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SURVEY, ECOLOGY, AND SYSTEMATICS OF THE UPPER POTOMAC ESTUARY BIOTA: AUFWUCHS MICROFAUNA

PHASE I

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WATER RESOURCES RESEARCH CENTER

SURVEY, ECOLOGY, AND SYSTEMATICS OF THE ZIPPER POTOMAC ESTUARY BIOTA: AUFWUCHS MICROFAUNA PHASE I.

by

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FOREWARN

This report presents the findings for the first year (1974) of a four-year program to better understand the microcosms of the upper Potomac estuary. The objectives of this project are to correctly identify the species and prepare illustrated keys, discover the trophic structure of food chains and webs, and monthly survey these microcosms. The first year (1974) has concentrated on the microfauna of the aufwuchs (periphyton) community, the second year will add the aufwuchs microf lora, the third year the plankton, and the fourth, the meiobenthos. This report includes the survey data collected not only during 1974 but also, for comparison, 1971. The taxonomic and trophic studies include work carried out since 1970; however, the-majority of these findings were made in 1974.

Sometime in 1977 or 1978, the Blue Plains sewage plant of Washington, D. C. will begin operating its new facilities at 309 mgd capacity effluent. Hopefully, it will meet the set standards of 96% removal of U.O.D. (ultimate oxygen demand), 96% removal of . phosphate, and 85% removal of nitrogen. At that time, other area plants should also be approaching this level of operational efficiency. Obviously, the tidal reach of the upper Potomac River from Chain Bridge to Mt. Vernon will respond to this reduction in input of organic materials. This four-year project is designed to provide baseline biotic and abiotic data prior to the onset of these new plant operations, and to determine how biotic and abiotic forces interact to determine species diversity and population numbers.

ACKNOWLEDGEMENTS

Dr. W. D. Burbanck, the author's graduate advisor at Emory University Department of Biology, is thanked for his help in developing this new system for studying the aufwuchs community and for encouraging the author to apply the system to the study of the Potomac River microfauna. Drs. Don Lear and Norm Jaworski gave encouragement and assistance when the author arrived in Washington six years ago. The author was permitted to accompany the E.P.A. sampling boat and its crew of Bob Vallandingham, Bill Thomas and Susy Smith of the Annapolis Field Station and set out and recover collection floats, as well as obtain their physicalchemical data. The studies- made in 1970 and 1971 would not have been possible without this kind assistance.

In the summer of 1970 the author received an N-S.F. faculty grant through the support of his chairman of the Biology Department at the American University, Dr. Falconer Smith. For two months in the summer of 1971, Dr. John Corliss, Chairman of the Department of Zoology, The University of Maryland, supported the author as a research associate on his grant with the systematics division of N.S.F. Thus this work has been supported in part by N.S.F., and copies of this report are being made available to N.S.F. systematic zoology division.

Dr. George Chapman, Chairman of the Department of Biology, Georgetown University, has given the author the space, equipment, material, and encouragement to pursue this work. He carefully read and edited the grant proposal and made valuable suggestions. He has collaborated with the author by applying his expertise as an electron microscopist to better understand how suctoria feed and defend themselves against their predators.

Mr. Ralph Palange, the first director of the O .W . R.T ., D.C. Center, is thanked for his experienced assistance. Great thanks go to Dr. Jim Burton, the current director of the Center, who has shown phenomenal patience and understanding, as well as a keen interest in this work.

Most of all, gratitude is expressed to the author's wife, Jeanette, who has edited and typed the proposal and this grant report. She and the author's little girl, Lora, have sacrificed so this work could be carried out.

This project is dedicated to Dr. Harold Finley, who passed away this summer as our collaborative project on the peritrichs was progressing. He loved the Protozoa, especially the peritrichs, and they taught him and his many students a great deal. We will carry forward the goals of this great and good man.

ABSTRACT

The aufwuchs microfauna was collected on inverted plastic petri dishes (Spoon & Burbanck, 1967) supported by floats composed of Styrofoam cup sections. These floats tethered to midstream buoys were colonized at one-month intervals at sites 3-1/2 miles apart, one below the outfall of the Blue Plains sewage treatment plant, and two downriver and two upriver from Blue Plains. Special effort was made to include all protozoan and micrometazoan species in the counts. Their abundance was.converted to numbers from one to seven representing rarity to super abundance. The species list is over 300. Physical-chemical data of the principal investigator is presented with the extensive E.P.A. data for these five collection sites. Tne biotic and abiotic data for 1974 was compared to similar data collected in 1571. Vie abiotic data showed a substantial improvement with increase in dissolved oxygen, decrease in turbidity, phosphorus and nitrogenous compounds and organic carbon.

The 1974 microfauna showed, a doubling in species number of protozoa and micrometazoa. Extensive study was made of the food web of the aufwuehs community using studies of isolated cultures, aquaria, and experimental rivers. It is concluded that predator pressure is a principal force determining aufwuchs species diversity and population numbers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Potomac River (Indians called it Cohonguroton, "river of swans") is 400 miles long and is tidal (average 2.9 feet) to above Washington, D. C. at Chain Bridge; however, the river is essentially freshwater down to Indian Head which is below Mt. Vernon. The volume of water flowing over Great Falls is quite variable C30 cms in drought, to 2,500 cms in floods (33) or 610 efs to 484, 000 cfs, average of 10,780 cfs (303 . Of the 3.3 million people living in the 14,670 square mile Potomac River Basin, over 80% (2.8 million) live in the Washington Metropolitan area (33). There are 18 sewage treatment facilities in the Washington area pouring a total of 325 mgd of wastewater into the Potomac River. Most of.these effluents empty into the upper Potomac Estuary. The wastewater discharge of these 18 plants accounts for 87% of the PO and 51% of the nitrogen in the upper Potomac River (41). In 191, these 18 facilities were pouring into the river 450,000 lbs/day of U..O.D.(ultimate oxygen demand, related to amount of organic carbon and nitrogen compounds present), 24,000 lbs/day phosphorus, and 60,000 lbs/day of nitrogen. Of the 2.5 million people in 1970 in the Washington area, 1.8 million were being served by the Blue Plains sewage treatment plant (31). This is over 70% of the Washington area population. This plant averages over 240 mgd of wastewater. It was designed for 75% removal of B.O.D., yet is presently very overloaded and operating well below that level. Nearly 15% more of the Washington area population is serviced by the large Arlington and Alexandria plants with their outfalls just across the river from the Blue Plains sewage treatment plant. Thus, a narrow 4 - 5 mile stretch of the upper Potomac estuary receives the wastewater from the majority of the Washington area population. The m driver sites chosen for this project are spaced 3-1/2 miles apart with two above and two below this stretch of the river (Figure 1). The shore site at Chain Bridge represents a relatively unpolluted "recovery" area with constant high oxygenation, high diversity of life, and presence of more complex organisms such as snails, mayfly larvae, and gammarid crustacea. The Key Bridge shore site has a fauna which varies greatly seasonally and has a reduced diversity of life.

A 1969 dye study (29) showed that the main Potomac channel of the upper Potomac estuary could receive and transport pollutants about 100 times more rapidly than the embayments such as at Piscat away Creek. This fact is another strong argument for selecting midriver sites as well as shore sites, only upriver at the river's narrowest points

CMS = cubic meters per second CPS = cubic feet per second

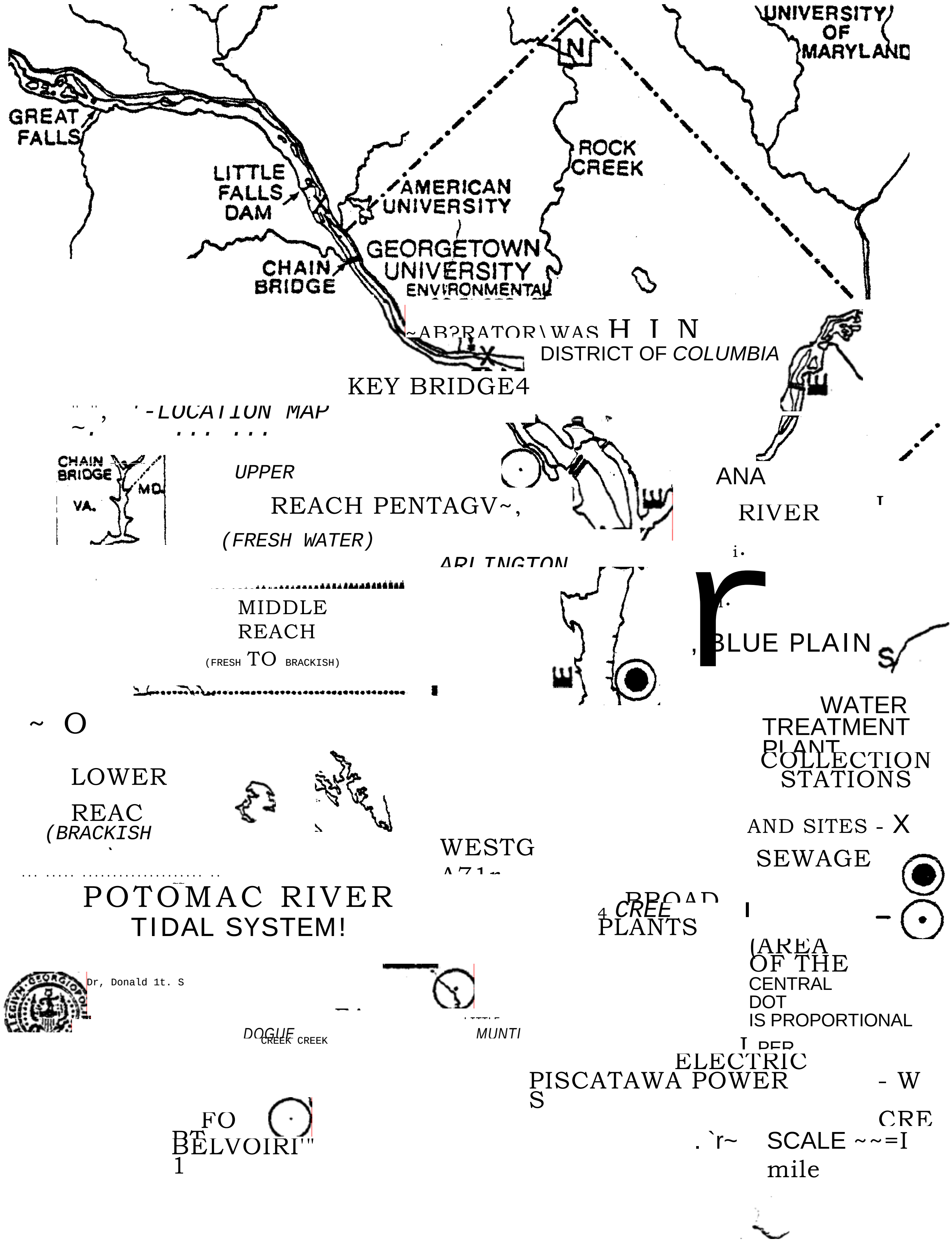


Figure 1. Map of the Upper Potomac Estuary showing project sampling sites.

The upper freshwater tidal Potomac River has been divided into sections based on the effects of these wastewater discharges; Chain77Bridge to Hains Point with frequently high fecal bacterial counts and moderately low dissolved oxygen due to overloaded sanitary sewers and combined sewer overflows; Hains Point to Piscataway Creek with low D.O., periodically moderate fecal bacterial counts and beginning of algal blooms due to wastewater plant effluents; and below Piscataway with nuisance summer and fall blue-green algal blooms due to the levels of PO 4 and NO following mineralization of larger organic molecules by river m Icrofauna (33). ,

Presently the area of the upper Potomac River with the greatest human bacterial contamination is from Chain Bridge (below the highly polluted Cabin John Creek) to Hams Point. This is primarily due to overflows of the overloaded sanitary sewer system. For example, until 1972, 25 mgd of raw sewage was overflowing at Georgetown into the river. This was partially corrected by pumping it under high pressure in a suspended pipe under Key Bridge to Boning Field where it is filtered and discharged into the river. Such overflows (which also occur regularly in the Anacostia River) have necessitated a moratorium until 1977 on further residential growth in Maryland and Virginia areas served by the Blue Plains sewage treatment plant (53). The set standard of 1,000 MPN (most probable number)/100 ml for fecal coliform densities from Key Bridge to the lower D. C. line is usually exceeded as shown in the routine sampling (since 1938) of the D. C. Department of Environmental Services. At Roosevelt Island the level of fecal bacteria runs from a low of 3,300 to a high of 350,000 MPN/ml. The standard of 240/100 ml for the area from the D.C. line to Cedar Point is also exceeded with a record of about 2,000,000 MPN/100 ml off from the Blue Plains sewage plant in 1966 (50). However, this now runs about 7,000 MPN/100 ml since 1969 when heavy chlorination was initiated (31). In 1969 (38) an extensive study of sanitary bacteriology was undertaken in the upper Potomac estuary.

Until 1935 when the population of the Washington area reached about 1/2 million, there was no sewage treatment plant. The river diluted the wastewater and the flora and fauna worked its self-purifying process on the added nutrients (77). Since 1935 the improvements in the effluents of the sewage treatment plants have not been able to keep up with population growth and increased wastewater discharge. For example,, since 1913 the wastewater discharge has increased from 42 to 325 mgd, phosphorus to 22-fold, nitrogen to ninefold,, and carbon twofold (30). Thus, since the 1913 (75) sanitary survey to present, the conditions in the Potomac River have worsened placing an increasingly heavy burden on the Potomac River biological self-purifying systeQ31). This is mainly due to the lack of sufficient 0 for the Potomac River biota to carry out their metabolic processes efficiently,, as well as the increasing presence of chemical pollutants which ~t as irritants or toxins ultimately preventing the reproduction of the biota, and its eradication is the result. Thus, the areas of downstream stages of self-purification have moved further downstre and the flora and fauna have been reduced to less desirable forms. Levels of toxins have built up in the bottom sediments which may take decades to remove.

It should be made clear that we have and we will continue to rely on biological systems in our activated sludge process and in the river self-purification process. These biological systems are undoubtedly dependent at their basic trophic level on saprophy such as bacteria, fungi and flagellates. However to run in a trul efficient manner, there must be protozoan and micrometazoan predat(feeding on the saprophytes to keep them functioning at top eff icier

In the 1971 (31) report of the Annapolis Water Quality Office; there is a review of the literature of studies of changing biota in the upper Potomac River. These changes progressed from normal plant life in 1913-1914 (24), the first year that sanitary surveys were made, to 1920 (40) when water chestnut appeared, to 1952 (4) when vegetation was nearly nonexistent yet no phytoplankton blooms were noticed, until 1959 (73) when nuisance blue-green algae (especially *Anacystis*) in bloom proportions were reported. This condition has continued to the present. In 1958 (25) a water milfoil caused nuisance conditions, yet by 1965 (5) a natural virus apparently ington metropolitan area with only 2,750 mgd used for cooling purpc and 99% of that used by the electric power stations. Two of these are on the Anacostia and one on the Potomac River across from the Blue Plains sewage plant. On a few of the hottest summer days wher the mainstream of the Potomac River may be 28.5^{0}C, the Anacostia River can be 33^{o}C. This is due to the very low flow in the Anacost River.

. On May 7, 1969, the Potomac River Washington Metropolitan Area Enforcement Conference set standards to limit by 1977 the amounts of ultimate oxygen demand (U.O.D.), phosphorus (P04)1 and nitrogen in sewage effluents to 96%, 96%, and 85% respectively. Their recommendations for improvements in sewage treatment are now beginning to be actualized in the new construction at many of the 18 major treatment plants in the Washington area. The total cost c these improvements from 1970 to 2020 will be 1.2 billion dollars or $54.8 million annually or per capita $13.50 to $18.30/person/yez (31).

By late 1975, the Blue Plains sewage treatment plant is expect to have in operation its expanded secondary treatment facilities with an increased capacity from 240 to 30. mgd. This should great decrease the L1-0,.D. in the river and cause a dramatic change in numbers of individuals in the microfauna populations. It may also change the types of forms which can live in this area of the Potomz River; however, this is not expected. More than likely, existing rare species will take over dominance rather than new forms taking advantage of the changed conditions. Somewhere between 1978 and 1979, the advanced tertiary treatment facilities for removal of phosphate and nitrate reduction will begin operation at the Blue Plains sewage treatment plant. (Presently, construction has been halted and a cost analysis is being carried out to see if the tertiary method proposed will indeed solve the problem of eutrophication.) This would be expected to reduce the levels of blue-green algal blooms allowing the existing presently rarer green algae to dominate.

Ecological studies are nearly useless without precise taxonomy. Two morphologically similar species may be able to tolerate drastically different abiotic and biotic conditions. The reason that the aufwuchs microfauna has not been adequately utilized in this country has been due to the lack of reasonably- prepared keys and trained personnel. The existing keys are designed by separate specialists or a region and include the common as well as the rare, exotic species. Most single stretches of a river or stream have a resident microfauna. This 25-mile section of the upper Potomac estuary probably has about 600 species in the aufwuchs microfauna as projected from *studies of* the *past* four years. Dominant indicator species *are found at certain sites* each year and seasonal fluctuations of these species reoccur. At any one site there are only 50 - 60 species for a single collection. This species diversity level seems to be true around the world, implying a restriction on available niches (15).

There is no shortcut to accurate taxonomy. Only a qualified specialist can confirm the choice of a species name. A considerable percentage of the species in an exhaustive study such as this will be new, eventually requiring full descriptions and approved species names.

There are certain well-known standard texts which can be used to begin a taxonomic study, such as Robert W. Pennakts 1953 FreshWater Invertebrates or Eddy and Hodson's 1961 Taxonomic Keys to Common Animals of the North Central States. Ward and Whipple's second edition of Fresh-Water Biology edited by W. T. *Edmondson* (1957) with sections by numerous specialists is still of great value, even though dated. Some of the keys permit accurate identification of the more common species. The current E.P.A. series on the Biota of Freshwater Ecosystems (for all of then United States) is of enormous usefulness for the groups so far considered; however, the format makes inclusion of the larger groups such as rotifers and Protozoa a monumental task. Considering that there are over 5,000 different species of suctoria and peritrichs alone, the feasibility of a complete key to the Protozoa with well over 25,000 free-living species becomes inconceivable. When one studies any one locale extensively, it becomes apparent that Protozoa are protean in structural features. The multiplicity of morphotypes reduces the usefulness of a key to the Protozoa of the United States. In contrast, a key to all the Protozoa and micrometazoa of one stretch of a river adjacent to a cultural metropolitan center like Washington is *both* feasible., practical, and a necessity if we are to know man's influence on *his* neighboring organisms.

Since 1913 (75) and more regularly and more completely for the last 35 years, the upper Potomac estuary has been surveyed for various physical-chemical parameters and total and coliform bacteria Macrofauna such as fish have been sampled periodically as have plankton and benthos. However., the surface-attached microfauna *(aufwuchs)* (59) has not only been neglected, but is poorly known.

Of the various microfauna, the aufwuchs is by far the easiest to collect. It is collected on various floated substrata and., being on a flat surface, can be scanned rapidly and directly counted without the manipulation and sampling methods and devices required for plankton and meiobenthos. The meiobenthos varies greatly with adjacent bottom conditions which vary from solid rock to silt. Sampling the meiobenthos *with a grab from* a boat in a moving river is difficult and dangerous. The plankton varies greatly from adjacent areas (as well as depths) appearing in clusters in the Potomac River as can be seen in infrared aerial photography (personal communication; Dr. Richard Anderson., The American University). Also plankton is dependent op water flow and upstream resupply which is exceedingly variable in"the Potomac River. The falls with their tremendous turbulence tend to select for certain hardier forms such as cladocerans and diatoms.

The Upper Potomac River is very turbid most of the year and *when* this *turbulence* interplays with the narrow (1-2 foot) euphotic zone, relatively little phytoplankton grows. Only below the sewage plants where tiny floating particles (caused by bulking in the inefficient sewage plants) abound and there is a broadening river condition, are [illegible] algae). This occurs mainly daring the late summer low flow conditions During this time the area from Chain Bridge to Roosevelt Island will sometimes show a green flagellate or diatom plankton bloom. Nevertheless, for the majority of the year this 25 mile reach of the Potomac River from Chain Bridge to Mt. Vernon is dominated by the detritus food chain (rather than the grazing one based on phytoplankton). This detritus food chain is fed by moms organic wastes which are concentrated by bacteria, flagellates, and fungi *which* serve as food for microfaunal protozoans and micrometazoans, which serve as food for macrometazoa like carp and catfish. These microfaunal organisms are too small to flee the conditions as can fish and thus the resident microfauna is an indicator of the conditions of the water.

The aufwuchs community is the truly resident microfauna. It lives attached to all kinds of surfaces where it is bathed daily by the river water. Thus, its species diversity and population numbers act as a living computer to monitor the water conditions. Aufwuchs community population numbers respond to organic contents which support its basic bacterial food. Changes in dissolved oxygen and other abiotic factors limit which aufwuchs predators can live at each site, which in turn determines which prey can become dominant (69). The aufwuchs community is more than just the periphyton, the firmly attached forms. It is also those forms which graze on the periphyton. Also, zooplankters use surfaces as resting places. Collateral plankton tows show the same species of zooplankton among the aufwuchs community. When plastic petri dishes with tight-fitting lids are used, 13.2 ml of water is trapped in each dash (12 x 50 mm). Turning the closed dish upside down allows sedimentation of the. phytoplankton onto the lid which can then receive a clean bottom for counting the phytoplankton. It has been found that midday collections of aufwuchs includes the highest numbers of plankters which migrate to the lighted surface.

The literature on the study of the aufwuchs community collected on artificial substrata in lakes, rivers, and streams was reviewed by Cooke (19) in 1956, and by Alena S1adeckova (62) in 1962. She and her husband Sl6de&k continue as European leaders in aufwuchs studies (60 and 61). The majority of the studies cited by these reviewers was by European workers, and then. they were more likely to be qualitative rather than quantitative studies. Sladeckova's review article on the methods employed to collect aufwuchs communities led the senior investigator to develop his own plastic petri dish method (70). This method overcomes nearly all of the obstacles to the collection, transportation, identification, and enumeration of the aufwuchs community. This method was applied by Burbanck and Spoon to toxicity studies on HgC1 (8) and more recently by Ruthven and Cairns (1973). Using this m;thod, Spoon, Krieger, and Burbanck (1969) reported their work on a Georgia pond and river aufwuchs communities at the Third International Conference of Protozoologists at Leningrad (68).

In 1963, Dr. Harold Finley and David McLaughlin of Howard University reported (37) on their now classic study of peritr.chs of the Kenilworth gardens which borders the Anacost a River. While not using artificial substrata, they did enumerate the aufwuchs sessile peritrichs on particulate matter in water samples. Their conclusion that the numbers of these peritr chs were directly related to the numbers of bacterial food has been supported by many other workers before and after them (37, 44, and 76).

Only a few studies have been published containing information on the aufwuchs organisms of the Potomac River. James B. Lackey, in 1938 (39), published his studies including study of free-living protozoa of the Potomac River, yet he collected sediments or surface water rather than use colonized artificial substrata. John Cairns, Jr. (12 and 13) has done extensive work on Potomac River protozoa, primarily using polyurethane foam as an artificial substrata. Recently, he proved to himself his critics' (including the senior investigator) suggestion that such substrata with their many protected pockets selected for unnatural populations by separating the dominant predators from these potential, easy prey.

River and stream surveys on the aufwuchs community compared to similar surveys on plankton and benthos are very rare.

Probably the best-known classic presentation on river biota is the training publication of Bartsch (1948) in which sessile ciliates and their crustacean predators are given their rightful importance in self-purification of streams and rivers. A recent note by Small (63) on the ecology of an Illinois stream supports the contention *of Bartsch* and many others that sessile *ciliates* are essential *for this self-purification process.* The doctoral dissertation of Dr. Martha Sager (1959) (6) is of use as it deals with Potomac

A mature work of monumental proportions (335 pages) and of the highest quality is *by the* German Ernst Nursh (1970) (45). It presents in detail, a correlation between aufwuchs *peritrich numbers* and *changes of abiotic parameters in* German reservoirs. He also reports some predations of micrometazoa on protozoa.

The literature concerning *trophic interactions* and food webs in the aufwuchs community is apparently not extensive; however, there are bits of information scattered throughout the literature

in such fashion that it is difficult to research. Titles of article containing *information on* predation seldom state if the organisms studied were members of the aufwuchs community. Studies on trophic interactions between Protozoa and micrometazoa are very rare. The principal paper which still dominates this area of thinking by protozoologists is by Picken (1937) (52). He believed that Protozoa had their own food web which was a dead end not contributing to metazoan food chains. (One cannot be too critical of this limited view when we realize that food chains per se were first fully described by Elton in the 1920's.) Barts-cF (1948) (3) clearly stat the role of protozoa as important food sources for Spoon. Kreiger, and Burbanek (1967) (68) observed numerous different micrometazoa *preying directly on* protozoa and pointed out the important role Protozoa *play* in the food chain: organic nutrients to bacteria to protozoa to micrometazoa to micrometazoa. Other workers have contributed evidence for this pathway (45). In 1973, Small (63) also reported this food chain. Spoon (1973) (71) states, that, in the upper Potomac Estuary, micrometazoa are the principal predators of protozoa, while protozoan predators of other protozoa dominated in laboratory aquaria.

The literature on the aufwuchs community of activated sludge is fairly extensive especially in Europe where the use of protozoa as indicators of sewage plant efficiency has been routine. Rosemary Reid, whale visiting in Harold Finleyrs laboratory, carried out extensive studies on the peritrich protozoa of the Blue Plains sewage treatment plant (54, 55, and 56). Many of the Vorticella species she studied are also abundant in the Potomac Rive" a=er findings on population dynamics of these ciliates can be partially explained by the predation studies of the senior investigator (71).

For instance,, her finding that Vorticella numbers decreased with increase in Amoeba discoides num`Eer~ s is explained by Spoon's discovery that *ti"F'is* amoe a is a voracious predator of vorticellids (71). Reid also found that peritrich numbers roughly followed fluctuations in bacterial numbers (56). The experimental work of Jensen and Ball (1970) (35) is a beautiful account of how population fluctuations of bacteriophagous protozoans follow fluctuations in organic nutrients and bacteria.

The role of protozoa in activated sludge has been documented in succeeding papers in-1942 by Jenkins (34), in 1949 by Henkelckian and Burbaxani (27), in 1953 by Baines et al. (2), in 1968 and 1973 by Curds (22 and 23), and in 1971 by`P3Tce and Curds (51). Curds, more than anyone else, has given Protozoa their rightful place in activated sludge. His 1969 taxonomic work on the ciliates of activated sludge (22) is of great usefulness all over the world. The species makeup of this fauna is based on the uniformity of human wastes and varies little from nation to nation. The most comprehensive review of the literature is by Pike and Curds (1971) (51).

In short, protozoa serve as predators of the bacteria that make activated sludge work. The protozoa crop off the bacteria and maintain them in the more efficient log growth phase. The presence of protozoa in experimental treatment plants (51) shows they greatly decrease the turbidity of the plant effluent and bacterial numbers. Apparently they join with bacteria like Zo lea to produce mucoid masses which clump together the bacteria an me e flocculation possible in the final sedimentation tanks (20). Probably even more importantly to man, the protozoa can remove up to 99.8% of the viruses (43 and 51).

Another area of research where the aufwuchs community has received much attention is in bioassay, toxicity, and tolerances studies (11, 16). Obviously, a population on a surface is easier to handle and count than a free-swimni.ng, swarming population such as Paramecium or Tetzah tena. A review of this literature can be foui27-n=ven an Cairns (1973) (58). John Cairns, more than any other protozoologist, has made practical use of the protozoa. In his work on the PEPCO Dickenson Power Plant on 647 species of protozoa (12) and 344 species of diatoms and 161 other algal species (13), he showed that the heated effluent had not altered the species diversity. His 1972 experimental study (16) on the effects of heated wastewater on protozoa includes many aufwuchs community organisms.

Dr. Ruth Patrick, member of the National Academy of Sciences and director of the Limnology department of the Philadelphia Academy of Sciences, has demonstrated the great usefulness of the aufwuchs microflora. She produced an excellent key for one group, the diatoms, and developed a diatometer to float glass slides to collect diatoms for their identification and enumeration (47 and 48). There is a problem with relying on one taxonomic group, such as diatoms, as a biotic measure of water quality. In the most seriously polluted section of the upper Potomac estuary; i'.,e., from Hains Point to Broad Creek, diatoms are absent or very rare, while peritrich ciliates and oligochaete worms are dominant. The microfauna has

a decided advantage (sometimes a disadvantage) over the such as diatoms; that is, most microfauna move or if sessile, an appendage or move a crown of cilia. Such movements denote whereas a diatom or other alga may be moribund yet still

SECTION A

'MATERIALS AND METHODS

Introduction

Nearly all of the methods described in this section have been developed independently by the senior investigator. As , a unit, they comprise anew. system for'collecting,.transporting, Y entifying,; t-6u *nting,. and* studying: the entire aufwuchs (periphyton) is an interacting community. '.

Basio flactic fetr'~. ~D'~.SI~:.-Collection *.Me~hpd.*

.The plastic petrV dish method .s ' a unique . and way of collecting aufwuchs communities from any body of water when used with the proper.flotation device (66). The method -uses commercially-available plastic petri dishes (12 x 5 0 mm) with *tight-fitting lids manufactured* by the Falcon Plastic Company *(Figure 2a). The procedure is as follows:*

Suspend the plastic,petr dish bottom:.in the inverted p~asit an to prevent.' :collection of silt.

B. Allow the dish bottom to:be colonized for a set of. time.

C . ,. ' Cap th dish bottom. with -the 'tight- . . exclude . all . air bubbles.

D. Transport the water-filled dish (bottom plus.lid) laboratory 'tor microseop .c study .

E. Wash; the outside clean .andVipe dry with a -soft paper or cloth-thus removing ail- periphyton attached to the . outside of the. dish°bottom..

F. Place the water-filled dish on a glass plate or grid . *on the microscope mechanical stage.*

G. Scan by viewing *the colonized* dish bottom inner surface through the clean lid (up to IOX objective lens of the compound microscope and on the dissection microscope). To go to higher power lenses (up to 44X) of the compound microscope,.,turn the d sh.over and view the aufwuchs through the dish bottom as if it were a cover slip.

The plastic petri dish method is very different from the standard glass slide methods. It has many advantages and some disadvantages over glass slide methods:

Advantages of the Plastic Petri Dish Method

A. Plastic petri dishes are colonized for algae and animals from two to six times more rapidly than glass. The surface is organic (polystyrene), not inorganic (glass), and is thus nonpolar and non-wettable like some plant surfaces. The plastic is not as smooth as glass and the organisms attach more firmly.

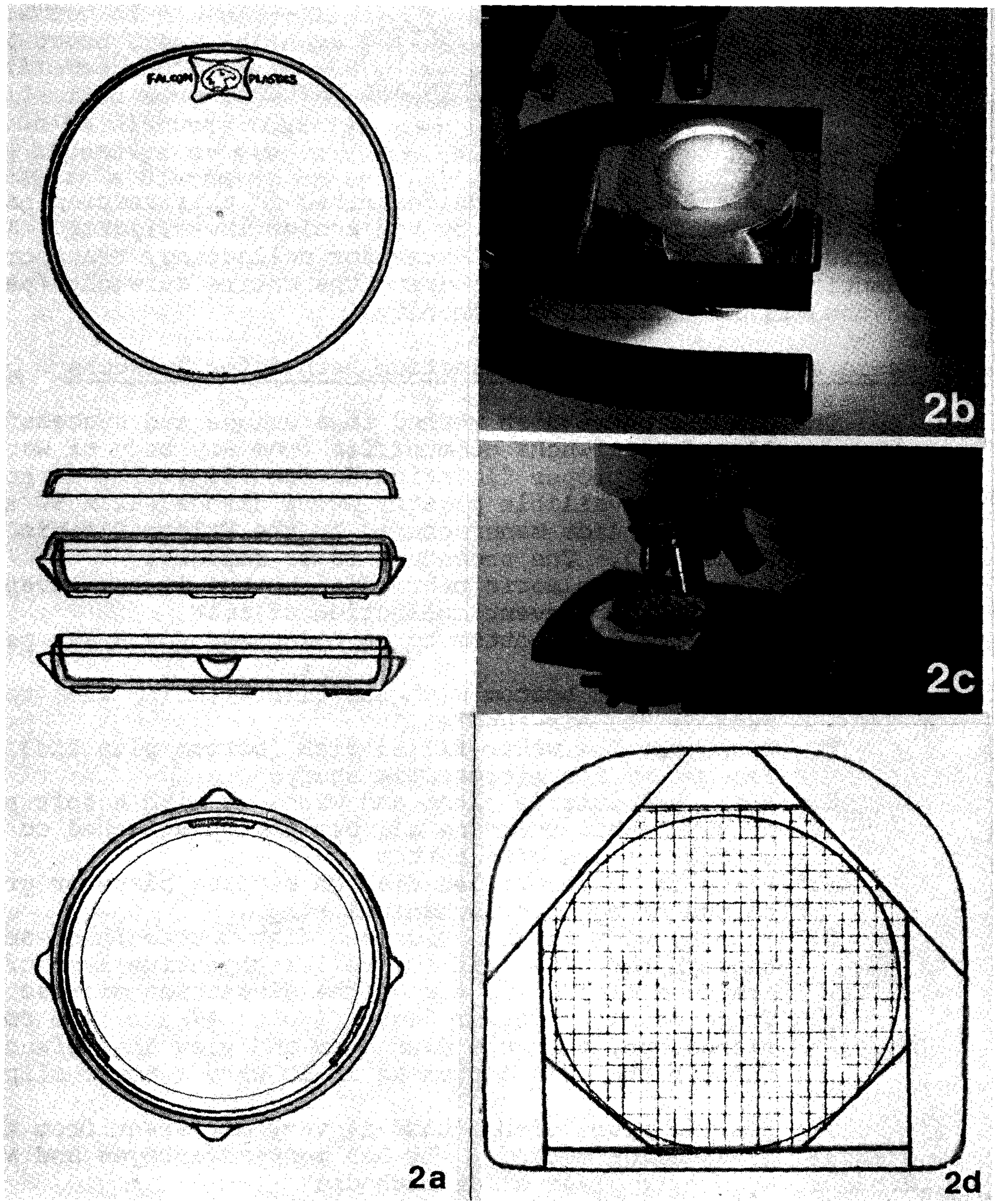


Figure 2. Basic Plastic Petri Dish Method of Studying Aufwuchs. actual size of 50 x 12 mm plastic petri dish. (2b) Plastic petri dish on dissection and compound microscope stages (2c). (2d) Actual size plastic plate with 2.5 mm grid squares.

B. The plastic is nearer to the density of water so that less flotation is required.

C. The dish bottom, once colonized and capped to enclose about 13.2 ml of water, can be easily handled and transported without loss of collected organisms.

D. The water-filled dish can be scanned at very rapid speed without surface film vibrations or internal vibrations. Thus the organisms tend to continue their feeding activities during scanning.

E. The plastic dish bottom can be returned to floats, position of sessile forms can be marked, holes can be drilled in the walls, etc., due to the softness of the plastic.

The disadvantages are primarily due to the softness of the plastic with possibilities for scratches that reduce optical quality. Also the thickness of the plastic prevents the use of highest magnification. The problemi of reduced optical quality of the plastic petri dishes is circumscribed by also studying colonized glass and plastic coverslips attached to the floats, thus allowing observations at IOOOX to 1,600X. The glass cover slips are used in making permanent slide preparations. The plastic cover slips are used for scanning electron microscopy.

Flotation Device for Sa lin the Aufwuchs in Rivers

The float assembly is designed to carry six inverted petri dish bottoms (50 x 12 mm, Falcon Plastic Company) just beneath the surface (Figures 3, 4a, and 4b). Each dish bottom is held in sections of two styrofoam cups allowing light penetration from above. The float assembly is constructed of inexpensive materials and requires about 20 minutes to construct. Scotch Brand filament tape is used to hold together the sections of styrofoam cups. All but the rubber stoppers and central wire are discarded. Between the two bottom stoppers, a larger 3-inch inverted plastic petri dish bottom is inserted and 12 glass and 12 plastic cover slips held in pairs in slices made in the edge of a styrofoam cup bottom. Also a plastic carer slip box with a window containing 12 glass and 12 plastic cover slips is attached to the bottom of the float assembly. These are necessary for use in microscopic studies at the highest magnification. The plastic of the plastic petri dishes is too thick (1 mm) for use with oil immersion lenses (100X). Also these cover slaps are used in making permanent preparations needed for exact identification.

These seemingly fragile floats hold up amazingly well in the Potomac River tethered to buoys by 1/4" nylon rope (Fig. 5). They last up to three months in the river. This is due to their low specific gravity, low profile in the water, and to their ability to sink beneath the surface in swift currents thus avoiding

.. surface debris of high flow periods following heavy rains. (The Coast`Cuard has given permission to have these f loatstied to these specific buoys.) To insure recovery, two floats on separate buoys are now put__out at each site where possible.

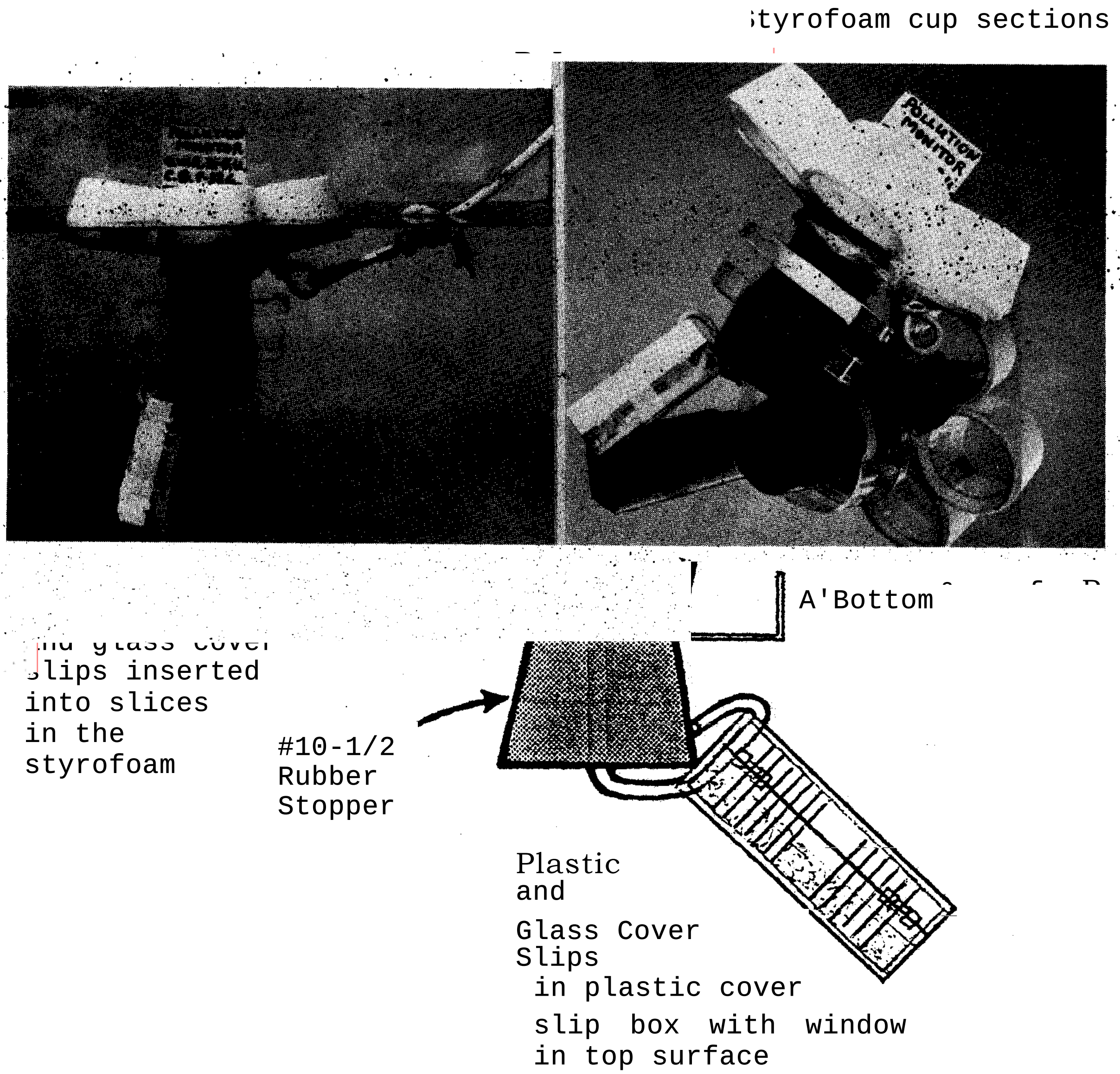


Figure 3._ Flotation Device for Sampling the Aufwuchs in Rivers

Figures 4a. and 4,. Sampling **float,in side view and** oblique., **(mirrored) showing ring** of six . sections **of styrofoar** „clzps **holding**

and bottom protecting 6-pairs of back=to-back cover slips held inserted in slices in cup bottom. **The float is held together with** Wire,:- **weighted with rubber stoppers and` carries a slide box with** one **side** cut **away.and containing 12, plastic and 12 glass cover** slips,. **Cellulose foam** is **wedged between the styrofoam** cup **sections**

Float Assembly **Collection**

Two **of the four-mid-stream buoys are collected** on **two closelyspaced separate collecting** trips. **The boat is tied up at the midstream buoy for the monthly exchange of float assemblies. The float (with dishes and coverslips colonized for one month) is collected by carefully encircling it in a large plastic bucket and bringing it aboard. Then the float, plus about 1-1/2 gallons of water, is triple-bagged in plastic bags and placed in a styrofoam chest. The two floats are transported to the laboratory in about one hour.**

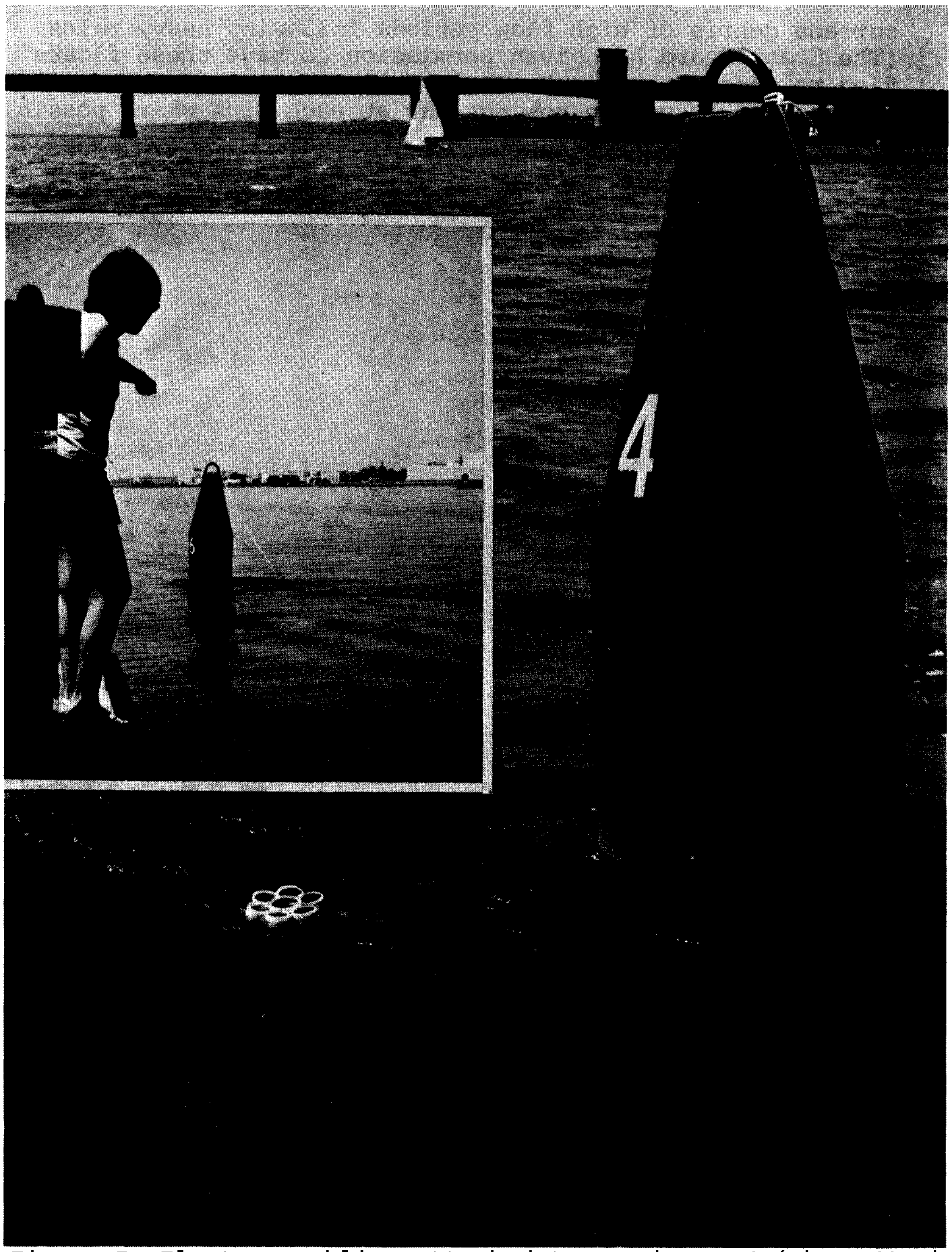


Figure 5. Float assemblies attached to nun buoys 4 (above Woodrow Wilson Bridge) and 6 just below the outfall of the Blue Plains sewage plant. The left panel shows Ms. Lizina Lee, graduate student assistant, standing on the gunwale of the Seagull, Department of Interior Lightship rangeboat, and pointing to the Blue Plains sewage plant on the horizon.

The rubber stoppers are removed from the float assembly and a razor blade is used to cleanly scrape off the aufwuchs into the large petri dish. These scrapings, containing numerous chironomid larvae, oligochaetes, and algae such as Cladophora and Stigeoclonium, are preserved in 70 % alcohol.

The circles of 12 glass and 12 plastic coverslips are removed and the glass ones placed in individual small pieces of styrofoam and returned to the 2-gallon aquarium. Later, these coverslips are used for high-magnification studies, photographs, identification, and drawings of the attached aufwuchs. The plastic coverslips are taken to Howard University for use by Dr. Harold Finley and his group for scanning electron microscopy studies.

After the plastic petri dishes are studied, the lids are removed and they are re-inserted into the six positions in the retain[illegible]op portion of the [illegible] assembly. One of the colonized dishes [illegible] preserved in Boui[illegible] cleared, and filled with clear [illegible] ning [illegible] mensional record [illegible]s [illegible] lastic Petri Dishes

[illegible] e selected randomly [illegible] ope using a 3" [illegible] d with a grid of 5 [illegible] numbers of [illegible] intermediate-sized forms (smaller micrometazoa) and make estimates of smaller forms.

3. Complete scan of wall and entire bottom surfac at 70X determining species present and determining estimates of abundance.

B. A. 0. MicroStar compound microscope using a grid marked in a plastic plate, over 2.5 mm squares (Figures 2c and 2d)

1. Complete scan at 40X looking through the clean lid.
2. Complete scan of bottom and walls at 100X with the dish inverted looking through the 1 mm plastic bottom. This is by far the most time-consuming, requiring at least 20 minutes per dish.

The float assembly and water is placed in a 2-gallon circular jar (Figure 6). The plastic petri dishes are capped with clean lids. Then the aufwuchs attached to the outside is scraped into a-large petri dish. Paper towels and running water are used to completely remove all attached material on the outside of the plastic petri dishes. With the colonized dishes removed, the fl[illegible]

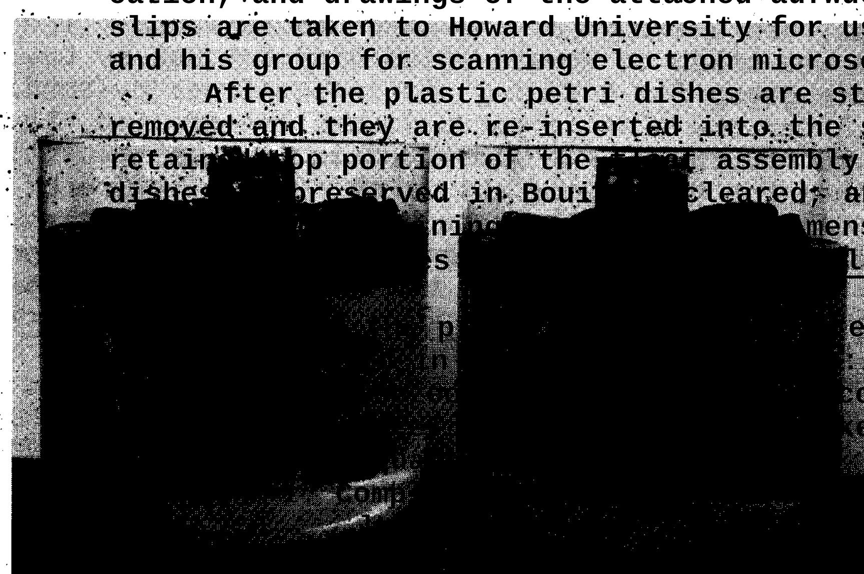


Figure 6. Two aquaria with floats after one month in the river, mid-stream, at Broad Creek and Piscataway Creek

The slide box with 12 glass and 12 plastic coverslips is removed. The 12 glass coverslips are placed in fresh Bouin's solution.:- These colonized coverslips are used to make permanent slides. About eight slide methods were tried. It was found that the Protargol silver impregnation method, using Bouints as fixative, gave excellent preservation and staining of nearly every group of the aufwuchs community. A film of parlodion is fully displayed as are other algae. This Protargol method, using a final oxalic acid treatment, gives distinct purple nuclei.

The ultimate objective of this procedure is to find very different microfaunal species present and recognizable at these magnification ranges, and to determine, or estimate as accurately as possible, the number present. When a species is too abundant, or too small and dispersed for a complete count, standard sampling methods are used from which estimates of the numbers are made.

The rubber stoppers are removed from the float assembly and a razor blade is used to cleanly scrape off the aufwuchs into the large petri dish. These scrapings., containing numerous chironomid larvae,, oligochaetes., and algae such as Clad22hora and Stigeoclo-nj!R, are preserved in 70% alcohol.

The circles of 12 glass and 12 plastic coverslips are removed and the glass ones placed in individual small pieces of styrofoam and returned to the 2-gallon aquarium. Later, these coverslips are used for high-magnification studies., photographs,, identification, and drawings of the attached aufwuchs. The plastic coverslips are taken to Howard University for use by Dr. Harold Finley and his group for scanning electron microscopy studies.

After the plastic petri dishes are studied, the lids are removed and they are re-inserted into the six positions in the retained top portion of the float assembly. One of the colonized dishes is preserved in Bouin's, cleared, and filled with clear plastic thus retaining a permanent 3-dimensional record.

Counting Procedures for Aufwuchs in the Plastic Petri Dishes

Three of the plastic petri dishes are selected randomly and each studied in the following fashion:

A. Stereozoom 7 dissection microscope using a 3" diameter plastic dish top (marked with a grid of 5 mm. squares) (Figure 2b).
   1. Complete scan at 1OX counting numbers of larger micrometazoa.
   2. Complete scan at 30X counting intermediate-sized forms (smaller micrometazoa) and make estimates of smaller forms.
   3. Complete scan of wall and entire bottom surface

      at 70X determining species present and determining estimates of abundance.

B. A. 0. MicroStar compound microscope using a grid marked in a plastic plate of 2.5 mm, squares (Figures 2c and 2d). 1. Complete scan at 40X looking through the clean lid.
   2. Complete scan of bottom and walls at 10OX with the dish inverted looking through the I mm plastic bottom. This is by far the most time-consuming., requiring at least 20 minutes per dish.

The ultimate objective of this procedure is to find very different microfaunal species present and recognizable at these magnification ranges, and to determine, or estimate as accurately as possible., the number present. When a species is too abundant, or too small and dispersed for a complete count, standard sampling methods are used from which estimates of the numbers are made.

Because of the large difference in size and subsequent ecological importance of the largest micrometazoa to the smallest protozoa, the actual counts and estimates are converted to the following numerical system which is nearly arithmetic for larger forms, and exponential, to the base 10, for smallest forms:

0 None Rare Scarce
1 Moderately abundant
2 Abundant
3 Very Abundant Dominant Dominant *and*
4 covering the entire dish
5
6
7

This method of reporting species and their abundance is believed to be superior to giving actual counts and estimates. A glance at the species list for each collection site can show dominance as well as rarity. Often it is the rare species which *blooms in the laboratory aquarium. Also,* the scarce to moderately abundant are usually predators, while the abundant and very abundant are bacteriovores or herbivores. Dominant plant species are those with some defense against the herbivores.

Subsequent studies with_. the aufwuchs_from each collection site

The *float* assembly, with the colonized dishes, is maintained in the 2-gallon aquarium aerated with air stones supported at the surface to prevent bubbles *forming* under the petri dishes. Weekly, TetraMin fish food *is added for* the detritus food web, and Gro-Lux fluorescent lighting is used to retain the grazing food web. The aquarium *is tightly covered with a* thin plastic sheet (Hand Wrap). Each day for five days, the live and dead adult dipterans are removed from the *plastic sheet or water surface and* fixed in 70% alcohol. A long tube with syringe is used to capture live dipterans. Sometimes over 100 per day are collected per aquarium.

About two weeks after collection of the float assembly, the dishes *and* coverslips are restudied to determine changes in species dominance. Also, samples of the sediment are placed in test tubes and an upright smaller glass vial inserted. This causes a fivefold increase migration of most species of meiobenthos from the sediment to the surface. Then a spring wire is used to sink and fill the vial with the concentrated meiobenthos at the meniscus. This method was developed by the senior investigator (70). It is the only efficient way of removing meiobenthos from f locculant material.

Determination of Links in Aufwuchs Food Webs

Predators in the aufwuchs community can be important deters masts of the species of prey present and their numbers. Thus a biological survey of the aufwuchs must take into account the lir of the food web. Of equal importance is the discovery of prey behavioral and structural defenses against predators. One would expect that defenseless prey would be absent in the presence of efficient predators. Yet, removal of the predators would select for the species which could feed most efficiently.

Links in the food webs are determined by the following methc

A. Direct observation is the most reliable. Many aufwuchs members are transparent. The food organism can be observed being grasped and then passed into the digestive system.

In the water-filled dishes one can follow the movements of the predator without *disturbing* it. By using low light intensities., many acts of predation are noted. Timed records with sketches are kept on these direct observations and photomicrographs are taken when possible.

B. Study of the contents of digestive chambers (food vacuoles in protozoa and gullets and intestines of micrometazoa) are studied at high magnifications by compressing the animal.

For this study, the principal investigator has designed a microcompressor which can be kept in place at all times on the stage of the compound microscope. The compressor portion can be-added-at any time. It allows for graded compression without shear force and can be used with all magnificati without extensive refocusing.

C. Through study of the changing species distribution in the 2-gallon aquaria, it is possible to deduce some food web link usually the ecological balance will favor the specialized pre; of the remaining predators. When no specialized predators remain., generalist prey dominate.

D. Predator-prey numerical studies can verify predations. For example, all free-moving aufwuchs are removed from the dishes by vigorous water currents leaving only sessile filter feeder Addition of varying numbers of motile predators are shown to correspond to reduction in sessile prey, compared to controls without predators. Motile prey are removed by micropipette and counted for similar studies using motile or sessile predators such as suctoria.

Physical-Chemical Data

Twice a month, the senior investigator, with two student assistants, makes a river sampling trip on a 23-foot, 45 mph range boat moored near Hairs Point at the Department of Interiorts Lightship Chesapeake. On each trip, floats from two of the four mid-river sites are exchanged and physical-chemical data obtained for the two sites. The boat trip takes a total of about three hours. At each site, the following measurements are made: air and surface water temperature and dissolved oxygen with Y.S.I. equipment,, turbidity with Secchi and Hack kit, pH with portable meter,, orthophosphate nitrate,, nitrite., chloride and D.O. with Hack kit,, B.O.D. by dilution and with the Hach manometric method., and total bacteria and coliform bacteria with millipore filter equipment. These easily-obtained measurements are compared with the much more extensive abiotic data collected monthly at these four sites by the E.P.A. Annapolis Field Station. These include water temperature,, dissolved oxygen (mg/1), Secchi disc (inches), turbidity (JTU), total P (P04 mg/1 mf)., inorganic P ($P0_4$ mg/1)., TXN (mg/1 N).,
$N0_2$ + N03 (NO - N mg/1),. NH (mg/1 N), TOC (mg/1),, Total C (mg/1) and Chhr-ophyl lophyll a (mgr?l).

It is necessary to"fake these minimal physical-chemical parameters because of the great variability of these factors in the Potomac River. The interval between our collections and the E.P.A. collections may vary several to many days. Since this project is primarily attempting to show that the aufwuchs community structure can be used as an inexpensive and rapid biotic means of detecting water quality, it is essential to know whether the *changes in* the biota are caused by chemical, physical, organic., or biotic factors,, or which combination of these factors.

SECTION B

Studies'on the Biology of the Potomac River Aufwuchs Community; Food Webs and Food Chains

Introduction

This section is a compilation of all the studies made on the biology of the Potomac River aufwuchs community since the study began in 1970 to the present. As seen in the list of publications in preparation, these findings will soon be in publication. Generally, the subsections appear in the same order as that found in the species list (Appendix A), and the survey biological data (Appendix B). All of these findings are original unless so stated in the text. The majority of the findings on food chains were based on direct observations, yet some, as stated, were based on indirect evidence. A careful reading of this section should make it clear that biotic factors, such as selective predation, can play an important role in determining the species present and their numbers.

Blue :green and green al ae

A float that as in the Potomac River for about a week during the summer will be covered with a filamentous green algal growth up to four inches in length. At Hains Point (Site 2) and Broad Creek (Site 4), this will be composed mainly of Clado2hora, Stigeocloni2D Oedo onium, and Spirogyra. A float in the river r more than a weei akyoai% e less or an algal growth, yet have more chironomid larvae. When these floats are placed in the laboratory in an aerated aquarium, the chironomids clean the float and dishes of filamentous green algae in a few days. Each chironomid clears an area around its tube, especially at both ends. In these areas, certain protozoans and micrometazoans can be found Filter-feeding peritrichs grow there benefiting from the current from the tube, yet they are eaten by some of the chironomids. Filamentous strands of the diatom Melosira are also found in abundance on these summer floats. Some -Mi-ronomids use them extensively in constructing their tubes. Also on the dishes are large plaques of various green algae which are very difficult to remove from the plastic petri dishes. Gelatinous masses of Anacystis as well as filamentous Anabaena, Oscillatoria, and Lyngby~a, are found in abundance growing in this alga mat. Large plaques of the golden-brown flagellate Chromulina grow over the surface of the dishes and as they spread, prevent growth of other algae. These plaques flake off in sheets. Suctorians like Solenophrya do not attach in the Chromulina plaques. Epistylis stalks are found there but probably 'attached before the Chromulina plaque was developed. Certain single species of diatoms and smids (Cosmarium. and Closterium.) were also found in this algal mat. Detritivoreg like oligoc es and chironomids keep detritus from smothering the algal mat and use the detritus in constructing their tubes.

In the summer, statoblasts of the bryozoan Plumatella are common and sometimes very abundant at Key Bridge. Some ch ronomids use the statoblasts in constructing their tubes.

Plankton collected in the petri dishes

In middle to late summer when periods of drought with low river flow occur, the river becomes more like a lake. In the area around Key Bridge or downriver at Broad Creek to Piscataway, *a green flagellate bloom occurs* periodically. Plankton samples show great numbers of cladocerans, rotifers (Branchionus plicatilis and B. bidentata) and *copepods.* At Key Bridge, a persistent zoo-plankter ounc occasionally resting on the collection.dishes is the large cladoceran, Cep a sp2. In these two areas are also found many planktonic protozoans such as the oligotrich ciliates Halteria Strombidium, and Strombilidium *as* well *as*
the tintinU Cod n a"~.iv g in a c *p-s5age~st.* Various

other ciliates a terotrich *species, Cond lostoma, the holo*trick ciliates Stokesia vernalis and Phasco o on vorticella the hypotrich 2o 'dim c5 -cum. an *the pera.tric* .astatella.

All of these represent adaptive ation of the respective ciliate groups into the planktonic community. One of the most unusual species found at Key Bridge was the non-sessile Vorticella ma eri, which has a *long tapering stalk which* it whips aEout .ce a sword. Free-swimming detached bells of several species of sessile peritrichs were abundant. These planktonic filter-feeding ciliates could serve as food for the abundant sessile predators in the aufwuchs, such as suctoria. These planktonic ciliates never survived in laboratory aquaria for more than a few days. This may have been caused by the lack of their more specialized phyto-plankton prey. It is hoped that the experimental river can retain these species and permit closer study of them.

At the height of the summer droughts, the salt wedge in the Potomac can have an influence up to or above Fort Washington. The Piscataway and even the Broad Creek floats have the colonial hydrozoan cnidarian Co o ra lacustris~ an indicator of weakly brackish water. Fresa-swimming re~o~N.agellates also are present *in* abundance. Also the brackish-water bright-red, hypotrichous ciliate Keronopsis r ra is present crawling on the collection dishes.

In middle to late summer, blooms of blue-green and green algae occur. These contain Anac stis and Anabaena, as well as S iro ra and Sti< eoclonium. t of aqua containing these blue-green algae' *a'nd* their zooplankton showed a gradual disap-pearance of the algae, with the cladoceran Bosmina lon irostris having a gut filled with material the color of the blue-greens. It should be noted that this cladoceran was quite abundant at Broad Creek and Piscataway the summer of 1974 when the blue-green bloom was poorly developed. A few organisms are known to feed on blue-greens, such as certain species of amoeba, some ciliates, and of

course, certain viruses. As this study progresses, emphasis will be placed on testing this hypothesis: Blue-green blooms occur under conditions which first disfavor their predators allowing them to increase under conditions favorable to their dominance over other phytoplankters. It is hypothesized that the dissolved H2S gas coming from the sediments could disrupt zooplankton feeding and permit algal blooms.

Diatoms and their grazing herbivores

In the early spring and fall, diatoms become abundant on the collection dishes as well as in the plankton. Also in abundance are the ciliate species which feed on diatoms. One of the most conspicuous is the large cyrtophorine holotrich, Chilodonella cucullus, the medium-sized C. uncinata,--and the s . nana. THe two larger species feed7on-Ti"a-tom species, while tSe 'sma 1 C. nana feeds on bacteria; it alone thrives in laboratory isolation cultures and aquaria in which diatoms are absent. Tear-drop-shaped chilodonellas are flattened and ciliated only on their ventral surface. They have an elaborate basket of kinetodesmal fibrils (formerly called trichites) around their antero-ventrally positioned mouth. They ingest slender diatoms like Navicula and Pragillaria. The large C. cucullulus has even been seen eating long, slender Asterionella. 3ther cyrtophorine holotrich of less abundance is a species of Nassula. There are many species of hypotrich ciliates which have -B-eenseen.feeding on diatoms. These include ""Asis Q2., Holosticha sp., and Uros . tyla sa - (we have-i=so ated Oxvtricha platvstoma in 1 oratorv SulfLures s-fea on wild-tvpe teria: rostyla is one of the largest and most primitive of the hypotrichs. All of these about with jerky motion, bending their bodies from side to side. Keronopsis is so plastic in movement as to resemble a snake. Mentor roeseli also includes diatoms in its catholic diet. Also many spe- c"Ife=6 amoeba (like the large amoeba Mayorella vespertilio) feed on the diatoms.

Diatoms offer a special opportunity for predator-prey studies because they can be accurately identified to species by microscopic study of their boxlike frustules composed of silica. In contrast, direct identification of prey species is impossible with bacterial prey. Thus one can determine if predators are specialists or generalist diatom feeders by studying the frustules in their food vacuoles. Ciliates fixed by the Protargol silver impregnation method can be accurately identified along with diatoms they have eaten. The Protargol method is especially good for making permanent slides of ciliates, amoeba,, and diatom frustules. Living ciliates can be compressed in a microcompressor and the diatoms in their food vacuoles identified to species.

Endozoic algae

During the early spring when diatoms are dominant on the collection dishes, many species of protozoa are seen to temporarily have endozoic algae. Species of Euplotes like E. eury stomus are filled with endozoic algae as are other hypotRc=hs Me- 97tylonychia mytilus and Uroleptus sp. Cnilodonella oucullulus often _a_r_e__F=e with zoochlorellae . -Tt'e a AT AMQhlys s o l was found with endozoic algae. The most unusual *find at the* runoff area was a long, slander species of Sgirostamum possibly S intermedij= .. which was solid green with its zo5ch o llae. attempts to culture this species in the laboratory failed.

No species of Spirostamum has ever been seen with endozoic During the summer, at the runoff area., some individuals of the fresh-water sponge Spongilla lacustris are solid green with endozoic algae, while some awe ~Mlr4llayyan flatworms of the genus Dugesia have algae endozoic in their tripartite gut. A strain -o-f- ra-ramecium bursar a, which always has endozoic algae,, was isolate ea-Tr-oma pond aBove Great Falls, Virginia, and is now in vigorous culture. Many such ponds, swamps, and streams which empty into the Potomac around Great and Little Falls were sampled. Many of the species of protozoa and micrometazoa found in the Potomac River were present.

Predaceous fungus, j=.hagus

The fungus Zoo us is rarely identified on dishes collected in the Potomac, Bu does become obviously abundant in some laboratory aquaria and cultures. This fungus feeds on aschelminthes., such as rotifers. It has been seen catching various species of Philodina and predaceous rotifers of the genera Cephaladella and AsplWhna. Rotifers are almost never abundant i activated sludge or in the river below the sewage treatment plant. Possibly the conditions favor Zoophyus allowing it to eradicate or severely control rotifer popu2ations. Crawling ciliates and gastrotrichs' were never seen caught by Zoophagus. Rotifers captured by L22h2012 were often shared by small MaFE5pagous holotrichous ciliates which swarmed inside the exoskeleton of the rotifer.

Sarcodines-_(amoeba d p;zqtpiz(?4)

In the Potomac River, W. greatest diversity of amoeba occurs in or below the Blue Plains sewage treatment plant. The most common are species of Vahih2m~fia Flabellula=j an Morella.
P

Direct identification `37 species of amoeba is questionable. They must be obtained in pure culture. Dr. Joe Griffin of the Armed Forces Institute of Pathology has cultured and identified some of the Potomac species including Conchilio odium bilimbosum. He also found heat-tolerant, yet non-pa-` thologic aeg Cerza - owleri like amoebae.

Dr. Griffin has stated in seminars and publications (27)

that the human pathogen Nae leri~a fowle-ri is favored by an aquatic environment which is warm, chlorinated mud-bottomed, like the Maryland swimming pools where most cases were reported. Dumping of chlorinated sewage effluent from the Blue Plains sewage plant directly across from the outflow of the major Pepco power plant where the water temperatures in the summer reach above 37^{0}C, is
a risky practice. This could be a hazard to the large number of unknowing sailors in this area who inhale the spray and contact the water when they regularly capsize. The power plant effluent should be used to enhance the activity of sludge by warming it in winter and partially pasteurizing it before inoculation with optimal activated sludge microbes. Any new power plant construction should be planned in *conjunction* with operational design of the sewage treatment plant.

A significant discovery was the direct observations of

Amoeba discoides feeding on Vorticella icta. The amoebats lobous pseudopodia, filled with characterJ.stsc granules, would contact the Vorticella stalk and cause it to contract. Then the amoeba would crawl over the bell-shaped body and phagocytize it. The process was completed in several minutes. Rosemary Reid (56) in studying Vorticella in the Blue Plains activated sludge, found decreases in vortice aids when Amoeba discoides increased. These predation observations may explaz~n er resu ts. The gelatinous material secreted around the peritrich h- diem protected it from attack by Amoeba discoides. Also sta2ke colonial peritrichs like E istr`Iis were not attached by the Amoeba.

bizarre amoeba appeared in an aquarium containing Potomac River floats. This was Biom a va ans which forms a relatively enormous mass of anastomos ng pse odia which can cover an area 6 - 7 mm in diameter, forming a large white spot on the aquarium wall or dark sediment. The pseudopodia rip the bell-shaped bodies of vorticellids from their stalks and phagocytize them. This giant amoeba disappeared several days after a naid oligochaete was first seen feeding on them.

Some species of amoeba are able to completely clean the plastic surface of all bacteria, algae, and fungus. Conchliopodium have been seen many times moving in lines acrose
aerial lawn leaving it cleared. Some amoeba can even remove iron bacteria. These bacteria form brown deposits on the dish surface that greatly affect the observation of the aufwuchs. Snails also clean off the iron bacteria deposit, yet incompletely, leaving characteristic chevron marks in the deposits (clear evidence-of past presence of snails).

In the middle and late summer, Arcel la and Centro__is become dominant as feeders on the bacterial-a a lawn, especially at *Hains Point.* Both genera appear *in* a small and large size of the same diameter. Centro is differs in having an acentric

opening into the beret-shaped ·test. Also Centropyxis tests are impregnated with *tiny* sand grains. In laboratory aquaria away from the riverts constant source of suspended sand grains, Centro is always disappear in several days leaving a large popu action 0 rcella sometimes not detected on the dishes when counted. Bote&ffK'pyxis and Arcella have from none to numerous peripheral spines. centro% cis O t e mail and large varieties can be seen grading from none to 10 - 15 entrically placed spines, and with the test *aperture very acentric to centrally located.* In laboratory aquaria, a dramatic shift was recorded in the form of Arcella. *The tests were counted as dead or alive, and* in six separate ye *overlapping categories from spineless to rough, bumped, few spines, many* spines, and many long upturned spines. The first *farm would correspond to Arcella, discoides and the last to Arcella coronata. Arcella with* upturneZ spines were seen to be *left* a *one by Eee ing r=5c oels which have soft pharynxes, yet these worms readily ate the smooth, spineless A. discoides especially if it were crawling over bits of debris. Tn contrast, the smooth form coexisted in* aquaria containing numerous *ostracods or snails whose rough feeding* parts would be aided by the handle-like spines. These studies are inconclusive, yet point to the hypothesis that all these varieties of C ntropn s and Arcella may be morphotypes of two or even one species.

Sarcodines,, the Heliozoans

Actinos haerium *eichorni is a giant* heliozoan which feeds as

a sessile`` pr~r on a g t variety of protozoa and micrometazoa. Prey happen to swim into its radially outstretched axopodia with their covering of adhesive cytoplasm. It is rarely found in river-collected dishes but is often abundant in laboratory aquaria established from Potomac River collections. Encystment is common. In a *pond,* these heli.ozoans *are epibenth c* and their population numbers are greatly affected by sediment which *can bury_* them. They can float to the surface under such conditions. In ponds

they have been found to be very abundant and effective as predators after long periods without rain. A slight current is needed to dislodge them, from *their* position on a surface.

Actinos haerium has been seen to capture free-swimming telb-trochs af" ice lac anula and the hypotrich Eu lotes eu . ~s_t_~omus . They eat many species otiFers such as the notommati which specializes on peritrich prey. Rotifers with *long caudal* toes or chaetae have been seen to scissor their way free from the heliozoan's food vacuole and then continue to struggle as they free themselves from the *clinging* strands of predator cytoplasm. The smaller related heliozoan Actinophrys sol has been seen eating the gastrotrich Chaetonotus

Rotifers which produce vertical loricas or long horizontal tubes can coexist safely in close proximity to these heliozoans. Very

often two heliozoans are seen sharing the same food prey organism, indicating that slow directional movement on the axopodia may occl
These heliozoans also eat developmental stages (nauplii) of copepods and ostracods and small rhabdocoel worms, yet coexist with the larger adults of these groups.

"Social Herding" in_grazing ciliates

Some of the grazing ciliates seen in the Potomac undergo "social herding;" that is, they move about in groups of two or more. Litonotus fasciola move about feeding in twos or more.
They are eg=ly esen conjugating in the collection dishes. The hypotrichs, Ltrol~tus Kerano. Isis and Actinotrichaa also social herd. The ciliate Lechr is ova¨c .',attened with oral ciliature forming a clearly vle diagonal line across the oral body from left to right. These ciliates exhibit the characteristic slowed, gliding motion when they contact one another.

This positive response might account in part for clustering in the social herding. An obvious advantage of social herding is seen when members of one species, such as seen in Lechrio la all congregate in one area around individuals whic are un ergoing conjugation. Possibly a sexual ectocrine is being released which attracts only members of one species, thus enhancing the quality of the gene expression through increased gene redistri

bution. These social herds of Lechriopyla were seen dispersed whe their predator Litonotus entered the mov3.ng herd.

The motile carnivorous ciliates

Among the grazing predaceous ciliates are certain rhabdophorine holotrichs which can be described as arch generalists.
One of the best studied is Dile tus anser which uses its toxocyst studded proboscis to inactivate an t en shove its prey into its mouth at the base of the long proboscis. Dileptus eats nearly every protozoan or micrometazoan in its size range. Dile tus have appeared in laboratory aquaria from the Potomac River but have not been collected on the counted dishes. A more common

Potomac River generalist ciliate predator is Homolozoon vermiculai
This long, slender ciliate is especially adept at eating rotifers such as Monostyla. The large, green Stentor coeruleus is a hemi
sessile, heterotrich generalist predator on ciliates and micromet azoa.
Most rhabdophorine ciliate predators feed only on other ciliates. Many are specialized to feed on only one narrow taxon and sometimes even one genera. A common generalist ciliate which eats only other ciliates is Lacr ria olor. It has been seen catching many types of small ciliates, yet seems to ignore

Aspidisca costata. An unusual observation-was its repeated captu3 of free-swimming peritrich telotrochs LacMZaria have been seen biting off chunks *of cytoplasm* from tie relatively enormous Stentor roeseli. Lacrymaria captures and eats Ampbile ptus an other ‾750‾‾′ FR=dpredator. Mynnotus rasciola is an elongigib, flattened ciliate predator with ciStion only on the ventral surface. It feeds on small flattened grazing bacteriophagus ciliates such as Chilodonella nana, Cinetochilum margaritaceum, and AspiNisca

costata. shaped Amp e p 3, Mich is s fusidens and Zn7che with ciliation only on the ventral suFace., been seen feeding on sessile peritrichs. Amghil *attaches anteriorly to the peristomal region* of the peritrich bell-shaped body and in seconds sucks out the contents. Bun-shaped Trachelius ovum is adapted for feeding selectively on peritri‾M‾7‾ =tswr=in slow circles above the peritrich repeatedly striking the peritrich's contractile stalk with its small proboscis until the discharge of the toxocysts has narcotized the contractile stalk. It then presses its mouth over the bell of the peritrich and ingests it. Peritrichs like Campanella and 22istZlis with noncontractile stalks offer little !′9"s=sAFFe. A growing population of any of these peritrich feeders can eliminate a *dominant stand of* peritrichs on a collection float in a day or two.

When the peritrichs are brought into the laboratory., ciliate predators usually greatly reduce peritrich numbers and make their culture difficult. The observation that the peritrichs attach on the wall of the aquarium. beside the bubbles to avoid ciliate predation., led to the hypothesis that these ciliate predators could not feed effectively in a current. Usually the micrometazoa peritrich predators, such as Chaet2gaster and rotifers which feed while firmly attached, did eventually reduce the peritrich pop*ulations in* the current. This demonstrates another advantage of *peritrichs forming large colonies as* the zooids are lifted up from the *surface into faster moving water.In* no case were ciliate predators absent from floats having large numbers of peritrichs. They were simply ineffectual compared to the abundant micrometazoans which fed on the current-protected peritrichs. Also Chaetygaster were seen to feed heavily on the ciliate predators or pe‾ritrichs such as An *R~Jleptus* and Hems ophys. A most effective means of outcompe Ing *is =oincluTe ‾antis› own* trophic level competitors in ones prey list!

These observations led to the discovery that peritrichs could be maintained for extended periods in the laboratory if a current was induced in their culture media. This was accomplished by placing the colonized dishes supported inverted in thin rings of styrofoam. and floating in 6-inch petridishes. A stack of four or five petri dishes were placed on a phonographic turntable at 16 rpm. It was found that by placing a Christmas tree current flasher (about 10 seconds on and off), an effective back and forth mixing could be obtained that aerated the water, created a current, and allowed the successful growth of numerous peritrichs. These included ercularia and E ist lis which were not cultured successively in static cultures. This culture method allowed the gradual adjust= ment of such peritrichs to the new conditions, and their progressive isolation from their predators. Since the closed culture dishes are aerated by this circular back and forth motion, contamination by cysts is prevented.

Peritrichs the Potomac River's most important bacterial feeders

The Potomac River from Key Bridge to Piscataway Creek is characterized by high organic and sediment inputs. Thus there is insufficient light penetration to support profuse phytoplankton.
The conditions of lowered dissolved oxygen and high organic content favors the growth of bacteria which serve as food for numerous animals. In the aufwuchs community the filter-feeding peritrichs are unquestionably the most abundant bacterial feeders. A central goal of this project has been to better understand the peritrichs and to determine the kind and extent of protozoan and micrometazoan p redation on these peritrichs. Figure 7 shows this key detritus food web of dissolved organics passing to saprophytic bacteria to filter-feeding peritrichs and to its numerous protozoan and micrometazoan predators which serve as food for macrometazoan predators like fish, birds, crustacea, and mammals.

In the Potomac River there are two motile peritrich species, Hastatella radians and Telotrochidium henne_u i. Both have been seen on s l:ng"'= as ions, trie first a m er of the Broad Creek zooplankton and the second from the pools at the runoff area. Telotrochidium readily forms cysts as bacterial numbers are lowered. o icella m~a e~ri. has also evolved into a permanent

member oft =ton ZEE its tapering contractile stalk incapable of attachment. $t is commonly found in late summer at Key Bridge. The sessile peritrichs Sc hidia and Paravorticella have no stalk, attaching by their scpu,ar region to the sur ace. Both are rare and found in protected areas. Sc)ahidia also occurs as an epizooic foam on the rotifer Brachionus.

Vorticella microstoma could be o"iu"red the arch generalist among t Fe peritrzc . t occurs in fresh, brackish, and salt water. It is found at all Potomac River sites including the runoff area.

It reaches its largest numbers in and below the Blue Plains sewage treatment plant, and could be considered a polysaprobic indicator. However, it also occurs in protected areas in small numbers in even pristine oligosaprobic environments. Thus, in terms of presence, it

PROTOZOAN-- PREDATORS -.MICROMETAZOAN

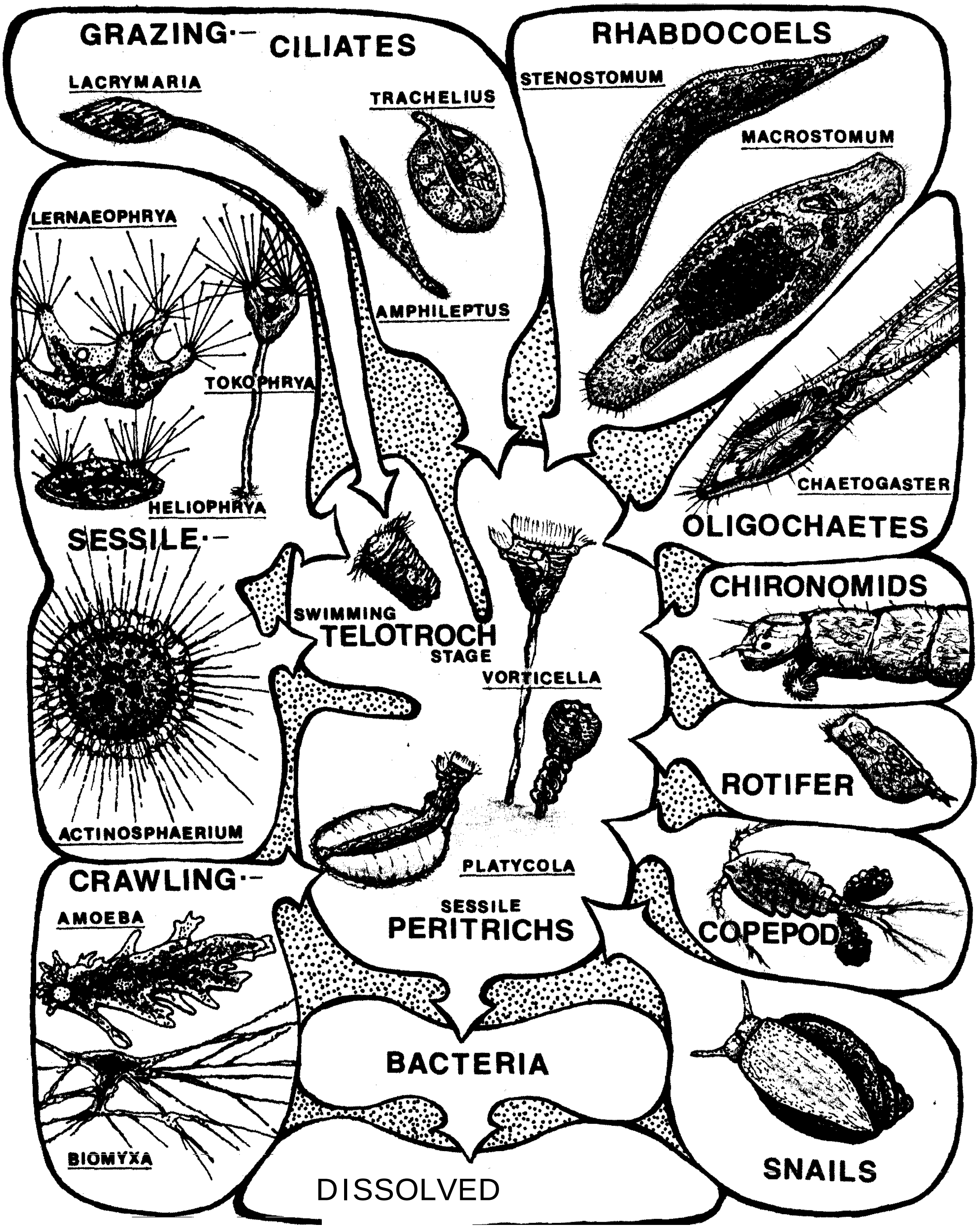


Figure 7. Detritus food chain from organic materials to bacteria to perztric s to protozoan and micrometazoan peritrich carnivores

to such environments, as well as the specialized predators living there. For example, specialists like Vorticella fromenteli are found only in the Blue Plains sewage treatment. p l a n t an -can coexist with ciliate predators like Lac maria sapro elica. Thus Vorticella microstoma and V. fromente i are believe to` be poly sapro is zn icators for di'fferen reasons.

One of the organisms of greatest number and importance in the Potomac River is Vorticella cola. It is distinguished by having abundant brownish cytop asmic granules which have been assumed by others to be storage granules. More likely these camouflage the vorticellids against the brownish aufwuchs coat. Possibly these brownish granules contain toxins to repel certain

prey. The success of V. campanula to coexist with certain peritricl predators such as copepods-an =gochaete worms suggests that these predators experience that V. campanula is not a choice food organism.

There are many small, clear vorticellids which can only be identified after careful scrutiny. Among these the more abundant are Vorticella iicctaa and V. striata. One vorticellid has become adapted to epizooic life attac e to the contractile stalks of

other peritrichs. This new species is tentatively called Vorticell~ finle i (in honor of Dr. Harold Finley). The species is four masn y at Key Bridge and Broad Creek. It has an unusually thin contractile stalk.

The colonial peritrichs are either stalked with contractile or noncontractile stalks. The senior investigator believes that these colonial peritrichs are polypheletic in origin arising in many separate branches from solitary vorticellids. The Zoothamnium species represent vorticellids which form colonies i n whlc'"~`e contractile spasmoneme branches dentritically. Zoothamnium represent at least two separate lines, one with cylin rica vorticellid-like telotrochs and one with telotrochs flattened dorso-ventrally like those of Opercularia. The senior investigator has had V. striata give rise -to a colonial peritrich in an aquarium. TFe Tol-ona.al branched somewhat like a species of Carchesium. The bells of the colonial were identical to the so itary vorticellid in size, form, and pell cular stride.

The colonial peritrich Carchesium polypinum has a great many similarities to Vorticella campanula. n er certain conditions Carchesium p o l y p s also-forms social clones like V. campanula. n w is e newly formed telotrochs attach beside the sessile sister colonies. Also it was discovered that V. campanula has a specialized microconjugant with a deep anterior notch that it uses to engage the stalk of the macroconjugant, and thus descend spiral up the stalk. Carchesium polypinum in colonies of four or more zooids forms roun mlcroconjugants that simply ascend by bouncing against the stalks. Yet when induced to conjugate at the one or two zooid stage, its microconjugants are very similar to V. c an ula. Carchesium of inum and V. cam,anula dominate in t7e otoma R-r.ver au .wuchs in the spring anc fall. archesium polypinum has a branching stalk with a spasmoneme which is discontinuous at each branch. Carchesium rraanu.-lata has the same arrangement, yet the outer sheatT h s ~~a distinct~~ contraction at each branch. Also the bell has large pellicular tubercles. It is believed that C. gra_n__ulata arose separately as a colonial from a solitary vorti= ce3.Txd" Uke V. monilata.

The group of species grouped under the genus name E ist lis are probably also polypheletic arising from separate so i˙ary vorticellids through formation of branching stalks lacking contrac tile spasmonemes. Some species may have arisen from Zoothamnium species that lost the spasmonemes. Some E is 1i s species Have specialized telotrochs like ercularia While ers have cylin

drical telotrochs like vortice i . E istylis licatilis has a

tiny *egg-shaped telotroch* which is unique. 'Some st"'T s species

have very thin stalks and are found *almost* entirely *epi* zooic *forms attached to stalks of other Epistylis species. Some may have arisen from V. f inle i .*

A unique ct on~:a peritrich with noncontractile stalk *is Cam anella umbellaria. Its relatively enormous bell* has *a perisAtomal* Fi liat"" o *ME* exceeds the normal 1-1/2 turns *of most* peritrichs and goes around 7-1/2 times. It is postulated that

its strong current allowed its bell to increase in size due to the improvement in gaseous exchange. This species has a brownish pellicle and always has brownish food particles in the food vacuoles, no matter where it *is found. The senior investigator* believes that Campanella produces a mucous secretion over its pel- licle. These mucous particles collect bacteria. Around the Campanella colony the rotating donut-shaped current carries these mucous sponges out into the water. They collect bacteria and become denser and move toward the center of the colony's vortex *passing into the cytostome of a C* anella zooid. This cylic move- ment of particles of mucoid partz~Fas also been observed in both fresh and saltwater vorticellids. It is commonly known that peritrichs improve the functioning of activated sludge by increasing the rate of *flocculation. It is believed* that the activated sludge process takes advantage of *this* feeding method of peritrichs which allows accumulation of bacteria in mucoid masses.

All the colonial Opereularia species in the Potomac River have been seen to have telo2rochs at' are flattened dorsa~ventrally. It has been observed that this shape causes the slow-moving telo
troch to be turned flat onto the surface whenever it approaches a surface. This is believed to occur spontaneously due to the Bernoulli effect whereby the water velocity drops to zero as a surface is approached. Other peritrichs which live in swift currents like Pla_t ~co~la and some suctorians also have telotrochs flattened dorsoventrally. They are all characterized by having myonemes that

and largest-peritrich bells. O~ercularia coarctata has zooids almost as small as Vorticella microstoma. It is rarely collected in the Potomac River yet grows we~~aboratory aquaria.

The loricate peritrichs of.the Potomac River include species of Va inicola, Cothurnia. Platycola and zcola.. keno hr s has been found occasionally at the runoff area. a cri~nico species live in an upright vase-shaped lorica attached at its base to the surface. The mouth of the lorica is constricted in some species. In Cothurnia the vase-like lorica is supported on a stalk.

lco a as a lorica like Cothurnia yet adds a lid which it uses to completely close the lorica.'-'Mservations on the feeding methods of rhabdocoel, oligochaete worms, and copepods as well as ciliate predators show these loricas, stalks, and lids are effective defenses against such predators. The Platycola lorica is attached flat on the surface with the small open g at one end. In Laegenophrys this opening is covered with a valve offering greater protection against predators. In spite of these protective mechanisms, loricate peritrichs seldom occur in large numbers at any site. It is believed that these loricate species thrive best in environments where the predators are those which the lorica is designed to defend against. If such specialized predators are absent then the defense is an unneeded liability. If predators are present which the loricate cannot protect against, then the lorica may become a trap. This seems to be the case for Platycola and the ciliate predator Lacrm a~ri_a__ olor.

This year a special et" ort as been made to collect, culture, identify, draw, measure, photograph, and make slides of these peritrich species. The Georgetown senior thesis student, Mr. Mike Phelan.. and graduate student of Dr. Finley, Mr. Coliston Rose, have nearly completed a complete cross-referenced review of all the literature on the peritrichs. We now have about 15 species in culture most of which have been measured, pellicular striae counted, and drawings made. About 30 other species have been studied yet are not in culture. It is believed that a complete description of about 75 of the more common fresh-water peritrichs that occur around cities and in their sewage treatment plants W1ll be of worldwide usefulness. This project is in collaboration with The worldts foremost expert on peritrichs, Dr. Harold Finley of Howard University. For each species we are preparing a single looseleaf sheet with one side with drawings and measurements of all stages including telotroch and microconjugant, and photographs of living and preserved material. On the back will be information on the taxonomy, biology, ecology, and behavior, and all references mentioning the species.

Suctoria, sessile, carnivorous species: stalked and loricate species

Among the stalked suctoria found in the Potomac River., Podg2hrya fixa is the smallest. The body is supported by a Mnder stalk rising from an expanded holdfast area. Freeswimming-larvae of Podophrya attach in groups of up to 14. Two Polo ghE~a could capture and eat a large prey., such as the hypoErich ciliate Euplotes curystomus,, which could escape from a single Podo2hrya. The hypotrichs were seen to use their long cirri givers to pry themselves free. Adjacent Podophrya would *unite and undergo* conjugation. Forming social groups thus aided the suctoria in competition for space, capture of prey, and success in sexual reproduction.

Acineta tuberosa was found in abundance during the summer months on als coed at Blue Plains sewage treatment plant., Broad Creek and Piscataway Creek. The short stalk supports a lorica that encloses the entire suctoria except for the top edge where the two bundles of tentacles project. This Acineta is difficult to count as it attaches in large numbers to FITZ"T strands of Clado2hora. Oedogonium (yet not Spirogyra) and MMelosira, as well as to the stalks of Fe-Fi t richs such as Epistylis. it also attaches to suctoria like Solenophrya and Metacineta and the perithecaof the cnidarian, CoFTy lop ho rM. Like the other sessile ciliates., it attaches directly to the plastic petri dish as well.

The giant suctorian Acineta r qandis was rarely seen., but then in fair abundance. This spotty occurrence may be caused by its special vulnerability to a commonly occurring predator which is less likely to eradicate smaller Acirsta tuberosa which are epiphytic and epizoic.

Tokkophrya quadripartata is a large stalked suctorian with four bundles of tent s. in the summers of 1970 and 1971, it was often found in abundance with Saleno aa.., a suctorian having a champagne glass lorica entacles with recurring beadlike *enlargements.* Tok2p ~a was found in round patches among the Solenophrya whi cTr covered most of the dish surface. When SolenoQy4 caqpletely covered the dish., there were no Vorticell7a campanula or Tokophrya even when abundant on oth rdisHe s Mi the same flob TMoRBUDEFSTa was seen to eat Vorticella campanula telo trochs. hrya were rare Ty seen an d most never In 157 when Tokophrya were present,, yet they were not abundant enough to invoke Fo-m-=pet tion for space. A more likely hypothesis might be that Tokophrya can catch and eat the larvae of Solenophrya. Solen o MW was also seen attaching epiphytically 7 o t'Fe side Wenches oFthe fungus Zooph2aus

The suctorian Metacineta occurred in four forms or species, each having a longer stem For the vase-like lorica that supported the round body. At the runoff.. from Little Falls, where there was a constant swift current, Metacineta stacina with the shortest

stem was abundant where it fed on the n3ant stentors. Also the snails feeding on the dishes would remove overcovering algae, fungus, and detritus from this low lying, but firmly anchored suctorian. The longest stemmed Metacineta *was found only* at Key Bridge or Hains Point, where its recurrent summer abundance made it one of the indicator organisms for site 2.

Suctoria sessile carnivorous ciliates: Stalkless s ecies

Suctoria of the aufvuchs community are sessile ciliate predators which eat only other ciliates. They feed on ciliate prey by tentacles with a knobbed tip, each serving after capture as a tiny mouth. From its tip, the slender tentacle conveys the prey cytoplasm into the suctorian. The body of the suctorian may be attached directly to the surface or be supported by a slender stalk or a vaselike stalk called a lorica. Adult suctoria are completely incapable of hunting movements and feed only on prey that swims haplessly into their tentacles. After feeding, the suctorian divides in a special way to produce motile, ciliated larvae from the sessile parent cell.

As sessile carnivores, suctoria compete with one another for attachment space. There is vertical stratification in both stalk-less and stalked species. The tiny stalkless Helio h a riederi larger H. rotunda and the largest H. erhardi attach fat on the surface: n a ition, H. erhardi has a roa peripheral adhesion band. The tentacles of suctoria usually arise in radiating bundles or fascicles; the area from which the tentacles extend in Helioh~a raise only a little above the surface. Trichophaa sg. Tascicles do have noticeable raised areas, which are even more raised in Lernaeophrya caiz~t~at~a, and called arms. In Astrop~hr_a_ arenicola, these arms extend up m dreds of microns and are covered with particles of detritus and silt. In Dendrosoma radians the long

arms are even branched and form a us likeinass superficially one might presume that these species represent a single adaptive radiation based on specialization for feeding. However, if the mode of formation of the migratory larval stage is considered, then it appears that they represent two or more separate convergent evolutionary paths. The migratory larvae of these stalkless suc - toria have the ability to clear a space in the bacterial lawn. Also once they have attached, diatoms and other algae do not grow under them; thus, their presence is clearly seen as translucent oval windows in the algal mat.

Most of these stalkless suctoria have an amazing ability to quickly capture and complete feeding on their prey in minutes, and then go without eating for days, weeks, and even months. Helio erhardi can starve at least four months. Even though there

the river, actual acts of predation are rarely seen. In the laboratory aquaria, other prey than those they feed on in the river may be abundant. Also these suctoria attached to the dish surface are being exposed to relatively widely-spaced freeswimming prey in the volumes of river water rushing past **the buoy. Ciliates which originated by division from daughters living in the benthos as well as planktonic ciliates and free-swimming migratory forms of hemi-sessile and sessile ciliates can** a l l **serve as prey. Nevertheless, these suctorian species do show specialization in feeding on ciliate prey because of their morphological limitations and physiological capabilities. For example, Helio haa riederi, with short tentacles which extend nearly horizontal to t e surface, have been seen to catch the flattened bacterial lawn grazers like Chilodonella.** Helio2hMa **rotunda and H. erhardi as well** as Tricho **hrys2**.can **capture** and **eat them, ye`t usually their** upturned **tentacles never encounter Chilodonella, allowing this ciliate to graze with immunity on the Bacteria overing these suctorians. Stalkless suctoria on dishes collected from the river have been seen feeding on the peritr ch motile stages called telotrochs. Helio h a erhardi** and **H. rotunda Trichophrya, Lernaeophxya** ca ata **antebe<u>n</u> rosoma** r a **z~have** a' **been seen ding on to otroc s of solitary and colon** a l **peritrichs. The great abundance of these suctoria in regions down-river from peritrich dominated zones indicates that peritrich telotrochs may be the major food source of these river suctorians.** The **author demonstrated in his masters thesis research that peritrich telotrochs swarm primarily at the surface. The river floats tethered to the mid-stream buoys support the inverted petri dishes with their colonies of suctorians at the surface of the water.**

Attempts have been made by the author to culture these stalkless suctoria in the laboratory with a measure of success. Whereas Heliophrya erhardi captures and thrives on paramecia, Dendrosoma radians can tT~eatch them at all, and Lernaeo h a cRitta rarely cats es them. **Presently, Helio ph a rime** e"ri pt **in complex** communities in aquaria in tie"' oratory, Mile **Heliophr~a erhardi and H. burbancki (tentative name) are cultured** o n **Paramecium.** Lernneo"~a Ea **hats is.cultured on the non-sessile** R=ich **e.ot'rooc i ium enne4 u i and telotrochs of the colonial Carchesium** ~*Ea.n.uu.* **ta The gra** irate student Mrs. **Hillary Boyle E1gert aid her electron microscopy project on this Lernaeo2 hx. a_ ~c_ap _i_t~at~a~_ and found that it did not** possess symbiotic bac eria **as does t~neralist feeder He liophrya erhardi. Also its pell cle was much thinner, its food vacuoles much smaller, yet its functional capture devices, called the haptocysts in the tentacle tip, were quite similar to H. erhardi.**

The senior thesis student, Miss Genie Shalhoub, did an extensive study on the biology of Lernaeo hr a ca itata. This species can be maintained on **Telotroc icium** 2Vyz.______**e suctorian**

in diameter. Upon feeding on the excysted Telotrochidium it can expand in size to over 800 across in three days o "`cueing. These giant forms.can have. over a thousand tentacles and be eating over twenty Telotrochidium at a time. Then it produces, simultaneously, scores o mo Z e arvae. Under aerated conditions, they can reproduce in less than 12 hours after feeding. This species, which is found below sewage treatment *plants, has* the ability to rapidly expand its own numbers and distribution to respond to a rapid increase in free-swimming telotrochs of peritrichs.

There are two basic approaches to ecological problems. On e can either study a single species or the whole ecosystem; that is, all the members of a community as they interact with the physical chemical parameters and influence certain species. The first approach attempts to take a part and see how it fits into the whole. The second approach attempts to learn how the whole functions and thus enf luence its parts. The first approach is called autecology and the second synecology. The fundamental *thesis* of this project is that the synecological approach *yields* the most realistic and most predictive information. Obviously it is the more demanding of the two approaches *in* terms of time and expertise. Also since it is based on sampling, it is inherently less conclusive and more frustrating. There is great value in the autecological approach if the species selected for intensive study is truly indicative of the microcosm under study. For the Potomac River. fresh-water estuary, the species of the stalkless suctorian Helioa were chosen for their great abundance and importance as

ee ers on bacteriophagous ciliates, which dominate in the aufwuchs community. One species, H. erhardi in particular, has been studiec in the greatest detail. X compete study of the light and electron microscopic biology of this species has been made by masterts studer Mrs. Ruth Li, Dr. George B. Chapman, Chairman of the Biology Department, and his assistant Mrs. Sandy Zane, and the senior thesis student, Ben Eng. Also the autecology has been

Symbioses in Mass-cultured Hello ht a erhardi, including flagellate predation on this Sudan. Donald M. Spoon. Georgetown University.

In the Potomac River, Hello hr a rotunda dominated with *H.* riederi scarce and H. erg i very rare . Present were *other sta* less suctoria: ric ophrya, Astro hr a and Dendrosoma and 15+ stalked species. Only *e* so a species

thrivec~ laboratory aquaria. In 1970, He *io* rya erhardi was isolated from an aquarium and fed in petri dishes with Cerophyll-nutrified, mass-cultured benthic ciliates. These mass cultures gradually lost other ciliates and micrometazoa leaving Paramecium aurelia and P. caudatum. In these sub

Until 1971, these cultures contained Disco. Rotifers, gastrotrichs, Chilodonella and hypotri"cs removed covering bacteria and'cLetritus. aching suctorian larvae selected areas where amoeba like Cochliopodium removed the bacterial lawn. The fungus Zoophagus caught b3th rotifers which ate suctorian tentacles *an* **food of paramecia. Nematodes were seen caught. on the tentacles, but struggled free. Numerous Paranema trichoshoruam and/or Notosolenus surrounded the sucto**-Ra-**,71gested their tentacles** and **penetrated their panicle to eat their cytoplasm. They attacked more readily attached suctoria than unattached morphotypes. In aerated, well-fed cultures., Paranema fed as scavengers on suctoriacaught-prey. Belbw**-*Wa*i**s=ngtonts major sewage plant outfall., Paranema were abundant year** *round.* **Suctoria however., were** *usuallyAbsent yet* **survived in this water, it if had been mMepore-f iltered.**

Predation Behavior of HeliopL2~2 erhardi on **27 species of Ciliates.**
Donald M. Spoon and Benjamin P. **Eng.**

Five separate predation sequences were followed for each ciliate eaten by attached Hellohxya noting rate and manner of capture, escape., death and-u-nTiv'**gested remains. Species ingested slowly or not at all were placed in small dishes + suctoria and counted for approximately 7 days. High temp= erature silicone grease layered on opposite sides supported cover slips with the attached suctoria. The non-toxic silicone gradually detached in the culture dishes. Polyox (2.5%) was used to immobilize prey ciliates for identification. The following prey information is abbreviated using "c" for capture and 'In" for no capture,, 11-11 for no ingestion and 11+11 for ingestion,, with average rate of ingestion in minutes: Dileptus anser (c-),, Trachelius ovum (c-), Didinium nasutuum (c+50), Cs Wt s (c+13),, -** L'**bum cam um 0+85; axenic w st5alln 1e**

-'`-tramsym **na pyrl-formis** c+7,) **(suctoria ate it and grew but would not divide)- Para ecium aurelia (c+25). P. cauu a (c.+45). P. multimicro cleatIum** (c+25)., P. richium (c+TU7-' f`pohtonia letrcas c Nassnla sp. (c+5'O)-, P-ro-ro- on,,_

platyod n (c- .,

) m on cinereus (c+?), Telotrochidi (c+30)., Vortice22a, picta telotrochs (c-), Metrpus QUallis (C+60)., n- *Mrisma* **undulMs .(c-) Spirostomum ambiguum (?w)., S. intermedium (c+?), S. teres (c+?), Stentor coeruleus (n-),, S'. roesell (60),, HaTte**-riasp. **(c+107,** By, hichidiuMm **cbnlcum n-), stylorf"Ttia myrtilus (n-), and Eupl tes eurystoma**

Last fall a second Heliophrya species was discovered that more closely resembles tipecies called H..erhardi by the Frenchmen Dragesco et al (1955). HeliophFya era i was first described by Rieder Ti-T936. His descRptio RE's ur first species. The second species studied extensively by Dragesco and called.H. erhardi should be renamed and. is tentatively called '1H. burbanckilf or possibly variety burbancki (after the senior investigator's major professor, Dr. W:)D. 9u`rbanck). This species is considerably smaller than the first and has three, rather than eight, morphotypes. The two . species will not cross conjugate. Dragescots description fits H. burbancki down to the slightest detail including the predominanc~eo 'Four fascicles.. Heliophrya erhardi has up to 12 fascicles. We confirmed that H. MrTancxi can undergo anhydrobios a,. recovering to feed in minutes after days of drying. Helio hrya erhardi cannot undergo drying.

Senior student, .Mr., 'J'a~mes 1:"~e"t te, set out to repeat the prey list study for H. burbancki as compiled by Ben Eng on H. erharda_. He obtained shorter average feeding times in minutes fo`r 1 n3.um nasutum (41, not 50)., Paramecium aurelia (23., not 2 5), P .. cau3etum
(25, not 45)., P. multimicronuc eaFumIS, not 25), and Min otes' eu .stomas (11f, not ; yet a longer time (38, not. 3 . or Telotroc idium henne u i. Also he found that Blepharisma undulans an ro on lat o on'were not eaten. Dragesco note that P.

caudatum was th of choice for H. burbancki. We found that this paramecium was eaten in almost na.l t e t3'.me it took H. erhardi to eat it. These predation studies would indicate the two organs are very similar and certainly have common ancestors. Neither of these species is very abundant in the Potomac River. Heliophrya rotunda which'is found at all sites and in abundance has recently been successfully cultured in the laboratory and will be studied intensively.

Stentors. hem -sessile heterotrichous ciliates

Of the species of Stentor, which number over 16, only the common giant blue-green Stentor coeruleus and the medium-sized S. roeseli are regularly Col ee e from`tMe Potomac River. Stentor coeru eus will shed a part of its green cortex with its. step-torn=eon .aining cortical granules when a rhabdocoel like Macrostomum attempts to eat it. The rhabdocoels are seen to violeSy re-ract and swim away, rapidly pulling in and out their pharynx. Stentor coeruleus in aquaria with the ostracod Cypri..dopsis have been seen too form tightly-grouped social groups of up to forty individuals which contract defensively in unison as.the ostracods scurry over the social groups. Stentor Coeruleus in the laboratory aquaria become cannibalistic. The cannibals are larger with much larger buccal cavities. A cannibal may contain up to five food vacuoles containing the remains of members of their own species. In such mass cultures, S. coeruleus with lighter green pigment or no pigment are seen. These tiny white stentors with only

5 to 10 beads of their moniliform macronuclei have been collected in the wild as well *and* exist without green Stentor for months in aquaria. Possibly they represent a new species.

Stentor coeruleus.as well as Ste~ ntor roe i are eaten by the relatZve y sma lsuctorian Metacineta micxna._These suctorians with their *bodies in* a five- ped lorica attach in social groups by a short tapered portion of the lorica. They can eat only a small portion of a large, *green Stentor coeruleus* but catch and *completely eat the small, white* MFEor coeru eus *and S. roeseli.* The stalkless suctorian Heliophry~er_a" l can eat *S.* roe-*se-= Sut* not S. coeruleus. Both suctorians mound *at the*-runo"~f.'. acid the Key lFri ge'sates where these stentors are also found. It is rare for any fresh-water suctorian to be able to eat very large heterotrichs like Stentor.

Stentors ee`~`as omnivores, eating both *protozoa* and micro-metazoa as well as bacteria, yeast and algae. They have been seen capturing and d,gesting in their food vacuoles, the nematode Rhabd,is. On most such attempts at capture, however, the nema-todes were seen to thrash their way out of the food vacuole, crawl about for minutes in the cytoplasm of their prey, until they finally successfully punctured through the cortex of the Stentor and made a complete escape. In the laboratory it can be readily shown that nematodes with their very thick and nearly impervious cuticles are far more resistant to dyes and toxins than are most protozoa. Nevertheless, nematodes are never abundant in the Potomac River in the aufwuchs community, yet are more common in sediments as in the Roosevelt Island marsh, *and in* the activated sludge of the treatment plants.

Encystment of Stentor coeruleus has not been reported-in the literature since the- te l tt century. In one small aquarium, cysts were common and encystment was observed. Stentor coeruleus often appear in aquaria even though they were not counte on tie dishes in the floats, indicating they were on the float.

Stentor roeseli (possesses rose-colored granules in a clear cytop asm as a gFeeatinous lorica which it produces and contracts *into when* it is disturbed. It has been seen that free-swimming S. roeseli are caught and eaten by the heliozoan Actinos]2_h_e_r_i_u_~m eicho-"'rn'. Yet the heliozoan and hemi-sessile S. roese inert heir or-cas can co-exist side by side. In the collection ishss, as debris and detritus builds up between the loricas, eventually only the clear holes where the stentors are feeding can be seen under transmitted light.

Competition between ciliate and rotifer ecological equivalents

The ciliates have adaptively radiated into almost every habitat and niche in aquatic microcosms. The only other group of animals that approximates their adaptive radiation is the rotifers. (Gastrotrichs may be considered a part of this adaptive radiation with the gastrotrichs as a group with ventral spines and especially adapted for grazing on surfaces.) For many ciliate types there are ecologically-equivalent rotifer types. This would seem to violate Gausets principle that two species cannot occupy the same niche. In the broader sense of niche, such rotifer and ciliate ecological equivalents may have similar form.. movement, and food, yet they diffl in their mode of reproduction, and subsequently their predator control. Multicellular rotifers reproduce sexually or parthegeneticall; with various types of resistant eggs. Many species can estivate
if they dry out. There are numerous micrometazoan predators, including species of carnivorous rotifers that feed on rotifers. Some generalist ciliate predators also feed on rotifers. Unicellular ciliates reproduce asexually and many species especially those living in sediments and soil can produce *dormant cysts,* however this occurs less frequently among ciliates of the aufwuchs *community. Only one* species of ciliate, Helio h a burbaneki (tentative name) has been reported (79) t able twithstand prolonged drying. Thus, even though rotifer and ciliate ecological equivalents may compete for the same food, their potential for reproductive response to the abundance of the food differs; and more importantly, they have different predators to control and limit their populations.

There are rotifers which compete for food with grazing ciliates. These include Lepadella patella, Monostyla, Ce halodell.a, Testudinella, and Tricc i Focerca. i`fiF er are 1 er-fe g r o i ers that
compete wit t e pritrichs. These include Brachionus Philodina roseola and a ploimate rotifer which attaches to e birancies o coonial peritrichs. It even has a form like the zooids of the colonial peritrichs, and superficially, could pass as zooids. There are colonial filter-feeding rotifers like Lacinularia f losculosa that produce a gelatinous mass to retract ~. t_O, as toes the per trich h datum *si oides. The* filter-feeding sessile rotifer Pt ra m ces test a.n which to retract as do loricate peritrichs. There are roofers which are planktonic in the Potomac River. Among them are species of filter-feeding Brachion~ Pol ar~th.~r.a~t
S nchaeta, colonial Conochilus and Kerate a americana as well a giant predator s and a prio onta which e~cle S heavily on other species of rotifers. interest to the senior investigator are the species of carnivorous rotifers which feed in the Potomac River outside their phylogenetic tree. There are four species of Ce halodella that have been seen feeding on ciliates including perms, Euclanis dilatata is a common feeder on peritrichs, especially

effective predators on peritrichs. They hold tenaciously to the peritrich stalk by their small cement-producing caudal toes. They eat away at zooids until the whole peritrich colony is reduced to stalks to which the rotifers attach their eggs. Even though these rotifers do consume many peritrichs, they are not able to create crashes in peritrich numbers as can the asexually-reproducing ciliate carnivores like Amphileptus and Trachelius ovum.

Rhabdocoel worms, generalist predators

Rhabdocoel worms are important microcosm predators, especially of peritrichs. These worms are among the most formidable and opportunistic of the predators of aquatic microcosms. Their long, slender bodies are covered with cilia allowing them to swim rapidly. Their cement glands (rhabdites) allow them to secrete a mucoid adhesive material and rest in position, pulling water laden with prey-detection chemicals to them in the current produced by their cilia. Some have two ciliated pits on each side of the head believed to be for chemical detection. They feed by stalking across the surface of the aufwuchs community. The rhabdocoel Stenostomum regularly feeds on small flagellates and algae such as the desrni losterium. Tney also catch small ciliates such as Chilodonella and engesF Arcella disco ides. Stenostomuum feeds on voTE

_ -i"`=i c~y opening tFeMF-p7ar JS 013dely a-ro-u-n-a-t- Fe deeding peritrich bell without touching it Then they quickly close the pharynx around the bell,, contract their body and break the bell from the stalk,, like eating the candy off a lollipop stick. They feed on rotifers and gastrotrichs by striking out snake-like at them. Stenostomum displays different behavioral patterns for feeding on different prey, indicating a relatively highly-developed nervous system.

In the Potomac River., there are two distinct sizes of Stenostomum. These Babdocoels, resemble rhabdophorine holotrichous- ciliate predators in being able to continue feeding as they divide asexually.
Such division produces, in tandem, a new daughter rhabdocoel of almost the same size with mouth parts of similar size thus able to feed on the same prey. Under ideal conditions, trains of four stenostomums intandeM are seen. Only the anterior one can feed and pass food to the rod-like gut of the developing daughters. Its ability to asexually reproduce allows Stenostomum populations to respond rapidly to the increase in its protozoan prey which also reproduces asexually.

In contrast, the rhabdocoel MAcrostomum reproduces sexually. It lays eggs with thick walls in which the embryos develop into larvae which batch and begin to feed immediately. Like the adult., the larvae have two ocelli and a very manuverable muscular pharynx with a ventral slit-like opening. Anteriorly., there are bristlelike hairs. As the larvae grow to juveniles and then to sexuallymature adults, the pharynx and mouth enlarge allowing them to include larger

Thus Macrostomum has the potential for feeding more broadly than Stenostom Tit does. In laboratory aquaria in which Macrostomum has become established, few other species can coexist
with 'it.=t can feed as a detritivore on sediments, or as a scavenger on the TetraMin fish food. The large (up to 3 mm long), broad, sexually-mature adults can be seen in glass aquaria living in the benthos. They do not move around much. Occasionally, large congregations of them are seen. The juveniles are much more active and travel throughout the aquaria feeding on whatever they can ingest. When the juveniles approach a sexually-mature adult, they are cannibalized. This shocking way of life is exceedingly successful for this species of worm. The highly motile juveniles range widely, feed broadly, and then serve as food for sexually mature, egglaying adults in the benthos.

Sexually-mature Macrostomum do feed on other prey than their own kind. They attacIZ newched snails and crawl into the shell under the operculum and eat the snail. Thus large adult snails may
coexist with Macrostomum in an aquarium, yet rarely do juvenile snails reach ac u: 1oO ." The large Macrostomum also catch and eat many species of oligochaete Worms. fey " at The smaller Chaeto
aste~r diastrophus but not the larger C. diaphanus.

Macrostomum eats microcrustacea such as ostracods, yet are

less successful with copepods. They have been seen feeding on rotifers of the genus Cephalodella. The rotifers Lepadella patella, and Monost.la spy. are` common prey. They ingest stato asts; the
dispersa oating structures of sessile bryozoans. Any moribund m1crometazoan such as raid worms and bryozoan zooids, are eaten by Macrostomum.

"`Macrostomum includes numerous ciliate species in its diet.

They eat ypotchs such as Eu lotes and Stylon chia which can avoid many other predators. When a tomuapproaches a hypotrich and
contacts their protruding cirri `tee prey dash away. Macrostomum circumvents this retreat by detecting the presence of the ypo rich in front of it, raising its blunt-shaped, flattened snout above the unsuspecting hypotrich, and then, lowering the snout to hold them down, shoves them into its muscular pharynx. The four upturned long caudal cirri of Stylon cy h a may account for its more frequent escape than Eu lotes.

crostomum eats vorticellids by pinching the bells from the contracts sta s by a quick motion of the muscular pharynx. After feeding, they settle and exhibit peristaltic motions in their gut. These interludes from feeding could be interrupted by 15 - 20 seconds of bright light causing them to repeatedly feed until they laboratory aquaria. Its tough-shelled egg probably protects it against certain predators that could eradicate the constantsized asexually reproducing Stenostomum. Nevertheless, it is Stenostomum that occurs more regu ar y and commonly on the

co ecti~ O floats.

The power of Macrostomum to limit species diversity was demonstrated by placing coon zed dishes from all sites in a 20-gallon Macrostomum-dominated aquarium for four years. Macro stomum elim1nate=ost all new immigrants and allowed on yy out ten pecies of protozoa and micrometazoa to coexist with it

Oligochaete worms

The oligochaete worm Chaeto aster is a dominant member of the Potomac River aufwuchs, espe is . y when there are abundant peri-tricks. There are two species of Chaeto""2caster, the larger C. diaphanus and the smaller C. diast~hus. Sot species reproduce asexually forming nearly single identical daughters which develop from the posterior segments. They continue to feed while the posterior daughter shares the common continuous intestine.

Chaeto aster d.i...aFhanus eats its relative C. diastrophus, which is about one third as urge. Chaet aster dia anus also eats the rhabdocoels, Stenostomum *and* juvenile c.ro stomum but not adults. It eats other nai worms like Nais communis. It feeds as a detritivore as well. It has been seen eating the rotifers Cephalodella sp., *and* ~Lep~ad,~ella patella. It is one of the few predators o the giant hetero rch cz late Stentor coeruleus, also eating the smaller S. roeseli. The relative gian zsm ot C.d3:aphanus over C. diastrophus a ows the larger oligochaete to coexist with or even era icate NTacrostomum while the smaller is eradicated by Macrostomum. If here is sufficient sediment in a laboratory aquarium, tie two Chaet aster species can coexist. They also coexist in collection s es which are overgrown with bryozoans, Cordylophora and filamentous algae.

The small Chaet aster diastrophus is more common in the Potomac River and is cons` is e key indicator predator for the whole upper Potomac estuary. In the following paragraphs Chaetogaster will refer to the smaller C. dust shus.

Chaet aster is the print pa Mcrometazoan predator of peritrichs.""s found :n scores on dishes colonized profusely with peritrichs. Chaet2gaster catches single vorticellids like V. cam arella V. macros oma, and V. mon~ lata by striking at tFle bells and catching them in its pharynx before the vorticellidts stalk is fully contracted. Many strikes are made before a vorticella is caught, illustrating how inefficient is this generalist (euryphagous) predator. Chaet aster also climbs into the branched noncontractile stalks of ist is and eats the zooids. It can eat the to remain attached in the recoiling colony of Carchesium.

Chaet aster has more difficulty eating the bells f th colonial pent' rich-aam aanella umbellaria whose bells are in clusters which contract into too large a mass. Resting Chaet aster like Macrosto~ can be induced to resume fee ing y turning up the microscopic light intensity for 15 - 20 seconds. Chaeto aster eats competing ciliate predators of peritrichs, such-as emz s and Amphileptus. It eats other ciliate predators like Loxop um

. ae_, togas er feeds on smaller sessile aufwuchs mem +ers lax e

the tiny choanorlagellates Codosi a s . It is a true omnivore including diatoms like Nav~iculaa an Gmphonema in its diet. It can feed as a detritivore or as a scavenger and has been seen eating the dead of its own species.

When feeding, Chaet aster diast„rroophus moves forward slowly using its two large batteries f anterior-ventral chaetae and the numerous smaller pairs of ventral chaetae on the posterior segments.

When it is threatened by a predator such as Macrostomum the larger chaetogaster species, or a copepod, it moves-TacTcwa s in a rapid inch-worm fashion. It responds in the same way to the suction of a compared to the many ciliates which feed on peritrichs. The ciliates do have an advantage in being able to produce cysts. Neither chaetogaster species has ever been seen to produce eggs.

Sessile peritrichs attach so tenaciously to the plastic petri dishes that vigorous agitation of the water in half-filled -dashes will remove most other aufwuchs microfauna including the predators of the peritrichs. The peritrichs are then counted and specific predators added in varying numbers and the prey counted after a period of predation. Such methods are used to confirm direct observations of predation. A senior thesis student, Mr. Richard Muckerman, placed 0, l, 2, 3, 5, or 10 of the oligochaete worm Chaetog.aster._diastro hus in dishes in which all sessile peritrichs were counted. The dishes were colonized in a 20-gallon aquarium stocked from the runoff area. After 6 hours exposure to the preda tion, the peritrichs were recounted. In each of the three replicate; of this experiment, as the number of oligochaetes were increased, th numbers of total peritrichs showed a steady decrease over the control.

The solitary peritrich Vorticella ~~icta showed a more precipitous and higher percentage decrease inn ers than did the number of the colonial Carchesium polypinum zooids. Direct observations indicate that this colonial with contractile branching stalks can contract into a large ball that can deter this oligochaete predator better than solitary Vorticellids.

Gastropod snails, pulmonate and gill-breathing

Gill-greathing snails seldom occur on the midriver buoys, however pulmonate snails of the genera _G ra_u_l~u _s, L aea and Ph sa are often collected. When such floats roug t~into theta *or-*atory, the snails survive and breed for years in the one or two-gallon aquaria. In all cases, only one species of pulmonate snail will remain in *a* single small aquarium.

At the Little *Falls* runoff area, there are normally large numbers of gill-greathing snails *such* as Lan?c, Bith nla and Goniobas . Most of these remain. under rocks or submerge " c *'-"in* sediment during the day. These snails do thrive in large, aerated 20-gallon aquaria, where they lay eggs which grow to fertile adults. In such aquaria are *found some* of the same aufwuchs species *which dominate at* the runoff area. These include the peritrichs *Vorticel*la *mono* ta, s stills hoffi and Platycola *to ic o* anc~t the suctorzans He o a rie eri H. rotunda an ttacineta stacina. Each of_ zese species as been sown to be b'ene itte *by the* presence of these snails and to be relatively immune to predation by them.

Vorticella monilata is the only one of the species of Vorticella that been sent to co-exist for extended periods with snai

This vorticellid forms large closely-attached groups that may number in the thousands. The whole group will form free-swimming telotrochs which swarm together as they migrate to a new attachment site. The telotrochs attach by jamming together on the surface as closely as possible and then growing their stalks. Swarms disrupted by shaking the closed dish will regroup at intervals of about 0.5 cm. New daughter telotrochs formed by division are found mainly around the periphery of the colony. These telotrochs attach within the colony, thus causing a state of overcrowding, which may eventually trigger the group to swarm. In the center of the colony, there are two morphotypes; one large with a long stalk and large bead-like pellicular tubercles on the bell-shaped body; the other is much shorter-stalked, smaller, and lacks the prominent tubercles. Tne smaller divides to form two microconjugants. These have a notch in the forward end which engages in the stalk of the maeroconjugant. The microconjugant moves spiraling up the stalk to the macroconjugant bell and unites with it. A haploid nucleus formed by nuclear *division* in the microconjugant unites with a similar nucleus in the macroconjugant, and fertilization occurs. A straight-line relationship was found between the number of conjugating stages and the size of the colony with a colony of 15 - 20 being needed to initiate this sexual process.

This close-knit social grouping of Vorticella monilata was also seen as a defense against snails. Sessile vort eli s are easy prey for snails, yet snails not only do not eat V. monilata but go

If the antennae of the snail touched the colony or they were placed on top a colony, the snails reacted violeiatly with thrashing movements. It is hypothesized that the large pellicular tubercles of the vorticellid contain mucous glands which secrete a chemical that irritates the snails. This proposed defense has
no effect on other predators of V. monilata such as the rhabdocoels Stenostomum and Macrostomum the ol.a.goc aete Chaeto aster certain c, it no=larvae, predaceous rotifers, or ci
predators such
as Trachelius ovum. In fact, the habit of forming the large social group may assist such predators. Social groups being heavily preyed upon have been seen to begin swarming activities.

Systilis hoffi is able to coexist with snails by forming a very stronstalk. - The telotrochs of S st_~~i_~~l~~i~s~~~ (as in O ercularia and some Zoothamnium species) are like a 1b'scuit, fla ene a=e anterior-p teRor irection and are very large. Upon attachment to the surface, they build a broad holdfast structure. Then they divide to form 10 - 16 zooids which form a fused mass of noncontractile stalks. Eventually the growing mass of zooids divides growing at right angles from two separate stalk bundles. In this way a large colony of thousands of zooids is formed. Feeding snails easily push over the single basal stalks of colonial peri= trichs with non-contractile stalks like Epistylis and Cam anella.
umbellaria yet they cannot push over the use stalks O a _ yS~t~1_1_i_~_s colony. ~lso the mass of zooids of S stllis contracts into a ro~mass too large for ingestion by certain pre aceous ciliates and rhabdocoels. Nevertheless, S stilis hoffi is rare in the Potomac yet sometimes dominates in laboratory aquaria. It has been found only at the runoff area and at Key Bridge. Often it is found attached to the shells of snails, which are regularly rasped clean by other snails.

Platyc.ol.ato icollis is a key indicator organism for the runoff area and Key Bridge. t has been collected regularly at Key
Bridge year-round since 1970. The clear lorica of Plat_yc~o_l~alooks like an old-fashioned hot water bottle lying flat on the surface with the feeding peristomal cilia of the peritrich sticking out the upturned bottle opening. The peritrich retracts into the lorica if disturbed. The loricas come in three distinct sizes; small, medium and large, holding up to one, two, or three Pla cola respectively. All three morphotypes occur concurrently in laboratory aquaria, yet the medium-sized one is the only one found in abundance in the river. Snails can not rasp off the lorica with its protected ciliate within. However, when the Plat cola is making the lorica, it can be squeezed out of the half-completed bottle. The lorica hardens and darkens with age. Eventually a hole appears in the brittle structure.
bacr rza olar have been seen entering such occupied or unoccupied orzcas and 'increasing in numbers and encysting inside the lorica. These predatory ciliates in their protected nook shoot

In dishes with snails, Chaetos ira mfllleri (protected only by its own lorica) are only found in protected areas such as under debris. Platycola are found distributed all over the dish surface.
Those stalkless suctoria with bodies flattened against the surface can coexist with snails. These include Hello h a riederi, H. rotunda, and H. erhardi. Also the small loricate suc oria'"_n

~etac neta mystaaina z.s ound in areas with snail predation. The Helio T i~a **species can not be dislodged from their attachment to plastic collection dishes by the strongest possible jet of water. After such treatment, the tentacles can be seen to be retracted or even lost. Also a percentage of the Helioghrva do not survive if the jet is very strong. Such washing** will **remove nearly all other aufwuchs organisms including algae. The Helloph ,a can withstand gentle rubbing with a horsehair brush, cotton,, orZ!hemWipes. Electron micrograph studies have shown Hello hr a erhardi to be covered with a mucous coat. Also it has .e thickest pellicle of any ciliate ever studied. The broad adhesive band in cross section shows the animal to be firmly attached at its periphery. Cultures of H. erhardi** var. **burbancki were sent to Bill Head of the University of Ueorg-`i=His scanning electron micrographs showed the pellicle to be covered with tiny bumps (also seen by us in transmission electron micrographs) and the broad band to form a smooth, tapering peripheral surface. The radula of snails would be less effective in feeding on Hel_~ iaphrya_erhardi due to its mucous coat, shape, surface texture, an thickness** of **the pellicle. The secreted broad band remains long after the Hello_h~ a.it surrounds are dead. Abrasive scrubbing is needed to remove**r **these circles from glass or plastic. They leave clear records of past populations.**

The broad band of Hello n a **erhardi is secreted by the elongated larvae as it settles-on a surface. The larvae spreads out on its cilia-covered ventral surface, loses its cilia, and secretes the broad band. During this time, the numerous contractile vacuoles (3 - 15) beat in almost exact synchrony.** A **senior thesis project with Tom McCarthy rvealed that colchicine, an anti-microtubular chemical at 1 x 10--l molar concentration, could enter the larvae as the cilia were being resorbed, disrupt the contractile vacuolar synchronous beating, and prevent the secretion of the broad band.**

Snails compete with amoeba, especially Arcella and Centro aan is as feeders on the aufwuchs covering of algae, ungs, **bacter detritus. Yet the snails make easy prey of such amoeba and thus eliminate them as competitors. Such amoeba are usually rare or absent at the runoff or Key Bridge or on floats with snails. Arcella and/or Centropyxis are so common and recurrent on the floats at aPoint as to e**

Also the specialized diatom-feeding holotriehous ciliates, Chilodonella and hypotrichs Urost la and Holosticha avoid snail pre~Tc.ation .ation. '"mien snails crawl about or a few minutes in -a white porcelain pan, their mucous trails become visible as suspended particles are caught on the sticky surface. By this mechanism, it is believed that snails can become plankton feeders especially on suspended bacterial and/or detrital particles. It was found that by adding gill-breathing snails to holding tanks containing rainbow trout fingerlings, the inevitable clouding of She water was prevented and the trout were maintained at 70 - 75 F for over three months without changing the water.

Thus snails can be selective predators rasping off individual sessile aufwuchs members, or randomly feed on the aufwuchs lawn; or, by recrossing their mucous trail, feed on bacteria, algae, and detritus caught in their trap. This illustrates that one must examine an organism's whole biology and ecology to delineate its niche. Another example of this would be the hypotrich Eu lotes eu. stomus which can capture and ingest individual holot S 'Tike Tetra Mme..na or Paramecium graze on surface aufwuchs algae and acteria., or rem~ain~-sessile and use its oral membranellae to bring in suspended food.

An experiment was designed to test the hypothesis that the presence of a specific predator like snails does influence qualitatively the species present in the aufwuchs community. More generally, it was postulated that organisms which are indicators of deteriorated conditions are those generalist species normally found feeding or in dormant stages in healthy: ecosystems--in small numbers. These generalists with minimal predator defense are easily controlled by the predators. When predator pressure is removed, then their prey, which is more widely feeding, dominates. Under such conditions of competition for food, defenses against predators can become liabilities.

A 20-gallon aquarium colonized from the Little Falls runoff area was used as the parent aquarium to set up four 2-gallon aquaria. The four aquaria received the same amount of parent aquarium sedi ment and water filtered through a #18 screen. Each received three petri dishes colonized in the parent aquarium. In two of the aquaria all juvenile snails were removed from the aufwuchs of the inverted petri dishes floated in styrofoam rings. In each

of the other two aquaria with juvenile snails, ten B_i_t_h~ yn_i_~a adults were added. The four aquaria, two with and two wit out~snai.ls received equally high aeration and a measured amount of TetraMin fish food (0.058) for one day. The following physical-chemical parameters were followed daily: D.O., turbidity, NO_3, P04, CO_2-9 H2S, and minimum-maximum temperature. Also total bacterial numbers were estimated using Tryptic Soy agar. Then aeration was made minimal and nutrification increased in two aquaria, one with estimated on the original three dishes colonized from the parent aquarium and the dishes colonized for four days.

In summary, in the two aquaria with lower aeration and high nutrification, a polysaprobic condition developed. As conditions worsened on days three and four, the gill-breathing snails in one of the polysaprobic aquaria were forced to the surface and most died. These polysaprobic aquaria were similar in having sessile, grazing, and benthic species, as well as similar bacterial numbers and physical-chemical conditions, characteristic of the area below the sewage treatment plant. It was believed that excystment accounted for some of the population appearances. In the well-aerated, less nutrified (ol gosaprobic) aquaria, there were clearcut evidences of the selective effects of snail predation on species diversity. (This was also seen to a lesser extent in the polysaprobic aquaria for days one and two.) In the aquaria without snails, small grazing ciliates such as Chilodonella, Cinetoehilum and As idisca increased in number. These s. owmoving ciliates arebelieved e` inadvertantly ingested by grazing snails. Known prey of snails, Arcella discoides, Ca anella umbellaria, and Vorticella increased in numb r a he aquaria w t out seal, s . Only in the, 3igosaprobic aquarium with snails did the loricate peritrich Plat cola and the stalkless suctoria Heliophrya rotunda increase in numbers. These were shown to be immune to`snail pr`3ation and profitted from their cleaning of the surface. Tnis experiment showed the need to include biotic forces, such as predation in evaluating species diversity changes. Past studies have tended to focus on physical-chemical influences and the presence of food and competition for food.

Cnidaria, sessile_predators

The colonial cnidarian Cord to hors was seen to catch and eat many types of microcrustacea 'T ng``t-1e cladoceran Ceriodaphnia, copepods, and ostracods. It was also seen eating oligochaete worms such as *Nais communis* and Chaet aster diastr hue. *The colony of* Co lo.p i~ o spover the sur ace or the` is sending up numerous hydra ontaining branches. In some dishes it completely covered the surface. Tnis enidarian is a good example of an aufwuchs organism that relies heavily upon the plankton for its food, again showing the need for the combined study of aufwuchs and plankton in order to understand biological factors in controlling species diversity.

This hydrozoan predator (Cordylophora) can be considered as an ecological equivalent of protozoan sessile predators like suctoria (a special analogy could b e made to the branching colonial suctorian Dendrosoma radians). Both are sessile predators which rely on random contact wit free-swimming prey. Hydra have not been collected in the Potomac River yet are abundant in tie swamps and ponds bordering the Potomac, especially on the undersurfaces and roots of duckweed. Tne tentacleless hydrozoan ~Protoh ~dra leukardi was found

Evidences of past populations on the dishes

During a collection period of from several days to a month or more, a succession of populations occurs on the dish surface. Many species leave clear evidence of their past population density even when they are absent from the dishes when collected. This is most dramatically seen in the stalks of peritrichs such as Epistylis and O ercularia which may cover the dishes. Without the living zooids on the stalks, the branches catch clumps of debris delineating each separate colony. Other peritrichs have loricas which take months to disappear.Tne flattened, oval loricas of Pla cola longic ollis have a small round opening at one end, and darken with time to a dark amber. Contractile stalks of Vorticella and Carchesium are broken down and disappear within houxgafter the liv ng bell dies or leaves as a motile telotroch. Yet some individual Carchesium of inum colonies leave a distinctive amber,spread ho fast with a central stalk-sized clear area. The tests of amoeba like Arcella, Centropyxis,and Diff lu iiaa remain many days after death of their occupants. The tubes -oot chironomids were usually occupied by a chironomid or oligochaete worm, these choice habitats being recolonized shortly after the builder pupated and metamorphosed into an adult dipteran. The square, tapering tubes of Rheota n Xt_a~rsus with their four slender projections at their entrance, existed tTor day's after the dipteran had vacated them. Bryozoan tests of Plumatella repans gradually disintegrate after the occupants died wit portions st1 present weeks later. Empty dipteran and bryozoan tests served as second homes for various oligochaete worms such as Chaeto aster, Nais and Dero. The branching theca of the colonial cni arian C~o_r_y ~lo,phora-'Tasts for months after the occupant is dead. The lorica o tori.a also lasted for several days after death of the occupant. Many of these are so morphologically distinct, that the species can be determined.

The presence of tests, chironomid tubes, bryozoan statoblasts, algae, and masses of detritus provide microhabitats for certain species of protozoa and micrometazoa. By providing topological barriers to predators, they allow an increase in species diversity.

Gnotobiotic studies with known, cultured populations

Generally, there is a broad gulf between those ecologists who approach ecosystem dynamics by analyzing natural systems and allowing nature to dictate their experiments, and those who create labor atory communities by combining cultured strains of only known organisms (or gnotobiotic communities). The senior investigator sees merit in both extreme approaches as well as many intermediate situations such as aquaria and experimental rivers composed of combined aquaria. Gnotobiotic systems offer the greatest repeatability; yet, at the same time, are the furthest removed from the reality of the natural world. Nevertheless, certain ecological questions can be

asked using gnotobiotic microecosystems, with reasonable scientific confidence that some unknown factor did not dictate the answer. In the natural world one is never as sure of such cause and effect relationships; however, one has a certain human satisfaction in suggesting the most probable causes and their effects. Two of the dangers in gnotobiotic studies are that you have chosen your isolated population or individual from the extremes of the population, and that your culture methods altered the organism.

The Potomac River sediments below the Blue Plains sewage treatment plant have been shown by a contractor for E.P.A. Annapolis Field Station to be quite high in certain heavy metals.
For example, lead, from the runoff from the city's vehicle emissions, reaches 90 parts per million in these sediments. Suctoria such as Heliophrya erhardi are rarely found at or below the Blue Plains sewage treatment plant. It was found that the surface water, when millepore filtered, did not affect isolated cultured H. erhardi. We had determined that benthic ciliates like Paramecium mu timicronucleatum do serve as food for these suctoria.
t was p so tulate tat the ead in the sediment was being concentrated by the bacteria and passed on in increasing concentration up the food chain to the bacteria-feeding Paramecium and then to the suctoria.

A senior thesis student, Mr. Raphael Schach, attempted to test this hypothesis with a gnotobiotic system of Eseherichia coli (cultured on buffered Cerophyll medium) --- Paramecium mult micro nucleatum --- Heliophrya erhardi. The P. mint' cronuc`leatumwere cultured monaxenically on E[7]. coli. Mass cultured non-moti e suctorians in their floating stage were washed of bacteria in sterile Cerophyll medium by the Parpartis method. Lead as Pb(NO was

added to the Cerophyll experimental petri dishes at 0, 6)2 ,40, and 90 ppm and an equal amount of E. cola., 25 P. multimicronucleatum,and
5 H. erhardi were added, and the sTzes place on a gent e mec meal

mixer. here were four replicates of each dish and the whole experiment was run twice. The paramecia and HeliophEZawere counted at three hours and then daily for seven days. A precipitate appeared in all cultures containing lead and increased with its concentration. These precipitate particles were ingested by the paramecia! Whereas the paramecia controls increased to a mean of 42 or 67 (Trials 1 and 2 respectively) at 72 hours, and leveled off; the 10 ppm increased to 42 or 55; the 40 ppm to 17 or 39 with some division in both trials, and the 90 ppm decreased steadily to 10 and 18 by 72 hours, falling to 4 or 0 by 144 hours. The suctoria were almost impossible to count hidden among the precipitate particles, yet in the controls a few did divide. Apparently these conditions did not favor the suctorian or the time scale was too short. Also difficulties arose due to foreign bacteria brought in

and Dickson (1973) found that 90 ppm lead was a lethal level for Paramecium. Our studies show that even lower levels disrupted repro upon so the exposed populations dwindle and die.

Much time has been spent by the senior investigator acquiring the skills and materials needed to carry out gnotobiotic studies. During the last year attempts were made to grow suctoria on Tetra h mena riformis grown on non-defined axenic media. The He iopz a wou peat them, grow,, but not divide. This year the labors-' ory as acquired the chemicals needed to grow paramecia on chemically-defined media, has overcome the technical problems and now has vigorous stocks of axenic Paramecium aurelia (Soldo strain 2995) growing in the laboratory. This common cue prey of many suctoria will allow even simpler food chain and toxin magnification studies, as no bacteria are present.

Aquarium studies

Many additional species appear in laboratory aquaria containing the floats collected from the sites. These species were not present when the counts were made of the populations on the collection dishes. The presence of some of these may be due to excysted ciliate predators or hatching of eggs of predaceous rotifers. However, these are believed to be present on the floats representing dormant populations. Each year for laboratory exercises, infusions from many plant sources around the laboratory are allowed to develop their excysted faunas in 250 ml beakers. The species which come from these windblown, ubiquitous cysts, such as Col2oda, Col imp dium, Tillina, and S athid um, are absent from the Potomac River and the aquaria colonize rom Potomac River floats. Possibly, aquarium rotifers such as Philodina arise from such wind-blown cysts. Also, sewage worms (Ps c_h_o~da or other insects may enter aquaria and lay eggs, even though eac'i aquarium is covered with HandiWrap plastic sheets. The TetraMin fish food used to nutrify the aquaria has been checked repeatedly and does not excyst protozoa or micrometazoa. The floats contain habitats which are not sampled for fauna, such as between the rubber stoppers, the interstices of the styrofoam cups, etc. Within these areas, nonencysting species such as Paramecium and S stomum can live. These have been counted as members off' the autwuc is only a few times in the past five years, yet over half the aquaria eventually show species of Paramecium or S irostomum living in their sediments. Great care is taken to avoi cross-contamination with each aquarium having its separate sampling tube. Also rhabdocoel worms such as Macrostomum may come to dominate an aquarium which lacked them in the"co ec ion dishes.

Successive follow-up studies of these aquaria with the river floats and their dishes have special value in observing predator-prey dynamics. A few hours after the float is placed in the aerated aquaria, many species migrate to the surface especially near the airstone. Sessile species form visible patterns against th l

Back-to-back cover slips inserted into a thin piece of styrofoam collect these species. These coverslips are collected after 24 - 48 hours and used to make excellent permanent slides, as there is little obscuring debris. The most drastic changes in the floats is the rapid loss of all algae unless artificial light is provided. Artificial light usually selects for blue-green algae rather than perpetuating the normal green algae--dominated community. The algae is eaten by chironomid larvae, snails, and various ciliates. Also the abundant filter feeders, such as peritrichs, rotifers, and bryozoa, rapidly *reduce in* number. For several days, there is a bloom of their predators or scavengers. Eventually the aquarium reaches a balance of species in an ecological equilibrium. An hypothesis was put forth that these represent predator-prey complexes of the detritus food chain. This hypothesis has been confirmed each time an established aquarium has been studied exten sively. Food chain links first found in these aquaria have then been sought out and found in collection dishes taken directly *from* the Potomac River.

Within weeks, a considerable amount of detritus forms on the bottom of these 1 or 2-gallon aquaria. This detritus has an orange oxidized top zone, a grey redox discontinuity zone, and a bottom reduced black zone. Hours after the TetraMin fish food is added

to the aerated aquaria (every other week), the water begins to cloud up with suspended, dividing bacteria. The organisms in the now less oxidized sediments move to the surface where the *floats* and dishes are suspended. The paramecia, S *irostomum* flagellates, small ciliates, hypotrich ciliates, rots, an ostracods in the sediment serve as food for the surface swelling suctoria, heliozoans, Cordy to. ph.ora and r bryozoans, predaceous rotifer, and other predators feeders. A similar process probably also takes place in the Potomac River with change in sediment oxygen flux dynamics during changes in flow rate and tidal currents. This illustrates the need for combining studies of the surface aufwuchs communities and the sediment benthos as well as with collateral studies of the plankton.

Ostracod predation on Spirostomum

Several students have done their senior theses on the organisms living in these aquarium sediments. Several aquaria had abundant S iro~stomum teres and S. intermedium which could be rapidly extract-ed from the se 3.ment using t" he akin test-tube method devised by the senior investigator. Mr. Terry McGovern tested the ability of these two species to withstand shortwave (2537P maximum) ultraviolet radiation. The 0.72 amp UV source was placed 10 cm above a drop of water on a cover slip containing the Spirostomum. Equal amounts of the aerobic black, or oxidized brown sec- iiment from the parent aquarium was added. Without the sediment, the S. intermedium

and S. teres lived two minutes and three minutes respectively,ut lasted 60 and 90 minutes in the brown, and 90 and 180 minutes in the black sediment. It is believed that this protection was made possible by the UV being detected along the whole length of these long, slender ciliates, allowing them to coil their whole bodies under the protective particles of detritus. It was postulated that the cortical granules were involved in this detection of UV. Another senior, Mr. Mark Nowel.l showed with electron microscopic studies, that the lethal dose of UV caused the cortical granules to be discharged from their vesicles. It is believed that these important bacterial feeders, which are abundant in tide-exposed mudf lats, sense the UV of the sun and hide beneath the sediment particles.

S iro~sto<u>mum</u> is a difficult organism to grow in large numbers. Senior sent, Mr. James Belluardo attempted a wide variety of culture media to obtain profuse <u>Spirostomum</u> growth. The senior investigator discovered that <u>Spirostomum</u> could be grown in large numbers in test-tubes containing pasturized aquarium sediment if a vial was suspended in the test-tube to reduce aeration. Periodic additions of cerophyll media mass cultured large populations of S irostomum.

The senior investigator has noted that in the benthic community extracted from aquaria containing Spirostomum, there were also abundant ostracods of the genera <u>iris</u> and7 <u>rid</u>_o sis. After several days extraction, the <u>Spirostomum</u> disappeared,, then the Paramecium and finally the Eu lotes. It was suspected that the ostraco ss were feeding on t ese ciliates. The feeding parts of ostracods are hidden beneath their two valves making direct observations of feeding very difficult. The senior investigator has watched maAy possible acts of predation., but only a couple seemed to be obvious examples. To test this link in the sediment food chain, senior student, Mr. Robert Johnson placed varying numbers (0, 1, 2, 3, S, and 10) of C ridopsis in petri dishes each containing ten S irostomum interme <u>ium</u>._For four replicates of each number of prey, the numbers of : irostomum remaining were counted after 8, 16, 24, 32, 40, 48, 5 anU 72 hours. All experimental dishes showed a decrease in <u>Spirostomum</u> over the controls as the number of ostracods was increased as the time increased. Mr. Johnson also saw direct acts of predation. It is also possible that the ostracods may be feeding by breaking up the [illegible]

Aquaria study. **<u>of role of predators in determining species diversity</u>**

After an aquarium has been set up in the laboratory for several weeks, its species diversity falls to a relatively stable level and a sort of ecological balance is obtained. It was observed that the species diversity from aquaria established from colonized floats often reached different ecological balances even when collected only a month.apart. It was postulated that the presence or absence of certain predators at the top of these aquarium food chains

determined the resultant species diversity. This was tested by setting up seven aquaria all from the same area, the Little Falls runoff area. Three of the aquaria were twenty-gallon aquaria established with rocks, mud, and water from this area. These maintained relatively high species diversities including several species of snails, Dugesia, the isopod Ascellus, and amphipod Gammarus. Four **-gallon aquaria were** se up **and stocked only with plastic petri dishes all colonized in the runoff area. After almost two months of continuous aeration and feeding of the**
seven aquaria with TetraMin fish food, they were sampled for all their fauna. Sediment was extracted, rocks studied, and all floating inverted petri dishes studied. The estimates of numbers of each species were recorded in table form as to their relative abundance using the forementioned scale from 0 to 7. The three large aquaria had 41, 43, and 48 species of benthic and aufwuchs fauna while the small aquaria had 18, 20, 25, and 35. Each twenty-gallon aquarium held about 5 gallons of water while each two-gallon aquarium held about 1 gallon. The large aquaria contained rocks and sandy sediment which provided additional habitats. A careful study of the species presence and abundance showed that specialized predators occurred in aquaria containing their prey. The most astounding results were the distinct role played by generalist predators like Chaetogaster diaphanus and C. ~diastrophus, Macrostomum, and Stenostomum~ in determining whi species were present. Only in one Urge aquaria with adequate sediment were both species of Chaetogaster found. Macrostomum was absent from aquaria possessing Chaeto aster diap hanus **eats its juveniles. When a predator was absent., such as the ostracod Cy** rido..Psis, **then its prey, Spirostomum, was much more abundant. Other examples were rotifer Lepadella patella rt ella having lowest numbers where its predator Homolozoon** was **abundant, and Stentor roeseli absent from aquaria having Chaetogaster dia hanus. Snails were abundant in the large aquaria yet absent from** al **the small aquaria except one that had a couple of small limpets. The flattened stalkless suctorian ~Heli2p~hr. a_rotunda and the loricate peritrich Plat cola was present in all three large aquaria with snails, but only** e **of the four small aquaria without snails.**

Since the four small aquaria and three large aquaria as groups were established with similar fauna, it is believed that these results do shed light on the role of predation in

Experimental Rivers and toxicity of sewage effluent to fish

a **5-gallon Nalgene bottle inserted halfway between for a sediment trap. Holes were drilled in the glass aquaria and Nalgene bottles at a height of 10 cm, and glass spouts attached with silicone aquarium cement. Each of the four pairs of glass aquaria received sediment and 15 gallons of water collected from the four sites: Hains Point, Blue Plains sewage treatment plant, Broad Creek, and Piscataway Creek. Each aquaria had vigorous surface aeration by means of a Silent Giant pump.** A **common 50-gallon reservoir was filled with water collected at Key Bridge. Pressure valves at the beginning and end of each experimental river were used to obtain an equal and constant daily flow of the Key Bridge water by gravity flow through each river.** (Figure 8)

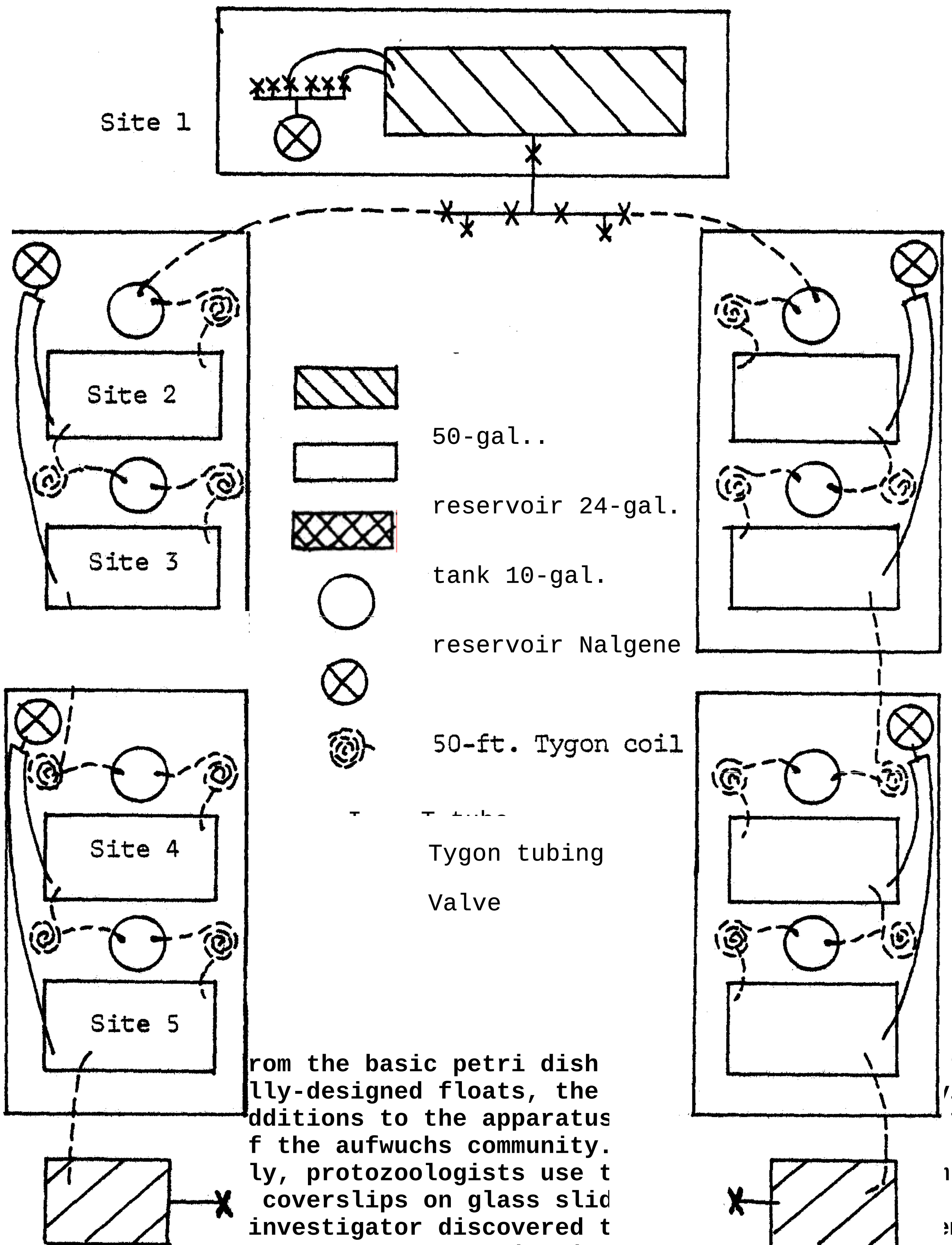
To pick a suitable test animal before the flow was begun, rainbow trout were placed in each aerated aquarium in one river, and golden shiners in the other. The rainbow trout died in a

day or more in the aquarium water from around Blue Plains, while the golden shiners did not appear effected.

Ten golden shiners were placed in each of the eight aquaria. In **one river, Blue Plains effluent water, in the farm of ice cubes, was added every eight hours to give a 1:20 flow of sewage water to Key Bridge water. The other side received dechlorinated tap water (which closely simulated the proposed 1977 sewage plant effluent). Physical-chemical parameters and bacterial counts approximated river conditions. A fish kill was produced on the experimental side in the aquarium receiving the sewage, and the next aquarium. When sewage water was discontinued, the neurologica.lly-disoriented dying fish returned to normal as the rivers were gradually f lush4d out with Key Bridge water. The experimental river allowed us to rule out dissolved oxygen, temperature, and bacterial numbers, as factors. Possibly an insecticide was responsible. At this time of year there was a heavy application of methoxychlor to Washington's elm trees to control Dutch Elm Disease. Methoxychlor is especially toxic to fish. Concurrent with our experimental fish kill, a fish kill of similar nature was occurring in the Potomac River at Blue Plains and below to Broad Creek**

Innovations and Inventions

In the spring of 1974, the senior investigator, assisted by two senior thesis students (Mr. **Don Macina and Mr. Rtck B.rhle) set up two experimental rivers in the observatory cottage.** Each **experimental river was composed of four 25-gallon all-glass aquaria joined together by 100 feet of 1/2-inch tygon tubing with**



rom the basic petri dish the
lly-designed floats, the /ised
dditions to the apparatus for the
f the aufwuchs community.
ly, protozoologists use t ı jelly to
coverslips on glass slid The
investigator discovered t emperature
Silicone Grease was superior in being non-toxic and more viscous.
It permitted prolonged observation of preparations, even up to
six days. To keep these preparations from drying out, a new moist
chamber was devised. It was constructed by affixing with
polystyrene

Figure 8. Diagram of the two experimental rivers located
in the Environmental Science Laboratory at Georgetown University

glue,a 50 x 12 mm plastic petri dish bottom in the center of a 3-inch plastic petri dish bottom. Water placed in the 3-inch plastic dish would not move up the non-wettable plastic and spoil the glass slide preparation supported on the walls of the 50 x 12 mm dish. The dry area in the 50 x 12 mm dish allowed for easy removal of the slide preparation.

As a slide preparation, with the cover slip supported by petroleum jelly or silicone grease, begins to dry, the organisms can be compressed by the coverslip. It was found that the cover slip could be glued permanently on two sides at a constant height with white silicone bathtub cement.

Many aufwuchs organisms move so rapidly that identification at high magnifications is not possible. A slowing agent is added to retard their movement. For protozoa, XA methylcellulose or commercial viscous mixtures like ProtosloLI can be used, however, these are relatively toxic. The senior investigator discovered a new slowing agent, poly(ethylene oxide), a water soluble resin of four million molecular weight, A senior student, Chip Feise, tested poly(ethylene oxide) at solutions of 0.25, 0.50, and 1.0%, to 1.0% methylcellulose and Protoslo for their relative ability to retard forward movement of five species of protozoa: Paramecium aurelia, Didinium nasutum Blepharisma undulans, Proro on' at odon an u g~lena rac lis ~liis vzscos astic resin was oun to e supers. r for sowing the protozoa. A toxicity study of these solutions on Paramecium aurelia showed 1% methylcellulose and Protoslo quite toxic lter our ours, while the poly(ethylene oxide)'was essentially nontoxic, even permitting divisions to occur after four days under a coverslip! This new slowing agent has great potential for applications in teaching and research.

Over twenty years ago, Dr. A. A. Schaefer invented a special device to place on a compound microscope stage that could compress a soft-bodied protozoan between a circular cover slip and piece of glass without producing shear forces. Over the years, hundreds of these were manufactured and sold. They have been used all over the

world for numerous studies, including studies of food vacuole content, and biomass of individual protozoans. This Schaefer microcompressor has limitations in its design which allow some shear movement. Also the Schaefer microcompressor complicates focusing, and in order to move to other objective lenses, the lens must be moved vertically, thus losing focus. Six years ago, the senior investigator designed a new microcompressor that has virtually no shear movements. It permits one to measure the amount of compression in microns, being sensitive to 0.2 microns vertical deflection. The microcompressorts low profile permits free movement of objective lens up to even oil immersion. The Spoon microcompressor can be mounted on the stage and compression commenced in seconds. Following present trials with the prototypes, funded by this grant, this microcompressor will be announced in scientific publication, and its manufacture and marketing announced.

SECTION C

1971 AND 1974 SURVEY POTOMAC RIVER AUFWUCHS COMMUNITY

Prologue

In the summer of 1971, the floats were put out and recovered from the Annapolis Field Station E.P.A. sampling boat, thus our biotic data and E.P.A. abiotic data fell on the same dates. The float recovery program did not begin until June 30 and was at monthly intervals through July 26, August 25 and September 30, then for 9 days to October 9, and 21 days to October 30. In 1974, our sampling was independent of the E.P.A. abiotic sampling, yet there was a correlation of about a week or less from January to July. In 1974, biotic data was collected on March 1, then
45 days to April 16, another 45 days to May 28, then 40 days to July 8, 31 days to August 8, and then 16 days from the October 4 set out of floats until the October 20 pick up.

Based on the time of collection, duration of colonization, and sites sampled, the best months for comparison between the 1971 and 1974 biotic data are June 30, 1971 to July 8, 1974,
and July 26, 1971 to August 8, 1914. The runoff site was sampled successfully only in April. At all other times it was vandalized, removed, or dc-stroyed by heavy flow rates.
Floats were set out throughout the year of 1974 starting in January 27 through to late November, with every intention of maintaining a monthly collection schedule. Early problems with breakup of the floats was corrected through structural redesign to strengthen the float, so that from April to August, recovery was 100%! The September mid-river floats were all lost by rusting of the float hooks. The October floats for areas 4 and 5 and
Key Bridge were collected, but illness prevented their being studied.
Repeated attempts were made to put out floats during October and November, yet were prevented by high winds, motor trouble, etc.
In all, 23 separate boat trips were made on the river in 1974 by the senior investigator to obtain this abiotic data and to collect and set out floats.
The Blue Plains sewage plant was sampled monthly during the summer, however, the studies were useful *only in* a qualitative sense. A new sampling float has now been designed that will permit quantitative studies.
Based on the studies of these data for 1971 and 1974, some changes are being made in the sampling program. First, two floats are being set out at midriver sites 2 and 3 to insure recovery.
The float at the runoff area is now out of reach of passersby.
The final sedimentation tanks at the Blue Plains sewage

plant will be sampled°monthly with the newly-designed floats. The rope from the buoy is now tied directly to the float without a metal hook that can rust out. The rope is thus collected with the float. We have added to our own abiotic sampling pro gram the following: D.O. by Winkler method,and B.O.D. using standard bottles and the Hach manometric method. A special effort is being made to have our sampling dates fall as close as possible to the E.P.A. sampling dates. Total solar radiation is being determined daily and data on daily water flow at Great Falls is being acquired. Also, we now have our own boat operational for a backup when the Lightship range boat is inoperative or unavailable.

Total occurrence of species for 1971 and 1974

Generally, the same species had the highest total occurrences for the 1971 and 1974 data (See Appendix B, far right columns marked TO, total occurrences). In 1971, there were 25 floats collected and studied, and in 1974 there were 27. In the following discussion where two numbers appear in sequence, the first denotes the 1971 total occurrence of the species, and the second denotes the 1974.

Zoof lagellate and sarcodine species were considerably more numerous in 1974. It is not believed that the differences were due to a more thorough search for these smaller species as similar scanning procedures, magnifications, and scanning times were used in 1971 and 1974. Note the occurrence of Codosiga bot tis (5,14), Cent ro is aculeata (13,10), and Mayorella vesper io 116).

m~t e olotrichs, the most recurring species for 1971 and 1974 was Chilodonella nana (12,20). The carnivorous ciliates Amphileptus sp. (4,13 , an LLiitonotus fasciola (2,14) were both seen more often in 1974.

Overall, the most frequently seen species of the microfauna for 1971 and 1974 was the peritrich Vorticella campanula (16,24). Vorticella microstoma (4 19) and V. iota 3 were common in 1974.~~The colonial Carchesium poly-pi 8,14) occurred in the highest population n ers on floats often reaching a 6 and even one 7 designation. E ist lis hentscheli (8,16) and Opercularia coronata (4,16) also recurrence on the floats. Tne heterotrich Stentor roeseli (3,14) was common in 1974. Note the numerous occurrences 7¯n=4 of Stentor coeruleus (0,10),_which was not seen on floats in 1971. Both~77¨these stentor species are large and conspicuous and are good indicators that the increase in number of species per float for 1974 was real and not based on differences in counting efficiency.

The numbers of species of hypotrichs showed a marked increase in 1974. Aspidisca costata (2,12) and the smaller A. sulcata (1,9) were common as was Actinotricha sp. (4,12). X11 t

During the summer survey of 1970, Helio h_r_ ya rotunda (10,14) was collected only in August at site 1.[I] ttIspread downriver in 1971, and by 1974 was the most recurring species of suctorian
being present at all sites. Acineta tuberosa (10,12) remained high in occurrence, while Soleno a s . , 3) fell greatly in
1974,and Toko hr a qadriprt_a 9, 7rdecreased. Note that each of the three occurrences of Solenophrya in 1971 are 1[1]s meaning only one specimen per dish

Among the micrometazoa, the bryozoan Plumatella repens (9,16) increased in occurrence in 1974. The diversity he rotIfers increased in 1974, yet the three most recurring species remained highest, Brachionus s2 Sat 15), Philodina roseola (6, 15), and

the ploimate rotifer at was epizooic on peri cch stalks (11,11). Also the two most recurring oligochaetes in 1971 were most recurring in 1974, Chaet aster diastrophus (7, 15), and Nais communis (15,18). Cnironomiccurrence o and 1974 were similar. These chironomids were not identified to genus, yet the scrapings from each float containing larvae and the winged adults are preserved for future study.

For the 25 floats studied for 1971, there was a total of 111 different species (including groupings), 69 protozoan and 42 micrometazoan. For the 27 floats far 1974, the total was 179 with 124 protozoan and 55 micrometazoan species. This shows that the increase in total different species was due mainly to a near doubling of the number of protozoan species.

The two early summer months were sampled both in 1971 and 1974. Table 1 shows a comparison of the number of species of protozoa, micrometazoa, and microfauna at the five river sites for these two months. When this comparison is made, it can be seen that there was about a doubling of total microfaunal species at each site for 1974 over 1971. The protozoan and micrometazoan component of the total microfaunal species number per site varied from site to site, generally showing a doubling from 1971 to 1974.

Table 2 shows the total number of species of protozoa and micrometazoa, and their combined total as microfauna. The number of species per float ranged in 1971 from 5 to 29. In 1974, the range was from 2 to 68. Overall, there is about a doubling of the number of species between the 1971 and 1974 collections. Table 3 shows the average number of species of protozoa, micrometazoa, and total microfauna at the sites going down the river. At most sites.,,. these averages showed about a doubling of the numbers of species for 1974. This shows that the average number of species tended to decrease going down river and the numbers did not recover at

TABLE 1. Comparison of numbers of species of protozoa, micrometazoa, and microfauna at the five river sites for summers of 1973 and 1974.

A. June 30, 1971 | C. July 26, 1971

B. July 8, 1974 | D. August 8, 1974

Site		1	2	3	4	5		1 or KB	2	3	4	5
Total Protozoan	A	1	-	13	19	-	C	7	9	21	7	
Species	B	25	25	29	31	17	D	38	30	36	41	23
Total	A	18	-	8	5	-	C	17	11	10	13	-
Micrometazoan Species	B	16	17	19	17	11	D	30	24	17	6	17
Total	A	29	-	21	24	-	C	24	20	31	20	-
Microfaunal Species	B	41	42	48	48	28	D	68	54	53	47	40

TABLE 2. Total of species of protozoa (Tp_{io}), Micrometazoa (TMM), and Microfauna (TMF) for all sites sampled in 1971 and 1974.

1971 June 30 July 26 August 25 Sept. 30 Oct. 9 Oct. 30 1

24 1 2 3 4 1 2 3 4 5 1 2 3 4 5 1 2 34 12 34

TPro D M F O

. N . ® ~ O

= R ® O O O

TMM ® M . 1 N

M M 1 0

1974 March 1 April 16 May 28 July 8 August 8 Oct.20

\- 2 3 4 5 KB 2 3 4 5 ROKB 2 3 4 5 KB 2 3 4 5

TPro - ~ 3 1 [2 2 2 3 5 2 7 1 3 i ~ 2 5 5 9 3 1 1 i 4 1 _ 5 2 5

ME

TMM e M 1 1 1

TMF

TABLE 3. Comparison of average number of species of protozoa, micrometazoa, and microfauna at the five river sites for 1971 and 1974.

A. 1971

B. 1974

Site	Times Sampled A	Times Sampled B	Average Species A	# Protozoan B	Average Micrometazoan Species A	# B	Average Microfaunal Species A	# B
1 or KB	6	4	10.7	32.0	12.0	20.3	22.7	52.3
2	5	6	10.4	26.7	4.8	13.8	15.4	40.5
3	6	6	9.7	21.0	4.8	9.3	13.7	30.3
4	6	S	11.0	24.0	5.7	7.6	16.7	31.6
5	2	5	7.0	18.0	6.0	8.6	13.0	26.6
Overall Average # of Species per Site			10.2	24.0	6.6	11.6	16.8	35.6

The <u>overall</u> **average number of species per site showed the protozoan species as 10.2 for 1971, and 24.0 for 1974, micrometazoan 6.6 and 11.6., and microfaunal 16.8 and 35.6. This shows again about a doubling of species numbers from 1971 to 1974 with the protozoan species showing a higher increase than the micrometazoan species.**

Tables 4 ; 5 , and 6 show a comparison of the 1971 and 1974 physical-chemical data for two summer months. Three different combinations are shown since the abiotic data did not coincide with the biotic. Table 4 **shows a comparison of the June 30, 1971 to June 18, 1974 abiotic data. The earlier 1974 data shows about a 3**^{0}C **difference in temperature with considerable difference in the dissolved oxygen in 1974 over 1971 making any comparison questionable.**

If we focus attention on Table 5 **comparing June 30, 1971 to July 15,. 1974, and Table** 6 **comparing July 26, 1971 to July 15.,1974, several trends can be seen. In Table** 5, the **tempera tures were about a degree different. Dissolved oxygen was about half at most sites for 1971 over 1974. At sites 2 and 3, the Secchi disc reading for 1971 was much lower showing higher turbidity. Data for phosphorous and nitrogenous compounds were higher at nearly all sites in 1971 over 1974.** In **Table** 6 , **the temperature was about 1.5**^{0}**C higher at each site in July 15, 1974 compared to July 26, 1971. In spite of the warmer water in 1974, the dissolved oxygen was about double at all sites but 4 (the 0.54 reading for site 1 in 1971 is suspect). The secchi disc reading indicates higher turbidity at sites 2, 3, 4, and 5 in 1971. Generally, phosphorus and nitrogen data for 1971 is higher than 1974. However., the ammonia level was higher at sites 3., 4, and 5, for 1974.** The **total organic carbon was considerably higher at all five sites in 1971.**

In conclusion, the comparison of the available abiotic data shows that the conditions in the river were improved for these two summer months between 1971 and 1974. From a quantitative point of view, in terms of species diversity,, there was a substantial increase in the number of species collected at each site from 1971 to 1974

Finally, we can show even more importantly a qualitative improvement in the microfaunal community collected in 1974 over 1971. This comparison is more useful if we compare only the two summer months for 1971 to 1974. To facilitate this comparison, the abiotic data in Appendix B is positioned so that these two months for 1971 and 1974 for each group of organisms is in the same rows (note dark black lines).

TABLE 4 .

Comparison of physical-chemical data determined by E.P.A. Annapolis Field Office for June 30, 1971 and June 18, 1974.

Site	A. June 30, 1971 B. June 18, 1974	1	2	3	4	5
Temp. ^{0}C.		28.0	28.0	29.0	28.5	28.0
Water	B	24.0	24.0	26.0	25.0	25.0
D. 0.	A	6.63	4.39	2.74	1.78	2.69
(mg/1)	B	7.38	7.76	7.18	4.71	4.94
Secchi Disc	A	22	13	16	22	23
(inches)	B	24	22	15	20	22
Total P	A	0.227	0.451	1.514	1.514	1.122
PO_4(mg/1)	B	0.165	0.238	0.654	1.005	0.866
Inorganic P	A	0.063	0.138	1.315	1.370	0.945
PO_4 (mg/1)	B	0.012	0.007	0.372	0.584	0.556
TKN	A	0.739	0.867	2.079	2.461	2.006
(mg/1)N	B	0.477	0.411	0.822	1.561	1.570
NO_2 + N03	A	0.188	0.272	0.393	0.453	0.614
$N0_3$ - N (mg/1)	B	0.580	0.500	0.720	0.695	0.905
NH_3 (mg/1)N	A	0.032	0.221	1.524	1.986	1.590
	B	0.070	0.080	0.385	1.095	1.145
chlorophyll a	A	33.3	45.0	26.3	27.8	47.3
	B	39.0	52.5	42.0	25.5	39.0

TABLE 5.

Comparison of Physical-Chemical data determined by E.P.A. Annapolis Pield Office for June 30, 1971 and July 15, 1974.

A. 1971, June 30 B. 1974, July 15

Site		1	2	3	4	5
Temp. ⁰C. Water	A	28.0	28.0	29.0	28.5	28.0
	B	29.0	29.0	29.0	29.0	28.5
D. 0. (mg/1)	A	6.63	4.39	2.74	1.78	2.69
	B	8.01	7.46	4.26	3.31	6.92
Secchi Disc (inches)	A	22	13	16	22	23
	B	23	21	23	25	22
Total P		0.227	0.451	1,.514	1.514	1.122
PO_4 (mg/1)		0.252	0.311	1.286	1.329	0.852
Inorganic P PO_4 (mg/1)	A	0.063	0.138	1.315	1.370	0.945
	B	0.008	0.023	0.868	0.900	0.392
TKN (mg/1)N	A	0.739	0.867	2.079	2.461	2.006
	B	0.507	0.530	1.871	2.222	1.556
NO2 + $N0_3$, - N kmg/1)	A N63	0.188	0.272	0.393	0.453	0.614
	B	0.001	0.001	0.161	0.204	0.430
NH_3 (mg/1)N	A	0.032	0.221	1.524	1.986	1.590
	B	0.022	0.022	1.375	1.716	0.913'
chlorophyll _a	A	33.3	45.0	26.3	27.8	47.3
	B	37.5	45.0	39.0	45.0	88.5

TABLE 6.

Comparison of Physical-Chemical data determined by E.P.A. Annapolis Field Office for July 26,,'1971 and July 15, 1974.

A. 1971, July 26
B. 1974, July 15

Site 0		1	2	3	4	S
Temp. C.	A	27.0	28.0	27.5	27.5	27.0
Water	B	29.0	29.0	29.0	29.0	28.5
D. 0.	A	0.54	3.45	2.83	4.66	3.96
(mg/1)	B	8.01	7.46	4.26	3.31	6.92
Secchi Disc	A	24	16	19	20	18
(inches)	B	23	21	23	25	22
Total P	A	0.277	1.590	1.627	1.205	1.055
PO_4 (mg/1)	B	0.252	0.311	1.286	1.329	0.852
Inorganic P	A	0.054	1.285	1.245	0.730	0.815
$P0_4$ (Mg/1)	B	0.008	0.023	0.868	0.900	0.392
TKN	A	0.855	2.588	2.340	1.630	1.539
(mg/1)N	B	0.507	0.530	1.871	2.222	1.559
N02 + N03	A	0.113	0.153	0.929	1.360	1.366
NO_3 - N (mg/1)	B	0.001	0.001	0.161	0.204	0.430
NH3 (mg/1)N	A	0.001	2.047	0.429	0.187	0.408
	B	0.022	0.022	1.375	1.716	0.913
TOC (mg/1)	A	6.66	7.29	7.06	6.90	6.59
	B	4.78	4.22	4.52	5.03	3.87
chlorophyll _a	A	39.0	30.0	65.3	72.8	86.3
(mg/1)	B	37.5	45.0	39.0	45.0	88.5

In 1974 from July 8 and August 8, there were considerably more algae on the floats at site 3 just below the Blue Plains sewage plant than in June 30 and July 26 of 1971. The diversity and number of zooflagellates, sarcodines, and ciliates improved in these summer months of 1974 over 1971. There is a pronounced increase in the number of ciliate species, such as certain holotrichs and hypotrichs, which feed on algae. Note especially the increase in diversity and *numbers* of ciliate species at sites 3 and 4 below the Blue Plains sewage treatment plant outfall from 1971 to 1974.

Predaceous species often require more oxygen tO function than their prey. Therefore, it is especially significant to note the *pronounced* increase in the diversity and numbers of suctorian ciliates *in the* summer of 1974 over 1971. Note especially the numbers of suctorians at site 3. In 1971 in late June, only the more tolerant species Tricho hrE a e ist lidis was present, while in early July 1974, ve bona suctorian species were present. In August 1974 the specialist species Dendrosoma radians was found at site 3.

Comparison of these two summer months for 1971 and 1974 shows the diversity and number of rotifers to be greatly increased in 1974. Probably the most startling differences for 1974 were the finding of a clam Pisidium at site 3, as well as gammarids moving down to site 2. vera l, the communities collected in 1974 for the summer showed higher diversity and number than in 1971 and indicated a decided qualitative improvement in the auf-wuchs community collected on the floats. There appeared to be a downstream movement of the microfaunal community of about one site from 1971 to 1974 showing significant and measurable recovery.

Many who have looked at this data remark that the senior investigator is exerting too much energy and time trying to qual-itate and quantitate the entire aufwuchs community. At this point it appears that the peritrichs and suctoria would be excellent indicator groups to be singled out for more intensive study. *Peritrichs and suctoria are* sessile, are not dislodged in transit, and can be easily counted. The senior investigator has chosen the suctoria and the peritrichs as the best candidates among the Potomac River microfauna for more extensive study as indicator species of water quality.

SUMMARY AND CONCLUSIONS

The microbial communities of the Potomac River include the plankton, the meiobenthos, and the aufwuchs (or periphyton). Turbulence precludes much development of a neuston at the surface. The plankters are at the mercy of the flow of the river and their numbers vary greatly, making single monthly sampling inadequate. Meiobenthic organisms are brought up by grab from a bottom that varies greatly in composition making standardization of sampling very difficult. The aufwuchs is the community that develops in time on a substrate. It is those firmly attached forms as well as those feeding or resting there. The plankton must be concentrated and the meiobenthos extracted from the mud to study and enumerate the species. Older techniques employing glass slides for collecting the aufwuchs., also caused it to be disrupted when collected or transported. Spoon and Burbanck (1967) devised a method using 50 x 12 mm Falcon plastic petri dishes as collection substrata for aufwuchs which overcame the problems with glass slides. The inverted dish bottom is supported in sections of styrofoam. cups until colonized. The clean lid is then applied excluding water. The water-filled dish then serves for transportation, scanning, counting,, and behavioral studies with a minimum of disturbance to the enclosed community.

A float has been devised to support six such dishes just below the surface (Figure 3). The float is tethered to a mainstream buoy. The float also carries glass and plastic cover slips., cellulose sponge, and to weight it properly, there are rubber stoppers which can be scraped to obtain a more numerous sample of the larger members of the aufwuchs community. The whole float is enclosed with site water in a plastic bag and brought to the laboratory where the dishes are capped with a lid and studied expeditiously to preclude increases due to divisions or decreases due to predation. After such study, the floats are placed in circular 2-gallon aerated aquaria and nutrified bi-weekly with TetraMin tropical fish food. The community can then be studied more extensively to determine trophic interactions

Sites were chosen to coincide with and to bracket the Blue Plains sewage treatment plant outflow which discharges the majority of the treated wastes from metropolitan Washington (Figure 1). The five sites were spaced 3-1/2 miles apart and coincided with sites routinely sampled by E.P.A. on a monthly basis for their physical-chemical data survey. The Coast Guard approved the tethering of the floats to their mid-stream buoys. This tidal section of the river from Key Bridge to Mt. Vernon is the uppermost part of the fresh-water estuary which has appreciable tidal mixing.

The aufwuchs community has been sampled in 1970, 1971 and 1974 and seasonal trends have been determined. In the winter, the community is dominated by protozoan species. There is abundant bacteria and fungi but minimal algae on the dishes. In winter, the deteriorated conditions extend much further downriver from the sewage plant outfall than in summer. In early spring, diatoms and their protozoan and micrometazoan feeders dominate. There is a great increase in filter-feeding species, especially the colonial peritrichs like Carchesium poly2inum. As the temperature warms above 10 - 15°0, micrometazoa including herbivores and peritrich predators increase. In the warm summer months, the dishes have profuse growths of green filamentous and plaque_ forming algae as well as certain diatoms, desmids, and blue-green species. Chironomids, bryozoa, rotifers and oligochaetes become abundant. In late summer, with low flows, the river becomes like a lake with green flagellate blooms and many zooplankters found resting in the aufwuchs community. The downriver sites may become slightly brackish with abundance of the colonial cn daria, Cord, yt,~o, hor , which feeds on microcrustacea of the zoop lankton. Also brackish red dinoflagellates and ciliates appear. In the fall, a second diatom bloom occurs on the collection dishes with their herbivores present. Once again, as temperatures drop below 15 C, the protozoan species again dominate especially the peritrichs like Carchesium polypinum.

The Potomac River has a year-round turbidity that restricts the euphotic zone to about two feet or less, thus limiting the role of the planktonic primary producers. With the great input of organic substrates from agriculture and the metropolitan areas, the detritus food chain dominates with its bacterial and other saprophytic consumers. The peritrichs of the aufwuchs community are highly efficient bacterial filter feeders. They serve as food for numerous protozoan and micrometazoan species (Figure 7) which serve in turn as food for macrometazoans like white perch and ultimately even humans.

In 1970 and 1971, the five sites varied in summer as follows going downstream. Site l at Roosevelt Island was quite diverse in species of protozoa and micrometazoa, especially hypotrich ciliate and lifer algivores and also suctoria. Gammarids, pulmonate snails, and bryozoans were present as were plankters like Gerioda h_n_~ia_. This community approximated the community collec 50 upstream at the runoff from Little Falls, which had a classic recovery community. Site 2 at Hains Point had less diversity with large numbers of mesosaprobic peritrich species like Vorticella cam anula, and testate sarcodines (Centro___is) and oligoc aetes
e on the algal and detrital lawn. Tolerant chironomids were present. Site 3 at Blue Plains had great numbers of a few

predators (Amphile tus and Trachelius). Almost no algae were found at site 3 an se om~ironomi cps or oligochaetes like Nais. Suctorians were rare to absent. Site 4 had numerous suctorians (Tokophrya and Soleno hrya)._Pilamentous and plaque-forming algae were abundant. Co.onial peritrichs like O ercularia formed large colonies. Microcrustacea like copepods an ostracods occurred. Stentor roeseli was abundant. Site 5 had bryozoans and Cordylo 1h ora an otherwise resembled site 4. At site 5, pulmonate snails an gammarids were sometimes found. In 1970 and less so in 1971, much blue-green algae was collected with the floats at site 5 where an obvious nuisance bloom was occurring. In 1974, none of this blue-green bloom was seen at site 5. In 1974, all five sites were greatly improved in number of species. The sites 1 and 2 community of 1970 and 1971 moved downriver to replace the deteriorated site 3 community.

The laboratory study centered its attention on the sessile ciliates such as the peritrichs and the suctorians, which prey on peritrich migratory stages and other ciliates. Peritrichs like Vorticella are equipped with ciliation around their mouth which pulls vortex of water, centrifuging the food particles to the center and down a funnel to the mouth. It was found that mucous particles produced over the peritrichts body sponged up bacteria and returned in the cycling vortex to the peritrich's mouth. The bell-shaped vorticellid body possesses at the smaller end a contractile stalk. When the body divides, one daughter builds a wreath of motile cilia and swims away to construct a new stalk. It was found that the migrator (the telotroch) would swim down and join the sessile sister, building the new stalk beside the old. In this way a social clone could develop from one individual. It was found that such groups aided in predator avoidance, feeding efficiency, and increased chance for conjugation. It was discovered that some peritrichs produce a special microconjugant which is flattened with a notch on the forward end. This shape causes it to move in circles on the surface. The notch engages the stalks of macroconjugants so the microconjugant ascends by spiraling up the stalk and unites with the macroconjugant allowing nuclear union and genetic diversity. Being sessile, peritrichs would seem to be easy food for many protozoan and micrometazoan predators; however, they have developed many defense mechanisms. The loricate peritrichs, Vaginicola, Pyxicola, Cothurnia, _Plat cola and Laegenophrys live in special transparent enclosures some even with lids) which protect them against certain specialized predators, yet may act as their death traps against other predators. Amoeba discoides phagocytize contracted vorticellids but not lorica e pert ric S, those like Ophrydium that live in gelatinous chambers, or stalked colonials. The giant sarcodine Biom x_a uses its net of pseudopodia to rip peritrich bells from their st al& s. The peritrich telotrochs, while hunting for a suitable place to attach, become food for sessile predators, especially the suctorians, and heliozoans like Actinosphaerium. Also grazing ciliates like Lacr aria olor can catch tree-swimming telotrochs with their whiplike p o.—The grazing holotrichous ciliates Am hile t,_u.~st Enchelyodon, Hemio h s and Trachelius can eradicate a peritrich community, yet are made ineffectual it-the community is subjected to a swift current. It was found that the attaching peritrich telotrochs selected swift currents. Peritrich telotrochs may be egg-shaped and very fast, cylindrical grading to Apollo spaceship-shaped to swim in a straight line, or flattened in the anterior-posterior plane so that the Bernoulli effect turned them toward a surface in a swift current. Some telotrochs like Vorticella monilata swam like bees and settle together in close-sp d patches sometimes containing thousands) which are avoided by snails which prey heavily on other vorticellids.

Rhabdocoel worms are common predators of peritrichs. Stenostomum expands its pharynx around vort cellid bells and encloses them, pulling the body off the stalk. If the vorticellid contracts, the Stenostomum fails. Macrostomum just makes vorticellids contract and pine es off`'the bell "'!rom 'h stalk. Its feeding method allows small peritrichs like V. microstoma to avoid predation by attaching in crevices. The large colonials mike Carchesium and Zoothamnium contract violently and dislodge the feeding r aab3ocoels fromir branches. Loricate peritrichs and those with loricas on stalks are passed up by rhabdocoels.

The oligochaete Chaeto aster has strong hooked chaetae allowing them to feed on peritrici n swift currents. They strike at the bells and break them from their stalks. Notommatid rotifers hold on to the peritrich stalks with their caudal toes and feed on the bells. Copepods alight on top of vorticellids and break up the bells with their chitinous appendages. These micrometazoan predators may graze heavily on peritrichs but seldom eradicate a community as do grazing ciliate predators.

Snails feed heavily on peritrichs, eating all vorticellids except Vorticella monilata with their lame pellicular tubercles which may contain 93[5]M c irritant. The colonial peritrichs are easy prey of snails; however, Systilus which builds a combined stalk of 10+ stalks cannot be pushed over and eaten by snails. The loricate peritrichs like plat c are not only protected from snail predation, but are actually ass sted by their surface-cleaning activities.

Suctorian ciliates are sessile predators with numerous mouths at the end of` tentacles which have terminal knobs studded with specialized bodies called haptocysts allowing attachment to the ciliate prey. The tentacle then moves a membrane-covered food vacuole down its microtubular inner tube to the body of the suctorian. After

The Potomac River aufwuchs community has numerous species of suctorians, some highly specialized (stenophagous) like Lernaeo hhrya ca ita~ta, feeding mainly on peritrich telotrochs, and others very generalized (euryphagous) like Helio erhardi, which eats almost every ciliate encountered. Electron micrograp is studies revealed that H. erhardi possesses coccoid symbiotic bacteria;

Lernaeoph a does not. The stalkless H. erhardi has an encircling broad adhesive band, a coat of mucous, and a spec lived very thick and textured pellicle which allows it to avoid certain predators like snails.

With the improvement in conditions in 1974 over 1971, these stalkless Helio hr a species replaced the stalked suctorians Solenophr a and To<op rya. It is believed that the presence of detrivor

algivores like oligochaetes and snails which eat the stalked suctorians but not the unstalked, keep the surface cleared so the stalkless forms are not smothered. This hypothesis was tested by setting up aquaria from a parent aquarium with oligosaprobic and polysaprobic conditions and with and without snails. Only in the oligosaprobic aquaria with snails did stalkless suctoria and 1Qricate peritrichs thrive.

Followup studies of the smaller laboratory aquaria have permitted the discovery of numerous food chain links. In these aquaria, a benthic community develops in the bottom sediment. The se contain various ciliates like Paramecium and Tetrahymena. When food is added and the aquaria cloud p ith bacteria, these ciliates are driven out of the benthos and become food for surface aufwuchs predators like suctoria. It is believed that the Potomac River benthos also provides food for the surface Potomac aufwuchs. In the upper oxydized zone of the benthos are ostracods like Cy2ridopsis. It was discovered that they feed on the long slender heterotrlc ous ciliate, S irostomum. These benthic organisms are removed from this sediment y use of the vial in tube method (Spoon 1972). Studies of laboratory aquaria and river floats have impressed upon the senior investigator the principle that predator pressure is a very important factor in determining species diversity and population numbers. Considering a species as an isolated indicator without knowledge of the whole community and its trophic structure has limited value as a biotic gauge of water quality. The whole community must be qualitated and quantitated.

During the course of this aufwuchs project, many new methods and apparatuses have been devised other than the basic aufwuchs collection system. Dow Corning High Temperature Silicone Grease has been found to be a non-toxic viscous material to support coverslips on slides for making long-lived preparations. Union Carbide's poly (ethylene oxide), a water-soluble resin, at 0.5% solution has been found to be a superior slowing agent. An improved moist chamber was devised with a smaller plastic petri dish glued inside a larger one in the laboratory if a current was induced in their petri dish by placing the dishes in stacks on phonographic turntables at 16 rpm with a 10-second current flasher to induce off and on, back and forth mixing of the media. The most elaborate invention was a new microcompressor which greatly facilitates study on food vacuole contents of soft-bodied organisms.

A comparison of the surveys of biotic and abiotic data for 1971 and 1974 yielded the following results. The number of species of protozoa, micrometazoa and total microfauna doubled at each site. The average number of species for 1971 and 1974 decreased from site 1 to 5, not increasing in number at sites 4 and 5 where the abiotic data indicated an improvement in water quality over site 3. Unmeasured forces such as heavy metal, insecticides, and H2S leaking from sediments may have been involved. Two experimental rivers were set up in the laboratory each composed of five 25-gallon aquaria with sediment and water from each site and separated by 100 feet of tygon tubing and a sediment trap. Blue Plains sewage treatment plant effluent was added at the site 3 aquarium in one experimental river and dechlorinated tap water in the other. Key Bridge water was flowed proportionally down each experimental river. Golden Shiner minnows used as test animals showed a fish kill like the one occurring in the Potomac at the same time.

Death occurred in site 4 and 5 aquaria even though there was vigorous aeration and seemingly good water quality.

The 1971 and 1974 biotic survey showed a 1971 range of species per site of from 5 to 29, and in 1974 from 2 to 68. The overall average of species per site for 25 collection floats in 1971 was 10.2; while for 27 collection floats in 1974, it was 24.0. Generally, the same species had the highest total occurrences on the separate collection floats in 1971 and 1974, yet the total occurrences were higher proportionally in 1974. The most recurring species for both years was Vorticella campanula on 16 of 25 collection floats for 1971, and '24 Or 27 FOF 1974. For the 25 floats studied in 1971, there was a total of 111 different species, 69 protozoan and 42 micrometazoan. For the 27 floats for 1.974, the total was 179, with 124 protozoan and 55 micrometazoans. The overall species list of microfauna including those collected at the Little Falls runoff, and the final sedimentation tanks of the Blue Plains sewage treatment plant, was about 330.

The 1971 survey ran monthly from late June to October while the 1974 survey spanned from March to October. The months which overlapped in colonization time were June and July. With similar water temperatures for these months in 1971 and 1974, the dissolved oxygen was much lower in 1971, and the phosphorus and nitrogenous compounds were generally higher in 1971. (Blue-green algal blooms occurred in 1971, but not 1974.) For these two months, the number of species of protozoa and micrometazoa were doubled at each site. This doubling was not due to sampling differences as the same procedure and times were used for identifying and counting the species.

Qualitatively, there was also an improvement in the community structure at each site in 1974 over 1971. Forms like gammarids which require more dissolved oxygen were found at site 3 in 1974. There was more algae and algivores in 1974. There was a significant increase in predaceous species of all groups. In 1974, there was a movement of species only found at sites 1 and 2 in 1971, down to sites 3 and 4. Overall, our study of

RECOMMENDATIONS

The multiple federal, state, and institutional biotic and abiotic sampling programs now going on in the upper Potomac River around Washington, D. C. should be better coordinated. Possibly, the Department of Interior could *help in the work of the Potomac Commission in* attempting *to coordinate these activities.*

2. The 0. W. R. T. Center of the District of Columbia should be given a larger role in the research and monitoring program on the upper Potomac River which is so important to metropolitan Washington, its citizens and its visitors.

3. The aufwuchs (or periphyton) community should be better studied and methods standardized so that results will be comparable. Possibly, the Department of Interior could sponsor a symposium on the study of the aufwuchs to bring together the workers from across the nation.

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APPENDIX A

Tentative List of Species of the Aufwuchs Microfaunal Community of the Upper Potomac River from Chain Bridge to Mt. Vernon (July, 1975)

PROTOZOA

Zoof lagellates
An~hoobysa vegetans *Any.*
n oroweobium
aQdQ. SSL•

C'tii '1 nmnna *s* ,
Codoaoclad= *=el*
9t~16 „ Collod .ctvon
tric l i atom
c?Zgtomonas =.
Ma2tiaella Ai=l=
Mastiaguoeba ,. _mSS l`
s;,_=.
M yarians Monos icxa
;a._2 Notosole us
apocAmotus Paranema
trichophorum
Peranemopsis inflexum

Sarcodines ActinophW 301
Agtinosphaerium e ch ml,
A,M$l discoides
A.Mgeb y=n3.gso
Amoeba v_e*2erti o
Aella- co
tata

d 2oides

A_,M211a, vulaaris M yacx
Centrovvxis aculeata Centr
is. ecornis
Centrogvxis hemis,p~aerica
Clathruline elegans
Conchiliooodium bilimbosom
Diffluaia corona Diffluaia
globosa Difflug'ia
urceolata Diplophrys
archeri Flabellula sp .
Gromla s
Hartman~1a s .
Hyaa *lscus i.*
Ma ore a ves ertilio __
_c~r_o gr,omia p.
Nae 'leri p .
enarj:a mix abilis
' ec O ba
verrucosa ahMam '"r
alimax Vanella =.

Ciliates Holotrichs A.mPb.ile tus
sp. Chilo one la cucullulus
Chilodonella uncinata
Chilodonella nana
Cinetochilum mar~aritaceum
Cole s hirtus
Coium co3poda
Colpoda cucullu~s
C clidlum sp.
Cyrtolop osis mucicola
Didinium armatum
Di inium ba iani Dileptus
anser Enchelyodon sp..
Prontonia leucas
Hemiophrys fusi ens
Homalozoon
ver~mlcu3are Lacrymaria
olor Lacrymaria sp. 2
Lechriopyla s p.
Lembadion sp.
Lembus sg.
Litonotus fasciola
Litonotus so. 2
Loxodes so.
Me s od um §a. et
us es Metapu§L
spiralis Nassula sg.
Paramecium aurelia
Paramecium calkinsi
Paramecium gaudat
um

Paramecium
Paramecium putrinum
Paramecium trichium
Peritromus sp.
Phascolodon vorticella
Prorodon teres Prorodon
sp. 2 Pseoprorodon s.2.
Stokesia vernalis
TetraFymena sp.
Trachelius ovum
Tracheophyllum sp. 1
Tracheophylium sue. 2
Trichopelma sp.
Llrocentrum turbo
Urozoma sp.

Suctoria

Acineta tuberosa
Acineta crrandis Acineta
foetida Anarma so·
Astrophrva arenaria
Dendrosoma radians
Heliophrya "burbanckitr
Heliophrya erhardi
Heliophrya rotunda
Lernaeophrva cagitata
Metacineta ystacina
Metacineta sp. 2
Metacineta ss. 3
Me acinetta sp. 4
Paracin~eta a a
Paracineta M. 2
Podophrva f ixa
. of _nonhrn; a
SDhaeronhrva magna_
Sphaerophrya pusilla
Sphaerophrya sp. 3
SQualoro hp,-„rya
macrostyla Trichophrya
epistylidis Trichophrya sp.
2 Tokophrya infusionum
Tokophrya lemnarum
Tokophrya q a r~p rtita

Ciliates Peritrichs Campanella umbellaria Carchesium polypinum Carchesium cgranulata
Cothurn ai sp.

Coth ur a s . 2 ar

EDistvlis bo t „2l1
Er tvlis
Epistvlis plicAtili:§ (3 varieties)
E ,tY.jjj urceolata
Hastatella radians
Laegenoph~va vacrinicola
OmnhWdium eichh2rn
O2ercularia coar Opercllara
a corronata 0p, gxcular .a m
n,a ,
Opercularia ohrycraneae
Platvcola lQncTicollis
(3 varieties)
Scyphid a SO.
Svstvlis hof i.
Telotrochidium hennecruvi
Vacrinicola vuryula Vacrinicgla
(Trais Vaainicola jgenita
Vacrinicola str,iata_ Vorticella
aequilata

Vorticella cam„panul
(4 varieties)
Vort; cei _-~ cnv.alla.a:
Vortic_e1la . "f in1gyi
Vorticella mayerx Vot
ic Ta miarosto„„mma~
`"(2 '···varieties)
Vorticella minuta
Vort ce ~~ mo~ta
V"o"rt`icgr7 oc ava "'
Vartsce`"M s "rIM
oot amn m add
Zoothamnium pycrmaeum
Zoothamnium simplex

Spirotrichs Heterotrichs
Condylostoma SP..
Sp.irgstom n a i u~m
Spirostomum .ntermedium
_SpIrostomum m n §
SpIrost„amum tere$ Ste_to.r
gogruleus

vi

Stentor ese 1
Oligotrichs
C,~odonehla crag, tera Ha
jter,, is „graDdine lla
StMg diuumm turbo
Strombidium sp. 2
Hypotridhs
Actinotricha sp_.
Aspidise ostata
A;Pidlsca lvnceus
Aspidisca sulcata 'ulow
aediculatus E,uplootes
eurvstomus ELF ot S
moe~bius
.otes patella CbAetospira mal
eri Chaetospira sp. 2
Holosticha sD. I ljolosticha
s_p,. 2 j_josticha sp._3
Hypotrichidium conicum lag
Oxvtricha ludibunda OxUtricha
. 3 Stvlonvchia mytills
Stvlo-nychia Dustulata
Uroleptus sp. 1 Uroleptus ;p. 2
U=2=14 'SD -

MICROMETAZOA

Coelenterates
Cordylophora lacustris
Hydra . smericaLa
P= obydra ap-•

Parazoa (sponges)
Sponcrilla lacu~stri_s
Sponcrilla §z. 2

Rhabdocoels
Stenostomum so. 1
Stenostomum s8..
2 Stenostomum so.
3 Microstomum av.
Macrostomum sT.

Triclads

Duqesia trigrina

Bryozoa

Plumatella repens
Pectinatella magnifica
Hyalinella ounctata

Gastrotrichs
Chaetonotus sp. 1
Chaetonotus &p_._2

Rotifers

Asplanchna priodonta
Branchionus bidentata
Branchionus,plero inoides Ce
halodella zgbba
C~e hp_ella auriculata
Cepha`tCa e~la sp. 3
Cephalodella sp. 4
Conochilus sp. Coolotheca
sp..
Erignat a sp. Euclanis
dilatata Ker` a- ella am----
ericana Laci- nulria
loscuosa LLecane
oiioensis Lepadel a ate ~a
Limnais me lcerta

Rotifers (continued
Monostyla sg.
Notommata sg.
Philodina roseola
Polyart ra L. P.y3ura
§~p• Rotaria sp.
Synchaeta sR· 1
Synchaeta sg. 2
Testudinella gk.
Trichocerca sg,.

Cladocerans
Bosmina sp.
Ceriodaphnia sp..
Daphnia pulex

Calanoid copepods
Diaptomus sp.
Limnocalanus sg.

Cyclopoid copepods Cyclops SL..
Megacyclops sp. Numerous
other species (20+)

Harpacticoid copepods 2
species

Ostracods

C pY ris §R.
Cypridopsis sp.

Other Crustacea
As ellus sp.
Gammarus sp.
1 Gammarus
sp. 2

Hirudinea

Closso;honia complanata
He ope ate. Illinobdella
richardsoni

Oligochaetes Aelosoma
hemorichi Aelosoma V,._2
Aulophorus furcatus,
Chaetogaster disphanus
Chaetogaster diastrophus
Dero so.
Nais communis
Ophidonais sj.
Pristina sp. Stylaria
proboscidea

Insect larvae

Chironomids (15+ species)
Rheotanytarsus sp,.
Psvchoda sg.
Stonef ly (10+ species)
Mayfly larvae (8+
species) Sialis M. 1
Sialis s_. 2

Mollusca Bithvnia .
Bulimid species
Goniobasis vircr ' n. ica
r3y ai l--.ate- ap.,

Lvmnaea s,Q.
Phvsa 1p .
Pisidium ibi
Planorbid species

PRESENT TOTAL

APPROXIMATELY 330

Introduction to Appendix B: Biotic Data

This data is arranged in nearly the same phylogenetic order as found in Appendix A. The major exception is the addition of the initial page on algae which is taxonomically imprecise for 1971 and 1974, but it will be given to species in the next phase of this study. Data for 1971 and 1974 are on opposing pages with the two summer months of closest *sampling dates above* one another. The five sites are shown across the top under the dates of collection. The 1971 Site 1 at Roosevelt Island was replaced with the adjacent Key Bridge (KB) site (the Roosevelt *island buoy was* removed by the Coast Guard in 1972). A dash (-) *means* that no *float was recovered* and no data is available. For 1974, there was one collection (April 16) for the Runoff (RO) site below Little Falls. The numbers 1 - 7 correspond to quantitative levels as shown below and explained in Materials and Methods. An X means present qualitatively. Across from major groups are totals of species present in that *group. When* no species are present an 0 is used. On the far right is a column which gives the total occurrences (TO) of each species. The opposite page preceeding the data tabulates the total number of species of Protozoa, Micrometazoa, and Microfauna for all sites sampled in 1971 and 1974.

0 - None I - Rare 2 - Scarce

3 - Moderately abundant
4 - Abundant
5 - Very Abundant
6 - Dominant
7 - Dominant and covering the entire dish

1971

June 30 Jul 26 August 25 Sept. 30 Oct. 9 4 Oct. 30 T

- 12 34 512 34 5 12 3 4 1 2 3 4 0

Site

Iron Bacteria																														
Blue-green algae																														
Anacystis sp.															4			5			3							3		
Lyngbya sp.																														
Oscillatoria sp.							5	5	5					2		2	5			4				3						
Phytoflagellates																														
Red dinoflagellate																														
Gyrodinium sp.																														
Chromulina sp.																														
Mallomonas sp. Euglena																	2													
sp. Chlamydomonas sp.																														
Gonium sp. Pleodorina																				5										
sp. Volvox sp.																														
Filamentous algae			2				2				2									3										
							2																							
Spirogyra sp.						3			3		3			6		3			5	3										
Ll lo thrix so.														4																
Oedogonium sp.						2	3				3			3		4	3		2	5										
Cladophora sp.	31 l '3					3	3								3	3										2				
Stigeoclonium sp.	t4			3i		3	3						2			3	3		3		3	3		3		3		4		
Plaque-.orming algae	i.			l I		3					3	3	2	3	3	4	3		3		3	3				3		4		
Desmids											4			2																
Cosmarium sp.				i							x			3							2									
Closterium sp.						x	x		x			4					4		4	3		2								
Pediastrum sp.	x					x		x							x							x								
Scenedesmus sp.	x						3				x																			
Diatoms	4					4					5			2		4					4	4				4	3			
Asterionella sp.																						3		3			x			
Diatoma sp.																								x						
Fragillaria sp.																														
Gomphonema sp.																			5		5									
Melosira sp.							x				4					5	4		5		5	3				3				
Navicula sp.	x					x					x					x					x	x					x			
Tabellaria sp.																														

1974

March 1					April						May 28					July 8					August 8					Oct.20				T
-	2	3	4	5	KB	2	3	4	5	RO	KB	2	3	4	5	KB	2	3	4	5	KB	2	3	4	5	.	-	-	-	O
			2									4	x				4	4	4	4	4	4	4	2			4	3		
	3					2										x		x	4	2		3			2					
										x		x						2	x	2		x		3	2		3			
					x										5		3	5	5	5	3	5	3	3	3		4			
																	1													
	1					2					1																			
			3		x						2						3		2											
					1						2																			
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						x								3					2				3	3	2			3		
						2																								
	3				x	x														4				2	4			4		
																	3													
						x			x			5						2	3	2		2	2	3	2			3		
			2									5		5	5		3	4	4	5	3	2	2	3	3		3	3		
	2					x					x						3	3		2		2	2				2			
					1	2							x		2	2						2		2	2					
																x														
								x									2				2									
	5	1	3	4	4	4	3	4	3	5	3	4	3	3	4	3	4	2	4	4	5	4	2	5	3			3		
					x	x							x		2				2	2				3						
						4					x		x			2	4		x		3	2								
			2		x	x				x			x							2		2			2					
																x														
			3	3	4	4	3	x			x	x	x	3	4	2	3	3	4	4			2							
			2	2	x	4	3	x		x	x								x			3	2		3					
					x							4							x									3		

... Site

Iron Bacteria Blue-
green algae Anacystis
sp. Lnygbya sp.
©scillatoria sp. Phyt
of lage].late s Red
dinoflagellate
Gyrodinium sp.
Chromulina sp.
Mallomonas sp.
Euglena sp.
C .amyia omona s
sp. Gonium sp.
Pl rina sp.
Volvox sp.
Filamentous algae
SF yra. sp.
tllothrix sp. Oedogonium
sp. Cladophora sp.
Stigeoclonium sp.
Plaque-forming algae De
smid s
Cosmarium sp.
Closterium sp.

Pe ia`_strum
sp. Scenedesmus sp.
Diatoms
Asterionella sp.
Diatoma sp.
Fragillaria sp.
Gomphonema sp.
Melosira sp.
Navicula sp.
Ta _ l aria SD_

1971 June 30 July 26 August 25 Sept. 30 Oct. 9 Oct.30 T Site ... 1 -
3 4 - 1 2 3 4 - 1 2 3 4 5 1 2 3 4 5 1 2 3 4 - 1 2 3 4 0

oflagellat
Anthophysa
Anisonema prosgeobium
Codonoclad
I ; , ~ i ~ . t
Codosiga
i Collodicty
Heteronema acus
Ma st ige
Monas sp.
Monosiga varians ;
Notosolenus apocamptus I
r'aranema
Peranemops
a rcodine s (# sp. 2 1- 2 1 5
Actinophry
Actinospha - ! I I ,
Amoeba
Arcella
Arcella
Centropyxis aculeata 2 4 '~ 3 !
Centropyxi
Conchiliop
Difflugia
globosa I
Diplophrys
Flabellula sp. ~ ~ 12 :
Mlcrogromi
Mayorella
Thecamoeba verrucosa (1 I ! I 1
Vahlkampfi . ' 26

March 1 April 16 May 28 July 8 August 8 Oct.20 T 1974

- 2 3 4 5 KB 2 3 4 5 _RO KB 2 3 4 5 KB 2 3 4 5 KB 2 3 4 5 - 2 3 - 0 . . . Site

2 3' 4 "3 3 3 61 Anthophysa vegetans
21 Anisonema prosgeobium
2' Codonocladium umbelatum
5 3 414 4 3 3 3 ' Codosiga botrytis
1 Collodictyon t
4 Heteronema acus
1 Mastigella simplex
1 Monas sp.
Monosiga varians
Notosolenus apocamptus
3 3' 3.2,2:2 2 3 aroma tric op orum
1 Peranemopsis inflexum
3 2/321,2 . 1 2 1 1 2 2141 8'64 _3: 31 Sarcodines(sp. present)
5 3' 3 3; Actinophrys sol
2-2! T Actinosphaerium eichorni
2 Amoeba discoides Arcella d
2 2 5 scoides Arcella vulgaris
Centropyxis aculeata
2, 3:3,4. 3' 3 , entropyxis emisp aerica
1 Conch liopodium sp.
1 Difflugia globosa
2! 4 Diplo rys archeri
fiabellula sp.
Microgromia sp.
3~3 2 10 Mayorella vespertilio
1 2 ecaoioeba
2 4 2 16 verrucosa Vahlkampfia
3 limax
3'.212

1971	June 30		July 26	August 25	Sept. 30			
Site ...	1 - 3 4 -	1 2 3 4 - 1 2 3 4 S	1 2 3 4 S	1 2 3 4 -	1 2 3 4 0			
Holotrichs(# sp. present)	2i-	-	1~,26 0;_	1 1 2i2!0!0	5 1	2 1		2
<u>Amphileptus</u> sp.								
Chilodonella			Ai1'	I			I	3
Chilodonella uncinata	|		|	I	2	j	1	5
Chilodonella nana			i 3'	2I3. I !	2 1	1 3	2	
'Cinetochilum margaritaceum								
<u>Coleps hirtus</u> <u>Colpoda</u>								
sp. <u>Cyclidium</u> sp.			2 1					
<u>Didiniumm armatum</u>								
<u>Didinium balbiani</u>								
<u>Enchelyodon</u> sp.								
<u>Hemiophrys fusidens</u>								
<u>Lacrymaria olor</u> <u>Lembus</u>				!	i			I
sp. <u>Litonotus fasciola</u>			1	!	2'	Iz	~	
<u>Litonotus</u> sp. 2								
<u>Mesodinium</u> sp. <u>Nassula</u>								
sp. <u>Paramecium aurelia</u>								
<u>Paramecium caudatum</u>								
<u>Paramecium trichium</u>	i !		1~i I	I 1				I
<u>Phascolodon vorticella</u>	2 1 1		!					
<u>Prorodon</u> sp.								
<u>Pseudoprorodon</u> sp.								
<u>Stokesia vernalis</u>					i I			!
<u>Tetrahymena</u> sp.								
<u>Trachelius ovum</u>	2_1 I		v_i_1 .	a	2 I	I		
			2		1			
Holotrich (sm) histophagous	I							
Holotrich unknown #1	2 1 I ;		I i i		~ i	||		
Holotrich unknown #2					2 I	IZ I		
Lechriopyla sp.					i			

T 1974 0 ... Site

	March 1					April 16						May 28					July 8					August 8					Oct.20				
	-	2	3	4	5	KB	2	3	4	5	RO	KB	2	3	4	5	KB	2	3	4	5	KB	2	3	4	5	-	2	3	-	
Holotrichs (#		7	1	7	3	13	9	5	2	3	10	9	3	4	4	4	4	4	8	12	7	11	5	10	10	7				-	
Amphileptus		2		2	1		4	5	2	2					2		1					2	2	2					2		13
cucullulus C		3					3				2					2		1	2	2			2	2	3						10
uncinata Chi		3			3		2				2	2	2			3			2				2	2	3	2					12
Cinetochilum		3				2	4	4			2	3	2	3		2	3		4	4	2	2	3	3	2	1		2	2		20
Coleps hirtu						3					2	2	2	2				2		2	2			2		2		2			11
Colpoda sp.											3																				1
Cyclidium sp				2																											1
Didinium arm																		1	3			2									3
Didinium bal																				3											1
Enchelyodon																				1											1
Hemiophrys f						2																			2						2
				2		3	2							3	3				2	2	1			2				3			10
crymar a c		1				1					1						3		1			1			2	1					8
Lembus sp. L											2									2											2
fasciola Lit						1	1	1			2	2						2		2	2	1	3	2	2			2	2		14
2 Mesodinium						1											2		3			2		2	2	2					7
Nassula sp.																						2									1
aurelia Param						2		2			2	2								2											5
caudatum Pa																			1			1									2
trichium Pha												1								1	1										3
vorticella Pro			1	2								1								1	1				1						6
Pseudoproroc								1																							1
to es a verna																				1											1
sp. Tracheli						1																									1
Holotri.eh															3	2															2
Holotrich u				2		1																							2		3
Holotrich u		2			1	2	2		2	3					2																7
Lechriopyla											3	2										3			3	2					5
		2		2		2	2					2									1	2		2							8
				2		2	2			1				2								2		2	2	2					9

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1971 June 30 July 26

August 25 Sept. 30 Oct

Site ... 1 - 3

Pe

ritrichs(# species		31-			214:8	1417AA		913		
Campanella umbellaria							2			
Carchesiu polypinum								Q		3
Carchesium granulata	I	~ +			~ ~	~ ! I		~ I	-	
Cothurnia sp.	-				I 3i	12A				
Epistylis plicatilis	71	T_2	3		! 1 5 7	46			2	
Epistylis urceolata						1 1				
Epistylis hentscheli	~	1 3	~	2	' 5 ! 6 3	1_13				
Epistylis cambari		*3			If	K 1		312		
Hastatella radians					i 1 i					
opercularia minima										
Opercularia coarctata	2				2!					
opercularia coronata						21 1)	~	(	j	4
Opercularia phryganeae	~	~	,		j!,,					1
ophrydium sigmoides										
Paravorticella sp.						T				
Platycola longicollis					1	141_1		4		
Pyxicola sp.										
Scyphidia sp.										
Systylis hoffi										
Telotrochidium henneguyi										
Vaginic ingenita										
Vaginicola striata										
Vaginicola curvula										
Vorticella campanula					6 16	4j 51 A! 3	2		4	4
Vorticella convallaria						=T-,				
Vorticella mayeri										
Vorticella microstoma		12				51 1	2			
vorticella pieta					14	6	2	1	4	5
Vorticella striata										
Vorticella finleyi										
zootham a amsi										
Zoothamium pygmaeum j	I	-				1_!_'	i_!			
Zoothlamium simplex ,_-_;	j ~	~	_	~	'.	~ -	I		I A	L

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4-0
LD

_ _ nr n....+. Z
n.,1

1971
Site ... Spirotrichs 1 - 3 4 - 12 34 - 12 3 4 512 3 4
(# sp. present)
Heterotrichs

2j-12 2 - | 1~0 3;0'0 | 0 0 0;1 '-0 | - 2-l0 | 0x 1

Condylostoma sp.
S2irostomum intermedium Stentor coeruleus Stentor finle i Stentor roeseli Oligotrichs

!2 | l | ij | l

Codonella craters Halteria grandinella

1 13. | l | l | 2i | i

l | il, | ll | 1

if | i

Strombidium turbo
Strombidium sp.
Hypotrichs

21 | 2i | l | 21 1 | o | i | 31' | l'

Actinotricha sp.
Aspidisca costata
Aspidisca sulcata Euplotes eurystomus
Euplotes moebiusi Eu l~ otes ate, ells

l(| f

21 ~ i | t ~ | I | ~

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March 1					April 16						May 28					July 8					August 8					Oct.20				
																										-	2	3	-	
-	2	0	3	1	10	8	5	0	1	8	7	5	2	2	4	4	3	0	9	4	4	3	5	15	3	-	7	2	-	
																			2					2						2
					4	3				4		2							2		2	2		2			5	3		10
					2	3				2																				3
					4	5	2		3	5		2				1			2		2		4	3	2		3	3		14
											2			2	2															3
																								2						1
											2	2												2						3
																			2					2						2
	4		2	4	2	1	2			2	2	2	4		4							2								12
	2		1		3	3	5					2	3		2				2		2		2	2						12
						3				2	2					2	2						2	2	2		3			9
																				1	2		2	3			2			5
										2									2					2			2			4
																			1			3	2	2	2					5
																3														1
					2					3					2		2										2			5
														2					3	2				2						4
					1		1																							2
			2								2					2								3						4
					3	2	2				2																3			5
					1												2		1	3				4						5
					2	2				3	1									2				2						6

Spirotrichs(#
Hete rot rich
sp. Spirostom
Stentor coeru
finleyi Stent
Oligotrichs
Codonella cra
eria
Strombidium tu
St
sp. Hypot ric
Actinotricha s
costata Aspidi
Euplotes eurys
moebiusi Euplo
Chaetospira mu
Holosticha sp.
W.potrichidium
Keronopsis sp.
rubra Oxytrich
fylonyc
Uroleptu
Uroleptu
Urostyla

.T„-~ zn J„lcs 7G ~)K Con+- *zn n„

1971

Site ... Suctoria(# sp.present) Acineta tuberosa Acineta grandis Anarma sp. Astrophrya arenaria Dendrosoma radians Heliophrya erhardi Heliophrya riederi Heliophrya rotunda Lernaeophrya capitata Metacineta mystacina Metacineta sp. 2 Metacineta sp. 3 Metacineta sp. 4 Podophrya fixa Solenophrya sp. Trichophrya epistylidis Tokophrya quadripartita

Fungus (Zoophagus) Bryozoa ~i Plumatella repens Plumatella (statoblasts) Pectinatella magnifica Tardigrade

Nematodes

Gastrotrich (Chaetonotus)

12 _ 1.4 -		0;1'5;-	.3		5	1
1 4j I	; 3 3 + . ~	4 i v ,	I ,	! X51 6		
2i f		j	!	I	~ 3	
	'51	;5i	4'51	1		
I I I	I . I	i	i		I	
31	. . j 3~	3j	4		5 1	
3	1 1'	_	5	~ 3		
31	-41-._	15 1 _5		1		4
		5! 5	31 j	~ 3 ~		
31 (i	2 2~ ~I2	4 5~5	5i4!	! ;		
	21		4i			2
3i I	3 2;2_41	3. . 5	3j	,	i	
{. i	1	i _i _i		i		
	3	2		~.-r-2		

March 1 April 16 May 28 July 8 August 0 Oct.20 T 197

6 6 6 4 2 1 1 Suctoria (# sp. present) 4 6 2 2 6 4 2 4

4 3 4 , 2 5 . 3 3 2 3 4 2 4 132 Acineta

Taxon	March 1	April 16	May 28	July 8	August	Oct. 20	T
Acineta gran		4	2		1		12
Anarma sp.					2		1
Astrophrya		3	2		3		3
I1endrosoma					2	3 4	3
_iophrya erhardi		1		2 2	3 3		5
Heliophrya				2			1
Heliophrya			2 5 2 4 3	3 4 3 5 2	4 3 3	2	14
Lernaeophaa						2 2	2
[etacineta mystacina							
Metacineta							
Metac		2	2				2
Metac neta s		4	4	3	2 4		5
Podophrya f			2		2		2
lenophrya sp.		1		1 1			3
Trichophrya	1	2 2 3		2		2	6
Tokophrya qu				2 2	3 2	2 4	7
Fungus (Zoopha							
Bryozoa							
Plu tella re		2 3	3 4 3	2 3 3 2 4	3 4 4 5	5 3	16
Plumatella		3	3	4 2 1	3		6
Pectinatella			2	2 1 4	2 2		6
Tard grade		1					1
Nematodes	1	1 2 2 2 2 1	2	1		2	10
Gastrotrich					2 2 2	2	4

Cnidaria

Cordylophora lacustris

Protohydra leukardi

Sponges

Spongilla lacustris

Rhabdocoel worms

Stenostomum sp. (large)

Stenostomum sp. (medium)

Macrostomum sp.

Rotifers (# species present)

Asplanchna priodonta

Brachionus sp.

Cephalodella gibba

Cephalodella auriculata

Cephalodella sp. 3

Lecane ohioensis

Lepadella patella

Monostyla sp.

Notommata sp.

Philodina roseola

PLoimate rotifer

Polyarthra sp.

Ptygura sp.

Synchaeta sp. 1 (large)

Synchaeta sp. 2 (small)

Testudinella sp.

1974

March 1					April 16						May 28					July 8					August 8					Oct. 20				T
-	2	3	4	5	KB	2	3	4	5	RO	KB	2	3	4	5	KB	2	3	4	5	KB	2	3	4	5	-	2	3		0
																									4		2			2
										1																				1
																					2	3					2			3
											1					1		1		1	4	2			3		2			8
											1					2	1	1	1		2						2			7
-	0	0	0	0	9	3	2	2	1	8	8	7	2	2	4	4	8	9	7	4	9	6	6	5	4	-	6	5	-	
														1				1	1			1	1	2						6
					2							2		3	2	2	2	3	3	2	3	3	3	3	2			3		15
					1	2				1											1		2		1		2	2		8
					1					2																				2
					2					2							1													3
					2					2	3	3					1		2								2			7
																		2												1
																					2	2								2
					3	1	2	2		2	2	3															2			8
																	1													1
											1					3					2									3
						2				2	2	2					2	2												6
											1					3	2	1	1		2						2			7
					2		2		3									2				2	3							6
					1			2		1	1				2	2		2	2	1	2	2	3		3		2	3		15
											1	4	2		2			3			4	4	4	3	3			4		11
																			1	1				2						3
												2					2				2									3
																								2						1
													2		2		1	2										2		5
																											2			1
					2					2	2	3							2	2	2									7

... Site Cnidari
Cordylophora

Protohydra leuka

Sponges
Spongilla lacust
Rhabdocoel worms
Stenostomum sp.(
Stenosto n
cros tomum s p.
sp. present) Asp
priodonta Brachi
Cephalodella gib
Cep lodella a
CeRhalodella
Cep!lalodella
Conochilus sp

-ignatha sp.
uclanis dilatat
Keratella ameri
Lacinularia flo
Lecane ohioensi
Lepadella patel
tyla s p. Notom
Ph lod :na ro
Pro i.materot
Polyarthra sp.

~ sp.

Synchaeta sp.
Synchaeta sp.
Testudinella s
Trichocerca sp

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1971

Site ...	June 30	July 26 1 2 3 4				'K fl Sept.	
Oligochaete worms present (# SP - <u>Aelosoma hemprichi</u> <u>Aulophorus furcatus</u> <u>Chaetogaster diaphanus</u> (lg.) <u>Chaetogaster diastrophus</u> (sm) <u>Dero</u> sp.	2' | i I 3 |i|	2 !	i 1 '2'2! 3212,2	2. I 121 ' '	2,~ljoj | | 1 I	o	
<u>Nais communis</u> <u>Pristina</u> sp. <u>Stylaria proboscidea</u>	12, I2j2; -	5	2,3 2 2; 1 _1!0 -	3 15 2`2- i 2, 3j0i0	2 2, 212 21 i01011 i1	0	
Crustacea (# sp. present) <u>Alona</u> sp. <u>Ceriodaphnia</u> sp. Cyclopoid copepod Callanoid copepod (<u>Diaptomus</u>) Ostracod (Cypridopsis)	' r ~2 I	2 2 1 1 2	3 j I ; i	2' ! 2, I	! I 2l I (! !) 2,2	_	
Gammarids Mayfly larvae Water mites	' a I 1 i , (		~ 1 1 i	i (|i i 1 1	i a } I I | ; +		'i I
Dipterans <u>Rheotanytarsus</u> sp <u>Psychoda</u> sp. Chironomid larvae large red	I 131 1 i		21212 i2i 12	2;21211 2 2' j	213 212 ~2' 3 ' '212	2 1	
medium red small clear medium clear green	! (j I I I f	2 2 '	l2 2I , 1 i i	- i j I 1 ~ I I	3 ! , I + , ,		, ,
Clam <u>Pisidium</u> Gastropods Bithynia			2i 3	. ; (	2j I I	!	

197

	March 1					April 16						May 28					July 8					August 8					Oct.20				T
Oligochaete	-	0	0	0	0	2	2	1	2	2	2	2	2	2	3	2	1	1	2	2		4	7	4	0	3	-	3	1	-	
Aelosoma he																							2								1
Aulophorus																							2	2							2
Chaetogaste																						2	2	2				2			4
Chaetogaste									334						2.2 2				4			2	3	3		3		2			15
De ro sp.												:2 3											2								6
Mais commun																		'3	412			2	3	3		2		2	3		18
Stylaria pr																,															
Crustacea (present) Al																	2					1	2			2					4
Ceriodaphni	-X0'0 '0					0,;0 0			0						0	1	3	2	0	2	0	5	2	1	1	2	-	1	0	-	
copepod Cel																				1		3									2
(Diaptomus)																	2					2	2	2		2					5
(Cypridopsi																				1		2			1						5
Mayfly larvae																															
Water mites																2	2	2				2				2		2			6
Dipterans												'1[1]:2					2	3				3	1								7
Rheotanytarsu																															1
Psychoda sp.																						1									1
Chironomid la																															
large red																															
medium red																															
small clear																															
medium clea																															
green																,	2					2	1	1		1					11
Clam Pisidium																												2			3
Ga st ropod s												3	3	3	3	3	3	3	3	2	2	2	2	1		2					16
Bithynia sp.												3	3	3	3	3	3	3	3	2	2	2	2	1		2					16
Gyraulus sp.																						2				2					2
Physa sp.																					1			1							2
																															1
																						1	2					1			5
																			1			2									5

Introduction to Appendix C

Physical-Chemical Data

The first two pages gives the E.P.A. data for the four collection times in 1971. Note that these coincide with the first four biotic collection times. No physical-chemical data was collected in October. The next six pages give the E.P.A. and the Spoon physical chemical data. The data is separated into three terms with the comparable E.P.A. and Spoon data on opposing pages. Missing letters from A to H indicate lack of correlating collection dates. Note that the E.P.A.data for 1971 is less complete than for 1974.

The data to *recorded* stepwise across the page to

PHYSICAL-CHEMICAL DATA E. P. A.

A. June 30, 1971 B. July 26, 1971

Sites 1 2 3 4 5 Roosevelt Hains
Blue Broad Piscataway Island Point Plains Creek Creek

Sites	1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B
Temp. °C.	28.0		28.0		29.0		28.5		28.0	
Water		27.0		28.0		27.5		27.5		27.0
D. O. (mg/1)	6.63	0.54	4.39	3.45	2.74	2.83	1.78	4.66	2.69	3.96
Secchi Disc (inches)	22	24	13	16	16	19	22	20	23	18
Turbidity (JTI1)										
Total P P0$_4$ (mg/1)	0.227	0.277	0.451	1.590	1.514	1.627	1.514	1.205	1.122	1.055
Inorganic P P0$_4$ (mg/1)	0.063	0.054	0.138	1.285	1.315	1.245	1.370	0.730	0.945	0.815
TKN (mg/1) N	0.739	0.855	0.867	2.588	2.079	2.340	2.461	1.630	2.006	1.539
NO + N03 N63 - N (mg/1)	0.188	0.113	0.272	0.153	0.393	0.929	0.453	1.360	0.614	1.366
NH$_3$ (mg/1) N	0.032	0.001	0.221	2.047	1.524	0.429	1.986	0.187	1.590	0.408
TOC (mg/1)		6.66		7.29		7.06		6.90		6.59
Total C (mg/1)										
chlorophyll _a (mg/1)	33.3	39.0	45.0	30.0	26.3	65.3	27.8	72.8	47.3	86.3

PHYSICAL-CHEMICAL DATA E. P. A.

C. August 25, 1971 D. September 28, 1971

Sites 1 2 3 4 5 Roosevelt Hains
Blue Broad Piscataway Island Point Plains Creek Creek C
D C D C D C D C D

Temp. °C. 28.0 27.5 27.5 27.0 27.0

Water 21.0 21..5 22.0 22.0 22.5
D. 0. 7.96 4.41 2.53 6.46 7.42

(mg/1) 8.85 6.91 6.11 4.54 6.59
Secchi Disc 26 16 20 22 30

(inches) 26 19 15 21 26
Turbidity - - - -
(JTU) - - -

Total P 0.205 1.086 1.701 1.231 1.193

P0$_4$ (mg/1) 0.265 0.330 1.489 1.346 0.898
Inorganic P 0.024 0.659 1.205 0.810 0.750
P0$_4$ (mg/1) 0.181 0.215 1.105 1.142
0.690
TKN 0.707 1.484 1.486. 0.991 1.102

(mg/1) N 0.426 0.458 1568 1.851 1.535
NO + N03 0.056 0.386 1..679 1.456 1.467

N83 - N (m3`/1) 1.133 1.022 1.032 0.951 1.050
3 (mg/1) 0.001 3.959 0.001 0.001 0.132
0.020 0.085 0.920 1.280 0.859

TOC (mg/1) 5.79 7.02 9.04 8.02 11.82 5.00 ,1.61 5.26
4.81 6.72

Total C - - -
(mg/1) 29.33 23.42 28.13 24.45 19.40

chlorophyll a 35.3 24.8 51.8 97.5 87.0
(mg/1) _ 6.0 11.3 5.3 9.0 28.5

PHYSICAL-CHEMICAL DATA First Term
D.M. Spoon
Georgetown University A. January 24, 1974

B. February 21, 1974

C. March 28, 1974

3 5
1 2 Blu 4 Piscat
Sites Roosevelt Hains e Broad away
Temp. °C. Island Point Plai Creek Cree C
Air A B C A B C ns C A B C k
11.0 11.0 A B 10.0 A B
10.0 10.0

16.
5 16.5 16.0 14.0 15.0

Temp. °C. 7.0 6.8 6.5 7.0 6.0

Water 5.0 5.5 6.o 5.5 5.5

10.
0 10.5 10.0 11.0 10.0

Dissolved 12.1 12.
4 12.3 12.0 12.0

Oxygen 12.8 13.0 11.9 12.1 12.0

(ppm) 11.
0 11.0 10.3 10.6 10.6

pH - - - -
6.6 6.6 6.5 6.7 6.7
6.75 6.65 6.6 6.7 6.65

Secchi disc 11 10 11 11 9 (inches)
44 40 31 29 28 56 40 25 24 19

Turbidity - - - - -

(JTU) 11 17 7 10 12

PO_4 (ortho

phosphate) 0.07 0.13 10.04 0.64 0.65 (ppm) 1.65 3.0 1.85 0.64 0.52

N03 (Nitrate) - - - - -

(ppm) 1.15 0.62 0.33 0.31 0.41
0.39 0.89 0.37 0.85 0.45

PHYSICAL-CHEMICAL DATA F^rst Tenn E,P.A^

A^ January 14, 1974

C , March 25, 1974

Sites	1 Roosevelt Island A	C	2 Hains Point A	C	3 Blue Plains A	C	4 Broad Creek &	C	5 Piscataway Creek A	C
Temp. ºC.	2.5		2.5		2.0		3.0		2.5	
Water		~	8,5	8.8				8.0	9,0	
D.O. (mg/ 1)	14.46	-	13.93	11,62	13.64	10,96	13,37	10,49	13.58	10,04
Gecchi Disc (ioche s)	8	~	8	-	6	-	8	-	12	
Turbid±ty (JTU)	45,0	-	46.0	7,5	48.0	15,0	38,0	15.0	26,0	24^O
Total P P⁰4 (mg/ 1)	0^400	~	0,367	0,136	0,727	0,979	MY	1.176	0,419	0.905
Inorganic P PD" (mg/ .	0,093	~	0.103	0,014	0,361	O^-~83	0.354	0.825	0,217	0.539
TKN (mg/1) N	0,507	~	0,499	0~468	0,892	1^135	0,941	1,587	0,826	1,262
0D2 + 0D~ 003 ~ 2J (mg/I)	1^085	~	1^020	0,880	1.020	0,900	1.040	0,870	1,120	0.825
(mg/ 1) yJ	0,175	~	0.125	0,050	0,485	0,730	0,545	1,090	0,325	0.845
T3C (mg/ 1)	5,86		6,99	5,73	7,11	9,77	5~74	7,75	4.52	8.53
Total C NN 1)	16.10	-	17,09	21.59	18.07	24.54	16,94	23,33	16.25	23.53
chlorophyll (mn/I) -	12.0	-	7.5	61,5	4.5	10.5	4.5	16,5	4.5	13,5

PHYSICAL-CHEMICAL DATA Second Term

D.M. Spoon
Georgetown University

D. May 3, 1974

E. June 6, 1974

F. July 8, 1974

Sites	Date	1 Roosevelt Isl. *	2 Hains Point	3 Blue Plains	4 Broad Creek	5 Piscataway Creek
Temp. °C. Air	D	-	19.5	19.0	20,0	18,0
	E	-	19.5	20.0	19.5	19.0
	F	-	29.0	28.0	34.0	31.0
Tep 1u.°C . Water	D	-	170	170	.160	,150 .
	E	-	19.0	22.5	19.5	20.0
	F	-	28.5	28.0	28.5	28.0
D.O. (ppm) (YSI)	D	-	7,0	8.0	6,4	7.1
	E	-	8.6	8.3	8.2	7.8
	F	-	7.3	4.3	5.3	7.0
pH (electrode)	D	-	6.6	6.6	6.5	6.5
	E	-	7.1	7,4	7,1	7.0
	F	-	7,4	7.3	7.2	7,1
Secchi Disc (inches)	D	-	19	22	20	22
	E	-	9	8	10	13
	F	-	24	22	24	19
Turbidity (JTU)	D	-	19	16	13	35
	E	-	45	40	10	12
	F	-	50	35	15	25
P04 (ortho-phosphate) (ppm)	D	-	0.62	0,62	1,28	11.00
	E	-	0.66	1.02	0.64	0.68
	F	-	0.30	0.85	1.00	0.10
N03 (nitrate) (ppm)	D	-	0.81	1.20	0.85	0.90
	E	-	0.80	1.20	1.-00	1.00
	F	-	0.50	0.75	0.90	0.75

J` This site had to be eliminated due to the removal of the Coast Guard buoy. _114

PHYSICAL-CHEMICAL DATA Second Term E. P. A.

D. May 1, 1974 E. June 18, 1974 F. July 15, 1974

Sites 1 2 3 4 5 Roosevelt Hains
Blue Broad Piscataway Island Point Plains Creek Creek

D E F D E F D E F D E F D E F

Temp. °C. - 20.5 20.0 19.0 21.5 Water
24.0 24.0 26.0 25.0 25.0 29.0 29.0 29.0 29.0 28.5

D. 0. - 8.23 8.80 7.92 8.08 (mg/1)
7.38 7.76 7.18 4.71 4.94 8.01 7.46 4.26 3.31 6.92

Secchi Disc - 24 25 30 26 (inches)
24 22 15 20 22 23 21 23 25 22

Turbidity - 12.0 10.0 10.0 5.5 (JTtl) 13.0 15.0 14.0 14.0 12.0 11.0 15.0
14.0 10.0 15.0

Total P - 0.299 0.577 1.346 0.264

PO 4 (mg/1) 0.165 0.238 0.654 1.005 0.866
0.252 0.311 1.286 1.329 0.852

Inorganic P - 0.018 0.096 0.672 0.018

PO 4 (mg/1) 0.012 0.007 0.372 0.584 0.556
0.008 0.023 0.868 0.900 0.392

TKN - 0.736 0.934 2.091 0.760

(mg/1) N 0.477 0.411 0.822 1.561 1.570
0.507 0.530 1.871 2.222 1.559

NO +NO3 - 0.755 0.755 0.730 0.635

N83 - N (mg/1) 0.580 0.500 0.720 0.695 0.905 0.001 0.001
0.161 0.204 0.430

NH3 (mg/1) N - 0.125 0.315 1.225 0.065 0.070 0.080 0.385
1.095 1.145 0.022 0.022 1.375 1.716 0.913

TOC (mg/1) - 6.32 6.75 10.41 6.91 9.89 8.16 5.46 6.65
8.82 4.78 4.22 4.52 5.03 3.87

Total C - 23.05 24.17 27.73 23.35 (mg/1)
21.90 19.32 17.80 20.83 22.96 20.05 20.35 24.38 26.20 23.12

chlorophyll _a - 31.5 26.3 33.0 30.0 (mg/1)
39.0 52.5 42.0 25.5 39:0 37.5 45.0 39.0 45.0 88.5

PHYSICAL-CHEMICAL DATA

D. M. Spoon Third Term Georgetwon University

G. August 8, 1974 I. October 4, 1974 J. October 12 (2 &

Sites	1 Roo Island G	1 Roo Island I	1 Roo Island J	2 Hain Point G	2 Hain Point I	2 Hain Point J	3 Blu Plains G	3 Blu Plains I	3 Blu Plains J	4 Bro Creek G	4 Bro Creek I	4 Bro Creek J	5 Pis Creek G	5 Pis Creek I	5 Pis Creek J
Temp. °C. Air	-	-		24	21	21	22	21	19	25	18	17	25	14	15
Temp. °C. Water	-	-	-	26	17	16.5	29	19	18.5	27	16.	14	26	16	15
D. O. (ppm) (YSI)	-	-		3.0	5.7	7.6	2.5	4.2	4.4	9.7	5.6	6.5	9.2	5.8	9.2
pH (electrode)	-	-	-	7.2	7.1	7.3	7.2	7.0	6.9	7.3	7.1	6.8	7.4	7.2	6.8
Secchi Disc (inches)	-	-	-	23	23	19	24	19	19	18	21	23	27	22	23
Turbidity (JTU)	-	-	-	-	19	15	-	15	35		40	14		20	20
PO_4 (ortho-phosphate) (ppm)	-	-	-	0.85	0.6	0.25	0.75	0.5	4.80	0.60	0.5	1.38	0.80	0.6	0.95
NO2 (PPM)	-	-		0.13	0.2	0.055	0.30	0.1	0.045	0.06	0.9	0.038	0.01	0.8	0.34
NO_3 (Nitrate) (ppm)	-	-	-	0.8	1.3	0.9	1.00	0.9	1.0	1.2	2.6	0.9	3.5	2.5	1.1
Chloride	-	-	-	0.4	2.5	12.5	0.5	0.0	27.0	0.5	5.0	25.0	0.5	5.0	15.0

This site had to be eliminated due to the removal of the Coast Guard buoy.

PHYSICAL-CHEMICAL DATA Third Term E.P.A.

H. September 5, 1974

Sit	1	2	3	4	5
	Roosevelt Island	Hains Point	Blue Plains	Broad Creek	Piscataway Creek
	H	H	H	H	H

Temp. °C.
25.5
26.0
25.0

D. 0. (mg/1)	8.44	4.72	2.40	2.78	5.06
Secchi Disc (inches)	16	15	13	20	20
Turbidity (JTLI)	15.0	20.0	22.5	12.5	11.0
Total P PO_4 (mg/ 1)	0.361	1.260	1.187	1.112	0.991
Inorganic P P04 (mg/1)	0.026	0.762	0.721	0.703	0.594
TKN (mg/1) N	0.912	1.825	1.659	1.189	1.124
N02 + N03 N03 - N (mg/1)	0.042	0.194	1.074	1.755	1.872
NH3 (mg/1) N	0.030	1.060	0.799	0.248	0.086
TOC (mg/1)	12.08	10.28	8.53	10.12	8.80
Total C (mg/ 1)	25.45	26.49	24.08	24.91	24.91
chlorophyll a (mg/ 1)	171.0	58.5	55.5	94.5	108.0