora of this pond indicate a situation of extreme environmental stress (Patrick, 1953; Rawson, 1956).

Nineteen periphyton species colonized artificial substrates in the rocket paste pond during the three-week incubation (Appendix C, Table 18). No more than 10 species were found in any one sample. As in the case of the nitroglycerine pond, the dominant organism was an unidentified coccoid blue-green algal species. Tolerant or pollution-indicating blue-greens also dominated the phytoplankton collection. Natural and artificial substrates showed large numbers of Microcystis sp. (blue-green). Only 9 species were found in the phytoplankton. Again, as seen in the nitroglycerine pond, the large numbers of a relatively few species indicate a situation of environmental stress. A summary table of species found appears as Appendix C, Table 37.

Community Structure. The algal community in the nitroglycerine pond was of poor quality being comprised largely of tolerant blue-green and green species. Diatom species comprised approximately 0.1 percent of the

attached community and 0.05 percent of the plankton (normally, and particularly in the acidic waters of this pond, the diatom percentages should be much greater) (Patrick, 1953; Villegas and DeGiner, 1973; Warner, 1971). Tolerant greens and blue-greens comprise 72 percent and 65 percent of the plankton and periphyton (attached) communities, respectively. The remainder in both cases consists of single-celled flagellates present in relatively large numbers as to indicate stress.

Figure 11 is a graphic representation of the status of the phytoplankton community at the time of sampling. Extrapolation of this species-area curve shows that few species would be added with further sample analysis. Total number of species (6) for this community is extremely low.

Species diversities and numbers of species remained consistently low during the entire incubation time of the diatometers (Table 16). Little difference was observed between natural and artificial substrates. Ash-free biomass showed a relatively high amount of organic material in comparison to the low amount of chlorophyll *a* present. Much of the biomass may be attributed to hereotrophic organisms (possibly some of the flagellates, bacteria, or other decomposers) or possibly to dead algal masses. The autotrophic index calculated from this pond (337.05) indicates a system of extreme organic pollution (Weber and McFarland, 1969).

Forty-five percent of the attached algal individuals found in the rocket paste pond were blue-green species. A coccoid green algae comprised 12 percent; diatoms contributed 0.1 percent. A single-celled flagellate accounted for 46 percent of the total individuals. The diatom population contributed 15 species to the total number of species yet were present in such low abundance as to be insignificant. A balanced algal community would be comprised of larger percentages of diatoms and greens and only a small percentage of blue-greens (Patrick, 1953).

Similar trends were found in the phytoplankton collections from the rocket paste pond (Appendix C, Table 36). Blue-greens accounted for 57 percent of total individuals, coccoid green species - 14 percent, flagellates - 28 percent, and diatoms - 0.3 percent.

Extrapolation of the species-area curve generated from the phytoplankton data shows graphically the status of the algal community at the time of sampling (Figure 12). Few species would likely be obtained with

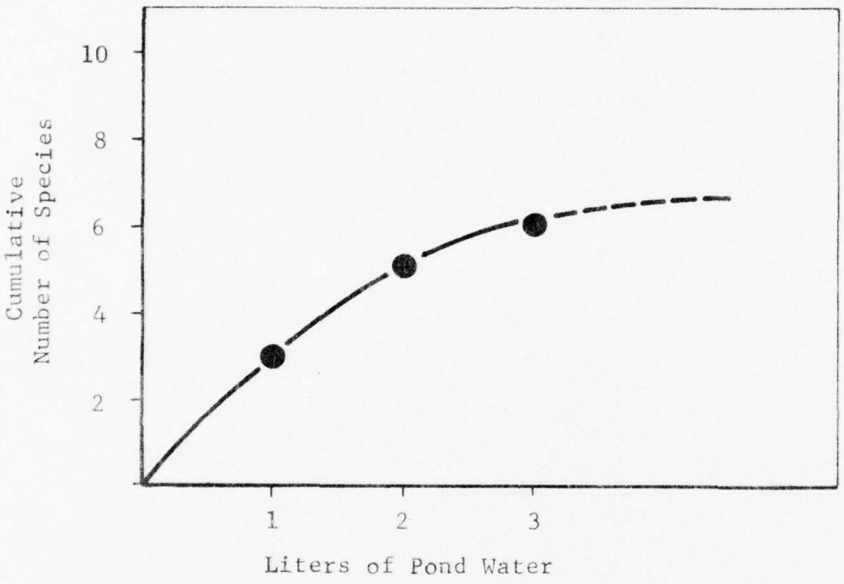


FIGURE 11. SPECIES-AREA CURVE OF THE PHYTOPLANKTON COMMUNITY OF THE NITROGLYCERINE POND

TABLE 16. SUMMARY OF ANALYSES DATA FROM PHYTOPLANKTON AND ARTIFICIAL SUBSTRATE SAMPLES FROM THE NITROGLYCERINE POND

		No. of Individuals	No. of Species	Species Diversity
Artificial Substrates	Week 2	1.16 [a]	3	0.70
	Week 3	1.40	6.33	0.68
	Week 4	2.50	6	0.63
Natural Substrates		20.9 [b]	3	1.04

Ash-free Biomass mg/m^2	111.9
Chlorophyll *a* mg/m^2	0.332
Autotrophic Index $\frac{\text{Biomass}}{\text{Chlorophyll } a}$	337.05

[a] x $10^4/cm^2$.

[b] x 10^5/liter.

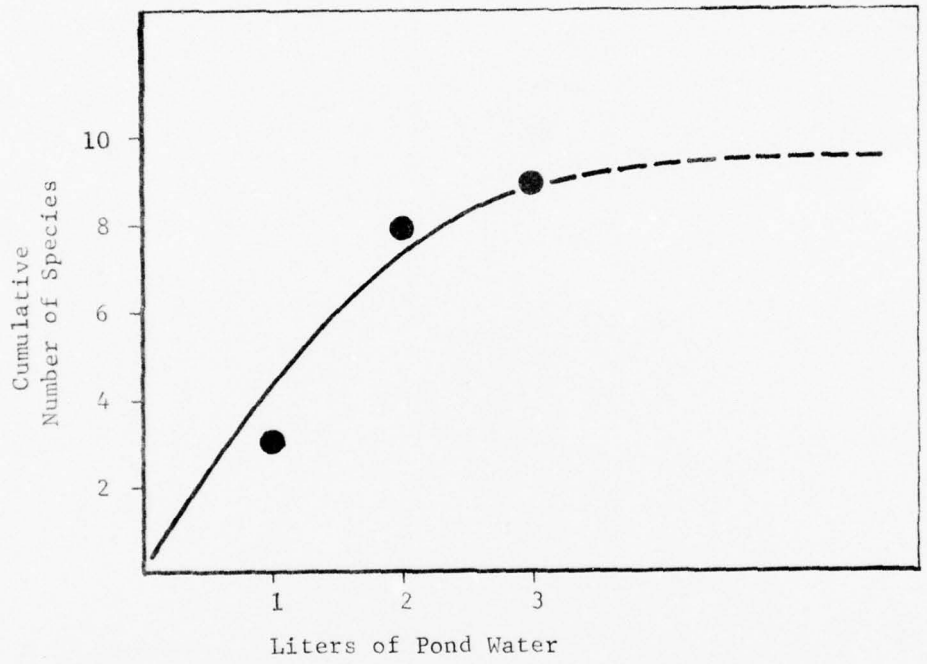


FIGURE 12. SPECIES-AREA CURVE OF THE PHYTOPLANKTON COMMUNITY OF THE ROCKET PASTE POND

further sample analysis. The total number of species found (9) defines a very depauperate algal community.

A peak population occurred during the second week of incubation of the artificial substrates (Table 17). Species diversities through the colonization period remained low and consistent with phytoplankton populations.

No autotrophic index could be calculated for the rocket paste pond. Analysis for chlorophyll revealed no detectable level in the sample. Calculated biomass, again probably represents bacteria, non-primary producers, or dead algal masses. The poor quality of the algal communities reflect an extreme environmental stress.

Benthic Macroinvertebrates

Benthic macroinvertebrate sampling in the nitroglycerine and rocket paste ponds revealed the absence of living organisms in the natural substrates and the inability of invertebrates to colonize artificial substrates placed in the pond for 3-, 4-, and 5-week incubation periods. Conditions in the water of these ponds have created environments unsuitable to benthic macroinvertebrate life.

TABLE 17. SUMMARY OF ANALYSES OF DATA FROM PHYTOPLANKTON AND ARTIFICIAL SUBSTRATE SAMPLES FROM THE ROCKET PASTE POND

		No. of Individuals	No. of Species	Species Diversity
Artificial Substrates	Week 2	0.58 [a]	3	0.01
	Week 3	1.80	8.33	0.47
	Week 4	0.76	4	0.65
Natural Substrates		86.6 [b]	3.67	0.60

Ash-free Biomass mg/m2	107.9
Chlorophyll *a* mg/m^2	0.00
Autotrophic Index $\frac{\text{Biomass}}{\text{Chlorophyll } a}$	-

[a] x $10^4/cm^2$.

[b] x 10^5/liter.

ASSOCIATION OF MUNITIONS EFFLUENTS WITH ECOLOGICAL RESPONSE

Nitrocellulose

Algae

Examining artificial substrate results from the ITP stream, SL-1 Weigand's Bay and Grueber's Bay (Tables 5 and 7), indicates the ITP stream had the lowest standing crop, diversity index, chlorophyll *a*, and ash-free dry weight biomass, indicating the presence of toxic substances. The four periphyton parameters listed above and nitrocellulose concentration were all greater in Grueber's Bay than in the ITP stream, indicating that nitrocellulose was not the inhibiting substance at the ITP station. Chlorination of the sanitary wastes discharged to the ITP stream probably caused the inhibiting effects observed. The standing crop, diversity index, chlorophyll *a*, and biomass were all greater at SL-1 than at ITP, but these parameters and nitrocellulose concentrations were still much lower than the corresponding values from Grueber's Bay. The inhibiting factor here was not clear, but it did not appear to be nitrocellulose.

At GBT-1, with the highest mean nitrocellulose concentrations, no overall toxic effects were observed in the algal community. The artificial substrate results indicate Grueber's Bay has a more abundant, diverse periphyton community. A species dominance shift was also observed between these two bays. The most common genera in Grueber's Bay were *Scenedesmus* and *Melosira*, with *Fragilaria* and *Synedra* most abundant in Weigand's Bay. All four of the above genera are cosmopolitan in distribution, generally indifferent to water conditions (Palmer, 1969), and were common in both bays. The most abundant phytoplankton genera were *Melosira* and *Asterionella*, and these two taxa were equally important in both bays. All species commonly found in Weigand's Bay were also present in Grueber's Bay.

Figure 13 portrays the range of species diversity indices of periphyton (dotted lines) and phytoplankton (solid lines) versus the nitrocellulose concentration found in the waters of Weigand's and Grueber's Bays. Plotting of both numbers of species and of individuals yields graphs almost identical to Figure 13. From comparisons of all the parameters considered in Weigand's and Grueber's Bays, the results suggest no negative effect on the periphytic or planktonic algae in Grueber's Bay.

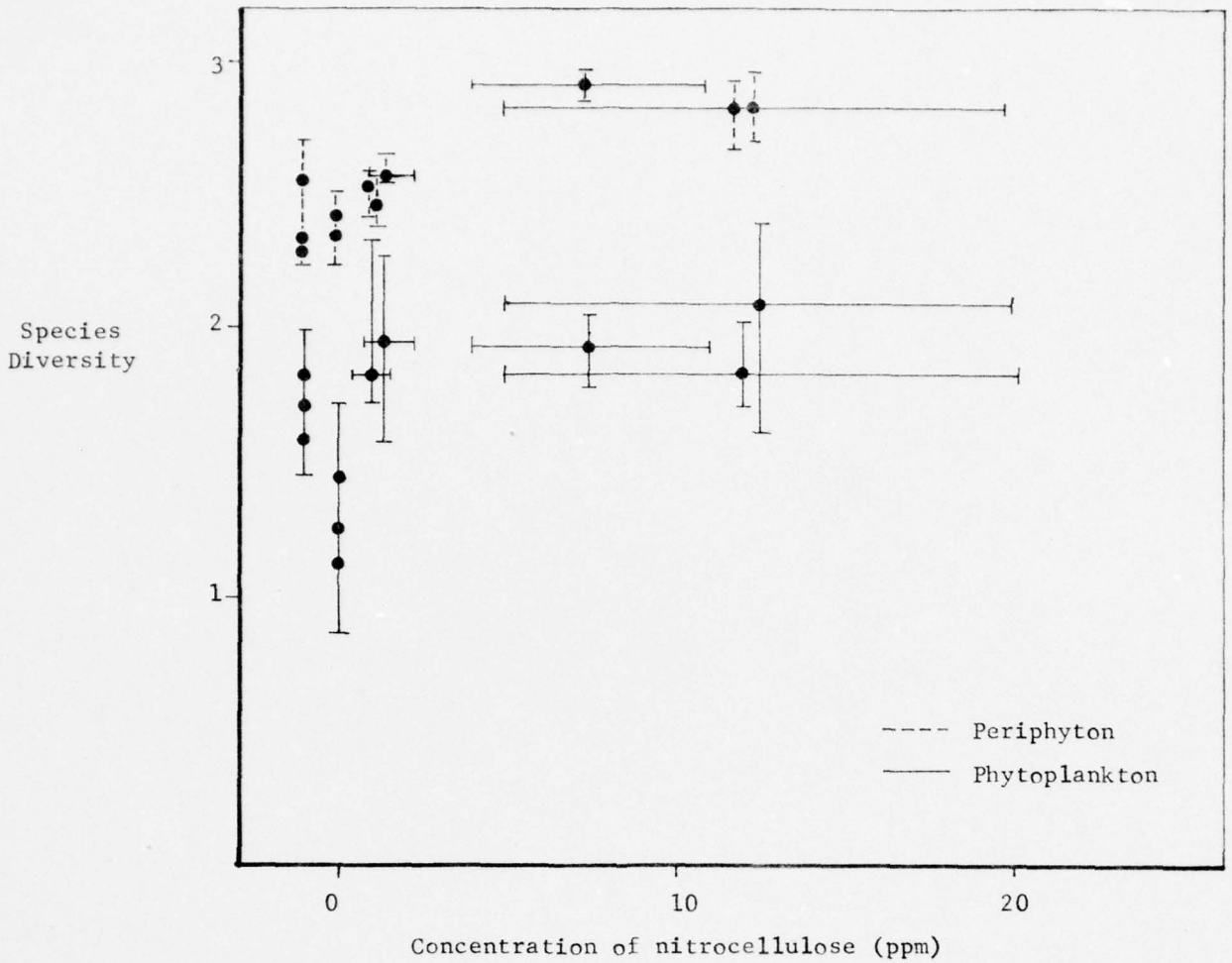


FIGURE 13. RANGES OF ALGAL SPECIES DIVERSITY VERSUS RANGES OF NITROCELLULOSE CONCENTRATION IN WEIGAND'S AND GRUEBER'S BAYS

Benthic Macroinvertebrates

The benthic macroinvertebrate communities in the area of the BAAP were adversely impacted by the discharge of munitions manufacturing and/or sanitary wastes into the ITP stream. This discharge rendered the ITP stream almost completely inhospitable to invertebrate colonization. Conditions have improved somewhat downstream in the first settling lake, where a few invertebrate organisms were collected from the bottom sediments and others colonized artificial substrates placed in the pond. Environmental stress is still evident in the bottom sediments of GBT-1. However, no perturbance can be detected in the waters of Grueber's Bay (artificial substrate data) nor the sediments of GBT-2.

The stress condition existing in the ITP stream and settling lake appears to be caused by poor water quality as few organisms were able to colonize either the natural or artificial substrates in these areas. This would seem to eliminate nitrocellulose as the cause of the environmental stress in these two aquatic habitats--as it is essentially insoluble in water. A possible explanation for these depauperate conditions may be the excessively chlorinated sanitary waste discharged to this stream immediately upstream from the sampling site. Additionally, high oxygen demand and sulfate concentrations may also adversely effect this section of the stream.

The situation in the settling lake may be affected by chlorination but also has highly polluted sediments, containing high volatile solids, COD, and nutrients which could cause periodic oxygen depletion at the substrate water interface. The water in this pond also has excessively high concentrations of NO_3, NO_2 and sulfate. Any of these parameters or a combination of many may be the cause of the stress observed in the settling lake as well as in the ITP stream.

The situation in Grueber's Bay is even more complex. Water quality parameters monitored in this bay are similar to those found in the control Weigand's Bay, which is considered to have good to excellent water quality for this area of Wisconsin. However, a reduction in numbers of individuals, number of species, and $\overline{H}$ is noticed in the bottom sediments of GBT-1. This is clearly a problem involving substrate quality rather than water quality as artificial substrate samplers were colonized by large numbers of a variety of invertebrates and supported communities similar to those found in samples from Weigand's Bay. As previously described in the sediment chemistry section,

sediments in this area of Grueber's Bay have high volatile solid, COD, and nurtient concentrations. These high concentrations would lead to periodic oxygen depletion and an anaerobic condition in the sediments which would be intolerable to some invertebrates. However, nitrocellulose concentrations are also highest in this area of Grueber's Bay. Figure 14 presents the mean number of species of benthic macroinvertebrates per sample compared with various nitrocellulose concentrations found in Grueber's Bay. Nitrocellulose concentrations of zero are from Weigand's Bay. The two points in the lower left of the graph are from WBT-2 where sampling difficulties were encountered. From this figure a correlation between nitrocellulose concentration and species reduction appears to exist. Similar reduction patterns are observed for a number of individuals and species diversity although not as dramatic.

If indeed such a correlation does exist it may be a physical effect rather than a chemical one. The nitrocellulose fibers of varying length may alter the substrate consistency and make it less hospitable to some benthic macroinvertebrates. It is in all likelihood a combination of factors that could be attributed to the discharge of munitions manufacturing wastes to this area of Grueber's Bay but not specifically to nitrocellulose concentrations.

Nitroglycerine

Algae

Manufacturing wastes containing nitroglycerine are discharged into two small ponds on the BAAP premises, the rocket paste pond and the nitroglycerine pond. Mean nitroglycerine concentrations in the rocket paste and nitroglycerine ponds were found to be < 1.8 mg/ℓ and 7.4 mg/ℓ, respectively. The range of number of species of periphyton (dotted lines) and planktonic algae (solid lines) versus the nitroglycerine concentration in water is portrayed in Figure 15. The mean numbers of these species found in the rocket paste pond and nitroglycerine pond are represented by triangles and dots, respectively. The expected range of number of species of algae in small farm ponds is 20-100 (C. Taft, personal communication) of each type.

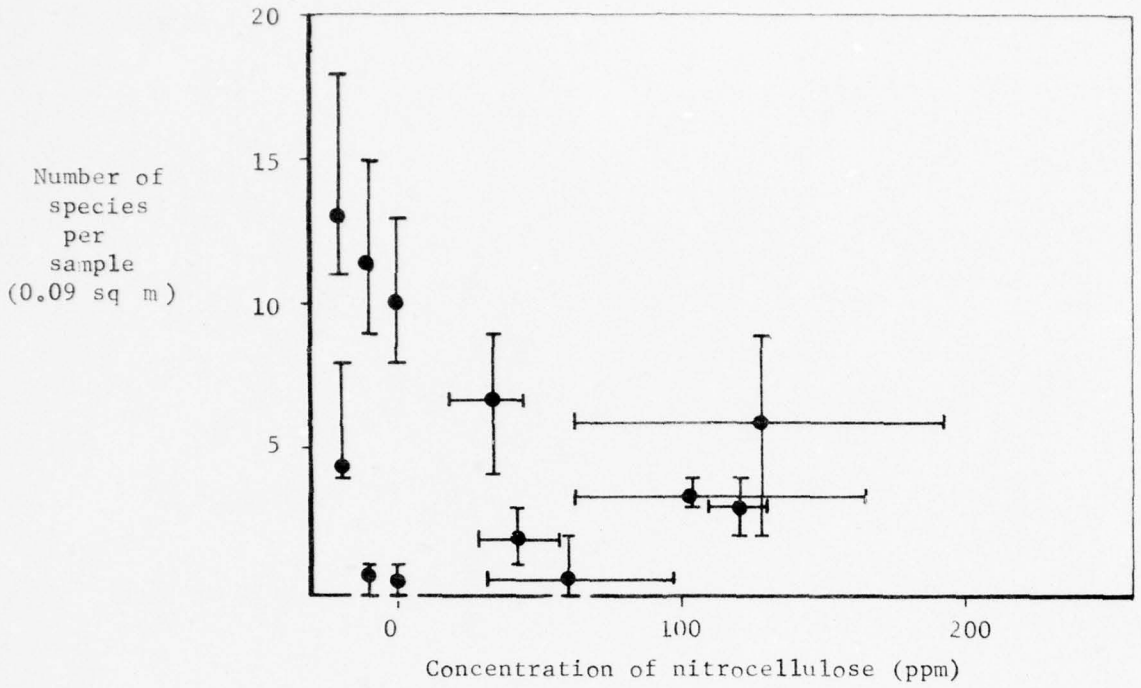


FIGURE 14. RANGES OF THE NUMBER OF NATURAL SUBSTRATE BENTHIC MACROINVERTEBRATES SPECIES VERSUS RANGES OF NITROCELLULOSE CONCENTRATION IN THE SEDIMENTS OF WEIGAND'S AND GRUEBER'S BAYS

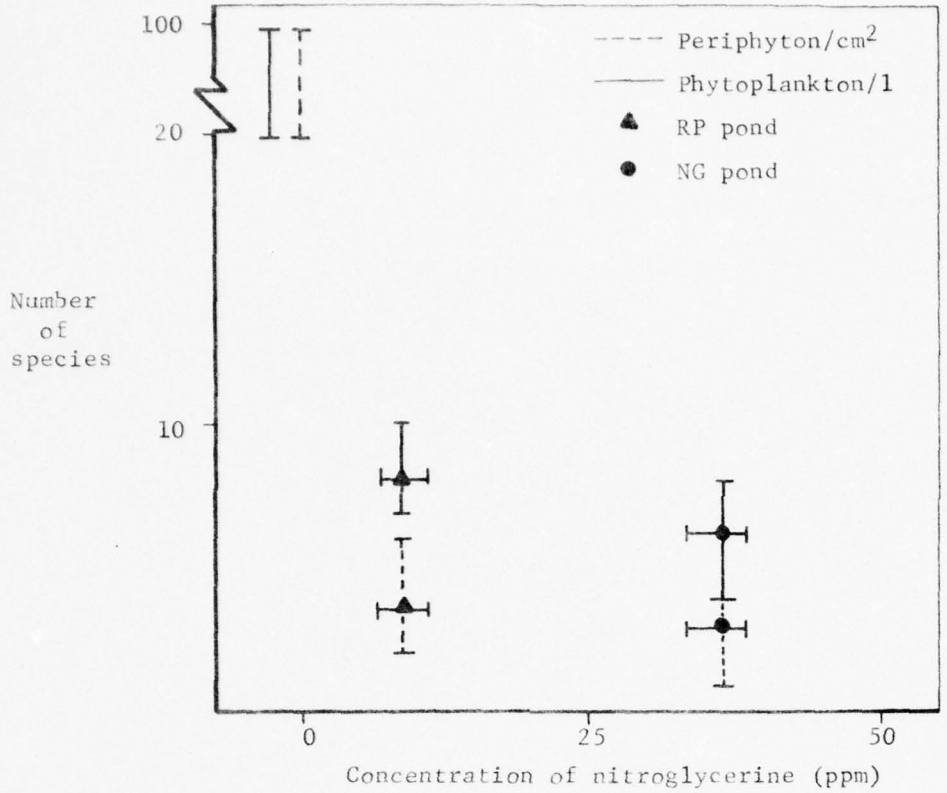


FIGURE 15. RANGES OF NUMBERS OF ALGAL SPECIES VERSUS RANGES OF NITROGLYCERINE CONCENTRATION

A significant reduction of both planktonic and attached algae species is observed in the rocket paste pond at nitroglycerine concentrations of less than 1.8 ppm. A further reduction in numbers of algae species is noticed in the nitroglycerine pond where nitroglycerine concentrations are even higher. In both pond communities, species present are only of the most tolerant type (Lowe, 1974; Palmer, 1969).

A clear relationship between increases in nitroglycerine concentrations and reduction in algal species can be observed (Figure 15). With higher nitroglycerine concentrations in the nitroglycerine pond, increases in chlorides, sulphates, conductivity, solids, and a decrease in pH also occur. Any one or any combination of these factors may be responsible for the further reduction in algal species. However, levels of these water quality characteristics in the rocket paste pond are all well within ranges conducive to luxuriant algal [particularly diatom (Lowe, 1974)] growth, yet no such flora exists there. It may then be reasonable to attribute the depauperate algal communities of both ponds to concentrations of nitroglycerine. (No synergistic effect of nitrocellulose in combination with nitroglycerine in the rocket paste pond was observed).

Benthic Macroinvertebrates

Nitroglycerine concentrations between < 0.6-12 ppm in water and 8-40 ppm in the bottom sediments have been found to create an aquatic environment inhospitable to benthic macroinvertebrates. No organisms were found in either the nitroglycerine pond, which had high nitroglycerine concentrations, nor the rocket paste pond, which had mean nitroglycerine levels < 2 ppm. A graphic representation of the number of species of macroinvertebrates found at different nitroglycerine concentrations is presented in Figure 16. The range of the number of species shown at 0.0 concentration is that expected to be found in similar-sized farm ponds in central Wisconsin (S. Richman, personal communication). As depicted in this graph, no species are found in concentrations of nitroglycerine as low as 1.0 ppm. As discussed in the preceding algae section a variety of water quality parameter changes are associated with increased nitroglycerine concentrations; however, a review of all the available data suggests nitroglycerine is toxic to aquatic life at concentrations of 1.0 ppm or less.

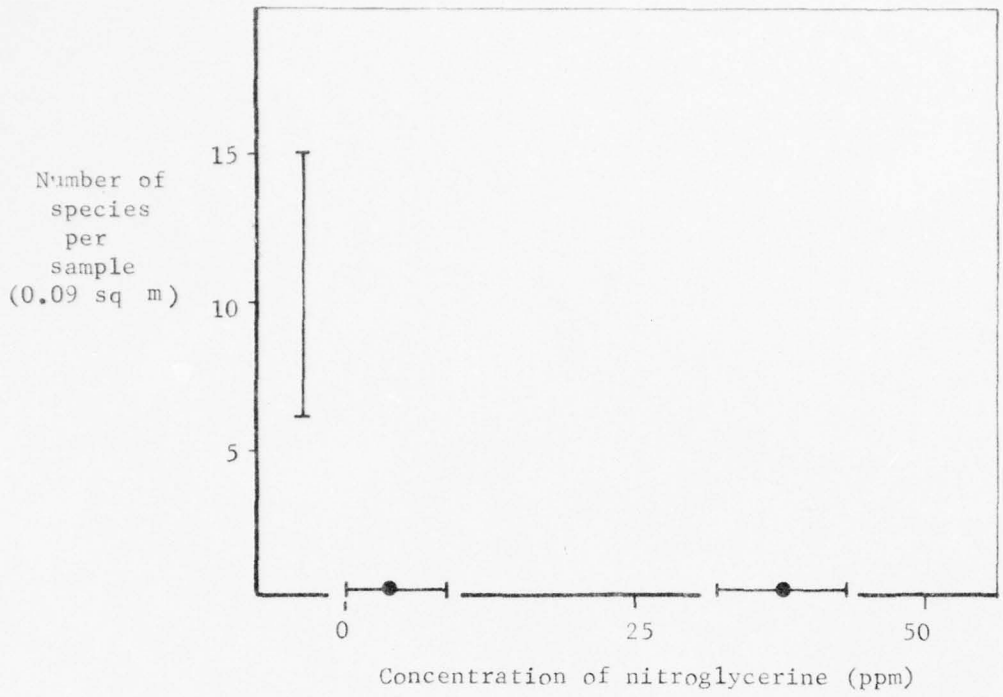


FIGURE 16. NUMBER OF NATURAL SUBSTRATE BENTHIC MACROINVERTEBRATE SPECIES VERSUS RANGE OF NITROGLYCERINE CONCENTRATIONS IN SEDIMENTS ROCKET PASTE AND NITROGLYCERINE PONDS

AD-A033 547 BATTELLE COLUMBUS LABS OHIO F/G 6/3
AQUATIC LIFE STUDIES AT BADGER ARMY AMMUNITION PLANT. VOLUME I.(U)
AUG 76 J M STILWELL, D C COOPER, M A EISCHEN DAMD17-74-C-4123
UNCLASSIFIED NL

2 OF 3
ADA033547

END
DATE FILMED
2 - 77

CONT

CONCLUSIONS RELATIVE TO ENVIRONMENTAL QUALITY STANDARDS

Nitrocellulose

Correlation Between Nitrocellulose Levels and Ecological Responses

Figures 13 and 14 in Chapter IV indicate the relationships between nitrocellulose concentrations and various ecological parameters measured throughout Phase II. These data and relationships were derived exclusively from field measurements, where a multitude of physical, chemical, and ecological variables interact in an unknown manner. Therefore, no conclusions as to causality can be drawn from the results of this research effort. Conclusions must be limited to the degree to which nitrocellulose concentrations are associated with ecological responses.

Phytoplankton, periphyton, and benthic macroinvertebrates on artificial substrates suspended in the water column at all sampling locations were exposed to nitrocellulose concentrations ranging from zero to 20 ppm. No significant variations or patterns of change of ecological parameters investigated were associated with nitrocellulose concentrations within this range.

Benthic macroinvertebrates inhabiting natural substrates were exposed to nitrocellulose concentrations ranging from zero to nearly 200 ppm. Some species were eliminated from sampling locations characterized by nitrocellulose concentrations in excess of about 100 ppm. By circumstance or cause, sediments containing higher concentrations of nitrocellulose were physically very different from those containing lower levels of nitrocellulose. Therefore, observed ecological changes at higher nitrocellulose concentrations may be due to habitat alteration rather than by effects of nitrocellulose itself.

In conclusion, nitrocellulose concentrations in excess of 100 ppm in the sediments may elicit ecological changes in the benthic macroinvertebrate community in the effluent receiving system. Whether this is brought about directly or indirectly, due to habitat modification, cannot be resolved at this point.

Stream Versus Effluent Considerations

The transformation of "no effect" stream concentrations to "no effect" effluent loading rates cannot be made without considering specific characteristics of the effluent and effluent receiving system. In the case of nitrocellulose, its relative insolubility in water will require specific knowledge on flow and turbulence of each effluent receiving system in question before "no effect" effluent loading rates can be determined.

Nitroglycerine

Correlation Between Nitroglycerine Levels and Ecological Responses

Figures 15 and 16 in Chapter IV indicate the relationships between nitroglycerine concentrations and various ecological parameters measured in nitroglycerine receiving systems throughout Phase II. As in the case of nitrocellulose, many variables interacting limit the conclusions relating to nitroglycerine effects accordingly.

The nitroglycerine effluent receiving systems at BAAP consisted of two small ponds. Nitroglycerine concentrations in pond waters varied from near zero to 12 ppm; nitroglycerine concentrations in pond sediments varied from approximately 8 ppm to 40 ppm.

Benthic macroinvertebrates were completely absent from pond sediments and artificial substrates suspended in the water columns. Environmental conditions evidently precluded survival of benthic macroinvertebrates in these ponds.

Periphyton communities developed on artificial substrates suspended in the water column of these ponds, but only a very depauperate flora developed, and numbers of organisms were also much lower than would be expected in these types of habitats. Slightly greater diversity and abundance was observed at nitroglycerine concentrations below 3 ppm, although still substantially less than expected values.

In conclusion, nitroglycerine concentrations in the low ppm range are associated with substantial ecological changes in benthic macroinvertebrate and periphyton communities; substantial changes are noticeable at nitroglycerine concentrations at, and even below, 3 ppm.

Stream Versus Effluent Considerations

"No effect" levels of nitroglycerine probably lie well below 3 ppm for benthic macroinvertebrates and periphyton. The transformation of "no effect" environmental concentrations to "no effect" effluent loading rates cannot be made without considering the effluent receiving system in question. In the case of nitroglycerine, its relatively high solubility in water mandates specific knowledge as to dilution and dispersion in each effluent receiving system in question before "no effect" effluent loading rates can be determined. This will require research efforts related to the hydrology of each receiving system for which no effect effluent loading rates are to be implemented.

REFERENCES

Anderberg, M. R. 1973. Cluster analysis for applications. Academic Press, Appendix E. New York, New York. 359 p.

Battelle Columbus Laboratories. 1975a. Data report on stream valley criteria to Stream Valley Board, County of Fairfax, Virginia. Battelle Columbus Laboratories, Columbus, Ohio.

Battelle Columbus Laboratories. 1975. An environmental and ecological assessment of the proposed Upper Darby water supply project, final report to Burgess and Niple, Ltd. Battelle Columbus Laboratories, Columbus, Ohio.

Boyd, M. B., R. T. Saucier, J. W. Keeley, R. L. Montgomery, R. D. Brown, D. B. Mathis, and C. J. Guice, 1972. Disposal of dredge spoil problem identification and assessment and research program development, Technical Report H-72-8. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Burks, B. 1953. The mayflies or ephemeroptera of Illinois. State of Illinois, Natural History Survey Division Bulletin, Vol. 26:1-216. Reprinted by Entomological Reprint Specialists, Los Angeles, California.

Cooper, D. C., M. A. Eischen, D. A. Holzworth, B. E. Jakobsen, J. M. Stilwell, and P. E. Strup. *Effects of selected munitions* plant effluents on selected aquatic receiving systems at BAAP, JAAP, and LCAAP. Contract No. DAMD-17-74-C-4123. Battelle Columbus Laboratories, Columbus, Ohio.

Corps of Engineers. 1970. Report of the Corps of Engineers on dredging and water quality problems in the Great Lakes--summary report. U.S. Army Corps of Engineering, Buffalo District, Buffalo, New York.

Duncan, D. B. 1955. Multiple range and multiple F-tests. Biometrics, 11:1-42.

Eckenfelder, W. 1970. Water quality engineering for practicing engineers. Barnes's Noble, Inc., New York.

Eddy, S. and A. Hodson. 1961. Taxonomic keys to the common animals of the north central states. Burgess Publishing Company, Minneapolis, Minnesota 162 p.

Edmonson, W. 1959. Freshwater biology, 2nd edition. John Wiley and Sons, Inc., New York, New York, 1248 pp.

Environmental Protection Agency Water Quality Office. 1973. Methods for chemical analysis of water and wastes. Cincinnati, Ohio.

Frison, T. 1935. The stoneflies, or plecoptera, of Illinois. State of Illinois, Natural History Survey Division Bulletin, Vol. 20: 281-471. Reprinted by Entomological Reprint Specialists, Los Angeles, California.

Fritz, J. and M. Freeland. 1954. Analytical chemistry, Vol. 26, 1593.

Heard, W. and J. Burch. 1966. Key to the genera of freshwater pelecypods (mussels and clams) of Michigan. Circular No. 4, Museum of Zoology, University of Michigan, 14 p.

Hester, F. and J. Dendy. 1962. A multiple-plate sampler for aquatic macroinvertebrates. Trans. Amer. Fish. Soc., 91:420-421.

Hustedt, F. 1930. Bacillariophyta, Heft 10. In: A. Pascher (ed.). Die süsswasser flora Mitteleuropas, G. Fischer, Jena. Reproduced in Xerox by University Microfilms, Ann Arbor, Michigan.

Johannsen, O. 1933. Aquatic diptera. Cornell Univ. Agr. Exp. Sta., Ithaca, New York. Reprinted by Entomological Reprint Specialists, Los Angeles, California.

Kaesler, R. L., and J. Cairns. 1972. Cluster analysis of data from limnological surveys of the Upper Potomac River. Amer. Midl. Nat. 88:56-67.

Lowe, R. L. 1974. Environmental requirements and pollution tolerances of freshwater diatoms. EPA-670/4-74-005. National Environmental Research Center. Office of Research and Development. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Mason, W. 1968. An introduction to the identification of chironomid larvae. Fed. Water Pollution Control Adm., U.S. Dept. of the Int. Cincinnati, Ohio, 89 p.

National Science Foundation. 1973. Proposed criteria for water quality--Volume 1. United States Environmental Protection Agency, Washington, D.C.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical package for the social sciences, 2nd edition. McGraw-Hill Book Co. New York. 675 p.

Palmer, C. M. 1969. A composite rating of algae tolerating organic pollution. J. of Phycology, 5:78-82.

Patrick, R. 1953. Diatoms as an indication of river change. Proceedings of the 9th Industrial Waste Conference, Purdue Univ. Engin. Extn. Serv. 87:325-330.

Patrick, R. and C. W. Reimer. 1966. The diatoms of the United States, Vol. 1. Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania. 700 p.

Pennak, R. 1953. Freshwater invertebrates of the United States. Ronald Press Company, New York, New York, 769 p.

Peterson, A. 1960. Larvae of insects, part II. The Ohio State University, Columbus, Ohio. 416 p.

Pinkham, C.F.A. and J. G. Pearson. 1974. A new measure of biotic similarity between samples and its applications with a cluster analysis program. Technical Report No. EB-TR-74062. Department of the Army, Edgewood Arsenal, Maryland. ADA-001-46612. 15 p.

Prescott, G. W. 1962. Algae of the Western Great Lakes area. Wm. C. Brown Co. Inc., Dubuque, Iowa. 977 p.

Reimers, R. S, N. A. Frazier, S. T. DiNovo, and D. L. Maase. 1975. Basic environmental concepts in the design and operation of diked disposal facilities in dredged sediments. 30th Industrial Waste Conference at Purdue University, West Lafayette, Indiana.

Richman, S. Department of Biology, Lawrence University, personal communication.

Rosenblatt, D., M. J. Small, and J. J. Barkely. 1973. Munitions production, products of potential concern as water-born pollutants, phase I. USAMEERU Report No. 73-07. Edgewood Arsenal, Maryland.

Ross, H. 1944. The caddis flies, or trichoptera, of Illinois. State of Illinois, Natural History Survey Division Bulletin, Vol. 23; 1-326. Reprinted by Entomological Reprint Specialists, Los Angeles, California.

Smith, G. M. 1950. The freshwater algae of the United States. McGraw-Hill Book Co., Inc., New York. 719 p.

Taft, C. E. Professor of Botany, The Ohio State University, personal communication.

Taft, C. E. and C. W. Taft. 1971. The algae of Western Lake Erie. The Ohio State University, Columbus, Ohio. 189 p.

Taras, M., A. Greenberg, R. Hoak, and M. Rand. 1971. Standard methods for the examination of water and waste water. Thirteenth edition. APHS, Washington, D.C.

Thiede, R. J. Chief Project Engineer, Olin Corporation, Badger Army Ammunition Plant, Baraboo, Wisconsin, Sanitary Treatment Plant Effluent Data. Letter to J. M. Stilwell, December 5, 1975.

Trowell, J. M. 1970. Gas chromatographic determination of nitrated derivatives of glycerine in aged double-base propellants. Anal. Chem., 42:1440.

Urbanski, T. 1965. Chemistry and Technology of Explosives, Vol. II, Permagan Press, New York, 510 p.

U.S. Department of the Interior, Geological Survey. 1963-1970. Quality of surface waters of the United States. U.S. Government Printing Office, Washington, D.C.

Usinger, R. 1971. Aquatic insects of California. Univ. Of California Press, Berkeley, California, 508 p.

Villegas, I. and G. DiGiner. 1973. Phytoplankton as a biological indicator of water quality. Water Research, 7:479-487.

Walter, H. and J. Burch. 1957. Key to the genera of freshwater gastropods (snails and limpets) occurring in Michigan. Circular No. 3, Museum of Zoology, Univ. of Michigan, 8 p.

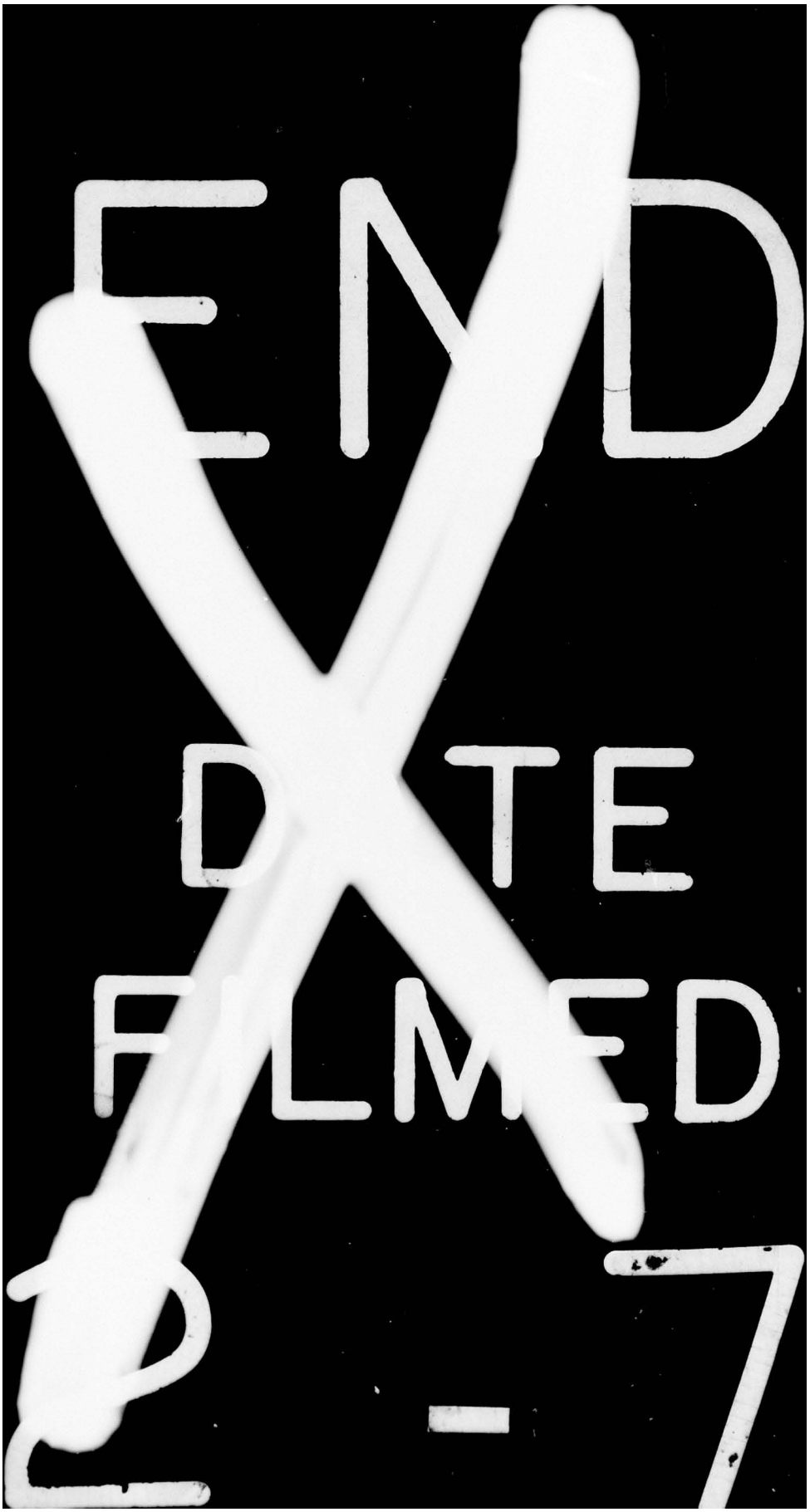
Warner, R. W. 1971. Distribution of biota in a stream polluted by acid mine-drainage. Ohio Journal of Science, 71:202-215.

Weber, C.I. (ed.) 1973. Biological field and laboratory methods for measuring the utility of surface waters and effluents. EPA-67014-73-001. National Environmental Research Center, Office of Research and Development U.S. Environmental Protection Agency. Cincinnati, Ohio. various paging.

Weber, C. I. and B. H. McFarland. 1969. Periphyton biomass/chlorophyll ratio as an index of water quality. Presented at the 17th annual meeting of the Midwest Benthological Society, Gilbertsville, Kentucky.

Wetzel, R. G. 1963. Primary productivity of periphyton. Nature 195:1026-1027.

Wright, J. C. 1959. Limnology of Canyon Ferry Reservoir II. Phytoplankton standing crop and primary production. Limnol. and Oceanog. 4:235-245.


END
DATE
FILMED
7
-

AD-A033 547 BATTELLE COLUMBUS LABS OHIO F/G 6/3
AQUATIC LIFE STUDIES AT BADGER ARMY AMMUNITION PLANT. VOLUME I.(U)
AUG 76 J M STILWELL, D C COOPER, M A EISCHEN DAMD17-74-C-4123
UNCLASSIFIED NL

3 of 3
AD A 033547

END
DATE FILMED
7-80
DTIC

SUPPLEMENTARY

INFORMATION

ERRATA

AD-A033 547

The Appendices, Vol II contained raw data only and was never published. Any/all references to Appendices, Volume II that appear in this Volume I should be deleted.

DTIC-DDA-2
5 May 80